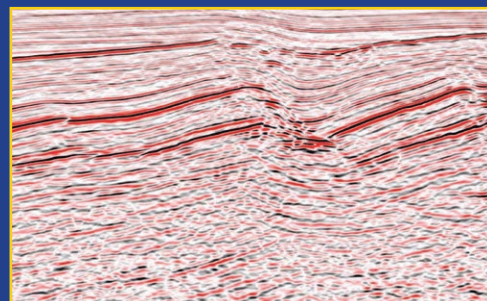




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WEDNESDAY
20 APRIL 2022
ORAL PRESENTATIONS

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: CBM, Source Rock Reservoirs and Offshore Potential of Colombian Basins: insights from the updated version of the Atlas of Organic Geochemistry of Colombia.

AUTHORS (FIRST NAME, LAST NAME): Roberto Aguilera¹, Liliana Sarmiento², Cristian Peñafort³, Diego Torres⁴, Nicolás Becerra⁵, Gloria Villafrade⁶, Lina Cardona⁷, Carlos Rey⁸

INSTITUTIONS (ALL):

1. Servicio Geológico Colombiano
2. Servicio Geológico Colombiano
3. Servicio Geológico Colombiano
4. Servicio Geológico Colombiano
5. Servicio Geológico Colombiano
6. Servicio Geológico Colombiano
7. Servicio Geológico Colombiano
8. Agencia Nacional de Hidrocarburos

ABSTRACT BODY:

Abstract Summary: In the last year a joint effort between the National Hydrocarbons Agency of Colombia (ANH) and the Colombian Geological Survey, to update the Atlas of Organic Geochemistry of Colombia has been carried out.

During this process a wealth of new data generated by the ANH and operators in the last ten years on all aspects of organic geochemistry, but particularly in Coal Bed Methane (CBM), Source Rock Reservoirs (Unconventionals) and offshore piston core campaigns has been gathered. From the integration and analysis of this geochemical data for the different type of sources, using a series of crossplots and maps for each basin, involving updated information on source rock quality, thermal maturity, biomarkers, etc., an updated look on the exploratory potential of the Colombian Basins for CBM, unconventionals and offshore areas has been obtained.

These results are compiled in the latest version of the Atlas of Organic Geochemistry of Colombia and provides a regional and up-to-date view on the subject, but also on the future work to be carried out in order to reduce the uncertainties, and the opportunities that still exist for oil and gas exploration and production in the country.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Geochemical characterization of natural gas and water released by mud diapirs in the Caribbean Colombia and its correlation with the Caribbean deformed belt and the petroleum systems

AUTHORS (FIRST NAME, LAST NAME): Felipe Gonzalez-Penagos¹, Eduardo Lopez-Ramos², Nestor Raul Moreno³

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Mud diapirs are geological structures form due to an upward flow of a ductile shaly intrusion in sedimentary basins. Mud diapirs are dynamic systems of muddy material with an active seepage of natural gas, oil, and water. These fluids released in surface provides information about the origin and presence of active deep petroleum system.

orthern Caribbean of Colombia is the most prolific area of oil and natural gas seeps, including additionally both onshore and offshore mud diapirs. In order to understand the subsurface root of the mud diapir, the origin of the fluids, the fluid-rock interaction, the maturity and migration of the hydrocarbons and the correlation with the adjacent petroleum systems, natural gas and water released in 14 locations of mud diapirs all along the Caribbean coast were collected, filtered, sampled, and analyzed in laboratory.

Analysis performed to characterized geochemically the fluids were molecular major composition C1-C5, He, Ar, O₂, CO₂ and N₂, carbon isotopic composition d¹³C₁ d¹³C₂ and d¹³C₃ and hydrogen isotopic composition dD for the natural gases and total salinity, composition of major elements and stable isotopes d¹⁸O and dD for the waters released.

The results show a wide variation of origin and mixture of fluid families controlled mainly by tectonic and structural features. Compositional and isotopic variations of the methane-dominated emission of natural gas suggest the presence of both microbial and thermogenic petroleum systems. Variations on d¹³C₁ from -65 to -35‰ demonstrate a wide range of the thermal maturity of the petroleum systems related with the progressive formation of the Caribbean deformed belt. Water released within the diapir show a progressive signature of heavy d¹⁸O from -2 to 8‰ coupled with lower salinity values and heavier values of d¹³C₁, suggesting a thermal relationship of the origin of the fluids.

SESSION TITLE: Theme 4: Reservoir Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Seismic stratigraphic analysis of Tumbes-Progreso basin (NW Peru) and E&P implications **AUTHORS**

(FIRST NAME, LAST NAME): Martin Oviedo¹, Victor Carlotto², Daniel G. Poiré³, Loeiza Gicquel⁴, Francois Lafferriere⁵

INSTITUTIONS (ALL):

1. Universidad Nacional Mayor de San Marcos
2. Universidad Nacional San Antonio Abad del Cusco
3. Centro de Investigaciones Geológicas (UNLP-Conicet)
4. Eliis
5. Eliis

ABSTRACT BODY:

Abstract Summary: The Tumbes-Progreso forearc basin (Neogene) located in northwestern Peru, reports the first well drilled in South America (11/1863). It has hydrocarbon producing fields and an active petroleum system. The stratigraphic record exceeds 7000m of sediments which is related to the rapid eustatic variations. The result of intense transtensional faults activity directly associated with terrane accretion (Cretaceous), the active margin, oblique subduction and the Dolores-Guayaquil-Patallanga Megashear system, Pull-apart basins have been generated as Talara and Tumbes-Progreso.

Due to the lack of integrated regional studies, and as part of understanding the basin evolution, a detailed regional seismic stratigraphic analysis was carried out with 2D & 3D seismic data, biostratigraphy, stratigraphic columns and exploratory wells. A comprehensive approach is applied where an automated process delivers faults and horizons respectively from signal discontinuities and reflections. A relative geological time model is built using this comprehensive approach and allows the delineation of key surfaces by combining attributes and generating Wheeler diagrams. A chronostratigraphic chart of Tumbes-Progreso basin is interpreted by detailing main sequence boundaries associated with three NE-SW regional fault systems (Amotape, Zorritos and Banco Peru). Those faults networks impacted sediment sources of the basin.

We suggest that, besides inheriting a pre-Tertiary structural framework, the basin is opening at 33 Ma until 10 Ma, presenting two progradational systems and a transgression (main source rock). At 10 Ma the basin shows a change in its structural configuration, it is restricted by four structural highs (Zorritos, Banco Peru, Barracuda and Punta Sal) generating a main depocenter (Cabo Blanco trough). The basin acquires a pull-apart geometry with an intense sedimentation recorded by progradational system with sediment supply from SE to NW and from E to W, controlled by syn-sedimentary faults, with roll-over structures, growth strata and tilted blocks that favored the generation of local depocenters.

The seismic stratigraphy analysis allows reconstructing the basin evolution and gets a better grip reservoir prediction. The complex structural framework controlled the sedimentation and favoured the generation of structural, stratigraphic and mixed traps, that may present great exploration potential. This work opens a new panorama of Tumbes-Progreso basin regional exploration.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Advanced Geochemical Technologies (AGTs) That Have Been Applied in Colombia and in Worldwide Exploration

AUTHORS (FIRST NAME, LAST NAME): Michael Moldowan¹, Jeremy Dahl²

INSTITUTIONS (ALL):

1. Biomarker Technologies Inc.

2. Stanford University

ABSTRACT BODY:

Abstract Summary: Petroleum exploration is all about creating prospects that can yield new discoveries. While classical geochemical technologies; such as, standard biomarker analysis and correlation by isotopes of oils and oil fractions are extremely useful, they have already been available for more than three decades and been applied to most of the mature basins in the world. Therefore, classical analytical methods are unlikely to support new exploration ideas. Repeating the same analyses in the same basins, time and time again, will most likely not result in startlingly new play ideas or discoveries. Advanced geochemical techniques based on diamondoids and compound specific isotope analysis (CSIA) can provide the necessary crucial information to reach those objectives that were previously unattainable and fill mature basins with new exploratory opportunities.

Quantitative diamondoid analysis (QDA) is used for determining the maturity of any oil (or condensate) sample in both conventional and unconventional applications. The high degree of accuracy needed for application of this method is achieved by spiking the liquids with deuterated diamondoids and hi-grading a diamondoid-enriched fraction before GCMS analysis. More recently, the ability to perform source correlations by using diamondoids has been developed. These correlation methods have an advantage over all others due to the recalcitrancy of diamondoids toward high thermal maturity and biodegradation. Thereby, all bitumen and oil samples (condensate, biodegraded oil, produced black oil, seepage oil, and extracts from source rocks and reservoirs) can be correlated by diamondoids. In particular, the analysis of suites of large diamondoid molecules (QEDA) and isotopes of diamondoids (CSIA-D) have been particularly fruitful in Colombia.

CSIA of Biomarkers (CSIA-B) has also been applied in Colombia. Applications there and in Brazil show the great potential for this method and the diamondoids to delineate depositional environments and aid the basin modeler. The relatively new CSIA-B technique provides greater details of water column euxinic trends and depositional environments than biomarkers alone. AGT examples from several Colombian basins onshore and offshore will be presented, and others from worldwide regions, i.e., Brazil, Mexico, Middle East, and Alaska.

SESSION TITLE: Theme 1: Source-to-Sink

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: The Present is not Always the Key to the Past: Exploring and Modeling the Cenozoic Endorheic Fluvial Systems of the Middle Magdalena Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Xavier Roca¹, Kurtis Wikel²

INSTITUTIONS (ALL):

1. Parex Resources

2. Parex Resources

ABSTRACT BODY:

Abstract Summary: Access to global satellite photography a decade ago led to three critical insights on fluvial stratigraphy. First, it allowed recognition of the fact that more than 90% of the surfaces of modern fluvial sedimentary basins are covered by aggradational distributive systems. Second, it showed that most of the types of rivers used to build fluvial sedimentological models are incisional and tributive, and therefore not representative of a substantial part of the fluvial stratigraphic record. And finally, it enhanced research on Distributive Fluvial Systems (DFS) that led to the development of predictive facies models able to support hydrocarbon exploration and reservoir modeling. The scarcity of axial fluvial deposits is accentuated in continental endorheic basins, where the blocked access to the sea precludes the development of large axial drainages. Paleotectonic reconstructions, petrographic data, and detrital zircons strongly suggest the middle Eocene to middle Miocene stratigraphic fill of the Middle Magdalena Basin (MMB) of Colombia was mostly internally drained. However, it is our perception that the tendency to use the modern Magdalena River as an analog for the Cenozoic fluvial systems of the MMB has prevailed in exploration depositional models, as well as in field development geocellular models. Integration of the new learnings on the global fluvial record is strongly encouraged to optimize the validity of the subsurface characterization work on both fronts. The basin arrangement of reservoir facies is substantially different in the DFS depositional scenario. This interpretation implies that 1) the coeval reservoirs of fields in geographic proximity were not part of a single trunk system, 2) the best reservoirs should be found in the proximal parts of the fans close to the edges of the basin, 3) the drainage area of each fluvial system is substantially smaller and therefore channel dimensions need to be reduced, and 4) there is a decrease in reservoir storage volumes and lateral connectivity downdip due channel divergence and progressively lower channel amalgamation. In fact, outcrop, well log, and core data suggests that most of the channel dimensions in the section of interest are not associated with large axial systems. Local tectonic controls on accommodation, as well as autogenic nesting of non-coeval sandstone bodies can set up enhanced reservoir deliverability, yet these cases are very likely the exception.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

EXTENDED ABSTRACT: Carbon Isotopic Fractionation of Gaseous Hydrocarbons: a Tool for the Determination of the Extent of Bacterial Gas Mixing in the Natural Gases of KG Basin, India

Upendra Pratap Singh^{*1}, Harish Chandra Pande², Mala Janardhanan³; Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE), Oil and Natural Gas Corporation Ltd., Dehradun, India.

Abstract

Natural gas occurrences in KG Basin exhibit discrete methane isotopic signatures: $\delta^{13}\text{C}$ -31 to -46‰ in the western part of onshore, $\delta^{13}\text{C}$ -48 to -64‰ in the coastal areas and primarily biogenic ($\delta^{13}\text{C} < -55\text{‰}$) in deep water areas. Mixing of bacterial and thermogenic gases in subsurface distorts $\delta^{13}\text{C}$ of methane which defies application of conventional correlation techniques. The study is an attempt to understand the trend of bacterial methane mixing in gases reservoirs in multiple stratigraphic sections ranging from Permian to Pliocene in KG Basin and is based upon the concept that mixing of bacterial and thermogenic gases alters the $\delta^{13}\text{C}$ of methane only.

There is a definite depletion pattern in $\delta^{13}\text{C}$ from heavier to lighter gaseous molecules during their thermal generation from parent kerogen via primary cracking pathway. The gases were plotted as inverse C-atom number ($1/n$) in the molecules against their corresponding $\delta^{13}\text{C}$. The altered (secondarily cracked) gases were identified using a cross-plot of C_2/C_3 vs $\delta^{13}\text{C}_2$ - $\delta^{13}\text{C}_3$ and were excluded in this plot. In the remaining gases the $\delta^{13}\text{C}$ of the pure thermogenic methane was obtained by extrapolating the trend line towards $1/n=1$. The percentage bacterial and thermogenic gases were calculated by benchmarking the average $\delta^{13}\text{C}$ value of bacterial methane in the area.

The gases from on-land wells in West Godavari area are of thermogenic origin with substantial secondary cracking and lack significant incorporation of bacterial methane. The on-land gases in East Godavari area exhibit wider variation in bacterial gas mixing. While in Permian and Permo-Triassic reservoirs the gases are of thermogenic origin, Early Cretaceous to Eocene reservoirs show mild mixing of biogenic methane. Natural gases of Oligocene-Miocene show significant contribution of bacterial methane trending up to 100% in shallower depths. Pliocene gases show bacterial gas input up to 100% in most of the studied wells. Secondary cracking is mild in gases reservoirs in Late Cretaceous and mild to severe in Early Cretaceous and Permo-Triassic levels. In KG Offshore wells, gases from Cretaceous to Oligocene exhibit minor to moderate concentrations of bacterial methane (0-24%). The Miocene gases show varying bacterial methane concentrations ranging from pure bacterial to thermogenic. The Pliocene reservoirs are bacterial in origin. Instances of secondary cracking have not been observed in the offshore part of the Basin.

Introduction

Natural Gas Geochemistry distinguishes two basic types of gases: bacterial/biogenic and thermogenic which are conventionally demarcated by their methane isotopic signatures. Substantial geochemical data generated on gases of Krishna Godavari Basin (KG Basin) indicate that biogenic gas contribution increases as we move from land part of the basin towards offshore. This phenomenon has also been supported by methane isotopic signatures ($\delta^{13}\text{C}$) in the KG Basin (Figure 1). Biogenic gas is generated at low

temperatures by decomposition of organic matter by anaerobic microorganisms, usually occurring in shallow, anaerobic and sulphate-free zones and are generally thought to form below 80°C (Rice et al., 1981; Wilhelms et al., 2001; Valentine, 2011). However, in laboratory, the methanogenic cultures can grow up to 122 °C (Takai et al., 2008). In the last two decades, it was deemed easy to distinguish gas generated either by thermal cracking or from methanogenesis, using the carbon and hydrogen isotopes

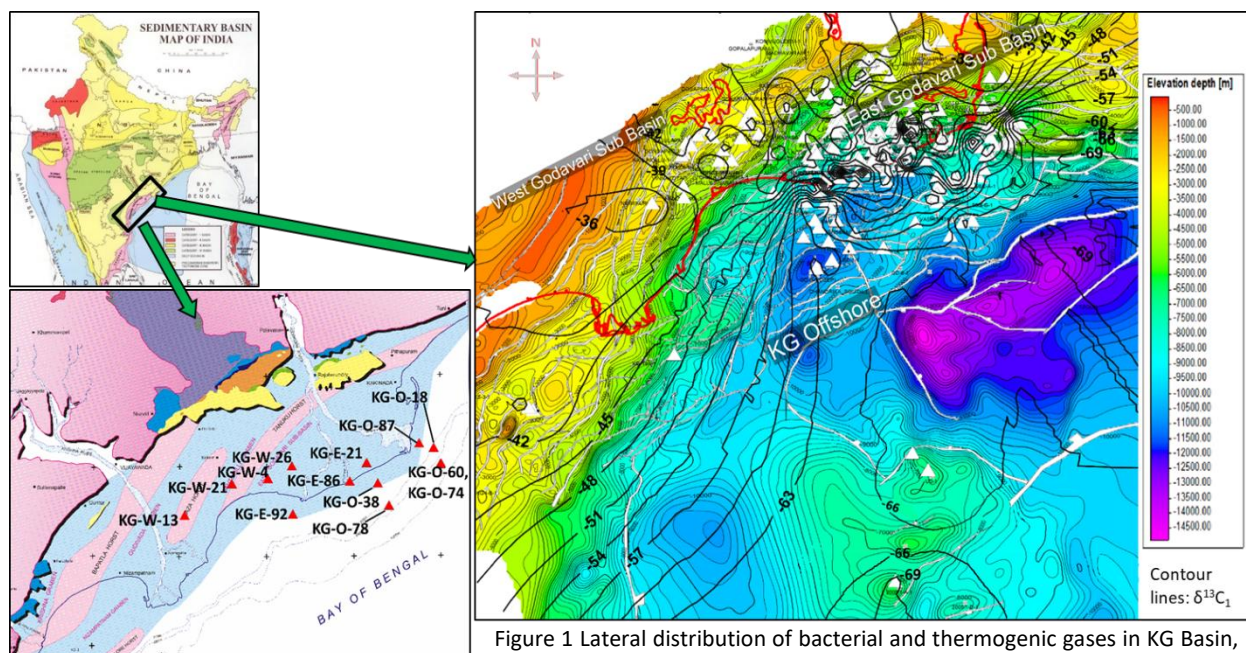


Figure 1 Lateral distribution of bacterial and thermogenic gases in KG Basin, based on methane $\delta^{13}\text{C}$ variations (superimposed over basement depth map)

(Bernard et al., 1976; Schoell, 1983; Faber et al., 1992). However, later studies have shown that microbial oxidation of bacterial gas may give a residual gas showing a thermogenic signature, whereas diffusive processes during migration may give a bacterial signature to a thermogenic gas. Such altered bacterial gases can be distinguished by absence of C_2+ hydrocarbons, and the diffused thermogenic gases by cross plots of $\delta^{13}\text{C}$ vs. C_2/C_1 (Prinzhofer and Pernaton, 1997, Prinzhofer and Battani, 2003).

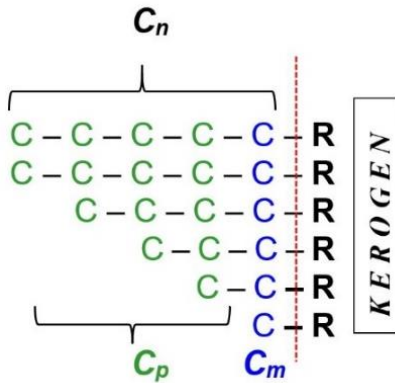
Though, in general, the methane $\delta^{13}\text{C}$ signatures are indicative of genetic origin of the natural gases, the amalgamation of biogenic and thermogenic gases in sub surface significantly alters the methane carbon isotopic ratios, making them inappropriate for genetic characterization of natural gases. In such scenario, determination of extent of mixing is vital. The study focuses on the estimation of the extent of bacterial gas in the entire KG Basin.

Theory

The study is based upon two assumptions: a). The biogenic gas mixing to thermogenic gas pool affects the isotopic properties of methane only as biogenic gases are mostly methane. b). The thermal generation of natural gases from kerogen exhibits definite isotopic fractionation among progeny gaseous molecules, which shows depletion in $\delta^{13}\text{C}$ from heavier to lighter gaseous molecules. Laboratory experiments suggest that the carbon isotopic ratios of hydrocarbons are controlled by kinetic isotopic effects occurring during

carbon-carbon bond breakage. To understand this $\delta^{13}\text{C}$ depletion pattern among progeny gaseous molecules, Chung et al. (1988) developed an equation by following model:

Various alkyl groups attached to a large kerogen molecule (R) are assumed to generate gaseous hydrocarbon fragments as shown below in (Figure 2)



C_n are the carbon atoms of individual hydrocarbon molecules. C_m is the carbon link that attaches to C, and also to other carbons of a kerogen molecule, and becomes a terminal carbon atom after fragmentation. This is the carbon atom that is isotopically lighter as a consequence of the generation of gaseous molecules. C_p are the other carbon atoms in a gaseous molecule.

The isotopic ratios of individual gaseous molecules generated from kerogen can be represented in the following equation:

$$\delta^{13}\text{C}_n = [\delta^{13}\text{C}_m + (n-1) \delta^{13}\text{C}_p] / n \quad \text{..... (1)}$$

Figure 2 Diagrammatic representation of generation of gaseous molecules from kerogen

Where n is the number of carbon atoms in gaseous molecule.

Rearranging the above equation:

$$\delta^{13}\text{C}_n = -1/n (\delta^{13}\text{C}_p - \delta^{13}\text{C}_m) + \delta^{13}\text{C}_p \quad \text{..... (2)}$$

(y = x . m + c)

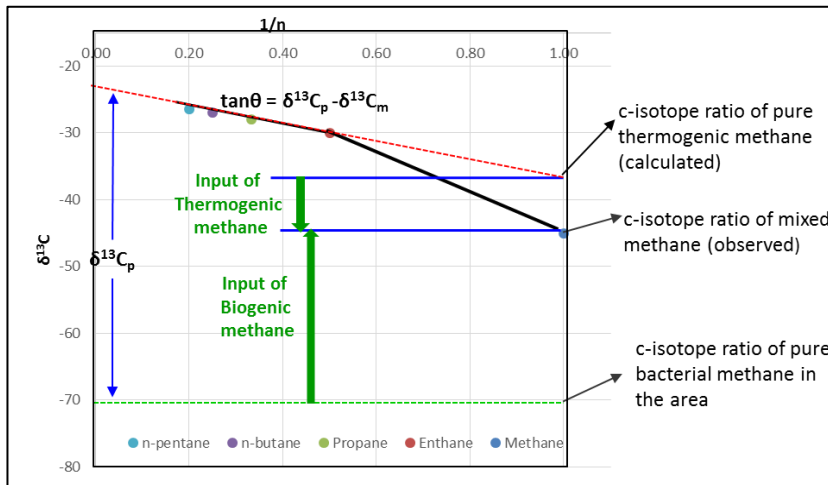


Figure 3. 'Natural Gas Plot' based on isotopic fractionation in gaseous molecules, for estimation of $\delta^{13}\text{C}$ of pure thermogenic methane (After Chung et al., 1988)

While plotting $\delta^{13}\text{C}_n$ as a function of $1/n$, the slope of this plot ($\delta^{13}\text{C}_p - \delta^{13}\text{C}_m$) represents the isotopic fractionation during formation of gaseous hydrocarbons whereas the intercept $\delta^{13}\text{C}_p$ represents the $\delta^{13}\text{C}$ of the largest fragment molecule formed by thermal decomposition of kerogen. Such a plot is referred to as "Natural Gas Plot" which is being used for calculating the unaltered value of methane in our study as shown in Figure 3.

While extrapolating the plot towards $1/n=1$, $\delta^{13}\text{C}$ values of unaltered thermogenic methane can be estimated as shown in 'natural gas plot' in Figure 3. The percentage bacterial gas mixing can be calculated based on available isotopic values of pure bacterial methane (benchmarked at -70‰ for our study area),

pure thermogenic methane (estimated by ‘natural gas plot’) and observed mixed methane, by the Equation 3.

$$\text{Bacterial Methane Mixing (\%)} = \frac{\delta^{13}\text{C}_1 (\text{mixed}) - \delta^{13}\text{C}_1 (\text{Thermogenic})}{\delta^{13}\text{C}_1 (\text{Bacterial}) - \delta^{13}\text{C}_1 (\text{Thermogenic})} \times 100 \quad \text{.....(3)}$$

This concept was applied by Janiga et al. (2015) for shale gas systems and more recently by Loegering et al. (2017) for understanding the origin of petroleum gases.

Geology of Krishna-Godavari Basin

The Krishna-Godavari Basin (KG Basin) lies along the East coast of India covering the deltaic and inter-deltaic areas of Krishna and Godavari rivers, and extends into the offshore. The basin has significant hydrocarbon potential both in the Tertiary delta as well as in the channel-levee-overbank play types in the deep-water. The structural trend of the basin is NE-SW and has sedimentary fill from Paleozoic to Cenozoic. Two major rivers, Krishna and Godavari and their deltas dominate main part of the basin. The end of the Mesozoic was marked by volcanic activity. A number of basalt flows belonging to the Deccan Traps are found in the sub-surface as well as in the outcrops. The oldest sediment resting over the basement is of Permian age, confined to the north-eastern part of the basin (Mandapeta trough). In the west, close to the basin margin, synrift sediments of Jurassic overlie the basement and extend up to ocean continental boundary in the present day offshore. The basin is broadly divided into five tectonic elements namely, (1) Krishna Graben, (2) Bapatla horst, (3) West Godavari sub-basin (including the median Kaza-Kaikulur horst separating the Gudivada and Bantumilli graben), (4) Tanuku Horst and (5) East Godavari sub-basin (extends into the offshore part). Hydrocarbons have been discovered in the West Godavari, East Godavari and offshore part of the Basin.

Experimentals

The natural gas samples were analysed for their molecular composition on Varian GC CP-3800 gas chromatograph equipped with TCD and FID detectors, using helium and nitrogen carrier gases. The TCD was used to analyse inorganic gases whereas the FID was used for the analysis of hydrocarbons from C₁-C₆ through a single injection. Stable carbon isotopic studies were carried out on Thermo Fisher Delta V Plus continuous flow-isotope ratio mass spectrometer (CF-IRMS) interfaced with Ultra Trace GC, which is equipped with a fused silica coating Poraplot-Q; 25m x 0.32mm x 25µm column. The mass spectrometer is standardized using standard laboratory gas which is calibrated with NIST (USA) gas standards NGS-1 and NGS-2. Results of isotopic values for natural gases are reported as δ¹³C ‰ with respect to PDB by using following equation:

$$\delta^{13}\text{C (\%)} = \left(\frac{^{13}\text{C}/^{12}\text{C}_{\text{sample}}}{^{13}\text{C}/^{12}\text{C}_{\text{standard}}} - 1 \right) \times 1000$$

Sample selection and data processing

Data of 367 gas samples from entire KG Basin which comprises 47 gases from West Godavari, 143 gases from East Godavari and 177 gases from KG Offshore area, were incorporated in the present study. The gases generated through secondary cracking were identified by the cross plot C_2/C_3 vs $\delta^{13}C_2 - \delta^{13}C_3$ (Prinzhofer et al., 2000) as shown in Figure 4 and were not incorporated in 'natural gas plots' as they would give incorrect results in the estimation of $\delta^{13}C$ of pure thermogenic methane. Such gases were considered pure thermogenic as the secondary cracking is the consequence of high thermal and pressure stress in the reservoir, the presence of biogenic gas is highly unlikely along with these

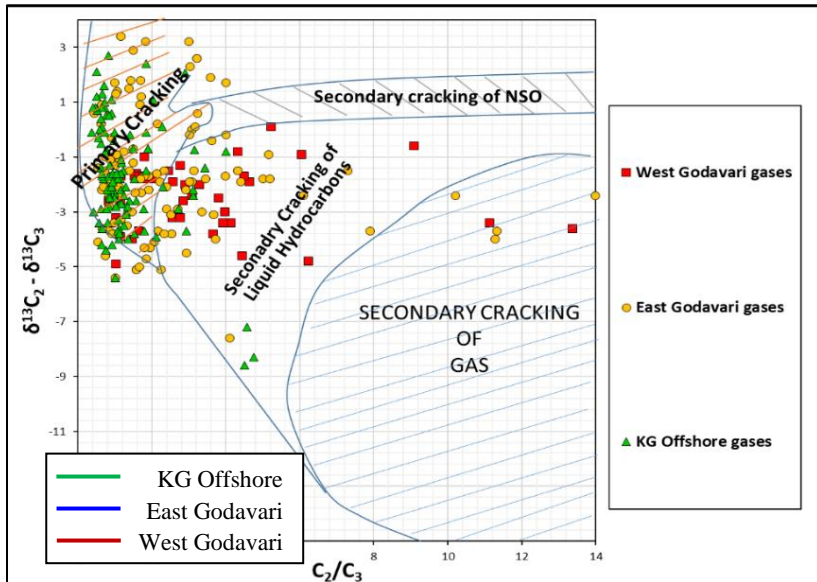


Figure 5. Cross plot by Prinzhofer et al., 2000, showing the degree of secondary cracking in KG Basin gases. The gases from West Godavari area show highest degree of secondary cracking whereas KG Offshore gases are predominantly primarily cracked

gases. Further, the gases having $\delta^{13}C_1 < -55\text{‰}$ and lacking C_2+ hydrocarbons were also considered pure biogenic as any incorporation of thermogenic gas would result in significant C_2+ hydrocarbon occurrences. The gases showing thermogenic signature but lacking C_3+ hydrocarbons were totally excluded as the 'natural gas plot' requires $\delta^{13}C$ data at least up to C_3 . In remaining gases, the $\delta^{13}C$ of ethane and heavier hydrocarbons were plotted against the inverse of C-number in respective moieties in the 'natural gas plot' for estimation of $\delta^{13}C$ of pure

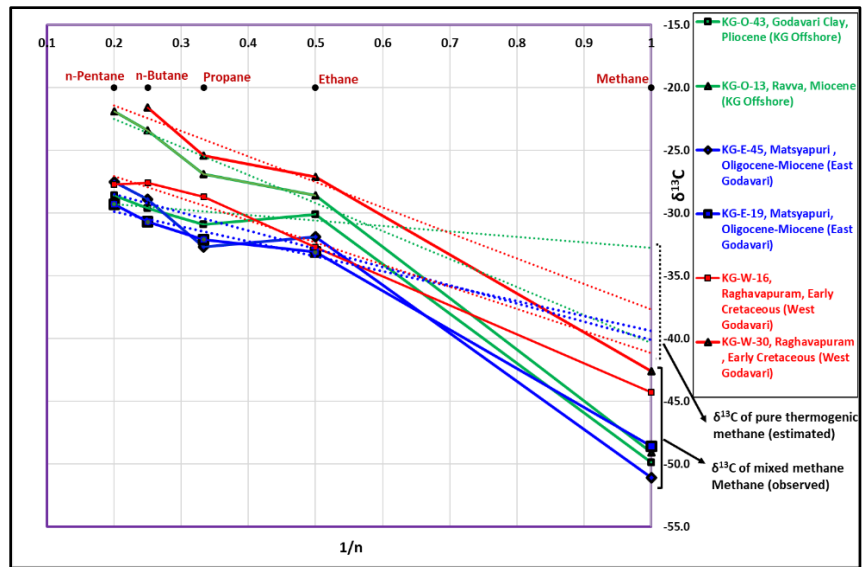


Figure 4. Some of the gases from KG Basin in 'Natural Gas Plot' for estimation of $\delta^{13}C$ of unaltered thermogenic methane

thermogenic methane component (Figure 5). The percentage biogenic gas co-existing with the thermogenic gas was calculated by incorporating $\delta^{13}C$ of pure thermogenic methane component, $\delta^{13}C$ of methane of the mixed gas obtained by the instrumental readings and the $\delta^{13}C$ of pure bacterial methane which is an average of pure bacterial gases in the area, and assumed as -70‰ .

Results and Discussions

The concise ranges of molecular and isotopic compositions, and bacterial mixing ranges in natural gases in KG Basin through different ages are placed in

S. No.	Reservoir Age/ Formation	West Godavari					East Godavari					KG Offshore				
		No. of Sampl	C ₁ (%)	C ₂₊ (%)	δ ¹³ C ₁	% Bacterial gas	No. of Samples	C ₁ (%)	C ₂₊ (%)	δ ¹³ C ₁	% Bacterial gas	No. of Samples	C ₁ (%)	C ₂₊ (%)	δ ¹³ C ₁	% Bacterial gas
1	Pliocene (Godavari Clay)	-	-	-	-	-	8	96.48 to 98.33	0.02 to 1.15	-66.3 to -59.3	54 to 100	86	66.48 to 100	0 to 24.12	-71.3 to -40.3	21 to 100
2	Miocene (Narsapur and Ravva)	-	-	-	-	-	7	53.4 to 96.3	0.07 to 31.50	-67.4 to -38	0 to 100	32	56.03 to 98.53	0 to 40.71	-69.2 to -36.7	0 to 100
3	L. Oligocene- E. Mocene (Matsyapuri)	-	-	-	-	-	25	66.9 to 98.52	0 to 26.31	-64.2 to -42.4	3 to 100	20	71.26 to 99.05	0.23 to 23.43	-62.5 to -36.6	0 to 100
4	Eocene (Vadaparru)	-	-	-	-	-	19	56.29 to 95.85	2.45 to 34.48	-49.1 to -33.2	0 to 37%	26	45.94 to 94.44	3.03 to 46.40	-47.2 to -29.9	0 to 19
5	Paleocene- E. Eocene (Pasarlapudi)	-	-	-	-	-	22	66.30 to 96.92	0 to 22.10	-43.8 to -35.9	0	1	60.62	30.07	-41.9	34
6	Paleocene (Razole, Palakollu)	2	82.7 to 93.14	2.02 to 14.28	-36.3 to -40.7	0 to 16.3	11	54.20 to 93.12	0 to 36.91	-41.9 to 34.5	0	-	-	-	-	-
7	L. Cretaceous (Tirupati, Chintalapalli)	3	71.94 to 78.88	1.58 to 22.14	-40.9 to -34.4	0 to 21.4	10	75.37 to 97.87	1.94 to 17.17	-41.3 to -32.6	0 to 18	-	-	-	-	-
8	E. Cretaceous (Raghavapuram, Gollapalli, Kanukollu, Nandigama)	42	38.53 to 93.52	0.69 to 37.31	-47.2 to -33.6	0 to 27.2	31	47.34 to 95.94	0 to 40.99	-46.3 to -29.2	0 to 26	12	54.41 to 92.92	0.03 to 38.28	-42.3 to -30.2	0 to 16%
9	Permo-Triassic (Mandapeta, Chintalapudi S.ST)	-	-	-	-	-	8	84.25 to 92.02	0 to 10.99	-32.7 to -28.5	0	-	-	-	-	-
10	Permian (Kommugudem, Rift fill sequence)	-	-	-	-	-	2	91.58 to 92.25	3.51 to 3.56	-28.2 to -27.9	0	-	-	-	-	-

. The extent of bacterial gas mixing in the entire KG Basin has been plotted as contour and colour variation maps, using “Surfer” software (Figure 6) and following observations are noteworthy:

A. West Godavari gases

All the studied gases are thermogenic in origin (δ¹³C₁ -33.6‰ to -47.2‰), and do not show substantial incorporation of bacterial methane. Though noticeable biogenic gas mixing is found in Raghavapuram (0-25%) and Kanukollu formations (0-27%), gases from wells KG-W-13 and KG-W-21 from the above formations respectively do not show any bacterial gas input. The Cretaceous gases from Chintalapalli Shale and Nandigama formations also do not show bacterial gas mixing.

The gases from Raghavapuram and Kanukollu formations show variation from primary to secondary generation processes. All the other gases show significant contribution from secondary cracking of oil. The KG-W-26 and KG-W-4 gases from Gollapalli and Nandigama formations respectively show intense secondary alterations, including secondary cracking of gas (Figure 4).

B. East Godavari gases

The East Godavari Sub-Basin shows wider variation of bacterial gas inputs (0-100%) in comparison to West Godavari Sub-Basin (

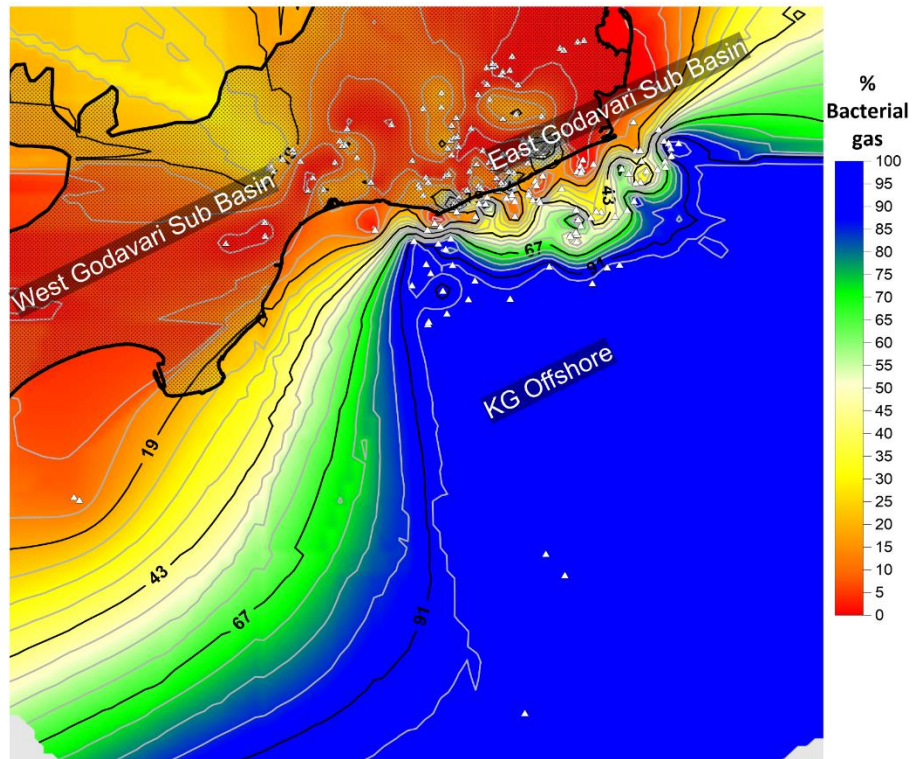


Figure 6. Lateral distribution of extent of biogenic gas mixing in entire KG basin

, Figure 6) with higher input in younger reservoirs and in general it increases with decrease in depth. The Permian and Permo-Triassic reservoir gases from Kommugudem, Chintalapudi Sandstone and Mandapeta formations show no bacterial methane with $\delta^{13}\text{C}_1$ values $> -32.7\text{‰}$. The Cretaceous reservoir gases show minor bacterial methane signatures (0-26%; $\delta^{13}\text{C}_1$: -29.2‰ to -46.3‰), out of which maximum

S. No.	Reservoir Age/ Formation	West Godavari					East Godavari					KG Offshore				
		No. of Sample	C ₁ (%)	C ₂₊ (%)	$\delta^{13}\text{C}_1$	% Bacterial gas	No. of Samples	C ₁ (%)	C ₂₊ (%)	$\delta^{13}\text{C}_1$	% Bacterial gas	No. of Samples	C ₁ (%)	C ₂₊ (%)	$\delta^{13}\text{C}_1$	% Bacterial gas
1	Pliocene (Godavari Clay)	-	-	-	-	-	8	96.48 to 98.33	0.02 to 1.15	-66.3 to -59.3	54 to 100	86	66.48 to 100	0 to 24.12	-71.3 to -40.3	21 to 100
2	Miocene (Narsapur and Ravva)	-	-	-	-	-	7	53.4 to 96.3	0.07 to 31.50	-67.4 to -38	0 to 100	32	56.03 to 98.53	0 to 40.71	-69.2 to -36.7	0 to 100
3	L. Oligocene- E. Mocene (Matsyapuri)	-	-	-	-	-	25	66.9 to 98.52	0 to 26.31	-64.2 to -42.4	3 to 100	20	71.26 to 99.05	0.23 to 23.43	-62.5 to -36.6	0 to 100
4	Eocene (Vadaparru)	-	-	-	-	-	19	56.29 to 95.85	2.45 to 34.48	-49.1 to -33.2	0 to 37%	26	45.94 to 94.44	3.03 to 46.40	-47.2 to -29.9	0 to 19
5	Paleocene- E. Eocene (Pasarlapudi)	-	-	-	-	-	22	66.30 to 96.92	0 to 22.10	-43.8 to -35.9	0	1	60.62	30.07	-41.9	34
6	Paleocene (Razole, Palakollu)	2	82.7 to 93.14	2.02 to 14.28	-36.3 to -40.7	0 to 16.3	11	54.20 to 93.12	0 to 36.91	-41.9 to 34.5	0	-	-	-	-	-
7	L. Cretaceous (Tirupati, Chintalapalli)	3	71.94 to 78.88	1.58 to 22.14	-40.9 to -34.4	0 to 21.4	10	75.37 to 97.87	1.94 to 17.17	-41.3 to -32.6	0 to 18	-	-	-	-	-
8	E. Cretaceous (Raghavapuram, Gollapalli, Kanukollu, Nandigama)	42	38.53 to 93.52	0.69 to 37.31	-47.2 to -33.6	0 to 27.2	31	47.34 to 95.94	0 to 40.99	-46.3 to -29.2	0 to 26	12	54.41 to 92.92	0.03 to 38.28	-42.3 to -30.2	0 to 16%
9	Permo-Triassic (Mandapeta, Chintalapudi S.ST)	-	-	-	-	-	8	84.25 to 92.02	0 to 10.99	-32.7 to -28.5	0	-	-	-	-	-
10	Permian (Kommugudem, Rift fill sequence)	-	-	-	-	-	2	91.58 to 92.25	3.51 to 3.56	-28.2 to -27.9	0	-	-	-	-	-

Table 1. Concise ranges of molecular and isotopic compositions and bacterial mixing ranges in natural gases in KG Basin through different ages

bacterial input is observed in Raghavapuram Formation (upto 26%) followed by Tirupati (upto 18%) and Chintalapalli formations (upto 15%). No bacterial gas input has been observed in Gollapalli reservoirs. The gases from Paleocene and Paleocene-Eocene reservoirs also do not show bacterial gas input ($\delta^{13}\text{C}_1$ -34.5 to -43.8‰). Most of the gases from Eocene pays of Vadaparru Formation ($\delta^{13}\text{C}_1$ -33.2 to -49.1‰) do not indicate bacterial gas inputs except in KG-E-21 (37%) and in KG-E-92 (25%) wells. In Late Oligocene to E. Miocene pays, the gases from Matsyapuri Formation exhibit rise in bacterial methane input from deeper (3-23%) to shallower (7-100%) depths. The $\delta^{13}\text{C}_1$ values also widely range from -42.4 to -64.2‰. Miocene gases also lack bacterial gas input, however, in wells- KG-E-34 (Narsapur Formation, $\delta^{13}\text{C}_1$ -67.4‰) and

KG-E-86 (Ravva Formation, $\delta^{13}\text{C}_1$ -50.2‰), the bacterial gas input is 100% and 34% respectively. The Pliocene gases from Godavari Clay Formation show the highest bacterial gas input among all (~100%, $\delta^{13}\text{C}_1$ -58‰ to 66.1‰).

The East Godavari gases are mainly generated through primary cracking of kerogen but secondary

S. No.	Reservoir Age/ Formation	West Godavari					East Godavari					KG Offshore				
		No. of Sample	C ₁ (%)	C ₂₊ (%)	$\delta^{13}\text{C}_1$	% Bacterial gas	No. of Samples	C ₁ (%)	C ₂₊ (%)	$\delta^{13}\text{C}_1$	% Bacterial gas	No. of Samples	C ₁ (%)	C ₂₊ (%)	$\delta^{13}\text{C}_1$	% Bacterial gas
1	Pliocene (Godavari Clay)	-	-	-	-	-	8	96.48 to 98.33	0.02 to 1.15	-66.3 to -59.3	54 to 100	86	66.48 to 100	0 to 24.12	-71.3 to -40.3	21 to 100
2	Miocene (Narsapur and Ravva)	-	-	-	-	-	7	53.4 to 96.3	0.07 to 31.50	-67.4 to -38	0 to 100	32	56.03 to 98.53	0 to 40.71	-69.2 to -36.7	0 to 100
3	L. Oligocene- E. Mocene (Matsyapuri)	-	-	-	-	-	25	66.9 to 98.52	0 to 26.31	-64.2 to -42.4	3 to 100	20	71.26 to 99.05	0.23 to 23.43	-62.5 to -36.6	0 to 100
4	Eocene (Vadaparru)	-	-	-	-	-	19	56.29 to 95.85	2.45 to 34.48	-49.1 to -33.2	0 to 37%	26	45.94 to 94.44	3.03 to 46.40	-47.2 to -29.9	0 to 19
5	Paleocene- E. Eocene (Pasarlapudi)	-	-	-	-	-	22	66.30 to 96.92	0 to 22.10	-43.8 to -35.9	0	1	60.62	30.07	-41.9	34
6	Paleocene (Razole, Palakollu)	2	82.7 to 93.14	2.02 to 14.28	-36.3 to -40.7	0 to 16.3	11	54.20 to 93.12	0 to 36.91	-41.9 to 34.5	0	-	-	-	-	-
7	L. Cretaceous (Tirupati, Chintalapalli)	3	71.94 to 78.88	1.58 to 22.14	-40.9 to -34.4	0 to 21.4	10	75.37 to 97.87	1.94 to 17.17	-41.3 to -32.6	0 to 18	-	-	-	-	-
8	E. Cretaceous (Raghavapuram, Gollapalli, Kanukollu, Nandigama)	42	38.53 to 93.52	0.69 to 37.31	-47.2 to -33.6	0 to 27.2	31	47.34 to 95.94	0 to 40.99	-46.3 to -29.2	0 to 26	12	54.41 to 92.92	0.03 to 38.28	-42.3 to -30.2	0 to 16%
9	Permo-Triassic (Mandapeta, Chintalapudi S.ST)	-	-	-	-	-	8	84.25 to 92.02	0 to 10.99	-32.7 to -28.5	0	-	-	-	-	-
10	Permian (Kommugudem, Rift fill sequence)	-	-	-	-	-	2	91.58 to 92.25	3.51 to 3.56	-28.2 to -27.9	0	-	-	-	-	-

cracking of oil and gas is also evident in some instances. The Early Cretaceous gases show mild degree of secondary cracking while Early Cretaceous, Permo-Triassic and Permian gases show mild to severe secondary cracking.

C. KG Offshore gases

The gases reservoired in Early Cretaceous (Gollapalli Formation) and Eocene (Vadaparru Formation) are thermogenic in nature ($\delta^{13}\text{C}_1$ -30.2‰ to -47.2‰) with minor inputs of bacterial methane (0-19%). The gas from well KG-O-18 (Late Paleocene) indicates slightly higher bacterial gas input (34%). Gases at Oligocene-Miocene boundary (Matsyapuri Formation) also exhibit limited bacterial gas mixing (0-24%), except in well KG-O-38, which is of bacterial in nature ($\delta^{13}\text{C}_1$ -58.8‰). On the other hand, Miocene gases from Ravva Formation are diversified from pure thermogenic to pure bacterial in nature and bacterial gas input ranges

from 0-100%. The Pliocene gases from Godavari Clay Formation also range from mixed to bacterial origin ($\delta^{13}\text{C}_1$ -40.3‰ to -71.3‰) and show richest concentration of bacterial methane among all studied gases (28-100%) (Figure 6). Almost all thermogenic gases are generated through primary cracking pathway except few gases of Godavari Clay (KG-O-60, KG-O-77 and KG-O-78) and Gollapalli Formations (KG-O-87), which show secondary cracking of oil (Figure 4).

Conclusions

- West Godavari gases do not show any significant incorporation of bacterial methane. The noticeable bacterial gas input is in Raghavapuram (0-25%) and in Kanukollu reservoirs only (0-27%). The Early Cretaceous and deeper pays show significant secondary cracking.
- East Godavari gases show wider variation of bacterial gas inputs (0-100%), which is absent in Permian and Permo-Triassic reservoir gases and significantly increases from Cretaceous (0-26%) to Pliocene pays (54-100%). Gases of Paleocene to Eocene sands lack biogenic input except in wells KG-E-23 (37%) and in KG-E-92. East Godavari gases are predominantly primarily generated gases in catagenetic stage. Secondary cracking is mild in Early Cretaceous and mild to severe in Early Cretaceous and deeper pay zones.
- In KG Offshore, gases from Early Cretaceous to Early Miocene sands exhibit minor input of bacterial mixing except well KG-O-38 (Oligocene-Miocene) which is purely bacterial in nature ($\delta^{13}\text{C}_1$ -58.8‰). The Miocene gases show diversified bacterial methane inputs ranging from 0 to 100%. The Pliocene gases are mixed to bacterial in origin and show richest concentration of bacterial methane among all studied gases of the sub basin (21-100%). Almost all KG Offshore gases are generated through primary cracking of Kerogen.
- The generation of bacterial gas at deeper formations is unlikely. However, presence of noticeable amount of bacterial gas inputs in Cretaceous age in the entire KG Basin indicate that diagenetic gases may have been preserved due to rapid sedimentation and seal formation, followed by generation of catagenetic gases.

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The views expressed in the paper are those of the authors and not necessarily of the organization in which they are working.

SESSION TITLE: Theme 1: Source-to-Sink

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Integrated Source-to-Sink assessment of the Argentinean South Atlantic Margin

AUTHORS (FIRST NAME, LAST NAME): Juan Pablo Lovecchio¹, Emilio A. Rojas Vera¹, Ofelia Silio², Federico Spath³, Sebastian Arismendi⁴, Sébastien Rohais⁵, Sofia Konig⁶, Nestor Darwin Bolatti⁷

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: The Argentinean South Atlantic Margin remains a frontier area with huge exploration potential for deep and ultra-deepwater exploration. The Salado, Colorado and Rawson-Valdes basin segments have attracted industry attention following a successful bidding round in 2019. The study area experienced multi-stage rifting throughout the Mesozoic and the opening of the South Atlantic Ocean in the Early Cretaceous. The first post-break marine transgression is believed to be responsible of source rock deposition, while the successive development of a continental shelf/slope system in the Cretaceous hosts various reservoir and seal units that are the main targets for exploration. Prediction of petroleum system elements presence and distribution is key to constrain the main uncertainties of the margin (source presence and richness, reservoir distribution and quality). To approach these objectives, we have carried out an innovative workflow based on three phases: 1. Characterization, 2. Modelling and 3. Uncertainties.

In the Characterization phase we assessed the evolution of main tectonic blocks that worked as sediment sources coupled with the evolution of the sinks (offshore basins). We built robust regional databases by compiling lithological, geochronological, and thermochronological data. We produced Quartz fertility maps for the different source areas from lithological data. The exhumation history of both proximal (coastal) and distal source areas (Andes) were constrained with thermochronological modeling.

In the sinks, we used regional structural maps (interpreted from seismic data) to produce isopach maps showing the sediment distribution. We also integrated biostratigraphic, sedimentary, seismic and non-seismic data into several regional paleogeographic (paleobathymetry) and GDE (Gross Depositional Environments) maps. To fully assess the sediment routing systems, the connections between independent depocenters were approached with gravimetric data and regional cross-sections were built.

This Characterization phase produced all the input data necessary to feed forward stratigraphic modeling in the next phase, that will be carried out in two independent stages: Aptian source rock modeling, and Cretaceous/Cenozoic stratigraphic modeling of reservoir and seal systems. Uncertainty analysis will finally be carried out to test several geological scenarios as well as to explore the entire range of controlling factors on play identification.

SESSION TITLE: Theme 1: Source-to-Sink

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Provenance of the Springhill Formation in the Austral/Magallanes and Malvinas basins from detrital zircon geochronology

AUTHORS (FIRST NAME, LAST NAME): Juan Pablo Lovecchio¹, Maximiliano Naipauer²

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: The Austral/Magallanes and Malvinas basins, located at the southern end of the South American continent, limit to the west with the Andean volcanic arc, to the east with the Malvinas (Falkland) islands, and are separated by the Rio Chico High. These basins originated in the Mesozoic and are associated with a generalized rifting episode that affected Patagonia in the Early-Mid Jurassic characterized by profuse volcanism (Chon Aike Magmatic Province, Tobifera Series). Since the Late Jurassic-Early Cretaceous, these basins went into a sag phase, with the onset of deposition of the Springhill Formation (main reservoir across the study area).

This study integrates U-Pb radiometric dating on detrital zircons recovered from twelve drilling cuttings and core samples, obtained from oil exploration wells from both basins. The objective was to determine maximum deposition ages, and to characterize sediment provenance in order to understand the participation of different sediment source areas in the contemporaneous volcanic arc, Rio Chico High/Deseado Massif, Malvinas (Falkland) islands and other possible source regions.

The external morphology analysis of the detrital zircons highlighted differences between both basins. Idiomorphic and prismatic zircons (of volcanic origin) predominate in the Austral/Magallanes basin, while in Malvinas rounded and sub-rounded zircons are more common and were related to a larger degree of reworking and a different source.

Regarding provenance, the histogram patterns of U-Pb ages for the Springhill Formation in the Malvinas basin shows dominance of Mesoproterozoic and Neoproterozoic-Cambrian sources related to the Deseado Massif and Rio Chico High. In the Austral/Magallanes basin Neoproterozoic-Cambrian zircons dominate while Mesoproterozoic zircons are absent, which was interpreted as produced by a more local source in Tierra del Fuego. Jurassic Chon Aike sources are present in both sets, as Springhill Formation regionally overlies Tobifera Series (synrift volcanism). However Andean volcanic arc-related zircons, contemporaneous with Springhill deposition, are very scarce. Therefore, it was not possible to determine maximum deposition ages for the Springhill Formation with stratigraphic value.

SESSION TITLE: Theme 1: Source-to-Sink

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Source-To-Sink: Tectonic Forcing and Catchment Evolution in the southern Caribbean Basin. Stratigraphic Forward Modeling, Sandstone Porosity, and Compositional Uncertainty

AUTHORS (FIRST NAME, LAST NAME): Luz Marina Duarte¹, Eduardo Lopez-Ramos², Fredy Cañon³, John Londoño⁴, Brad Prather⁵

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: Source-To-Sink: Tectonic Forcing and Catchment Evolution in the southern Caribbean Basin. Stratigraphic Forward Modeling, Sandstone Porosity, and Compositional Uncertainty

Luz Marina Duarte, Eduardo López, Cañon Freddy, Londoño John, Ecopetrol S.A., Bradford E. Prather, Kansas University

The source-to-sink concept is best implemented through stratigraphic forward modeling (SFM), particularly when only a handful of key questions are addressed. In the Colombia Basin, quantification of reservoir presence risk, and porosity & permeability uncertainty, are critical to assessing the potential of this frontier exploration area. Two key outstanding questions need to be considered: 1) ¿What is the chance of sandstone presence along with the distal Magdalena Fan, and what is its composition? 2) ¿What is the likely contribution from the various onshore catchment areas and feeders to the basin floor fans and their impact on porosity/permeability uncertainties?

The SFM incorporates a tectonic model that includes an autochthonous, but heterogeneous and hyper-extended Caribbean Plate, as well as a mass balance analysis of sediment yield from paleo catchment areas of the Magdalena and Cauca Rivers, in addition to the input of some coastal - rivers of the Guajira Peninsula during the last 7 million years. Provenance analysis was constrained by sediment yield and flux models along with the catchment areas.

Additionally, the sensitivity of the model to physiography-slope changes was tested when the convergence of the Caribbean Plate and the resulting uplift of the Southern Caribbean Deformed Belt were considered with regards to their impact on sediment routing.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Characterization of Severe Biodegradation in Crude Oils Using High Resolution Geochemistry

AUTHORS (FIRST NAME, LAST NAME): Miguel Jimenez¹, Jorge Armando Orrego-Ruiz², Fernando Andres Rojas-Ruiz³, Hui Pu⁴

INSTITUTIONS (ALL):

1. University of North Dakota - Ecopetrol S.A.
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4. University of North Dakota

ABSTRACT BODY:

Abstract Summary: Biodegradation reduce dramatically the quality of hydrocarbons after its accumulation in reservoirs. Traditional geochemical techniques do not favor the understanding of this phenomenon, especially when its action is severe, since most conventional tracers are reduced or disappear due to the effect of microorganisms on the oil's light fraction.

A new approach to biodegradation analysis using oxygen species, measured by high resolution mass spectrometry, (-)ESI FT-ICR-MS were completed in twenty samples from six different fields into the Nare production area, located at the western flank of the Middle Magdalena Valley, Colombia, in order to extend the application of petroleomics in the geochemical characterization of heavy crude oils.

All the samples show null values in the DBE 4 of O1 class, a strong indicator of highly biodegraded crude oils because phenolic and/or benzylic compounds with DBE 4 are more easily degraded by microorganisms. On the contrary, DBE 5 to 7 show values between 0,11 to 0,65, which indicates that these persist in the O1 species of highly degraded oils. These compounds, may corresponding to phenols with naphthenic rings, are more resistant to biodegradation according to the results of previous works (e.g., Lepik and Tenno, 2012; Pradeep et al., 2015; Martins et al., 2017; Oldenburg et al., 2017).

Supported in the previous observation, a new parameter is proposed that use the class of heteroatoms O1 to evaluate the biodegradation in highly altered oils; that is, an alternative monoaromatic index (AMA), calculated by the ratio DBE 5 over DBE 7. This new index complements the approaches that other authors have developed with similar indexes to evaluate crude oils with a light to medium levels of biodegradation.

Like AMA, the ratio O1 over O2 decreases with biodegradation, since O1 is mainly linked to paleoenvironmental conditions related to the genetics of crude oil and source rocks, and the content of O2 increases principally in the hydrocarbons as an effect of post-accumulation biological activity. Using this new index, it is possible to verify differential biodegradation (from lower to higher intensity) even within a set of severely altered samples. In this case, the samples from the Moriche and Nare Sur fields show severe type I alteration, those from the Jazmin, Girasol fields and some from the Abarco field have severe Type II alteration and most of the samples from the Abarco and Underriver fields have severe Type III alteration.

SESSION TITLE: Theme 1: Source-to-Sink

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Provenance reconstruction case study for the Guyana-Suriname Basins – new insights

AUTHORS (FIRST NAME, LAST NAME): Pieter van Heiningen¹, Nuretdin Kaymakci²

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: Despite the recent exploration successes in the Guyana and Suriname offshore, there is still a need to reduce the exploration risk. Key is to improve the understanding of clastic reservoir presence- and quality spatio-temporal evolution. This is achieved by provenance reconstruction (source-to-sink analysis).

The present-day drainage demonstrates short river networks for the Suriname and Guyanan margins whereas the Brazilian margin benefits from one of the largest drainages on Earth, that of the Amazon River. A first glance at the coastal region of northeast South America gives the impression of a stable configuration of drainage which is considered to have existed since the opening of the South Atlantic. Our study demonstrates that this is a not justified by any observation.

Our detailed and integrated analyses include river networks and related drainage characteristics, morphotectonics, supported by gravity and magnetic interpretation as well as a thorough denudation analysis of entire northern South America, including the Andean Cordilleras. A complex history of drainage evolution is revealed on the Suriname and Guyana hinterland since the opening of the South Atlantic. Unravelling the capture and beheading of drainage basins of the Orinoco-Amazon-Parana River networks besides our new insight in the exact time and location of the final Andean closure are key ingredients. This leads to an improved understanding of erosion in the provenance and sediment composition within the basins.

In this contribution we present the spatio-temporal evolution of sediment sources and constrain the composition and quality of clastic reservoirs in the Suriname and Guyana basins in selected key time intervals as a tool to reduce the exploration risk.

SESSION TITLE: Theme 3: Colombia Deepwater Hydrocarbon Potential

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Tracking a Late Cretaceous-sourced petroleum system in the offshore Sinu belt, the Magdalena fan, and the offshore Guajira of the Caribbean margin of Colombia

AUTHORS (FIRST NAME, LAST NAME): Juan Pablo Ramos¹, Paul Mann²

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: Exploration of the Caribbean margin of Colombia over the past decade have shown the presence of a thermogenic petroleum system based on piston core and gas samples recovered from exploratory wells. In this study, we integrate 2D seismic data, high-resolution bathymetry and published well information to better understand the potential source rocks, reservoirs, and seals and that may extend the play fairway of this petroleum system into deeper water areas of the Colombian maritime zone. The key source rock for the region is a Late Cretaceous, organic-rich limestone found both in an undeformed state covering large areas of the subducting Caribbean Large Igneous Province (CLIP) and in folded and thrust state as part of the submarine accretionary prism of the overriding South American plate. These accreted rocks are known as the South Caribbean Deformed Belt (SCDB) and North Panama Deformed Belt (NPDB) in a deepwater settings and as the Sinu-San Jacinto belt in the subaerial, coastal setting of northern Colombia. Basin modeling in the Venezuela basin has shown that this Late Cretaceous source rock is locally mature at depth along the deeply buried but active trench axis of the SCDB. We review seismic reflection and well data along with previous natural seep and geochemical studies and direct hydrocarbon indicators to better constrain the location and thickness of the source rocks, carrier beds, reservoirs, and structural and stratigraphic traps from both the deformed accreted belts of the overriding plates and the undeformed and subducting Caribbean plate. A key element for maturation is the 68,000 km² Magdalena fan that provides a 10-km-thick overburden and extends the maturity zone of the subducting Late Cretaceous source rocks further north into the Colombia basin.

SESSION TITLE: Theme 2: Tectonics

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: A New Interpretation of the Formation of the Gulf of Guayaquil and Its Impact on the Configuration of the NW Peru Basins.

AUTHORS (FIRST NAME, LAST NAME): Daniel Flores¹

INSTITUTIONS (ALL):

1. Consultant

ABSTRACT BODY:

Abstract Summary: Active margins are subjected to stresses that do not always act homogeneously along the deformation fronts. Likewise, the mechanical analysis of the surface expressions of these deformations is not always analyzed from tangible evidence such as the zone of influence of the volcanic arc or the corresponding island arc, to name a few. One of these features is the Gulf of Guayaquil, which was studied and analyzed based on establishing its genetic relationship with the Dolores-Guayaquil Megashear. Due to the dimensions of the gulf, the displacement (pull-apart) that produced this great depression should have generated large dislocations or associated folds which are not reflected either on the surface or in conspicuous stratigraphic changes in seismic sections or in sections built with wells. Thus, a model is proposed that, although it coincides with that of Mega-Shear in some aspects, better explains other aspects such as onshore inverse faults, block rotations, variations in the direction of main stresses, among others. This model proposes an evolution and opening of the gulf which begins as an underwater canyon originated by transtensive stresses on the slope transmitted in turn by a "transtensive" subduction of the oceanic crust. One of the conclusions reached is that the variation in the direction of subduction along the active margin in addition to the angle of subduction of the benioff plane are the product of a differentiated acceleration of the subduction between the parallels 10 ° N and 5 ° S. Finally, the influence and impacts of this configuration on the formation of active petroleum systems in this region are discussed.

SESSION TITLE: Theme 2: Tectonics

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: A New Deformable Plate Model for the Nova Scotia-Morocco Conjugate Margin and its Implication for the Opening of the Central Atlantic.

AUTHORS (FIRST NAME, LAST NAME): Richard C. Whittaker¹, Bridget E. Ady²

INSTITUTIONS (ALL):

1. Global Tectonics Ltd.
2. Global Tectonics Ltd.

ABSTRACT BODY:

Abstract Summary: The separation of Northwest Africa from North America during the breakup of Pangea and initial seafloor spreading in the Central Atlantic took place in the Jurassic Magnetic Quiet Zone (JMQZ), well before the earliest identifiable Mesozoic magnetic chron in the Late Jurassic (M25 at 156 Ma). As a result the timing of the onset of rifting, hyperextension, breakup, and early seafloor spreading, as well as the direction and mechanism of separation have been the subject of much debate.

We present a new deformable plate kinematic model for the early opening of the Central Atlantic that utilizes a new interpretation of the continent-ocean boundary, integrates existing geological data with a key new seismic reflection survey and recent biostratigraphic data from a deep-water exploration well from the Moroccan margin, and is consistent with global plate kinematics. The deformable plate kinematic method employed quantifies the timing, amount and direction of Mesozoic rifting and hyper-extension and its relationship to salt deposition; Cenozoic compression related to the Atlas Fold Belt; and deformation related to strike-slip motion along the Newfoundland-Azores fracture zone. The modelling method is particularly effective for restoring hyperextended margins through time to their pre-rift configuration. It also provides numerical input into tectonic subsidence and flexural uplift modelling for paleogeographic studies.

The new plate model identifies the presence of a more or less symmetrical (approximately 150 km wide) faulted proto-oceanic crust from the Blake Spur to the Grand Banks and sheds light on some of the more enigmatic features of the Central Atlantic such as the age of breakup and the nature of the transition from magma-rich to magma-poor in the northern part of the conjugate margins. The model serves as a tectonic framework with which to examine the influence of structural inheritance, restore basin palaeogeometry through time, and determine marine connectivity to the Tethyan oceans. Our modelling reveals the potential for an exciting new deep water Jurassic petroleum play overlying the faulted proto-oceanic crust of the Central Atlantic conjugate margins, which we will discuss.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Physics embedded machine learning for producer to injector conversion optimization in a mature waterflood.

AUTHORS (FIRST NAME, LAST NAME): Javad Rafiee², Carlos Mario Calad Serrano¹, Pallav Sarma³, Sebastian Plotno⁴, Fernando Gutierrez⁵

INSTITUTIONS (ALL):

1. Tachyus
2. Tachyus
3. Tachyus
4. Tachyus
5. Tachyus

ABSTRACT BODY:

Abstract Summary: Objectives/Scope A viable option for development of old fields is conversion of producers with low oil production rates and high water cuts to injectors. This will avoid the cost of drilling new injection wells for enhancing the recovery of oil. In this paper, a workflow for finding the best candidate production wells for conversion to injectors is proposed to maximize the production of the field.

The workflow utilizes a history-matched Data Physics model as the forward model in two steps of optimization performed using cloud-computing resources to reduce the wall-clock of the overall process. The Data Physics model is the amalgamation of the state-of-the-art in machine learning and reservoir physics into a seamless full field model. In the first step, the production wells are ranked based on the increase in the cumulative production as they are converted to injectors. The injection rates of the top candidates for conversion along with existing injectors are then optimized in a multi-objective optimization (MOO) problem using a cloud-distributed evolutionary algorithm to maximize the long and short-term productions and minimize the injection capacity.

Results, Observations, Conclusions The workflow is utilized for a real field where optimization of the current injectors did not yield a noticeable increase in production as the injected water from existing injectors was being produced. In the first step, we found that the top 10 candidates for conversion increase production by up to 30% which shows a huge potential for improvement. The results of rate optimization shows that there is more potential for enhancing the production by redistribution of current injection capacity to have more injection in the newly converted injectors that can yield more than 10% additional increase in production. The resulting pareto-front shows that it is possible to decrease the injection capacity while achieving production increase.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Seismic attributes and machine learning techniques for identification and characterization of carbonate seismic facies of the Barra Velha Formation, in the Wildcat Prospect, Santos Basin

AUTHORS (FIRST NAME, LAST NAME): Raísa Carvalho Silva¹, Maria González², Wagner Lupinacci³

INSTITUTIONS (ALL):

1. Emerson
2. Emerson
3. Universidade Federal Fluminense

ABSTRACT BODY:

Abstract Summary: Machine learning techniques have been applied to seismic interpretation to help identify seismic patterns, which are difficult to map, especially, in new discoveries and large volumes of seismic data. This work aims to apply a methodology for identification and characterization of carbonates facies in the Barra Velha Formation, on the Wildcat Prospect in the Santos Basin, from seismic attributes and a non-supervised facies classification. The machine learning method used is the Self-Growing Neural Network (SGNN). In our workflow, we performed the following steps: (i) carbonate seismic patterns identification through seismic amplitude, where was possible to identify the build-up facies, characterized by chaotic seismic textures with a conical external geometry and internal fracturing; debris facies, exhibit prograde geometry with chaotic internal texture; carbonate platform facies showing a well-defined flat parallel reflectors; and the bottom lake facies, that does not have specific geometry and internally the reflectors are chaotic; (ii) seismic attributes generation and analysis of seismic patterns, the chosen attributes were eigen coherence, dip steered enhancement, relief and relative acoustic impedance. (iii) Then, we performed a principal component analysis (PCA), with seismic amplitude filtered from dip steering enhancement (DSE), eigen coherence and relief as inputs, and (iv) Finally, we carried out the classification using the seismic attributes and PCA results. It was possible to differentiate between the carbonate platform from fractured areas, especially those related to the build-ups. This is important for field development, as in the study area, build-ups represent the best reservoirs. Even from the PCA, which helps in a better clustering, one of the difficulties encountered has been to differentiate the build-ups from the debris facies. To overcome this challenge, other seismic attributes are being evaluated. Finally, our results help in a better tectono-stratigraphic understanding of an important prospect in the Santos Basin, which is the most important basin in hydrocarbon production in Brazil, accounting for more than 70% of all production in the country.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Applying data mining techniques for the estimation of the CO₂ storage capacity of the Irati Formation, Paraná Basin (Brazil)

AUTHORS (FIRST NAME, LAST NAME): Stephanie San Martín Cañas¹, Nathália Weber², Haline De Vasconcellos Rocha³, Richardson-M Abraham-A⁴, Colombo Celso Gaeta Tassinari⁵

INSTITUTIONS (ALL):

1. Institute of Energy and Environment - University of São Paulo / Research Centre for Greenhouse Gas Innovation (RCGI)
2. Polytechnic School of University of São Paulo / Research Centre for Greenhouse Gas Innovation (RCGI)
3. Institute of Energy and Environment - University of São Paulo / Research Centre for Greenhouse Gas Innovation (RCGI)
4. Institute of Energy and Environment - University of São Paulo / Research Centre for Greenhouse Gas Innovation (RCGI)
5. University of São Paulo (USP)

ABSTRACT BODY:

Abstract Summary: Techniques involving Data Science and Artificial Intelligence are important to address the difficulties related to proper data integration during oil and gas exploration activities in new frontier basins with insufficient data. Therefore, this study constructs a data-driven methodology to predict the most suitable areas for the co-development of shale gas and CO₂ geological storage in the Paraná Basin and to estimate the theoretical CO₂ storage capacity of the Irati Formation. The proposed methodology involves a set of data mining techniques combined with Inverse Distance Weighting (IDW) interpolations while using organic geochemical parameters and well information as inputs. The workflow consists of six stages: data collection, data understanding, data cleaning, data preparation, data mining, and spatial data analysis. The above-stated processes aided to describe the quality and content of the datasets, put the data in the required formats, correct missing data issues, select the final working datasets, define the analytical variables, implement ad-hoc classification tests, and apply machine learning algorithms such as K-means, K-Nearest Neighbor, and Support Vector Machine. The approach also assisted the IDW interpolations and geo-reference of the machine learning predictions for the final assembly of the prospect maps of the Irati Formation based on shale gas and CO₂ geological storage potential. The results show that data-driven methodologies can effectively eliminate issues related to short budgets by reducing the time to complete geological evaluations and entire research projects in new frontier basins. The ad-hoc classification testing presents preliminary but valuable insights into the source rock potential within the Irati Formation. The machine learning algorithms with the best performance based on the research focus were K-means and Support Vector Machine. The study identifies areas that comply with the technical and environmental requirements for the co-development of shale gas and CO₂ geological storage in the State of São Paulo, Brazil. It presents an average capacity of 4.34 GtCO₂ for the area suitable for the combined shale gas production and CO₂ geological storage perspective and another of 2.69 GtCO₂ for the area recommendable for CO₂ geological storage.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Interactively Predicting Faults Using a 2D CNN and a Base Solution generated by a 3D CNN

AUTHORS (FIRST NAME, LAST NAME): Samuel Chambers¹, Jesse Lomask²

INSTITUTIONS (ALL):

1. IHS Markit

2. IHS Markit

ABSTRACT BODY:

Abstract Summary: Fault detection is an important part of interpretation of seismic images and has been a focus of machine learning in seismic data. Since, at its base, fault labeling is pattern recognition, it is perfect for machine learning. However, because of the variety within seismic data, from sampling, to noise, and general geological differences that occur in the subsurface, creating a well-defined and robust training data set is difficult. The proposed implementation utilizes an established 3D solution as a starting point and then allows for additional input from a user's hand drawn faults to further increase the accuracy and allow for a customizable output of fault attributes.

The utilization of the 3D solution as an intermediary step provides a few benefits. First, it allows the 2D model to capture information that could have been missed by the 2D model alone. Second, it allows the model to become robust to the differences between seismic datasets. Third, it reduces the number of necessary labels from a user for the final training and prediction. The final step of correcting false positives and false negatives on the images is done on a small set of inline or crossline slices and allows for the user to control what kinds of faults are output. The utilization of a 2D CNN has computational benefits in that training and prediction times are drastically decreased allowing a user to train the model as well as predict. Using both solutions together allows for a customizable, and highly accurate output that still acquires the information of a 3D solution.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Computer vision applied to the detection of drilling cavings in a laboratory setting

AUTHORS (FIRST NAME, LAST NAME): Cesar Eduardo Herrera Quintero¹, Helver Alvarez Crispiniano², Hernán Darío Mantilla Hernández³, Carlos Eduardo López Suarez⁴, Oscar Danilo Olejua Santos⁵, Hans Yesid Garcia Arenas⁷, Reinel Corzo Rueda⁶

INSTITUTIONS (ALL):

1. Universidad Industrial de Santander
2. ACIV
3. Ecopetrol
4. Trilobyte
5. Trilobyte
6. Ecopetrol
7. UIS

ABSTRACT BODY:

Abstract Summary: Computer vision applied to the detection of drilling cavings in a laboratory setting Geomechanical stability problems in the Oil & Gas industry in the well drilling process constitute one of the most complex challenges. Related to the impact of stability problems with non-productive times (NPT) and consequently in the final cost of drilling projects. The observation and analysis of surface information in real time such as drilling cuttings and cavings allows the identification of well instability by anticipating costly incidents and clogged pipes, additionally these studies can be complemented with data from MWD (Measure While Driller): Drilling parameters, LWD (Measure While Logging): Gamma Ray, Resistive, Sonic, Caliper well logs. These situations lead to the importance of using a system that performs analysis in real time and automates the process, focusing this technology on providing an artificial vision system that uses computer vision and algorithms to: detect, classify and estimate the volume of Cavings in a Laboratory scenario in real time, using a Shale Shaker with Cavings washing and drying system, as infrastructure. The methodology included design, construction, programming and development in the stages of: 1) Hardware, 2) Software, 3) Data capture, 4) Data labeling, 5) Training of models and algorithms, 6) Validation. The system uses: RGB camera with depth sensor (Depth) located perpendicular to the cavings conveyor belt for data capture, Computing equipment with GPU for: transmission, processing, inference and visualization. The results obtained in the tests show a success rate greater than 95% in detecting Cavings in a dynamic way and 99% in a static way or low speed of the belt. In synthesis with these results, the technology can be adjusted to be applied at an industrial level or external to the laboratory in the identification and detection of cavings in order to evaluate the stability of wells drilled in real time, allowing to generate alarms in the increase of Cavings and decision making with greater agility.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Development of a Global Reservoir Recovery Factor Predictive Model Combining a Novel Machine Learning Technique and Reservoir Complexity Index

AUTHORS (FIRST NAME, LAST NAME): Camilo Rodriguez¹, Hamed Tabatabaie², Ivan Olea³, Tabata Funke⁴

INSTITUTIONS (ALL):

1. IHS Markit
2. IHS Markit
3. IHS Markit
4. IHS Markit

ABSTRACT BODY:

Abstract Summary: With the increased popularity and success of machine-learning (ML) techniques, there is continued interest in developing new tools. In this work, we use ML techniques to identify reservoir engineering, geological, and development features that influence the ultimate recovery factor in a group of fields, and in turn develop a model that provides the relationship between recovery factor (RF) and these influencing features. Furthermore, we use techniques that allow for the opening of the “black-box model” to decipher the relationship between the model output and the individual features.

We collected the field data from IHS Markit international database (EDIN), which includes more than 76,000 reservoirs from around the globe. From this number of reservoirs, we focused on oil fields only, and those with a higher ranked recovery factor in terms of confidence level, leaving us with a population of 18,719 global oil reservoirs. This number is considerably high as all of the previous studies we researched on predicting recovery factor in reservoirs exceeded even 1000 reservoirs for their analysis, and all were targeting specific geographical regions.

With this large number of samples, sophisticated machine learning algorithms can be used to predict recovery factor. Hundreds of reservoir features were initially considered. With a combination of subject matter expert knowledge and statistical techniques for multicollinearity analysis and variable reduction, we selected about 50 features for the predictive model. Using XGBoost, many models were systematically built using different combinations of features and their SHAP scores were calculated. This allowed for the investigation of feature importance and their contribution to the prediction of the RCI for each reservoir. As a result, we found that 6 features can reasonably capture the multivariate relationships that impact RCI and the oil recovery factor. The model exhibited an accuracy of $\pm 5\%$ for 50% of the test data (between P25 and P75) and $\pm 10\%$ for 80% of the test data (between P10 and P90). While this work falls within a growing category of similar work, its novelty is in demonstrating the strength of XGBOOST in modeling, and of SHAP in deciphering the inner dynamics of the model. The resultant recovery factor predictive model can then be used to compare the performance of existing fields against analogs by just inputting the 6 critical variables identified in the methodology.

SESSION TITLE: Theme 5: Application of New technologies in Unconventional Resources

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Evaluating the Effect of Reservoir Quality on Stage-by-Stage Forecasted Production along Multi Fractured Horizontal Wells: A Case Study from the Montney Formation, Canada

AUTHORS (FIRST NAME, LAST NAME): Daniela Becerra¹, Christopher Clarkson², Amin Ghanizadeh³, Rafael Pires de Lima⁴, Farshad Tabasinejad⁵, Zhenzihao Zhang⁶, Ajesh Trivedi⁷, Roman Shor⁸

INSTITUTIONS (ALL):

1. University of Calgary
2. University of Calgary
3. University of Calgary
4. Geological Survey of Brazil
5. University of Calgary
6. University of Calgary
7. University of Calgary
8. University of Calgary

ABSTRACT BODY:

Abstract Summary: The current industry practice for exploiting unconventional reservoirs is to drill long horizontal wells and hydraulically fracture the lateral section in multiple, evenly-spaced stages. While this practice has resulted in the commercial exploitation of these resources, it ignores the intrinsic vertical and horizontal heterogeneity of unconventional reservoirs, sometimes resulting in uneven production from fracture stages. An alternative approach is to selectively complete intervals with similar and superior reservoir quality (RQ) and completion quality (CQ). In this study, along-well reservoir characterization is performed using data from a horizontal well completed in the Montney Formation in western Canada. Log-derived petrophysical and geomechanical properties, a drilling-derived Mechanical Specific Energy (MSE) log, and laboratory analyses performed on drill cuttings are integrated to evaluate RQ and CQ variability along the well. Based on the observed heterogeneity in reservoir properties, the lateral length of the well was subdivided into nine segments. Superior RQ and CQ intervals were found to be associated with predominantly (massive) porous siltstone facies; these intervals are regarded as the primary targets for stimulation. In contrast, relatively inferior RQ and CQ intervals were found to be associated with either dolomite-cemented facies or laminated siltstones.

The interpretations from the along-well characterization are propagated into a fast-yet-rigorous semi-analytical dynamic-drainage-area (DDA) model to forecast the oil production (150-day forecast) for the 50 stages completed in the well. The forecasting demonstrates that the best 30 stages (60% of the total number of stages) result in 80% of the total oil production forecasted for all 50 stages. Therefore, for the studied well, it is concluded that a significant reduction in the number of stages could have yielded most of the oil production obtained from all 50 stages over the forecast period. The methods outlined and applied in this study serve to illustrate how selective stimulation of RQ and CQ “sweet spots” could lead to improved development efficiency.

SESSION TITLE: Theme 5: Application of New technologies in Unconventional Resources

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Data-driven Kerogen Kinetics from Rock-Eval data of the Middle Magdalena Valley Basin, Colombia.
Implications on the prospectivity of unconventional.

AUTHORS (FIRST NAME, LAST NAME): Roberto Aguilera¹

INSTITUTIONS (ALL):

1. RA GEOLOGIA E.U.

ABSTRACT BODY:

Abstract Summary: The Middle Magdalena Valley Basin is a very prolific oil basin, with an important potential for unconventional in the Cretaceous sequence. The assessment of this potential is part of a continuous effort from the industry in recent years at the basin.

As part of such efforts a study was carried out of more than 16000 thermal maturity and source rock quality data from more than a 100 sites including wells and outcrops, of the Cretaceous rocks present in the basin.

From this data, data-driven kerogen kinetics from rock-eval and transformation ratio models have been generated and integrated with 3D maturity in order to better assess the potential of these rocks as unconventional reservoirs, considering that this sequence is mainly composed of fine-grained clastic and calcareous rocks, known to be the main source of conventional hydrocarbons in the basin. From the integration of these models a better understanding of the unconventional play for the Middle Magdalena Valley Basin has been obtained, showing that the remaining potential in the basin can not be properly assessed from simple kinetic models but that data-driven kinetics is a more robust approach to this matter, because better reflects and accounts for the lateral and vertical variations in the quality of the source rocks. This approach provides a better definition of sweet spots for future exploration in the basin.

SESSION TITLE: Theme 5: Application of New technologies in Unconventional Resources

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Detecting the depletion around fractures using common drilling data.

AUTHORS (FIRST NAME, LAST NAME): Kevin Wutherich¹, William Katon², Jason Glascock³, Brian Sinovic⁴

INSTITUTIONS (ALL):

1. Drill2Frac
2. Drill2Frac
3. Drill2Frac
4. Drill2Frac

ABSTRACT BODY:

Abstract Summary: It is well known that pre-existing fractures and depletion play an integral role in the completion and production of infill wells. However, it is often left to speculation as to where and how these depleted fractures are distributed along the wellbore. This paper will discuss a new methodology that uses common drilling data to map the depletion halo created during the production of these fractures.

Through analysis of hundreds of wells, it has been observed that there is a very unique drilling signature associated with drilling through depletion. Through the examination of standard drilling data available on almost every well, these signatures can be isolated, and mapped along a wellbore, as well as estimates created for the level of depletion. This data is currently being used to characterize fracture growth and depletion patterns in unconventional reservoirs throughout north and south America.

Several case studies will also be presented which will show how this data has been validated including through comparisons to image logs, pressure responses, tracer response and more. There will also be discussion on how this data can be used to mitigate fracture interactions during completion resulting in improved well productivity.

SESSION TITLE: Theme 3: Colombia Deepwater Hydrocarbon Potential

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Tectonostratigraphy and gas potential of the South Caribbean offshore region of Colombia

AUTHORS (FIRST NAME, LAST NAME): Diego Nicolas Iaffa¹, Juan Carlos Llinas², Edgar Rueda³, Henry Rivera⁴, David Izquierdo⁵, Adriana Prada⁶, Clara Sotelo⁷, Martha Serrano⁸

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol
8. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The southern region of the Colombian Caribbean offshore is an important gas province. A good image quality PSDM 3D survey was the base for the interpretation in this work. The research area is located offshore of Colombia, near the border with Panama where 3 wells have discovered gas accumulations and proved the play.

The detailed seismic interpretation is based on the different tectono-sequences and main regional faults.

The identification of 3rd order tectono-sequences provided a chrono-stratigraphic framework for the stratigraphic and geographical distribution of source, reservoir, and regional seal rocks. A series of structural and GDE maps of Plio-Pleistocene age, plus two cross sections were constructed to improve the understanding of the stratigraphic and structural evolution and to predict the presence of the turbidites in the basin.

The area is set on the oceanic Caribbean Plate overlain by a Neogene and Pleistocene sedimentary cover consisting of hemipelagic sediments, large mass transport complexes (MTCs), and turbiditic deposits remobilized by sea bottom currents. In the northwestern margin of Colombia, the Caribbean oceanic Plate is being subducted below the continental South American (SA) Plate with a low angle and strong coupling. The Panama terrane has been colliding against South America since the Early Miocene. Fault propagation folds are found in the southernmost part of the seismic cube, linked to regional stresses of the compressive deformation of Panama. Two extensional structures are recognized, affecting the oceanic crust and the sedimentary cover, a main central graben with a NW-SE orientation and a secondary hemi-graben with NE-SW trend. The central graben was formed at a very distal position with respect to the present SA active margin and Panama plates. The NE-SW extensional structures are reactivated as the crust reaches the trench zone and flexes down beneath the SA Plate.

In general, the plays identified in the southern Colombian Caribbean offshore are associated with Pleistocene turbidites charged with biogenic gas generated by a source rock that is commonly interbedded with the reservoirs, and intraformational seals in structural and combination traps.

Ecopetrol and its partners are heading towards the development of these gas discoveries that will position Ecopetrol in the deep waters of the Colombian Caribbean and will leverage the transformation of the company and the country.

SESSION TITLE: Theme 5: Application of New technologies in Unconventional Resources

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Imbibition Studies in Unconventional Reservoirs : Insights into Origins of High Salinity Flow Back Water

AUTHORS (FIRST NAME, LAST NAME): Clara Palencia¹, Lori Hathon², Michael Myers³

INSTITUTIONS (ALL):

1. University of Houston
2. University of Houston
3. University of Houston

ABSTRACT BODY:

Abstract Summary: Although hydraulic fracturing fluid is typically fresh water, in gas reservoirs, produced water or flowback, is often very saline. This observation suggests that flowback water is gaining salt from the formation. It is not currently known whether the recovered salt comes from dissolution of mineral salts, or interaction between bound water and frac fluid. In the absence of flowback water data, obtaining petrophysical properties, such as clay mineral content, permeability, porosity and in situ salinity from spontaneous imbibition experiment, as an insight into flowback water salinity, is the primary objective of these research.

Dual spontaneous imbibition (water and oil), ion releasing experiments and sample characterization are combined to develop rock properties models. These techniques in combination will allow us to gain insight into effective characteristic time coefficients, total porosity, clay mineral content and in situ salinity, to develop models for shale reservoirs. The Bossier and Haynesville Formation in the United States and La Luna Formation in Colombia were the samples for the experiments.

Experimental and modelling results suggest that the summation of the NaCl in the fluid due to anhydrite (salt dissolution) plus the NaCl due to the clay minerals (cation exchange capacity), result in the high saline flowback water associated with the Haynesville, Bossier and the La Luna Formations. Cation exchange capacity and salt volumes from ion detection analysis might be used as a proxy to predict this flowback salinity. Imbibed water model shows to be a promising technique for estimating organic porosities in gas shale reservoirs and it could provide a basis for a possible GRI (Gas Research Institute) total porosity measurement correction, particularly in high carbonate content rocks.

SESSION TITLE: Theme 6: CCUS: Feasibility Studies, "New" Exploration Methodologies and Piloting

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: The Carbon Utilization and Storage Partnership: Accelerating Commercial Decarbonization of the Western United States

AUTHORS (FIRST NAME, LAST NAME): Robert Balch¹, Brian McPherson², George El-Kaseeh³, Richard Esser⁴

INSTITUTIONS (ALL):

1. New Mexico Tech
2. University of Utah
3. New Mexico Tech
4. University of Utah

ABSTRACT BODY:

Abstract Summary: The Carbon Utilization and Storage Partnership of the Western United States (CUSP) is one of four regional Initiatives sponsored by the US Department of Energy (DOE) in 2019. The initiatives were formed to continue work performed under the DOE Regional Carbon Storage Partnership program (RCSP). Each initiative covers a portion of the United States and is tasked with compiling and analyzing data to better understand the CO₂ sources, sinks, and commercial projects within their region, building from the 20 year RCSP program. The CUSP region Includes 13 western states, has 16 founding organizations including Universities, Research Centers, State Geological Surveys, and US National labs and is comprised of three of the original RCSP's. With US tax credits for CO₂ storage, interest has grown in deploying commercial projects. A primary CUSP task is to accelerate development of projects in the western US. The CUSP has a current budget of \$18 million. Projects benefit from experience gained in the region over two decades of storage research and assistance is given in: Geologic and geophysical characterization of storage sites; in preparing and assisting with permits, monitoring plans, and injection permits. The CUSP also assists with economic analyses and in identifying opportunities. In 2020 the CUSP funded three projects: Conversion of a mature EOR project at Farnsworth Texas from an EOR focus to a storage focus by designing a Monitoring, Verification, and Accounting (MRV) plan approved by the US EPA in May 2021; Conversion of a midstream facility from an acid-gas disposal focus to a regional carbon storage hub in the Permian basin of New Mexico, with an MRV plan in final review; and by contributing to the MRV plan and permits for the San Juan generation station in New Mexico, which is converting a coal plant to 95%+ carbon capture. These projects will store ~10.2 million tonnes of CO₂ per year with injection already occurring at Farnsworth, scheduled for 2022 in the Permian basin, and by 2025 at the San Juan Generating station. In 2021, the CUSP identified 23 additional projects in the region that could be operation within 1-3 years, and funded work to support 12 projects. The CUSP has two additional projects funded directly by industry. This paper will present an overview of CUSP goals, summaries of the 17 current projects, plans for furthering the program, and will describe processes for optimizing and commercializing projects in the Western US.

SESSION TITLE: Theme 6: CCUS: Feasibility Studies, "New" Exploration Methodologies and Piloting

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Estimation of Geological Storage Capacity of CO₂: Regional Pilot in the Central Sector of the Middle Magdalena Valley Basin

AUTHORS (FIRST NAME, LAST NAME): Claudia Cardozo¹, Eduardo Lopez-Ramos², Lorena Suarez³, Cesar Patiño⁴, Andrea Ortiz-Karpf⁵

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The goals that Ecopetrol has set in terms of reducing CO₂e emissions are ambitious and are aligned with national and global decarbonization objectives. The CO₂ capture, use and sequestration technology (CCUS) is part of the portfolio of solutions that is being evaluated worldwide to reduce emissions and is also considered within the actions to meet Ecopetrol Group's goal of net-zero carbon emissions by 2050. This technology has two fundamental components: the capture and sequestration of CO₂; and it is in this last part that the Geoscientists and Petroleum Engineers have a great contribution to make. As it is an emerging technology, pilot projects have not been implemented in Colombia yet, and there is no official estimate of the CO₂ geological storage capacity in Colombian basins. Quantifying the capacity for CO₂ storage in a basin has a considerable impact since it allows resource estimation, a key input for decarbonization plans of nations and O&G companies. Additionally, regional geological studies constitute the first step to identifying prospective CO₂ storage fairways, from which hubs for CO₂ capture, utilization and storage can be envisaged. Ecopetrol is working towards a first pilot project that starts with the estimation of CO₂ storage capacity on a regional scale. The central area of the VMM basin was selected, considering that it is close to emission sources such as the Barrancabermeja refinery and cement plants. In this location is where most of the O&G fields of the basin are, and therefore, it has extensive subsurface information to estimate volumes. The estimation of storage capacity was first implemented for unit T2 (Mugrosa Formation), since it is the unit with the largest O&G reserves and production in the basin. To estimate the storage capacity, we started from existing regional studies, thus taking advantage of the subsurface data and knowledge constructed from decades of O&G operations in the VMM basin. In this first phase of the pilot, the theoretical reservoir storage capacity was estimated based on the methodology proposed by Bachu, 2008. We also performed an initial risk assessment, adapting the traditional play-based exploration methodology. This is a first attempt at characterizing CO₂ storage capacity in Colombian basins and a small step towards materializing a CO₂ storage project in the country, a technology that is essential for meeting national and global CO₂ emissions goals.

SESSION TITLE: Theme 6: CCUS: Feasibility Studies, "New" Exploration Methodologies and Piloting

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Advanced Numerical Modeling of CO₂ Storage in a Challenging Reef System

AUTHORS (FIRST NAME, LAST NAME): Joachim Moortgat¹, Derrick James²

INSTITUTIONS (ALL):

1. The Ohio State University
2. The Ohio State University

ABSTRACT BODY:

Abstract Summary: In recent years, Carbon Capture and Storage (CCS) has become a commercially viable process due to technological developments and the issuing of new UIC Class 6 carbon injection permits. An important step in the development of commercial carbon storage reservoirs is to verify through numerical simulations the viability of a candidate reservoir or aquifer as a storage site. In this work, we demonstrate the importance of partially miscible, compositional simulations in assessing an evacuated petroleum reservoir for carbon storage use. The complicated phase behavior present in this scenario has significant impacts on the injection plume geometry, flow pathways, and pressure fronts present in the reservoir. We examine the Chester-16 CCS test site in Michigan, USA, in which over 140 MT of CO₂ was injected between 2017 and 2019. The Chester reef contains producing carbonate structures that are encased laterally and above by thick layers of salt, anhydrite, and tight carbonates. The reservoir has undergone both primary and secondary recovery, leaving an existing infrastructure that makes it an attractive option for use as a storage site. To assess storage viability, we model several different injection scenarios in the domain, which we discretized by approximately 350,000 tetrahedral elements adapted from a corner-point static model of the site. Our test scenarios showcase non-trivial fluid behavior that varies based on the facies of rock into which the fluid is injected. The simulations are performed with our in-house research simulator Osures, a finite element flow and transport research simulator that uses higher-order numerical methods to reduce numerical dispersion. This allows for a higher level of accuracy and helps resolve complex phase boundaries even on relatively coarse unstructured grids. We also adopt an accurate (cubic plus association) equation of state to describe the non-linear phase behavior of the involved fluid phases. Simulation results show the CO₂ flow pathways in the challenging Chester-16 reef system and demonstrate powerful features of our modeling approach.

SESSION TITLE: Theme 6: CCUS: Feasibility Studies, "New" Exploration Methodologies and Piloting

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Deploying Petroleum Play-Based Exploration methodologies for Carbon Storage site characterization

AUTHORS (FIRST NAME, LAST NAME): Katya Casey¹, Kevin Schofield²

INSTITUTIONS (ALL):

1. Actus Veritas Geoscience
2. GeoAdvisors

ABSTRACT BODY:

Abstract Summary: The EPA application process for the injection project permit is an iterative process, requiring the completion of an extensive questionnaire that covers a detailed description of the subsurface, addressing regional and local aspects of the storage container. We propose that the Play-based assessment methodology developed and successfully used in Petroleum exploration during the last two decades could be deployed for the characterization of the risks and uncertainties of the Area of Review (AoR) as defined by Environmental Protection Agency (EPA) for Class 6 well (CCUS) permit approval process. The first application for this permit took six years to get approved, largely because of "recycling" as the requirements were properly understood. Recently, data show that Class 6 well permit approvals now take about two years. The utilization of play-based assessment methods offers opportunities to further reduce the cycle time of the application and improve the quality of the subsurface characterization.

The Common Critical Risk Segment methodology used in play-based assessment defines the risks and manages the uncertainties in the critical elements used to characterize a hydrocarbon accumulation (Source, Reservoir, and Seal). Well, seismic, and potential fields data are used to reduce the uncertainty in the ranges of the parameters used in the characterization. The same data sources and methodology can be applied to understanding the range in critical parameters required for developing an appropriate injection site...the absence of petroleum fluids, the presence of saline aquifer with sufficient porosity and permeability, and an overlying seal of known capacity. Using the language of the Petroleum industry and translating it into the critical elements for carbon storage characterization we can say that elements assessed in the CCUS permit application process are:

Petroleum Reservoir = CCUS Container quality: Storage (bulk volume, porosity, saturation) Injectivity (geometry, permeability, relative permeability) Petroleum Trap = CCUS container definition: Geometry confining elements Petroleum Seal = CCUS upper AND lower seals: Max seal capacity for injected volumes (capillary entry, fractures, faulting) CCRS maps may be used to define a sweet spot for injection well positioning determined by the configuration of the most favorable parameters of each critical element.

SESSION TITLE: Theme 2: Tectonics

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Structural framework and chronostratigraphy of the Talara Basin (NW Peru) and its impact on hydrocarbon E&P

AUTHORS (FIRST NAME, LAST NAME): Martin Oviedo¹, Victor Carlotto², Carmen Canales³, Daniel G. Poiré⁴

INSTITUTIONS (ALL):

1. Universidad Nacional Mayor de San Marcos
2. Universidad Nacional San Antonio Abad del Cusco
3. Consultant
4. Centro de Investigaciones Geológicas (UNLP-Conicet)

ABSTRACT BODY:

Abstract Summary: The Eocene forearc Talara basin located in northwestern Peru has been producing hydrocarbons for more than 150 years. Its geological complexity has generated controversy about the different structural studies, overall thickness of 9000m and records within its stratigraphy the complicated history of the obliquity between convergent plates along the active margin, terrane accretion resulting from the Caribbean plate's migration and Andean orogeny, associated with a crustal suture zone developing the NE-SW strike-slip fault system of Dolores-Guayaquil-Patallanga Megashear (DGPM). They have been following the pre-existing structural configuration (Cretaceous) and generating the formation of Pull-apart basins associated with transpressional and transpressional events.

The stratigraphic record reports rapid sea-level variations, from deep marine deposits to fluvio-deltaic successions and vice versa. These processes must have been produced by climatic and/or tectonic factors, developed along strike-slip fault systems, which explains the structural configuration and geometry of the Talara basin.

Talara basin is opening at 56 Ma, tectonic inversion at 40-42 Ma, at 33 Ma the eastern portion of the basin is exhumed, between 21 to 10 and 5 Ma the basin is preserved and at 3 Ma it is totally exhumed. Three fault systems have been identified, one main (NE-SW) and the other are normal faults (E-W) and local reverse faults (tectonic inversion and fold bend faults). Several faults are associated to transtensive and transpressive events related to the large strike-slip MDGP system, which has produced complex structural compartmentalization, this is reflected in the different fields that have been producing hydrocarbons.

An updated structural framework and an integrated regional chronostratigraphic chart are proposed, highlighting the main tectonic events that controlled the sedimentary fill and pointing out areas with potential for exploration of conventional and unconventional resources like the Lagunitos structural low located to the south and the offshore deep-water area to the west of the basin. The constant and diachronic uplift and subsidence processes, generating structural relevant highs and lows allowing the contribution of sediments from different areas as Lancoces basin. This study will help to better understand the geodynamics of the basin and will contribute to solving questions for future studies, besides opening a portfolio of opportunities in the area.

SESSION TITLE: Theme 3: Colombia Deepwater Hydrocarbon Potential

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Mass Transport Complex Characterization Offshore Colombia and its implication for the geological top seal risk

AUTHORS (FIRST NAME, LAST NAME): Karilys Castillo¹, Eduard Maili², Wesley Ball³

INSTITUTIONS (ALL):

1. OXY, Occidental Petroleum
2. OXY
3. OXY

ABSTRACT BODY:

Abstract Summary: Mass Transport Complexes (MTCs) are profuse within the Plio-Pleistocene sequence of offshore Colombia, representing up to 40% of the total sedimentary record in some areas. Recent exploration wells from the basin have demonstrated the sealing capacity of MTCs. Similarly, in blocks COL-1, COL-2, COL-6 and COL-7, multiple exploration prospects are overlain by MTCs, which are speculated to provide an effective regional top seal to the hypothesized petroleum system. It is therefore critical to fully characterize MTCs when assessing the risk of individual exploration prospects and the expected outcomes of exploration campaigns.

In an attempt to evaluate the top seal risk, 9500 km of 2D and 29000 km² of 3D seismic data were interpreted to define the geographical extent of MTCs across blocks COL-1, COL-2, COL-6 and COL-7. The aim of this study was to characterize the morphology of MTCs. By mapping top and basal surfaces, and performing amplitude extractions inferences about thickness, transport direction, and heterogeneity were made.

Interpreted MTCs are highly heterogeneous, with well-defined compressional/pressure ridges where better sealing capacity is expected, and extensional-compartments with rotated-slide blocks that could be potential vertical pathway for leakage. Within blocks COL-1, COL-2, COL-6 and COL-7, a shallow and massive MTC exists with an area in excess of 50,000 km² and thickness of more than 300m, considered to be the ultimate top seal for most of the prospects. This gigantic MTC may be also responsible for the sealed petroleum system observed in piston cores and samples collected from the seabed in the Colombia Basin.

SESSION TITLE: Theme 3: Colombia Deepwater Hydrocarbon Potential

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Structural Interpretation of the Guajira Offshore Basin. Implications On Hydrocarbon Exploration.

AUTHORS (FIRST NAME, LAST NAME): Juan Carlos Ramon¹, ANDREA PABLOS², Victor Ramirez³, Andrés Fuenzalida⁴, María Cerón⁵

INSTITUTIONS (ALL):

1. SGC - Servicio Geologico Colombiano
2. SGC - Servicio Geologico Colombiano
3. SGC - Servicio Geológico Colombiano
4. Servicio Geológico Colombiano
5. Agencia Nacional de Hidrocarburos

ABSTRACT BODY:

Abstract Summary: We present a new interpretation of the South Caribbean Deformed Belt (SCDB) of the Guajira offshore from an analysis of about 29,000 km of high-resolution 2D seismic, including several regional traverses from very good quality 3D seismic volumes. The SCDB is 30-50 km wide. Strata within the SCDB are disrupted by high-angle fold propagation faults with steep limbs, and by positive flower structures. Fold axes are commonly (30° - 45°) oblique to the local strike of the fold belt. Structural shortening is less than 10%. Piggy-back strata are generally rotated indicating an out-of-sequence order of thrusting. 3D seismic volumes display rotated unconformities and onlap terminations, as well as abrupt geographic changes in stratal thicknesses, suggesting multiphase deformation during the Miocene.

Beyond the SCDB is wide (up to 150 km) marine platform on top of continental basement. Strata within the marine platform has low deformation and are broken by normal listric fault complexes and strike-slip faults. Reflectors from oceanic crust dip south about 5°-6°, in agreement with published values. The continental crust thins to zero over a short (50-70 km) distance. Strata above this area of thin crust are mildly folded. This interpreted basement geometry is coherent with available Bouguer gravity data. The topography slope (Alpha angle from accretionary prism models) range from 3-7 degrees but locally is much higher.

These observations suggest that the SCDB is not an accretionary prism related to a subduction as current literature suggests. Instead, the structural style, the combination of snake-head folds with abundant positive flowers, the drastic lateral changes in stratal thicknesses and the occurrence of regional strike slip faults (10s km lateral displacement) associated to the oceanic-continental crust contact indicate that the SCDB is the result of deformation along a transform continental margin. This helps explain the absence of volcanism and seismicity, which previously has been explained by inferring flat subduction. These clearly match all GPS and vector data that indicate that the Caribbean plate is moving eastward relative to the South American Plate. This new view impacts the way we model hydrocarbon charge, trap formation and the oil prospectivity in the basin.

SESSION TITLE: Theme 3: Colombia Deepwater Hydrocarbon Potential

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Pacific Origin of Caribbean Oceanic Lithosphere Revisited: What it Means for Caribbean Exploration

AUTHORS (FIRST NAME, LAST NAME): James Pindell¹

INSTITUTIONS (ALL):

1. Tectonic Analysis Ltd. and Rice University

ABSTRACT BODY:

Abstract Summary: Recent literature, exploration studies, and internet posts continue to question the Pacific origin of the Caribbean oceanic lithosphere. As presented, these viewpoints appear to result from misunderstanding of geologic data and processes. A review of original and newer data/arguments greatly supports the Pacific origin and explains key issues causing apparent misunderstanding. I argue that the negative perceptions of the Pacific origin are over-fearful. 1) An in-situ interpretation is attractive because it would allow for direct basinward extrapolation of northern South America's (nSoAm) onshore petroleum systems. However, nSoAm's (and Guatemala's) petroleum habitat has little to do with the Jurassic. Although in-situ models would predict marine Jurassic on the Caribbean seafloor, such a section would be completely unrelated to nSoAm's prolific petroleum systems. 2) nSoAm's Turonian-Coniacian-Santonian primary source rock section is, in fact, present in most of the Caribbean basins. The uncertainty regarding its potential concerns not presence but thickness and richness, both of which would be primary concerns whether the lithosphere was Pacific-derived or not. The view that this source section is thin likely pertains to DSDP/ODP having drilled only basement highs, leaving more favourable lows untested. 3) By the time of Turonian-Santonian source rock deposition, the Pacific origin model places the Colombian and Venezuelan basins west of Colombia and south of Mexico, with Caribbean–American tectonic interactions already underway. I see no reason why an oceanic position north of nSoAm (in-situ model) should have been more favourable to source rock deposition of this age than a position directly to the west (Pacific model). 4) Although more quartzose reservoir detritus might have reached the Colombian Basin earlier in in-situ models, the Pacific model allows for plenty of sand to reach it eventually. In fact, the later arrival of these sands in the Colombian Basin (relative to in-situ models) might enhance HC potential by triggering younger critical moments in maturation due to late burial, and by allowing more structures to pre-date maturation. 5) Backstripping suggests the Caribbean Plateau crust was quite shallow (locally emergent) in the Late Cretaceous, negating the need to invoke abyssal source rock depositional models in many areas. In summary, there is no great reason to resist the obvious Pacific origin when exploring in the Caribbean.

SESSION TITLE: Theme 3: Colombia Deepwater Hydrocarbon Potential

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Petroleum Geology of the Sinu Basin, Deepwater Offshore Colombia

AUTHORS (FIRST NAME, LAST NAME): David Reed¹, Nadeer Khan²

INSTITUTIONS (ALL):

1. Royal Dutch Shell
2. Shell - Trinidad and Tobago Limited

ABSTRACT BODY:

Abstract Summary: Royal Dutch Shell acquired a 50% working interest in 3 license blocks in deepwater offshore Colombia in 2020 – Fuerte Sur, Purple Angel and COL5. Early in that year work began on evaluating the recent discoveries by Anadarko and partners – Gorgon and Kronos. In parallel work began on a regional evaluation of the Sinu basin, its petroleum system and exploration potential within the basin.

This presentation will give an overview of the key elements of the petroleum system of the Sinu Basin – the structural framework, trap types, stratigraphic section, reservoir and top seal types and depositional model, discovered hydrocarbons and charge system and seismic responses of existing discoveries.

The Sinu Basin is flanked on both the east and west by accretionary prisms of Colombia and Panama respectively and is dominated structurally by Miocene detached fold and thrust belt inboard with footwall traps and incipient folds outboard. Continuous fold belt activity has resulted in extensive mass transport deposits within the basin, which also modify many traps creating erosional stratigraphic components.

Reservoirs are Plio-Pleistocene thinly bedded turbidites, sourced primarily from the Central and Western Cordilleras onshore and delivered to the basin via erosionally confined channel systems across the active fold and thrust belt with inputs in the form of gullies. Top seals are extensive mass transport deposits. Thermal modeling suggests burial depths within the study area are unlikely high enough to result in thermally mature source rocks – aside from beneath the inboard fold and thrust belt – resulting in primarily a biogenic gas play in the area of interest. Gas charged reservoirs show bright Class 3 AVO responses and seismic DHI analysis is key to quantifying the key risk of residual or low saturation gas. The key uncertainty for field development is reservoir quality – particularly permeability distribution at a field scale – which is complicated in the area by bottom current re-working of these sediment gravity flow deposits.

SESSION TITLE: Theme 4: Reservoir Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Seismic Reservoir Characterization and Inverted Lithotypes Distribution in a Lower Miocene Turbidite Channel Complex, Salina del Istmo Basin for Appraisal Purposes.

AUTHORS (FIRST NAME, LAST NAME): Oscar D Machado P1, Pedro Vieira2, Elvira Aguilera3, Manuel Gonzalez Quijano4

INSTITUTIONS (ALL):

1. Repsol Exploration Americas
2. Repsol
3. Repsol Exploration Americas
4. Repsol Exploration Americas

ABSTRACT BODY:

Abstract Summary: The study area lies in the deep-water extension of the Salina del Istmo Basin, Mexico. Exploration and appraisal campaigns have discovered and delineated an early Miocene clastic reservoir which records deposition in turbiditic deep-water facies within a channel complex setting, which has migrated laterally and vertically due to allochthonous salt activity. The reservoir structure is that of a thrust anticline that involves the Mesozoic section. It is apparently detached in the salt layer, forming a typical 3-way dip closure trap against salt.

The objectives of this study are the seismic characterization of the reservoir, defining lateral and vertical changes in geometry, and to quantify rock quality properties based on lithotypes probabilistic distribution integrating: a) petrophysical evaluation, b) post-stack geometrical seismic attributes, and c) inverted impedance volumes from the Simultaneous pre-stack seismic inversion. In addition, multicolor spectral scale, and tools such as opacity, blending, and mixing function were used to enhance the 3D visualization of geological features.

The reservoir consists of four amalgamated channel complexes in an overfilled, sand-rich system mapped at seismic scale. Six lithotypes were defined to describe in detail the reservoir facies, from Two wells. The petrophysical evaluation shows that the reservoir has a high net-to-gross ratio (over 80%) and a porosity ranging from 20 to 35%. Moreover, no classic curvy levee geometry, typical of mud rich systems, has been interpreted in depth seismic imaging. Instead, overbanks are uniform isopachs indicating a sand-rich depositional environment.

The resulting reservoir geometry was characterized based on conventional seismic mapping methods, Coherence and Curvature seismic attribute extractions, and spectral decomposition maps, which identified geomorphological features of a turbidite depositional system, such as: channel complex and overbanks. The reservoir properties distribution was obtained from the probabilistic classification of the lithotypes elastic response applied to inverted P impedances and Inverted S impedances volumes (3D distribution).

The results of this study have not only reduced the reservoir property distribution uncertainty, but also impacting favorably the hydrocarbon reserves estimation and the future production development plan.

SESSION TITLE: Theme 4: Reservoir Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Exploring in the Trujillo Basin, offshore Peru, by use of Seismic QI and Rock Physics Modeling

AUTHORS (FIRST NAME, LAST NAME): Eduard Maili¹

INSTITUTIONS (ALL):

1. OXY

ABSTRACT BODY:

Abstract Summary: With a total of 4 exploratory wells drilled to date, the Trujillo basin of offshore Peru remains relatively underexplored. Within blocks Z-61, Z-62 and Z-63 a database containing 1,600 KM² of reprocessed 3D seismic data, 3,500 KM of reprocessed 2D seismic data, 9,472 KM² of high-resolution bathymetry data and 245 piston cores, has recently been assembled. Seismic interpretation has helped define an exploration portfolio of 25 prospects. Analysis of data obtained from piston-cores and active seeps has confirmed the presence of a prolific Cretaceous-Tertiary petroleum system. The primary risk associated with hydrocarbon exploration in the Cretaceous-Tertiary sequence is the presence and quality of reservoir.

To help quantify the exploration risk associated with reservoir presence and quality, a detailed seismic QI and rock physics analysis was performed. In areas of the basin with well control, AVO modeling shows that reservoirs typically have a very-low impedance contrast and weak class II AVO response. By contrast, away from areas with well control, direct hydrocarbon indicators (DHIs) and strong negative amplitudes are associated with potential reservoirs.

To account for discrepancy in seismic response, we hypothesize that reservoir properties may significantly improve away from existing well control. Porosity perturbation (10% increase) produces a stronger impedance contrast at the shale/reservoir interface and allows for a better match in amplitudes between modeled and real seismic data.

Intercept, gradient, and AVO classes calculated on the conditioned seismic data, combined with relative extended elastic impedance (EEI), correlated to reservoir porosity, were used to quickly map prospective reservoirs. Seismic facies inversion, using depth trends from wells inside and outside the seismic survey, enabled prediction of possible facies, including those related to the presence of oil and gas.

The QI and Rock Physics study presented here will help to better-define potential reservoirs and assess the risk of reservoir presence in existing prospects as well as the identification of new leads and prospects further expanding our exploration portfolio.

SESSION TITLE: Theme 4: Reservoir Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Reservoir characterization using direct probabilistic inversion: case studies

AUTHORS (FIRST NAME, LAST NAME): Raul Cova¹, Evan Mutual², Andrew Mills³, Henrik Hansen⁴, Ask Jakobsen⁵, Rob Ross⁶, Wendell Pardasie⁷

INSTITUTIONS (ALL):

1. Qeye
2. Qeye
3. Qeye
4. Qeye
5. Qeye
6. Qeye
7. Qeye

ABSTRACT BODY:

Abstract Summary: Deterministic AVO inversion techniques have become a common practice for subsurface reservoir characterization. The elastic properties that are derived through these techniques can later be used in additional inversion workflows to estimate rock properties that are easier to understand and communicate across G&G and engineering teams. This two-step process typically involves two deterministic inversion runs which will provide a single “optimal” solution according to a predefined objective function. At each inversion step, practitioners are challenged by the non-unique character of the inversion solution. This non-uniqueness is compounded by the need of running multiple inversion steps. Direct probabilistic inversion (DPI) attempts to solve this problem in one step and provides a tool for exploring a wider range of possible solutions. Moreover, the Bayesian framework that governs DPI allows for the integration of additional geological information that is difficult to include in deterministic inversions. Important geologic knowledge like stratigraphic transitions, thickness statistics, and fluid contacts can be integrated and exploited to provide superior vertical resolution on the inversion output. In this work, we present three case studies where DPI was applied to address different reservoir characterization challenges. The first case study illustrates the uplift in the vertical resolution that DPI is capable of. Additionally, we show how DPI can provide surfaces with probabilities that can be used to map low reflectivity facies across the seismic volume. In the second case study, DPI is applied to improve the characterization of the Mannville sequence, an interval known to have interpretation challenges due to thin reservoirs, extreme elastic responses in thin organic-rich shales, and complex structural control in the underlying Paleo unconformity. These case studies illustrate how infusing more geological information in the inversion problem can lead to more accurate and geologically consistent inversion results. The last case study shows how DPI can provide more confident lithology predictions. The presence of very thin coals in this project challenged the mapping and identification of hydrocarbon sands. The DPI output in this case study is compared against the results obtained using a deterministic approach. The statistics obtained from the DPI results show how DPI was able to provide a more accurate understanding of the sand distribution in the area.

SESSION TITLE: Theme 4: Reservoir Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Innovative Workflow for Prospect Definition and Evaluation in a Stratigraphically Trapped Reservoir, an application in an Area in the Middle Magdalena Valley.

AUTHORS (FIRST NAME, LAST NAME): Erick Illidge¹, Maria del Pilar Stifano², Luis Gerardo Figuera³, Oscar Moreno⁴, Yolima Blanco⁵, Angela Ramirez⁷, Jaime Arias⁶

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Stratigraphic traps in over-pressured reservoirs are perhaps one of the hardest prospects to properly evaluate, thus creating challenges in exploration that concern not only the interpreter but also specialists in petrophysics, geomechanics, geophysics, reservoir engineering and geochemistry. Recently, there have been many developments for characterization of fluvial reservoirs in a stratigraphic trap framework from individual points of view that are missing looking at the big picture of the prospect as a whole. In this project, a detailed interpretation of the seismic data available was carried out first, delivering a structural and stratigraphic framework that can be used for later steps. Then, the geological framework was used for the construction of a basin model where the charge of the potential reservoir was confirmed and valuable information about the kind of hydrocarbon to be expected was obtained. Reservoir interpretation in a fluvial environment is particularly complicated due to the presence of high clay content in the sandstones. This is a concern not only from the petrophysical point of view, for the assessment of volume of clay, water saturation and permeability model, but also for seismic characterization since it is harder to differentiate the elastic properties of sandstones from those of clay-rich rocks. We defined the clay volume model by integrating the information from gamma ray, neutron-density and SP logs, resulting in a clay volume model that is highly correlated to the elastic moduli. Coupled with the petrophysical model, a seismic inversion feasibility model was performed to verify that it was possible to elastically differentiate clean sandstones from clay rich rocks at the zone of interest, and therefore giving green light to the pre-stack seismic inversion process. Moreover, the results of the seismic inversion were used to extract sandstone-prone geobodies that served as input for the volumetric evaluation of the prospect.

The workflow shown in this paper allows the interpreter to integrate results from seismic quantitative interpretation, petrophysics analysis, reservoir production data, and geochemical geomechanical analysis, providing an excellent exploration tool to minimize uncertainty, improve subsurface knowledge and support the definition of a prospect in a stratigraphic trap, enabling the incorporation of new opportunities into the exploration portfolio that could represent potential reserves for the company.

SESSION TITLE: Theme 4: Reservoir Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

EXTENDED ABSTRACT: DAS on Hybrid Logging Cable: Changing the Status Quo of Borehole Seismic Acquisition

Helman Duque ¹, Diego Morales ¹, Manuel Useche ², Alejandro Martinez ², Diego Sanchez ²;

1. Ecopetrol, 2. Schlumberger

Summary

Borehole seismic data from vertical seismic profiles (VSP) provides relevant information in different stages of reservoir evaluation. However, integration with surface seismic surveys and well log data is needed to carry out accurate seismic reservoir characterization. Borehole seismic surveys are often removed from the well planning stage or canceled during the acquisition stage for several reasons. Apart from technical challenges or well results, VSP acquisitions face several obstacles, such as the time taken to complete the acquisition, the mechanical condition of the wells and the risk of tool sticking, and limitations from having communities close to well locations where jobs are taking place.

The introduction of a novel acquisition technique using a DAS fiber optic-electric hybrid logging cable as a seismic sensor addresses these limitations, allowing rock velocity information to be efficiently obtained over the entire drilled interval in a fraction of the time required by conventional methods. Depending on the acquisition geometry, it is possible to record seismic reflection images in the vicinity of the borehole, in addition to the standard corridor stacks. The fiber optic is deployed as part of a hybrid logging cable that leverages any downhole logging intervention to acquire seismic data. This eliminates the need to convey geophones downhole, which reduces the risk of tool sticking and limitations due to adverse geomechanical conditions in the well. On many occasions, data acquisition is carried out in areas close to communities, houses, or infrastructure that may eventually be affected in some way by vibrations emitted by the seismic source. Also, high levels of noise for long periods could distress nearby inhabitants. By reducing the number of sweeps to a fraction of a conventional acquisition and having them concentrated in short periods of time, the problems derived from the nearby presence of communities or infrastructure are greatly minimized.

This study showcases the results of a zero offset vertical seismic profile (ZOVSP) survey with DAS on hybrid logging cable in an onshore well drilled in 2020 in Colombia. The VSP data were acquired while conveying ultrasonic-imager and cement-bond tools with a hybrid optical heptacable. The ZOVSP objectives were both general well-tie analysis and imaging near the well. A one-to-one comparison was made with conventional geophone tools to benchmark the technology.

The reduction of carbon footprint is an added benefit when using this technology. Less operating time can save more than 90% of CO₂ emissions (over 6 T of CO₂) in a VSP acquisitions like the one described here. The ZOVSPs with conventional technology were estimated to take around 15 hours in wells with this profile. With DAS on hybrid logging cable, this operation takes less than 1.5 hours.

Technology

Distributed acoustic sensing (DAS) technology uses optical fiber as a seismic sensor; the fiber is deployed along the entire well, either permanently or temporarily. The principle of DAS is that a short pulse of light travels down an optical fiber and, as the pulse of light propagates, a small amount of energy scatters at each elemental section of the fiber. A small fraction of the scattered light is captured and guided back to the launching end. The returning scattered light is acquired as a function of time elapsed from launching the probe pulse. Since group velocity of light in the fiber is known, the timing of a sample of the acquired trace is related to the location in the fiber where light was scattered (Frignet and Hartog, 2014).

A hybrid logging cable has been designed for VSP acquisition using DAS technology (Varkey et al., 2008). As shown in Figure1, the hybrid optical heptacable is an innovative way to acquire borehole seismic data during any other descent scheduled in the wellbore, either open hole or cased hole (i.e., reservoir pressure/sampling, petrophysical, casing evaluation, etc.). It provides access to any well, at any time to collect borehole seismic measurements. This simplifies the planning and logistics around VSP operations, and it significantly reduces the overall cost of collecting such information because a dedicated logging run for seismic is eliminated.

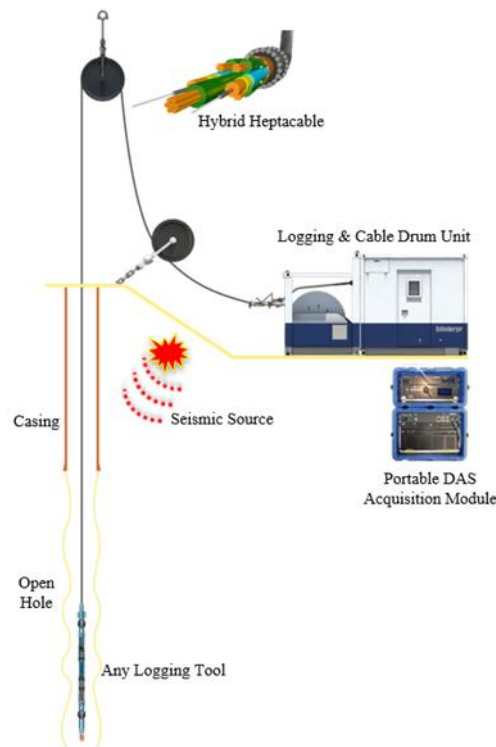


Figure 1. Description of hybrid optical logging cable operation for DAS-VSP acquisitions (Martinez et al., 2021).

The advantage of acquiring borehole seismic with DAS is clear. The operator can acquire seismic using minimum rig time (Useche et al., 2020) to zero additional rig time when the tools conveyed with the hybrid cable are required to remain stationary as part of the operations, such as collecting reservoir samples (Guerra et al., 2020), sidewall coring (Kimura et al., 2017), calibration of nuclear magnetic tools (Martinez et al., 2018), well integrity logs in cased-hole environments (Martinez et

al., 2021), and even hybrid DAS-geophone operations in the case of complex seismic jobs such as 3D VSPs (Kimura et al., 2018).

Acquisition Planning and VSP Modeling

Operational planning and survey modeling are key for successful data acquisition with VSP surveys. In this project, a detailed ray-trace VSP modeling was performed prior to evaluating candidates for source location. Two-dimensional modeling was carried out mostly for evaluation of optimal incidence angles. In general, direct P-wave incidence angles are preferably less than 20° to avoid any hard corrections during travel time verticalizations for further sonic calibration and time-depth curve calculation (Figure 2).

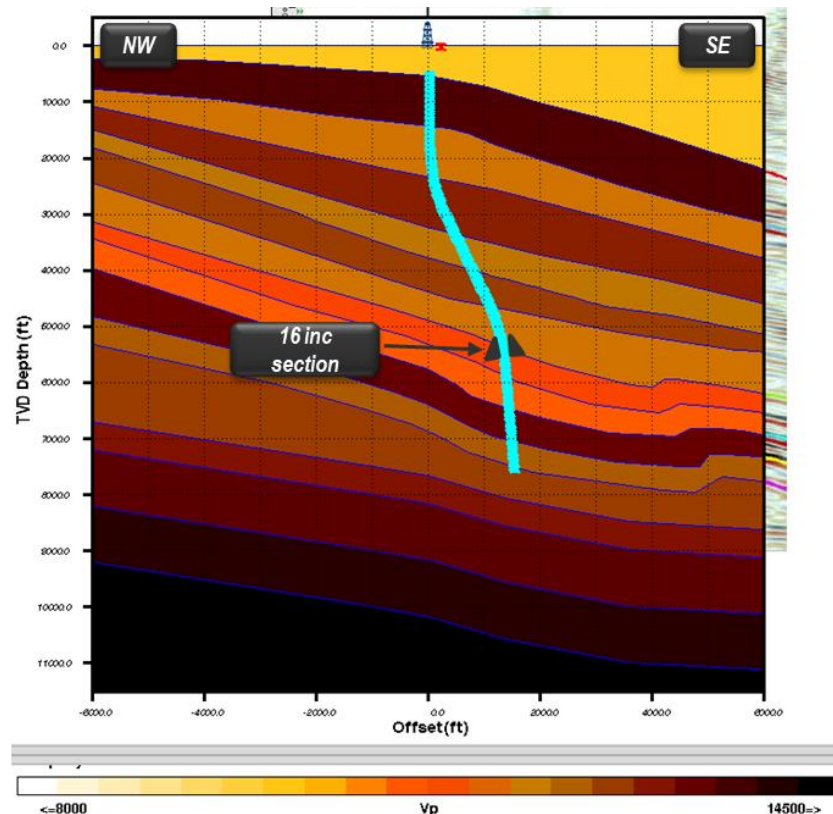


Figure 2. 2D model for VSP ray tracing

In Figure 3, 3D modeling offered information on reflected energy and out of plane reflections when evaluating, ZO VSP and offset VSP (OVSP) source locations.

Illumination towards the northeast of the well was of interest for the project. However, almost all reflections were coming out of the source-receiver plane (Figure 3a), which made both processing and migration difficult. In addition, the source could not reach the area due to roads and topography conditions. Therefore, VSP acquisition was constrained to a ZO scenario. The next action was to identify a location to place the vibrator by scouting the area.

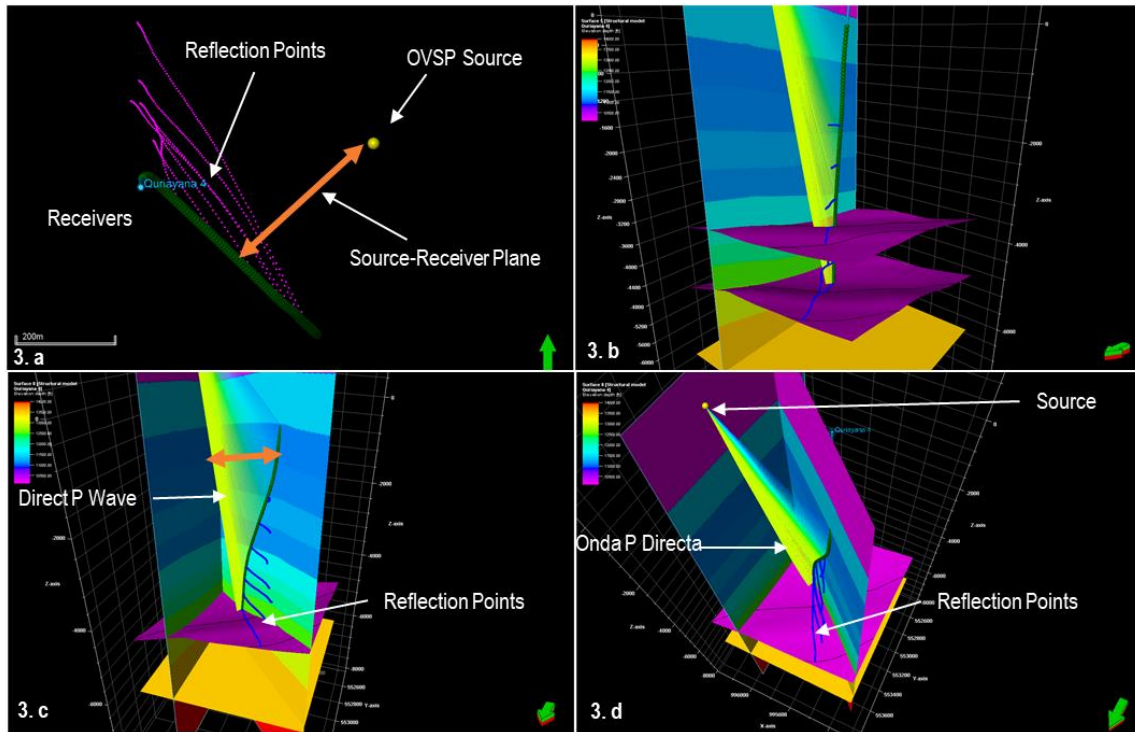


Figure 3. 3D VSP modeling for survey design. Green arrow indicates magnetic north.

Source location is important not only for incidence angle control, but also in the mitigation of tube waves that can affect the recorded wavefield. Scouting confirmed that well location was small and no physical barrier between the wellhead and possible source positions was available. Hence, places outside the well location were considered. This led to the final source position located in the access road to the rig, which was within the range of subvertical incidence angles and far enough from the wellhead to mitigate ground roll.

The 2D/3D ray tracing confirmed that the final source location outside the well location was compliant with technical requirements and minimum illumination objectives.

VSP Data Acquisition

The ZOVSF acquisition was performed with the source at an offset of 635 ft and azimuth of 72° and 1,876 ft above MSL. A truck-mounted vibrator of 60,000 lb was used as seismic source, using a linear sweep from 6-96 Hz, 12 seconds long.

Two seismic profiles were acquired: one with conventional geophones and the other with DAS technology integrated in a hybrid wireline logging cable. An array of four shuttles containing three-component geophones spaced every 50 ft was used for conventional acquisition, whereas DAS acquisition was done when conveying cased-hole integrity logging tools (ultrasonic mapping and cement bond tools).

Acquisition with conventional geophones took 15.5 hours, rendering 73 VSP traces every 50 ft. DAS acquisition was performed in 1.2 hours, recording 411 traces over the same well interval. This represents nearly 95% operation efficiency. Figure 4 shows a direct comparison of the volume of VSP data acquired with both technologies.

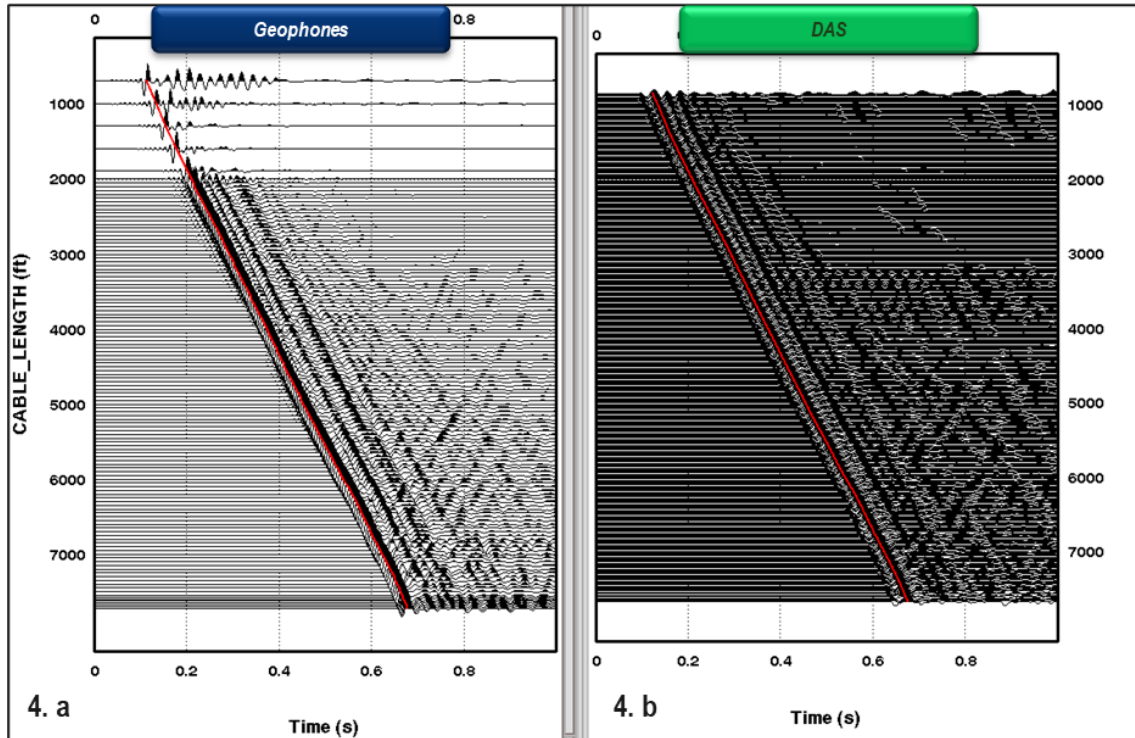


Figure 4. Geophone vs DAS acquisitions. Left: Geophone Z component, 73 traces. Right, DAS stack data, 411 traces.

Conventional Geophones vs. DAS Data Comparison

Both geophone and DAS data sets were of excellent data quality for VSP processing. As shown in Figure 4, first breaks, downgoing multiples, and upgoing reflectors are clearly visible in raw VSP data using both technologies.

The left panel in Figure 5 shows the DAS data in variable density with the travel times from geophone and DAS datasets (red line). Consistency between both time-depth curves is exceptional (differences ± 1 ms), making it difficult to differentiate them. Similarly, Figure 5 (right panel) presents an outstanding correlation of formation interval velocities measured by three different acoustic methods (sonic, geophones, and DAS). Moreover, we merged both VSP datasets into a single data cluster for further comparison by decimating DAS data to 32-ft spacing to facilitate visualization (Figure 6).

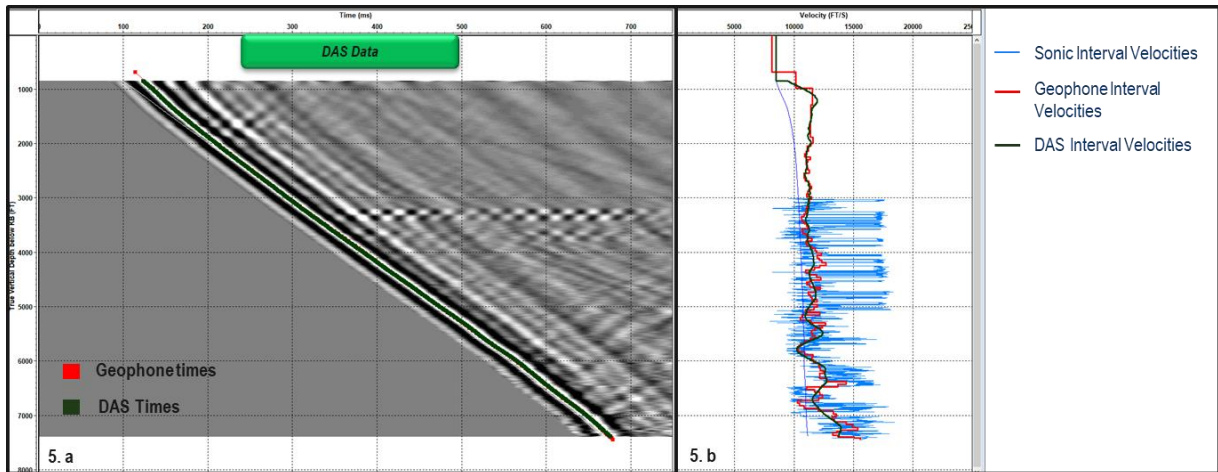


Figure 5. Geophone vs DAS comparison: travel times (left) and interval velocities (right).

In Figure 6a, transit times have been subtracted so that first break events, as well as downgoing multiples, are evaluated for consistency. Clearly, the first arrivals are consistent both in time and phase between the data sets. Also, the downgoing multiples are well preserved in geophone and DAS data, giving full confidence in the full waveform reliability of DAS data under the same acquisition conditions. The same behavior is noted in Figure 6b.

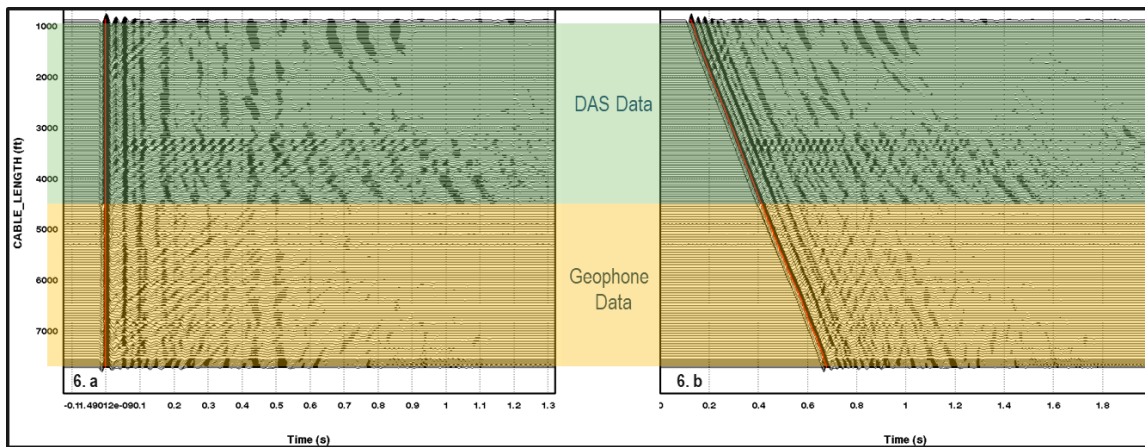


Figure 6. Geophone and DAS (32-ft spacing) merged raw data. Left panel shows data aligned by transit time. Right panel shows the raw downgoing wavefield.

Full VSP processing workflow was carried out, using geophone and DAS data. For the geophone data, component rotations and axis projections were performed to generate the true vertical component for wavefield separation and deconvolution. Processing steps were the same for both data sets with some minor differences in the parameter adjustment. Wavefield separation took place by employing median velocity filters using the 2D model as reference. From this step, downgoing and upgoing wavefields were obtained and used for deterministic deconvolution of the upgoing data.

Geophone and DAS deconvolved data were used for corridor stack generation; a narrow window of 90 ms was selected for stacking, keeping last 15 traces for geophone data and last 20 for DAS. Corridor stacks from both technologies have excellent correlation (Figure 7), showing consistency in the reconstruction of the 1D acoustic impedance profile.

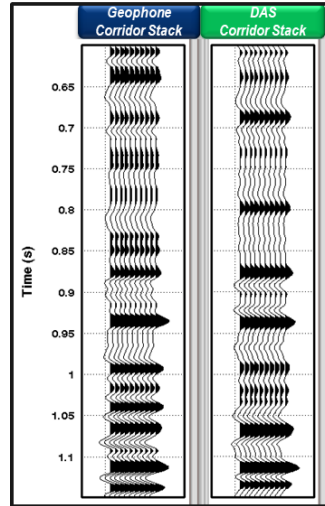


Figure 7. Corridor stacks with geophone (left) and DAS (right).

The upgoing deconvolved data were used for migration and generation of 2D images below the well trajectory. In terms of image comparison, the larger number of traces in DAS produced enhanced resolution compared to that obtained with geophones (Figure 8). Both migrations used the same velocity model, with slightly different apertures (8° for geophone and 10° for DAS). Here, the DAS data have a wider coverage, both laterally and vertically, due to the increased VSP traces along the well trajectory. In addition, the extra DAS data were acquired without additional acquisition time or source effort.

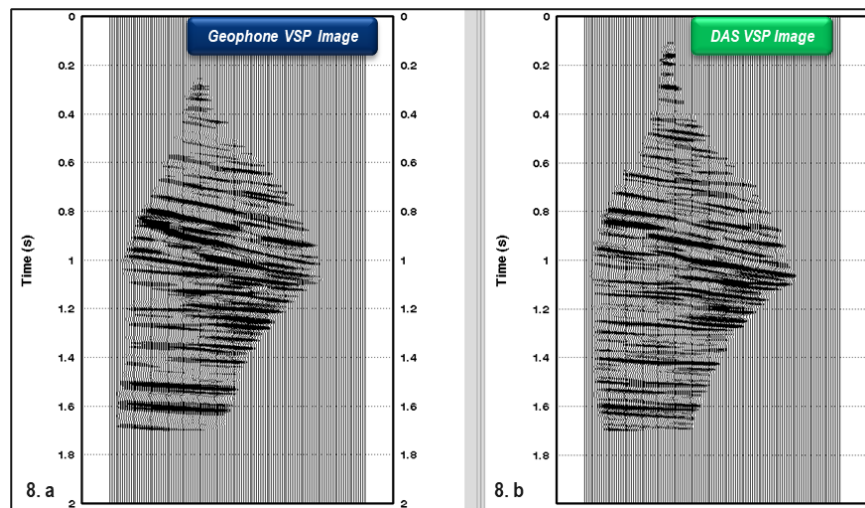


Figure 8. Migrated upgoing wavefield of geophone dataset (left) and DAS data (right).

Integration of Results and Added Value

Migration results were integrated with 3D surface seismic data for correlation of the main seismic horizons. The relationship between both VSP images and surface seismic data is very good in terms of event discretization, dipping, and validation of amplitudes. A high-amplitude reflector area is clearly identified in the surface seismic data, which is perfectly reconstructed by geophone and DAS images. Moreover, DAS migration enables the identification of additional structural elements, such as faults and thin reflectors, which enhances the illuminated area when compared with surface seismic data.

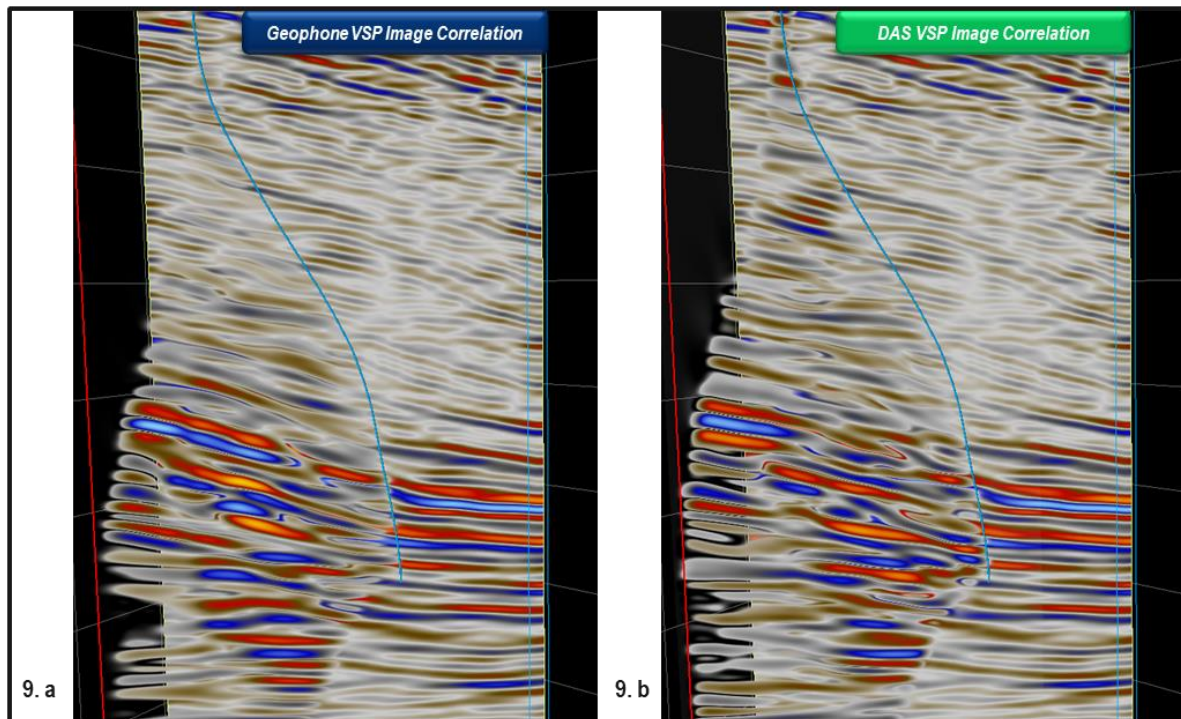


Figure 9. Correlation with surface seismic data. Geophone data (left) and DAS data (right).

When the VSP migrated images are superimposed on the surface seismic section in Figure 9, both images reveal details that can be interpreted as subseismic features, such as faulting and potential compartmentalization in the reservoir. A possible realization of such interpretation is shown in Figure 10, where faults overlay the DAS 2D image. This interpretation validates three faults that are clearly visible in the reservoir zone. It also reveals the existence of additional faults in the same area that escape the conventional geophone VSP image and are impossible to visualize with surface seismic data only.

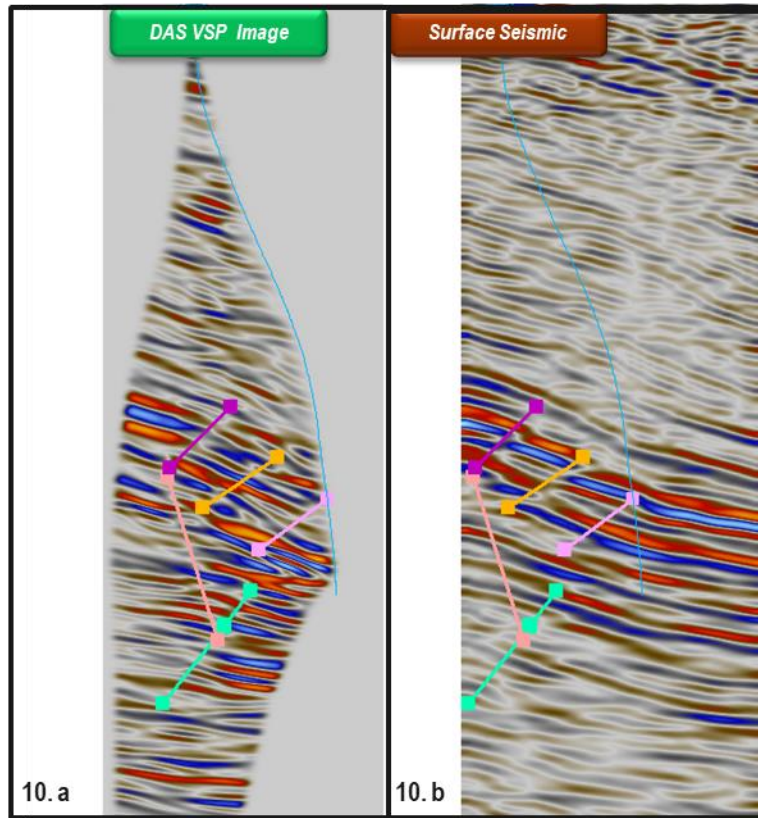


Figure 10. Enhanced structural interpretation driven by high-resolution DAS VSP image. Faults interpreted on the DAS VSP image (left). Interpreted faults superimposed on the surface seismic section (right).

Conclusions

The example shown in this work showcases the exceptional operational efficiency of hybrid logging wireline DAS, where the technique acquired excellent quality data in a fraction of the time used with conventional geophone technology. With the 95% operation efficiency achieved in DAS acquisition, this immediately translates into a lower carbon emission footprint of more than 90%, equating to an estimated ~6.5T CO₂ equivalent saved in this job.

In future operations, the elimination of a logging run would clearly translate into operating time optimization and rig time savings. Additionally, by not having a fit-for-purpose logging descent for seismic acquisition, risk exposure to downhole equipment failure or malfunctioning is avoided. Also, fishing of seismic equipment, which is typically a time-consuming and risky operation, will be spared in future projects. Virtual elimination of nonproductive time associated with downhole equipment failure is possible since several logging runs enable multiple attempts to collect seismic data, which minimizes the possibility of failing to obtain a log due to equipment failures.

Environmental benefits also result from minimizing the number of sweeps and in the reduced time of operations, which translates into less noise exposure to surrounding communities (i.e., ground vibration, nuisance to residents, traffic effects on local roads, exposure of personnel to security

concerns) and/or disruption of local wildlife. The latter is particularly significant when considering marine protected species in potential offshore operations.

The corridor stacks and the migrated images obtained using DAS and geophone techniques are strikingly similar, which has also been observed in other jobs carried out in the area (Martínez et al., 2019, 2021). The images obtained with DAS are also of great quality, and in this case study, they fully replace those obtained with conventional geophone technology.

With DAS in hybrid cables, all wells can potentially have seismic data. The technology will eliminate seismic cancellations due to well results because seismic acquisition can be done in reduced logging case scenarios that require the logging cable for conveyance anyways (i.e., dry case vs. success scenario). Also, appraisal and development wells where seismic data could be useful but is often disregarded (due to cost or other factors) may be more accessible with this technology.

Additional seismic data for further characterization is a lot simpler with this technology. A simple checkshot ZOVSP could be upgraded easily to a more complex survey. For example, the first logging descent is used for a ZOVSP evaluation, and subsequent runs may be utilized for multi-offset VSPs to probe the formation in different azimuths. The cost of acquiring VSP in this scenario is marginal compared to the overall logging cost.

Acknowledgments

The authors express their gratitude to Ecopetrol and Schlumberger for supporting the publication of this case study. Thanks to Professor David Hodgson for reading the paper and providing insightful feedback.

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SESSION TITLE: Theme 5: Application of New technologies in Unconventional Resources

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: Fracture Characterization and Evaluation: From The Wellbore Into The Far Field Using Sonic Imaging.

AUTHORS (FIRST NAME, LAST NAME): Manuel Useche¹, Edgar Arteaga², Carlos Duran³, Claudia Hincapié⁴

INSTITUTIONS (ALL):

1. Schlumberger
2. Schlumberger
3. Petroleos Sudamericanos
4. PetroSud

ABSTRACT BODY:

Abstract Summary: Development on Lower Magdalena Valley Basin is known to be influenced by the presence of natural fractures, and therefore the understanding of their distribution is key to understand the well production along the presence of non-expected water production that is not explained with the petrophysical model. Standard logging programs of these wells includes a microresistivity image and sonic log with traditional acoustic processing (i.e Anisotropy and Stoneley analysis).

For this paper a new sonic-imaging technique uses azimuthal receivers to determine individual reflector locations and attributes, such as the dip and azimuth of formation layer boundaries, fractures, and faults, called 3D Far Field, the technique consists of an automated time pick and event localization procedures collect possible reflections from filtered waveforms; followed by an automatic ray tracing and 3D slowness time coherence (STC) procedure that determines the ray path type and a 3D structural map of the reflector, as well as its true dip and azimuth Direct integration with borehole resistivity images provides an opportunity to extend the knowledge of the geological behavior from the borehole-wall to several meters away into the formation.

Three zones of reflectors were established, near field reflectors can be correlated with the events observed by the geological image logs, since both methods are basically looking at the borehole wall. However, medium and far field illuminate areas around the well (up to 40 ft) that are not possibly to analyze with conventional well logs. Results from these areas confirmed the extension of fractures that crosses the well, thanks to the state-of-the-art 3D sonic imaging technique, and enables to identify geological features that are not in contact with the well but may have an impact on reservoir dynamic behavior.

SESSION TITLE: Theme 2: Tectonics

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Oral

TITLE: A Review of the Tectonic Evolution and its Impact on the Distribution and Potential of Petroleum Provinces of the Gulf of Mexico

AUTHORS (FIRST NAME, LAST NAME): Luis Enrique Salomon¹, Leonardo E. Aguilera-Gomez¹

INSTITUTIONS (ALL):

1. Petroleos Mexicanos (PEMEX)

ABSTRACT BODY:

Abstract Summary: Different plate tectonic models have been proposed to explain the origin and evolution of the Gulf of Mexico basin (GoM). The present tectonic framework derived from two main processes, the sea floor spreading in the central basin, and the translation and rotation of the Yucatan block. Sea floor spreading and translation-rotation of Yucatan require formation of regional lateral strike-slip faults, transform faults or megashears in continental and oceanic crust. In general, the plate tectonic evolution model of the GoM consists of four phases: pre-rift (pre-Late Triassic), syn-rift or rifting (Late Triassic to Middle Jurassic), late syn-rift or drifting (Late Jurassic to Early Cretaceous), and post-rift or passive margin stage (Early Cretaceous to present time).

The evolutionary model for the origin of the GoM basin presented here derived from previous works, but has integrated potential field data, and historical seismic and well information acquired by Pemex. As a result of this tectonic evolution, development of sedimentary basins and distribution of petroleum provinces, as well as presence and timing of different elements of the petroleum systems in every province are relevant topics; in particular, the proper geological and environmental conditions for deposition of source rocks.

It is general accepted that main source rocks in peripheral provinces and central and deep sectors of the basin are the Upper Jurassic Tithonian marine carbonates. It is also established that translation of the Yucatan Block during the Late Jurassic to Early Cretaceous period caused adverse conditions for deposition or absent of Tithonian units. However, sea-floor coring campaigns in some petroleum provinces far from the main basins associated to salt tectonics support hydrocarbon generation and migration corresponding to Jurassic source rocks. Based on this evidence and geological and geophysical data, it is proposed that some key points need to be analyzed and integrated to regional interpretation to update the most accepted model of evolution of the basin. However, other disciplines, such as geochemistry and sedimentology must be integrated to geodynamic and tectonic studies in future works. This will help improve our understanding of the evolution of the basin and identify new plays in frontier areas for hydrocarbon exploration.

WEDNESDAY
20 APRIL 2022
POSTER PRESENTATIONS

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Seismic Facies Classification with Wavelets and Deep Learning

AUTHORS (FIRST NAME, LAST NAME): Akhilesh Mishra¹, Samvith Rao², Mil Shastri³

INSTITUTIONS (ALL):

1. MathWorks
2. MathWorks
3. MathWorks

ABSTRACT BODY:

Abstract Summary: With the huge growth and complexity of seismic data, manual labeling of seismic facies has become a significant challenge. Recently, deep learning algorithms (particularly CNNs) have been used to simplify this task. In this submission, we demonstrate the advantage of using advanced signal processing techniques to preprocess signals before feeding them to deep learning algorithms. Our approach combines maximal overall discrete wavelet transform with recurrent neural networks (RNN) to improve the automated seismic facies analysis. This proposed framework generates more accurate results in a more efficient way. The combination of RNN with wavelets achieves more accurate results than just using CNNs. The results were demonstrated in a recent hackathon organized by SEAM AI where the MathWorks® team was ranked at the top – our F1 scores on test data were significantly higher than other teams

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Geo-Steering Enhanced With Real-Time 3D Numerical Simulation Productivity Forecasting to De-Risk Horizontal Drilling of Interbedded Sandstone Reservoir With Complex Structural Geology

AUTHORS (FIRST NAME, LAST NAME): Manuel Lavin¹, Igor Hernandez², Yira Vasquez³, Dario Solohaga⁴, Debdeep Ghosal⁵

INSTITUTIONS (ALL):

1. Schlumberger
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ABSTRACT BODY:

Abstract Summary: Horizontal drilling allows to maximize well-to-reservoir connectivity to achieve higher production rates in reservoirs with poor petrophysical properties or interbedded sands with small thickness. Real-Time geo-steering is a fundamental technique to properly land this type of wells, ensure navigation in the best petrophysical zones and optimize the well trajectory by detecting faults, stratigraphic changes, and fluid contacts ahead of the bit. However, determining the impact that these geological uncertainties will have in the productivity of a well is a complex activity, for which traditional analytical methods might not be able to capture with enough representability, or for which numerical modeling would be suitable, but might require a large amount of human and computational resources. A novel workflow enables the Real-Time creation of a 3D dynamic model to perform productivity forecasting through numerical simulation based on logging-while-drilling data. A near-wellbore grid is constructed and populated directly with formation well tops, well trajectory and Real-Time petrophysics. Numerical simulations are performed at certain key moments during the horizontal section drilling to calculate the productivity index for oil, gas, and liquid. Sensitivities to ten key reservoir parameters like permeability, distance to Oil-Water Contact, thickness, etc. are performed and an overall uncertainty is calculated for the expected well productivity. This information is analyzed in Real-Time to support decisions like continue drilling to achieve a productivity that makes the well economically successful, steer the trajectory to maximize contact with high productivity zones or to increase distance from fluid contacts if water or gas conning is likely. Also, this methodology can help to reduce the length of the horizontal section versus the plan if it is determined that a productivity target has been reached, optimizing time and resources. This methodology has been successfully deployed in a development mature field where horizontal wells are drilled to maximize contact with the bypassed oil zones in an interbedded sandstone reservoir that produces from Hollin formation in the Oriente basin in Ecuador. A case study is presented where the length of the horizontal section was maximized because the simulations showed a high water-cut production that was confirmed by a well test.

SESSION TITLE: Theme 2: Structural Styles and Kinematics I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Revisiting Structural Settings of Shushufindi Asset and their Important Role in the Development of this a Mature Field in Oriente Basin, Ecuador

AUTHORS (FIRST NAME, LAST NAME): Andres Acevedo¹, Johanna Navarrete¹, Jorge Bolanos¹, Cristina Lopez¹, Maria Barzallo¹, Oscar Morales¹, Jorge Vega¹, Willem Sepulveda¹, Gabriela Soria², Jairo Bustos², Oscar Ponce²

INSTITUTIONS (ALL):

1. Schlumberger
2. Petroecuador

ABSTRACT BODY:

Abstract Summary: Shushufindi (SSFD) is a very mature field in Ecuador with more than 50 years of production and 250 wells mainly targeting cretaceous sandstones formations T and U. It consists of 3 main accumulations: SSFD, Aguarico and Aguarico intrusive fields. After years of thorough static and dynamic modeling, it is observed that some wells near the main fault were having early and abnormal increase in water cut (BSW). This BSW could not be history matched under normal conditions considering a fully sealing fault. To understand this water entry from the east faulted flank and its effect in the field development, the fault characteristics are revisited and reinterpreted.

The formation of SSFD's structures have been reported to correspond to an early (late Cretaceous - Paleocene) stage of a tectonic inversion resulted of a transpressive regime. There is an older and deeper fault-system oriented NW-SE. This deeper fault system does not cut the target units but instead is resolved as local minor flexures oriented similarly. Additional detailed analysis provides insight in changes in fault geometry (FG), fault seal capacity and their relationship to water movement.

3D seismic and map-based attributes such as of variance, dip, edge-detection and maximum curvature were used to define a new FG. Also, juxtaposition and shale content analysis are being included. It is observed that throughout the field the main FG changes from a clean cut in a narrow zone to a wide flexure with presence or not of a sub-seismic fault. Also, the areas with a wider fault zone or flexure correlate in most cases to the areas of higher early BSW. These findings support the inclusion of a high permeability corridor in areas along the fault for a new dynamic simulation. It is assumed that production-related changes in reservoir pressure affect the initial sealing condition of the fault. New simulation better history matched the total water production and capture the mentioned higher BSW in wells near the fault. The new FG is also used in the planning of upcoming wells providing justification to move locations to gain better structural position.

Regardless of the long history of a mature field, assuming static fault sealing conditions is proven not always to be the case. Capturing reservoir properties in a static model is critical but the implication of a detailed structure configuration is also key in reservoir simulation and forecast. This approach could apply to similar fields in Oriente basin.

SESSION TITLE: Theme 2: Structural Styles and Kinematics II

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: The role of thick vs thin skin tectonics in the Medina basin, Eastern Cordillera, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Juan Pablo Arias¹, Jaime Castellanos², Eliseo Teson³, Daniel Bello-Palacios⁴

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: The timing of different deformation events has been extensively studied in the Eastern Foothills. In addition, further information from recently-reprocessed 3D seismic data, geomorphological analysis and fieldwork data, allowed to identify with more precision geometries of deformation and growth strata. Therefore, in a comprehensive view of the geometry of deformation linking thick vs thin-skin tectonics, overburden, and regarding the timing of deformation, we present a proposal through a sequential kinematic restoration aimed to explain the different structural levels and their impacts in the petroleum systems.

In this work we use all the recent information available to propose the presence of three deformation levels within the Eastern foothills in the Medina Basin. These include: 1) an initial stage (late Eocene) of activation of an Upper Cretaceous detachment and associated low-relief-low-amplitude folds that display late Neogene reactivation; 2) a subsequent early Neogene to recent activation of a Paleogene detachment horizon; and 3) a late Neogene activation of a Lower Cretaceous, low-angle transition between thick skin and thin skin, shown in this section as a lateral ramp. All three of these deformation levels imply vertically-stacked detachments, thrust sheets, and a linked, thick-to-thin-skin deformation that forms a frontal response to the late Eocene to recent, thick-skin uplift and exhumation of a basement high to the West. Deformation in such a basement high starts with the classical geometry of an inversion-related, harpoon-shaped structure, which transfers thick-skin shortening and deformation to the coeval thin-skin deformation to the east. The narrow zone of active deformation and vertically-stacked, thin-skin deformation causes the earlier structures and traps to be transported by the younger ones. In the meantime, adjacent kitchens only reach maximum temperatures during the late Miocene deformation phases, so that recent and active charge of the equally-recently-formed traps is likely. On the other hand, we hypothesize that the diachronous activation of different detachment levels is a response of the increasing overburden within the Medina Basin (Upper Cretaceous and Paleogene detachments) and the interaction with inherited half-grabens (Lower Cretaceous detachment).

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Unconfined Compressive Strength and Elastic Anisotropy of a Tectonically Deformed Calcareous Shale, Santiago Formation, Mexico

AUTHORS (FIRST NAME, LAST NAME): Jubier Alonso Jiménez-Camargo², Mariano Cerca¹, Dora Carreón-Freyre³

INSTITUTIONS (ALL):

1. Centro de Geociencias Universidad Nacional Autonoma de Mexico, Juriquilla
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3. Universidad Nacional Autonoma de Mexico

ABSTRACT BODY:

Abstract Summary: Shale rocks are globally abundant fine-grained materials of ultra-low permeability that play an important role in the development of multiple emerging engineering applications. These rocks exhibit complex spatial arrangements at the microscale producing intrinsically anisotropic rocks in their physical properties and mechanical response when loaded. We carried out unconfined compression tests (UCS) on cylindrical samples of a highly deformed Jurassic calcareous shale from the Santiago Formation in eastern México to evaluate the effects of fabric anisotropy on strength and elastic behavior. Cylindrical specimens were prepared in vertical and in the two horizontal directions defined by foliation attitude (strike and dip). Petrography of oriented thin sections, X-ray diffraction and fluorescence, and scanning electron microscopy (SEM), and physical properties (density, porosity and permeability) were used to assess the rock composition and microstructure. The results of the UCS tests indicate that mechanical anisotropy in these shales is not only limited to different responses in the vertical and horizontal directions but also a contrasting behavior between the two mutually orthogonal horizontal directions. Young's modulus (E) recorded higher values in the H2 direction (13 - 22 GPa), lower values in the H1 direction (8 - 10 GPa), and intermediate values in the V direction (8 - 15 GPa). All the specimens yielded very low Poisson's ratios (<0.12). Similarly to Young Modulus, higher K/G ratios were obtained for the H2 direction, and lower values for the H1 and V oriented specimens. H2 samples were stronger (47 to 83 MPa) and more deformable (0.4 to 0.7 %). Weakest specimens were tested in the H1 direction (15 to 29 MPa) and accommodated limited strain (0.22 to 0.35 %). The vertical samples yielded intermediate values of strength (25 to 58 MPa) and strain (0.31 to 0.48%). Elastically stiffer specimens yielded also higher UCS values. Anisotropy in rock fabric and elasticity strongly influenced the shear and splitting fractures formed at failure. We relate the main geometrical characteristics of the fracture with specific structural elements found in the rock. In summary, a direct relation between textural complexity, elastic stiffness, UCS, and failure mode in the three orthogonal orientations was documented for these rocks.

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Multiscale Analysis of Fractures on Plutonic Rocks Affected by Thrust Fault in the Eastern Flank of Central Cordillera: an Outcrop Analogue of a Naturally Fractured Basement Reservoir.

AUTHORS (FIRST NAME, LAST NAME): Maryi Rodríguez-Cuevas¹, Juan Camilo Valencia-Gómez², Agustín Cardona³, Tiago Miranda⁴, Sebastián Zapata⁵, Astrid Siachoque⁶, Sebastián Ramírez⁷, Gaspar Monsalve⁸

INSTITUTIONS (ALL):

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2. National University of Colombia
3. National University of Colombia
4. Federal University of Pernambuco
5. National University of Colombia
6. National University of Colombia
7. National University of Colombia
8. National University of Colombia

ABSTRACT BODY:

Abstract Summary: Natural fractures play an important role in the permo-porosity distribution in the crystalline basement reservoirs. Fractured crystalline basement reservoirs host a huge reserve of hydrocarbons worldwide. However, this type of reservoir is poorly explored in Colombia.

The Upper Magdalena Valley has a proven Cretaceous petroleum system where, locally Jurassic intrusive body thrusts over the source rocks (Villeta group) by the La Plata-Chusma fault as suggested by seismic profiles. An analogue of this structural arrangement is found in the Páez massif near to La Plata-Huila, which exposed an intrusive body lithological composed of quartz monzodiorite, tonalite, and granodiorite in the hanging wall of La Plata-Chusma thrust fault.

This paper sponsored by The Colombian Ministry of Science and ANH investigates an outcrop analogue to quantify the spatial distribution of fractures in the plutonic basement rock. The outcrop data can overcome scale limitations and/or lack of consistency of subsurface datasets. Additionally, a regional topographic lineament analysis was made using a digital elevation model (DEM) and showed two predominant directions of structural lineaments, N45E and N30W. To determine the degree of the La Plata-Chusma fault effect on the crystalline basement rock we performed scanlines and scan areas surrounding the La Plata-Chusma fault zone. The fracture intensity values range between 0.8 to 33 fracture/m, whereas preliminary topological observations show a predominance of X and Y nodes over I nodes of the main fracture families identified at the outcrop.

The N45E structural lineament direction coincides with the La Plata-Chusma thrust fault and confirmed the genetic relationship between topographic features and regional fault systems, whereas N30W could be related to transversal structures genetically associated with the La Plata-Chusma thrust fault or structures formed in deformational events before the La Plata-Chusma fault. The main mineralogical composition of this intrusive body is quartz and plagioclase that deform in a brittle way in the upper crust and generate multiple directions of fractures according to the stress direction. The connected network and high intensity of fractures enhance the storage and flow capacity, improving the permo-porosity distribution of basement reservoir and suggesting that intrusive bodies in the subsurface could be an exploratory target.

SESSION TITLE: Theme 2: Structural Styles and Kinematics II

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

EXTENDED ABSTRACT: Structural and kinematic model of the Ene basin in the Peruvian Sub-Andean

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Introduction

The Ene Basin is an intermountain basin located in the sub-Andean system of the Central Andes of Peru. It is an exploratory frontier basin, with an active petroleum system, that covers an area of more than 40,000 km² and a stratigraphic column exceeding 7,000 m of sediments that ranges from the Ordovician to the Quaternary. During the last decade, numerous exploratory works were carried out, among which the drilling of the first exploratory well stands out.

Objectives and methodology

This work presents an updated structural evolution model of central zone of Ene Basin. All the information collected during the drilling of the well (Boca Satipo Este – 1X) and subsurface geophysical information (2D seismic, velocity models generated from refraction tomographic inversions and magnetotelluric data), surface geological mapping, biostratigraphy, and thermochronology acquired in recent years is integrated.

Geological and stratigraphic overview

Ene Basin, is located in the sub-Andean system of the Central Andes of Peru, ~350 km to the east of Lima and ~150 km to the west of the Camisea gas fields. It is bounded to the west-southwest by a major east-verging reverse fault that forms the deformational front of the Eastern Cordillera. To the north the Ene Basin transitionally passes into the less deformed Pachitea sub-Basin. To the east, Shira and Otishi Highs, separate the intermontane region from the Ucayali Basin which includes the prolific Camisea gas and condensate fields. The Pre-Andean tectonic evolution of the Central Andes is characterized by a complex history of terrane accretion, orogenesis, and extension (see Ramos, 2018 and references therein). It is considered that during the Phanerozoic, the Ene Basin was in a back-arc position (e.g., Sempere, 1995). The stratigraphy was divided into several cycles limited by major unconformities unconformably overlaying basement units (Iribarne et al., 2018) (Fig. 1). The Proterozoic basement crops out in the Eastern Andes and in the Otishi and Shira Highs and comprises plutonic and metamorphic rocks (see Iribarne et al., 2018 and references therein). The lower to mid Paleozoic sequence is more than 1,000 m thick and is represented by Ordovician marine shales and sandstones of the Contaya Group followed by fine-grained shallow marine and fluvial deltaic clastics of the Devonian Cabanillas Group that crop out in Otishi and Shira Highs (Sempere, 2016; Zamora et al., 2019). Subduction and strong magmatism started at early Carboniferous, as well as typically marginal marine and deltaic Ambo Group organic rich deposits, that comprises between 600 and 800 meters thick of shales and interbedded sandstones, conglomerates and coals deposited unconformably over Cabanillas Group. A rapid climate change from cool to warm modified the late Carboniferous–early Permian sedimentation along the Central Andes (e.g., Sempere, 1995). In the Ene Basin, this time span is represented by the basal shallow-marine transgressive green sandstones and limestones of the Tarma Group and the overlying carbonate platform of the Copacabana Group that were deposited unconformably over Ambo Group and have more than 1,000 meters thick (Sempere, 1995). A variable stratigraphic relationship between the Paleozoic and the overlying Mesozoic is recognized in the Ene Basin, the “Pre-Cretaceous cycle”.

In the southeast area, the Permian succession is composed of less than 200 m thick of a restricted-marine and fluvial/eolian succession of Ene, Noi and Shinai Formations (Sempere et al., 1992; Sempere, 2016). In the central part of the Ene Basin, where the BSE- 1X well is located, a regional unconformity (DBK) causes the absence of more than 1 km of upper Paleozoic rocks between the Ambo Group and the basal Cretaceous units.

In the northern part of the Basin a continuous stratigraphic column from Paleozoic until Cenozoic units is recognized, similar to the Pachitea and Ucayali Norte basins. The Upper Permian–Jurassic siliciclastic, carbonates and evaporites units of the Mitu and Pucará Groups and Sarayaquillo Formation cover the Paleozoic units and are associated with a syn-rift to post-rift period (Sempere, 2002; Rosas et al., 2007).

Overlaying the DBK, the Cretaceous units are mostly related to a series of transgressive-regressive cycles of approximately 800 meters thick, represented by fluvial and marginal marine deposits interbedded with more distal facies of Oriente Group and Chonta and Vivian Formations. Finally, a column of at least 3,500 m thick of Cenozoic synorogenic sediments were deposited conformably overlying the cretaceous units.

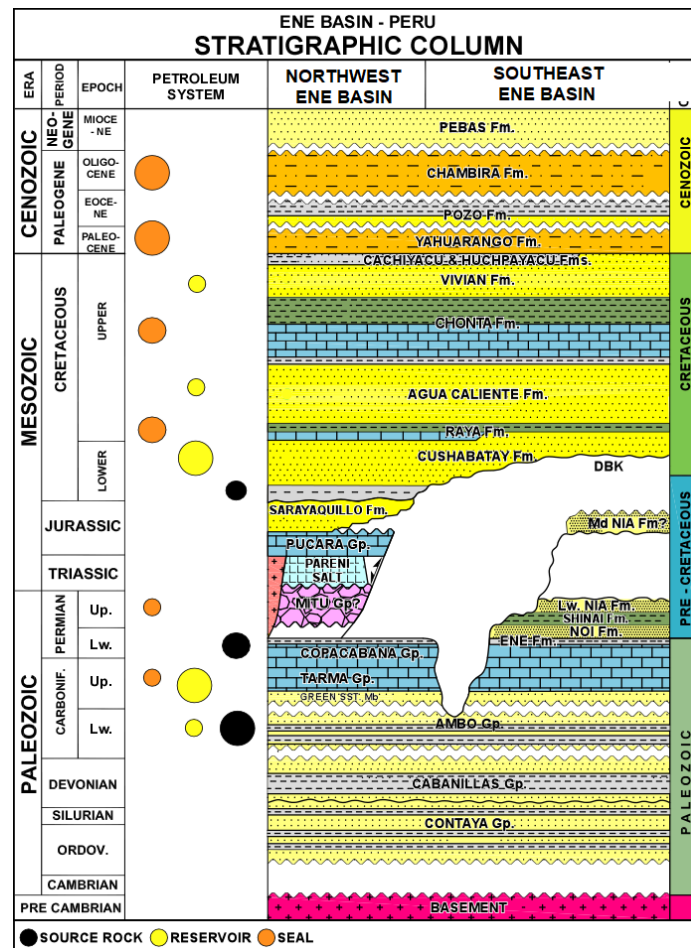


Fig. 1. Generalized stratigraphic column of the Ene Basin, which can be divided in northwestern and southeastern domains. The elements of the petroleum system (source rocks, reservoirs, seals) are indicated with bubbles (diameter represents their presumed importance). Modified from Iribarne et al. (2018).

Structural framework and domains

The Ene Basin is located in the Peruvian Subandean fold-and-thrust belt between two basement blocks: the Eastern Cordillera and the Shira-Otishi Highs. The Eastern Cordillera is deformed by a series of east-verging thrusts that involve basement and propagate tectonic shortening toward an intermediate detachment level in the Paleozoic units into the Ene Basin. To the east, the “Shira Massif” constitutes a basement high, that locks the propagation of the deformation. Two main structural domains, northwestern and southeastern structural domains can be recognized based on their stratigraphic characteristics (Iribarne et al., 2018).

The deformational style in the northwestern domain is dominated by inversion of the pre-Cretaceous rift system that develops a NW-oriented thick-skinned fold-and-thrust belt (Iribarne et al., 2018). Deformation is represented by NW-trending inverted normal faults, east-verging thrusts that involved basement and salt related structures associated to the existence of a shallow salt detachment (Pareni Salt) (Callot et al., 2018).

The southeastern portion of the basin is characterized for the absence of the Triassic and Jurassic stratigraphic units and the presence of the DBK unconformity at the base of the Oriente Group, similarly to what is found in the southern Ucayali region (Camisea). The absence of the rift and a thick Paleozoic stratigraphic column favored the development of a thin-skinned deformation style (Iribarne et al., 2018). The southeastern domain presents well-developed NNW-SSE-oriented anticline trends, related to east-verging thrusts. Main surface structures are characterized by asymmetrical and very continuous along strike folds with Paleozoic and Cretaceous rocks outcropping in the anticline cores. From west to east, the Boca Satipo and Puerto Ocopa structures represent the two main structural trends of this domain. BSE-1X well was drilled between these trends, to explore one of the structures of this fold-and-thrust belt.

108 Block exploration history and dataset

Block 108 was studied by several companies during the last 30 years. The most remarkable jobs in the block include: i) 5,530 km of high sensitivity magnetic survey acquired by Eurocan (1992), ii) acquisition of 230 km of 2D seismic as well as land gravity/magnetic data along the seismic lines, fieldwork geology and airborne gravity and magnetic data survey acquired by Elf Aquitaine (1994-1997), iii) 2D seismic reprocessing, extensive geological field work, 525 km of new 2D seismic acquisition, gravity and magnetic data acquisition along the lines and surface geochemistry by Pluspetrol and partners (Woodside and Perinti) since 2006.

Boca Satipo Este well

The Boca Satipo Este – 1X exploratory well was drilled in the central part of Block 108, to explore the Boca Satipo Subthrust East prospect. Boca Satipo Este – 1X well was drilled as a “Play Opener”, since no well had been drilled before in the Ene Basin. The main objectives were i) Drill a wildcat well BSE-1X in Ene Basin in order to confirm the presence of a petroleum system and explore hydrocarbon resources in Block 108, ii) obtain information about stratigraphy, reservoir properties and fluids characteristics in the Boca Satipo Subthrust East Prospect, mainly in four targets: Vivian, Agua Caliente, Cushabatay and Basal Tarma reservoirs. Boca Satipo Este – 1X well was spudded in October 2018, and drilling operations ended in February 2019 reaching a TD of 3020 mMD. The well prognosis was based on structural models made from surface geology information and interpretation of 2D PSTM and PSDM. The models included the presence of a Cretaceous anticline in the Boca Satipo Este prospect with a high degree of confidence, but still great uncertainty about the geometries, faults and position of the stratigraphic units. The hypothesis of the presence of structural repetitions of Cenozoic sequences on the Boca Satipo Este prospect was considered the most likely case and was used in the well prognosis (Fig. 2A)

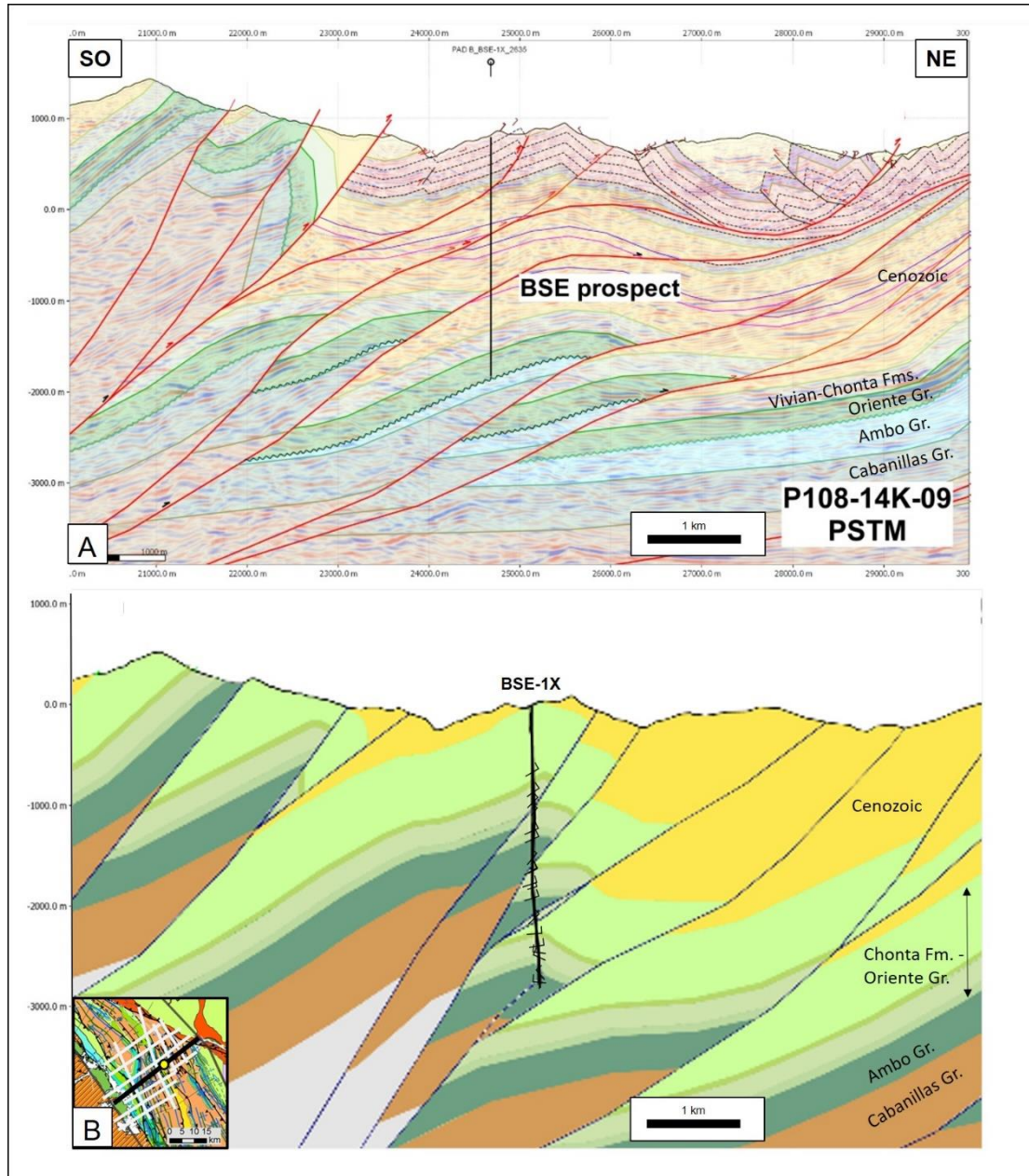


Fig. 2. Pre-drill (A) and Post-drill (B) structural models for seismic section P108-14K-09 at BSE-1X well position. Note the Cenozoic repetitions above the Boca Satipo Este prospect pre-drill case (A) and their absence in post-drill interpretation (B). See location in bottom left. Oriente Group include Cushabatay, Raya and Agua Caliente Fms.

The outcrop section of the eastern flank of the Boca Satipo Anticline was the type column of the prospect, with a thickness of around 520 m of Cretaceous units.

The original prognosis expected to find two Cenozoic thrust sheets and one Cretaceous-Paleozoic thrust sheet in the well. Although the well crossed 3 thrust sheets, the three repetitions included Cretaceous and Paleozoic intervals, without the presence of Cenozoic units. The well investigated the stratigraphic column and gas readings and oil shows confirmed the presence of an active petroleum system in Ene Basin. The comprehensive evaluation of all well studies allowed to conclude the absence of intervals of interest to be tested in BSE-1X well and led to the decision to definitively abandon the well.

Seismic Interpretation

The post-well seismic interpretation comprised the review of seismic sections, magnetotelluric data and velocity models that were obtained from refraction tomography inversions.

2D magnetotelluric modeling without data restriction acquired on line P108-14K-09, shows cores of high resistivity in the central part of the section. These resistive anomalies are associated with a close position between the Boca Satipo and Boca Satipo Este structures that show the presence of Cretaceous and Paleozoic units near surface. In the same way, it identifies a good correlation between the presence of Cenozoic units with low resistivity zones. On the other hand, tomography inversions were performed in order to build velocity models from surface to maximum depths reached by seismic rays. This is achieved reading first breaks in full offset ranges from shots and using them as input for inversion. Interpretation of velocity values distribution shows that high values match with Cretaceous and Paleozoic units while low values are associated with Cenozoic deposits.

Regarding the seismic interpretation of P108-14K-09 line in time domain (Fig. 3.), the main faults crossed by the well were interpreted and a deeper thrust sheet that was not reached was identified. From SW towards NE, the main structural features can be summarized as follows: a) Presence of the Maranquari anticline with post-rift facies outcrops (Fm. Sarayaquillo) interpreted as the result of inversion of an easterly dipping normal fault developed during the pre-Cretaceous rift period; b) syncline with prominent Cenozoic deposits thickness. The eastern flank represents the backlimb of Boca Satipo anticline (BS), with strong dips to the west; c) Boca Satipo anticline showing the presence of Cretaceous and Paleozoic units near surface; d) Boca Satipo Este anticline (BSE), characterized by continental red Upper Cretaceous outcrops in the well position and at least four thrust faults; e) Frontal syncline of Boca Satipo Este structure. The eastern flank corresponds to the backlimb of the Puerto Ocopa anticline (PO) and f) Puerto Ocopa anticline showing presence of Cretaceous and Paleozoic units in shallow positions.

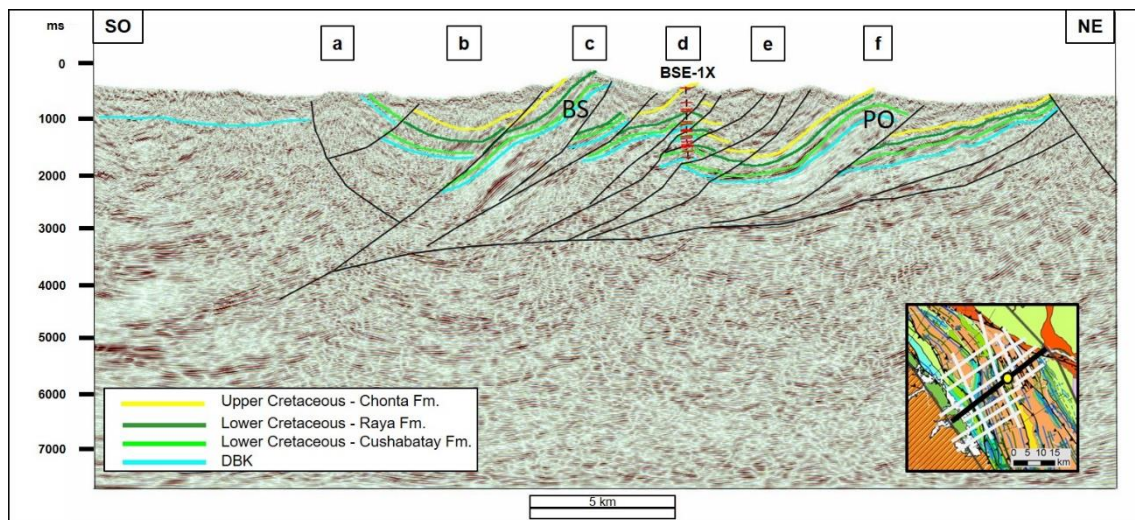


Fig. 3. Seismic interpretation of line P108-14K-09 showing the well location. See location in bottom right.

Structural balanced cross section

A balanced structural section was built over line P108-14K-09 position (Fig. 4) The objective of this work was to obtain a geometrically consistency of the structure and validate the seismic interpretation especially where the seismic is very noisy.

The structural modeling of the Boca Satipo Este structure honors i) well data: tops, faults and dip meter data, ii) 2D seismic sections: PSDM and PSTM P108-14K-09 line and PSTM nearby lines

were used to validate the model, iii) velocity models built with refraction tomography inversions, iv) magnetotelluric information, v) thermochronology data.

It is interpreted that the basal detachment is developed in lower Paleozoic sequences located at approximately 5,000 m depth, and that it dips to the WSW. The increased in the angle of the basal detachment in the east of the section could be reflecting an early exhumation of the Shira High.

Thermochronology

The data set included 43 surface samples collected over 108 Block. Thermochronology fission tracks in apatites (AFT) and He in apatites (AHe), supported an in-sequence deformation that would have started in the west in the early Miocene and propagated to east till recent (Fig. 4.). Also, Early Cretaceous aFT ages occur in the “Shira High” evidencing previous exhumation (Ruiz, 2017).

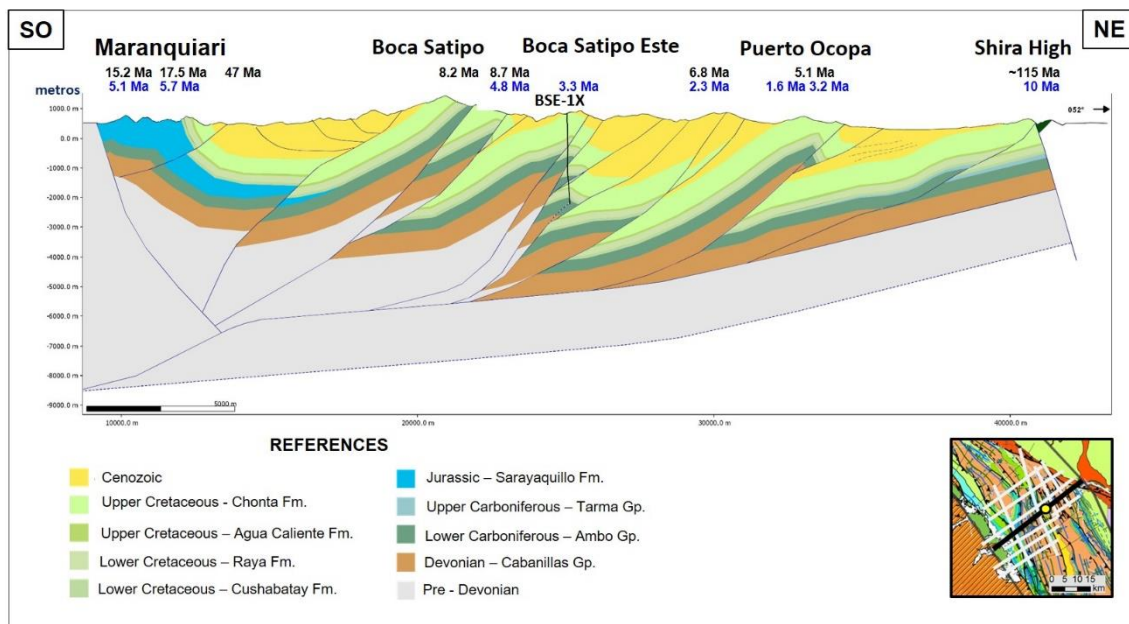


Fig. 4. Balanced cross-section of line P108-14K-09 showing the main surface structures. Projected AFT ages are in black and AHe ages in blue. See location in bottom right.

Kinematic forward modelling

The geometric reconstruction and flexural slip unfolding method was used for the restoration of cross section on line P108-14K-09. A shortening of approximately 21 km was estimated, with a negligible lateral shear required to adjust the model. According to regional data and thermochronology, structuration in the fold and thrust belt of the Ene Basin would have started during the Eocene. The deformation began in the western portion of the basin with the inversion of basement structures probably related to pre-Cretaceous extensional faults. The load of the Eastern Andes resulted in the folding and the onset of the foreland basin. Shortening migrated eastward during the Miocene and reached the Boca Satipo structure at ~9 Ma. A previous uplift of the Shira High may have acted as a buttress to the propagation of the thin skin deformation, resulting in the intense deformation of the Ene Basin and the tilting of the basal detachment. The proposed kinematic evolution considers an in-sequence deformation of the structures. However, it is expected that the deformation has developed simultaneously in two or three contiguous structural trends. Foreland propagation reached the Puerto Ocopa structure around

5 Ma. Nowadays, the western part of the basin shows intense deformation, probably due to recurrent out-of-sequence reactivation of structures.

Results and conclusions

The Ene Basin is characterized by an intense deformation that started during the Eocene with the inversion of pre-Cretaceous extensional faults located in the western sector. Since the Miocene, the propagation continued in-sequence to the east, with a thin-skinned style of deformation involving at least four thrust sheets in Boca Satipo Este structure, detached in Devonian shales. The presence of Shira and Otishi Highs constitutes the eastern limit to the propagation of the deformation.

Acknowledgments

The authors would like to thank Pluspetrol, Woodside Energy (Peru) Pty Ltd and Perinti for the authorization to publish this work and to Sebastian Galeazzi, Juan Soldo and Mariano Ragazzi for their constructive suggestions that helped to improve this manuscript.

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SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Mostardas Low (Pelotas Basin, South America) - An example of a graben evolution and infilling in passive margins of the South Atlantic Ocean

AUTHORS (FIRST NAME, LAST NAME): Sabrina Ramos¹, Mateus Vargas², Claudia Domingues Teixeira³, Henrique Serratt⁴, Marcelo Souza⁵, Tiago Girelli⁶, Gisela Oliveira⁷, Farid Chemale Jr⁸

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ABSTRACT BODY:

Abstract Summary: The processes that originated the rupture of the Gondwana Supercontinent and the consequent opening of the Atlantic Ocean are fundamental to understanding the complex tectonostratigraphic stages of the Pelotas Basin. One of those stages encompasses the formation of the Mostardas Low, which comprises deep-marine deposits of the Barremian age. We integrated seismic and structural interpretation, well-log data, and potential methods (magnetometric and gravity) to understand the negative topographic feature's tectonic and sedimentary evolution. The tectonic in this region can be divided into two domains. The first occurs in the proximal region with NE-SW half-grabens, filled by basalts flows identified in seismic data and deeper regions with high-density as seaward-dipping-reflectors (SDRs). The second occurs oceanward with two border faults NW-SE. The stratigraphic surfaces were mapped based on the biozoning of calcareous nanofossils in the RSS-2 well. Such data show that the tectonic control and sedimentation influenced the Mostardas Low between the rift and drift phase. The process that built-up the syncline and asymmetric structure of the Mostardas Low was directly connected with the rifting linked to the Atlantic Ocean opening. Generation of the Pelotas Basin's passive margin. Our results allowed us to detail the complex events of the Mostardas Low structure and define more clearly the tectonic in this region that is divided into two domains, NE-SW half-grabens and NW-SE border faults. It was also possible to determine the activity time of sedimentation that controlled the Mostardas Low from the stratigraphic surfaces, between the Barremian to Oligocene, beginning in the rift phase of the Pelotas Basin.

SESSION TITLE: Theme 2: Structural Styles and Kinematics I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Reservoir Breaching: Knowing the Threats to Assess a New Prospect

AUTHORS (FIRST NAME, LAST NAME): Sandra Janeth Montoya Osorio¹, Juan Carlos Alzate², Luis Gerardo Figuera³

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ABSTRACT BODY:

Abstract Summary: The geological processes that control how reservoir rocks are charged with hydrocarbons occur over millions of years of geological time. Those processes control the accumulation and transmissivity of reservoir fluids. A viable prospect with a good potential for hydrocarbon reserves requires three components: a source rock to produce the hydrocarbon, a reservoir rock to host the hydrocarbon, and a good cap rock to trap it and stop its migration away from the geological trap. The absence of any of the stated components can lead to the failure of the whole prospect.

A well known cause for reservoir breaching is seal failure. Some of the seal integrity symptoms and prognosis can be assessed during the prospect generation phase and ahead of spudding the well location. Some indicators of seal failure are faults that reach the mud line in deep water, active mud diapirism, the presence or lack of a seismic velocity reversal vs. depth (top seal), a narrow drilling tolerance window where the pore and fracture pressure are close and the presence of a large hydrocarbon column that breaks the seal. There are two methods to evaluate seal capacity: one method uses the capillary pressure for a sealing layer, to compute the maximum hydrocarbon column that a sealing layer can withstand without leaking. The other method uses the fracture pressure estimated from a geomechanical model that incorporates leakoff pressure measurements across the sealing layer, to compute the maximum pressure that the shale layer above the reservoir can resist without fracturing.

This paper describes how geomechanical models can be used to assess seal risk in exploration wells in the Caribbean basin. In this study, some examples of hydrocarbon accumulations with effective seals, and some breached seal prospects were evaluated.

The emphasis will be on how geomechanical interpretation can be used in an integrated workflow to constrain uncertainty on both seal and charge for hydrocarbon exploration. Such criteria can then be applied to predict seal integrity on un-drilled prospects.

SESSION TITLE: Theme 2: Structural Styles and Kinematics I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Gravitational Tectonics Evolution of the Rio Grande Submarine Fan, Pelotas Basin - South America

AUTHORS (FIRST NAME, LAST NAME): Gisela Oliveira¹, Mateus Vargas², Henrique Serratt³, Claudia Domingues Teixeira⁴, Marlise Cassel⁵, Marcelo Souza⁶, Tiago Girelli⁷, Sabrina Ramos⁸, Farid Chemale Jr⁹ **INSTITUTIONS (ALL):**

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ABSTRACT BODY:

Abstract Summary: Submarine fans are singular depositional features of active and passive margins and contain an essential dynamic record of the sedimentary basins. The Rio Grande Submarine Fan (RGSF), located in the southern sector of the South Atlantic passive margin, comprises the main geomorphological feature of the offshore Miocene in the Pelotas Basin, involving a deformed area of approximately 16,000 km². Integration of seismic and potential geophysical and wells data reveals those mechanisms of gravity tectonics in the Pelotas Basin. It includes a tripartite configuration: a proximal extensional domain, a transitional domain, and a distal compressional domain with a common Langhian detachment underlying the system, located approximately 9km deep. The deep-water fold-and-thrust-belts which comprise the compressional domains of these gravitational systems are considered important frontier provinces for petroleum exploration. The geometry and complexity of the gravity tectonics vary as a function of spatial changes in the development of the main depocenter of the RGSF. The proximal extensional domain comprises basinward-dipping, synthetic, and antithetic listric faults controlled by the NE-SW master fault. These structures become more complex towards the deep basin, and we define this as the transition domain. The distal compression domain consists of continent-dipping reverse faults, folding, and overlapping the layers. The master fault is connected to the detachment and operates on a regional scale in the Pelotas Basin. Transmission of compressional-induced stress linked to the Andean tectonism is interpreted to be the tectonic trigger for the deformation processes of the RGSF. Growth stratal patterns suggest that the gravity tectonics of the RGSF's is currently active, and the gravitational collapse can occur affecting submarine cables from Argentina and Uruguay which cross South Brazil.

SESSION TITLE: Theme 1: Reservoir Studies II

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

Finding New Opportunities in a forgotten Field Through 3D Seismic Interpretation: San Luis Field - Middle Magdalena Valley- Colombia

ROJAS A., NELSON, Ecopetrol, Bogotá, Colombia

Abstract

The Middle Magdalena Basin of Colombia (VMM) is one of the most prolific oil-bearing basins in Colombia, where the San Luis Field is located, which although it was discovered in 1923 following the drilling of 10 appraisal and production wells until 1963, today remains without any activity.

The Field was discovered through field geology and after that 2D seismic lines were shot 2-5 kilometers away between them and just in 2011 a 3D seismic survey was acquired, which covers an area of 36.4 square kilometers.

The San Luis Field is located toward the east central area of the VMM influenced by a system of thrust faults related with the foothills of the Western Flank of the Eastern Cordillera, being the Peña de Oro Fault one of the most important in the trapping of Oil in this Field. As was mentioned in this Field 11 wells were drilled many years ago, two of them were outside of the structure and others had mechanical problems during drilling or completions resulting thus that only four wells have a basic set of logs from that time (SP, Resistivity) and only two wells have oil production resulting in a total of 927 thousand barrels of accumulated oil from 36 °API from the Mugrosa, Esmeraldas and La Paz Formations at depths between 1500-2300 feet true vertical depth subsea.

The 3D Seismic interpretation was carried out integrating the geological surface map and the data of the four wells with logs and tops. Four horizons were selected for interpretation, which from top to base are: Intra Mugrosa, Esmeraldas, la Paz, Eocene Unconformity and La Luna. Previously to the interpretation some seismic attributes were run to help and improve the interpretation. Once interpreted these Horizons with the faults in the time domain, a 3D velocity model was made for the time depth conversion and to get the structural maps in depth.

The structure interpreted at the San Luis Field corresponds to an approximately North-South anticline cut on its west flank by the Regional Peña de Oro Fault, with some minor splays and back thrusts associated to the main fault. At level of Intra Mugrosa in the Southwest of the area this is outcropping and at level of Esmeraldas and la Paz the anticline structure is open to the south because the 3D Survey finished there but according to 2D seismic lines to the south of the 3D survey, the structure continues which opens a new prospective area as will be mentioned ahead.

As result of the seismic interpretation with the structural maps at each top of interest and the lowest known oil (LKO) of the two producing wells, is clear that there is still an area up dip for new wells in the structure of the Field (a P50 estimated of 260 MM barrels of oil in place). Also, there is a potential of prospective resources below the Eocene Unconformity in the Umir and La Luna Formations in the hanging wall of the structure and other prospective potential in the foot wall of the structure as a sub thrust Play and for La Luna formation as a non-conventional reservoir. So, there are many opportunities with low risk to find new oil reserves in the San Luis Field, which until today is a forgotten Field.

Introduction

The San Luis Field is located in the central part of the Middle Magdalena Valley, to the southwest of the well-known giant field La Cira Infantas (Figure 1).

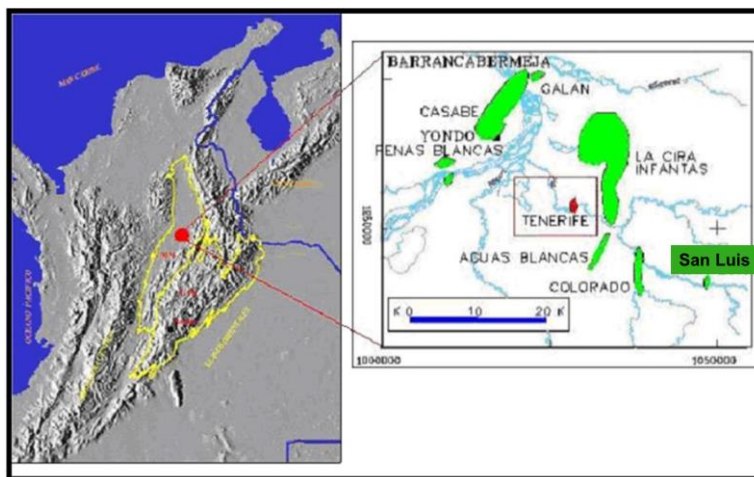


Figure 1. Location of the San Luis Field.

11 wells had been drilled in the field until today, the first well was drilled in 1923, the next 5 wells until 1929, and the last 5 wells were drilled between 1958 y 1963. Today we just know the basic electric logs from 4 wells.

Geological Background

The main reservoirs correspond to Mugrosa, Esmeraldas and La Paz Formations of late Eocene to Oligocene age (Figure 2) at depths between +500 to -2300 feet TVDSS. The accumulated total production is of 927 K barrels of oil 36 ° from just two wells (San Luis 4 and 7), the others wells had mechanical problems or were out site of the structure.

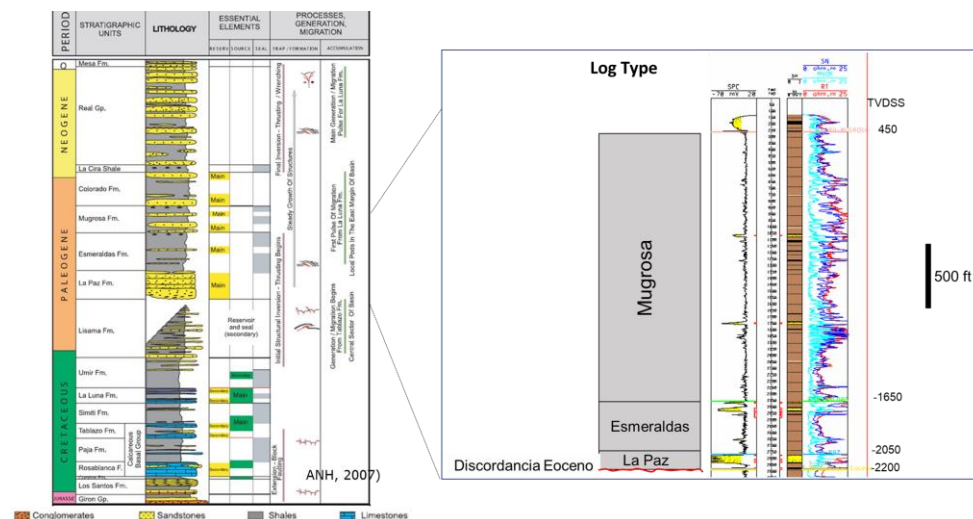


Figure 2. Generalized Stratigraphic Column Middle Magdalena Valley and log type of the Field.

Structurally the field is located at the west foot hills of the Eastern Cordillera of Colombia (Figure 3), in an area where there are many oil seeps and it is controlled by reverse faults (Figure 4).

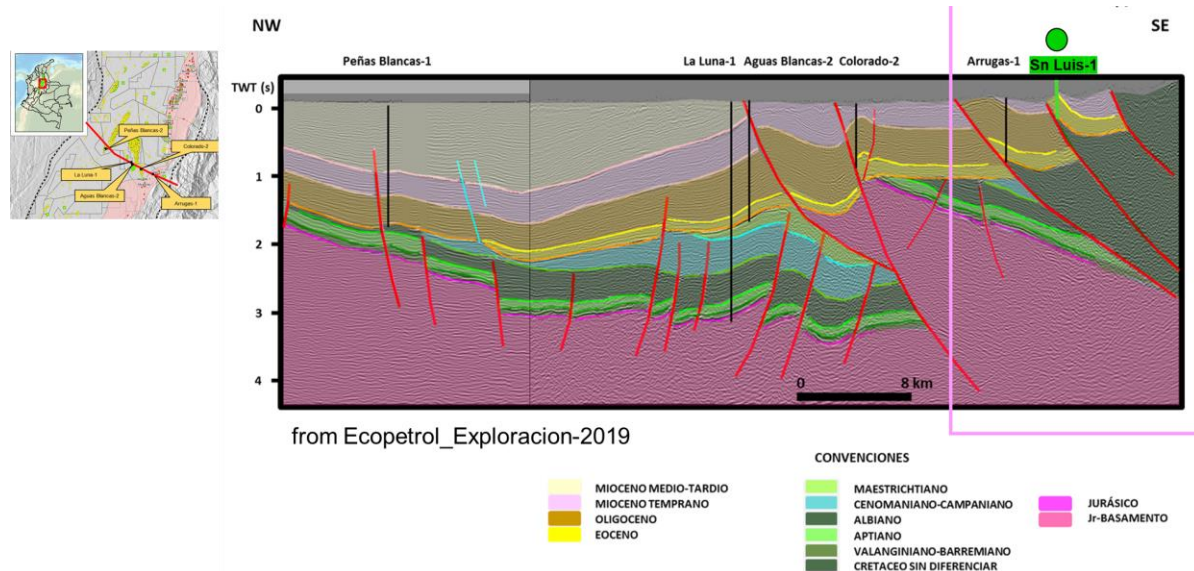


Figure 3. Geological Cross section trough the MMV and the San Luis Field.

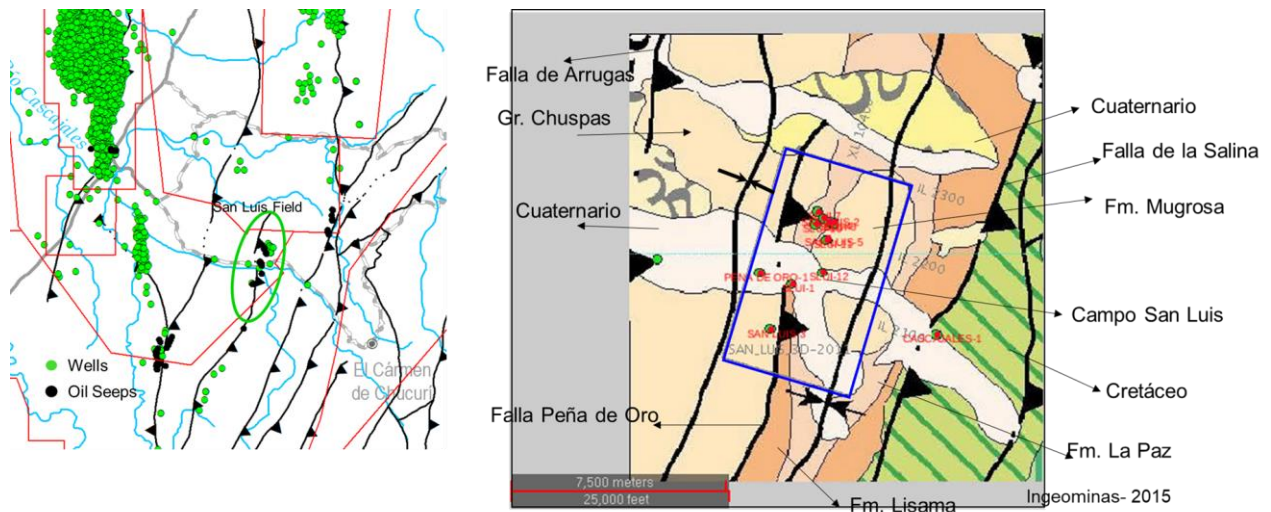


Figure 4. Left: regional map. Right: Geological map around the San Luis Field.

Seismic Data

In 2011 was acquired a 3D seismic survey (36.4 km²) with a square bin size of 25 meters, a nominal fold of 45, 18 lines by shot and 50 channels by line (Figure 5).

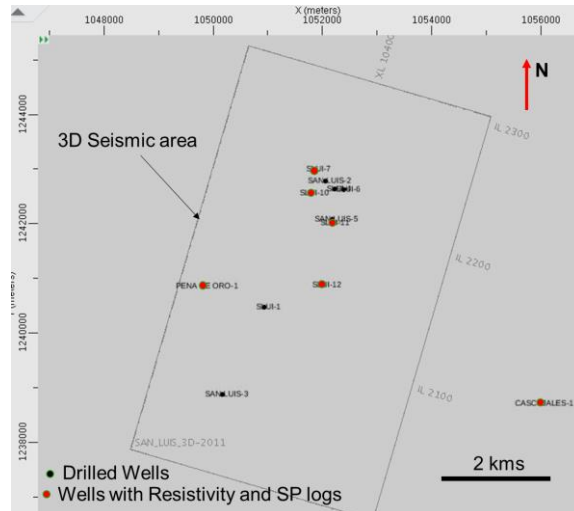


Figure 5. 3D seismic map at the surface.

The seismic was processed as a conventional Prestack Time Kirchhoff Migration which produced a fairly to good seismic image, just in the crest of the structure, the image is poor, as I will show ahead.

Seismic well tie

The tie between the tops of the wells and the horizon selected to interpret in the San Luis 3D Survey is showed on Figure 6, A check shot of the San Luis 12 well was used for the well tie.

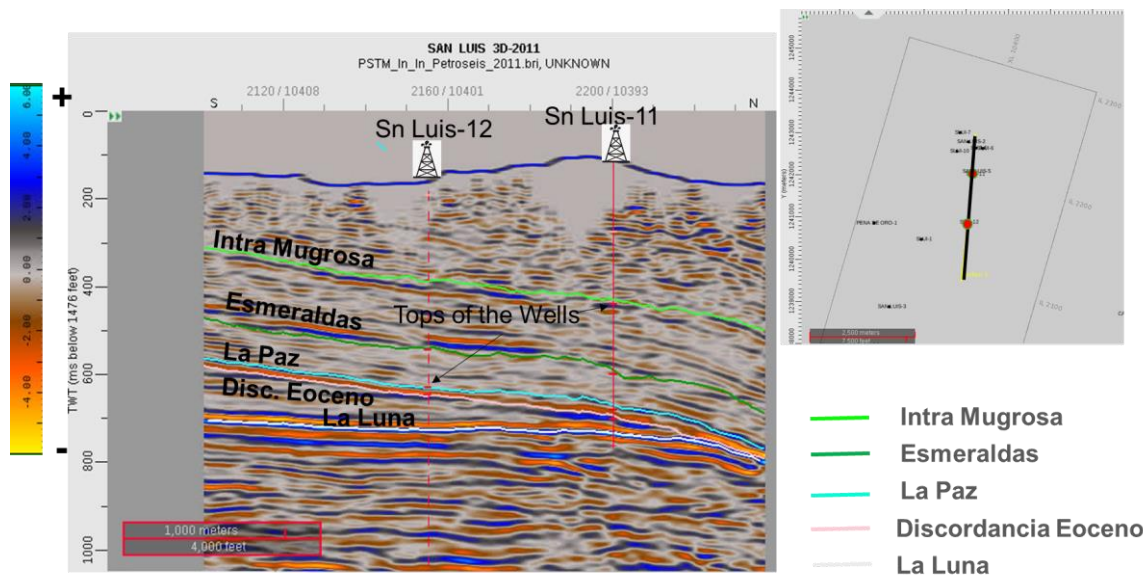


Figure 6. Arbitrary line showing the tie between top wells and the horizons selected to interpret.

Seismic Interpretation

In figures 7 to 10 are showed some representative seismic lines which depict the structure of the San Luis Field. In figures 11 to 12 are showed the structural maps to the top of the main formations

of interest, these maps were obtained from a time depth conversion through a 3D velocity model generated using the horizons and fault interpreted in time and the check shot from the San Luis 12 well.

The structure of the San Luis Filed corresponds to an approximately South- North anticline cut on its west flank by the Regional Peña de Oro Fault, with some minor splays and back thrusts associated to the main fault, the anticline plunges to the north; to the south the closure of structure is not covered by the 3D seismic, but by some 2D seismic lines there, is confirmed the continuity of the Peña de Oro Fault and probably the closure of the structure, otherwise we wouldn't have oil production from the northern wells.

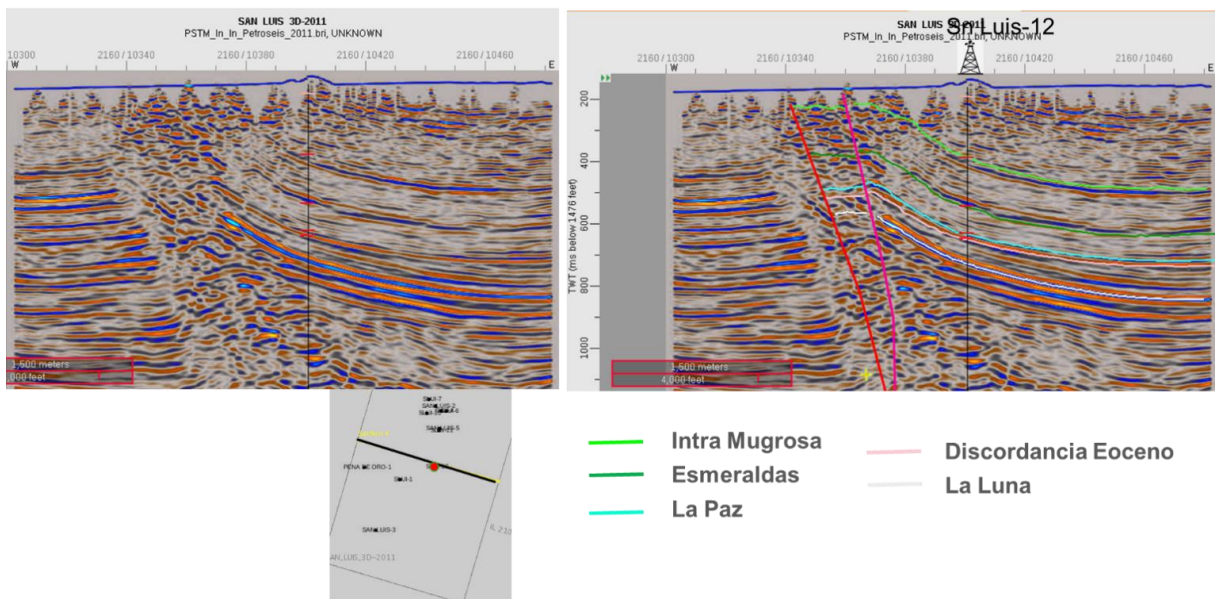


Figure 7. Dip seismic section through the San Luis 12 well. Left: without interpretation Right: with interpretation.

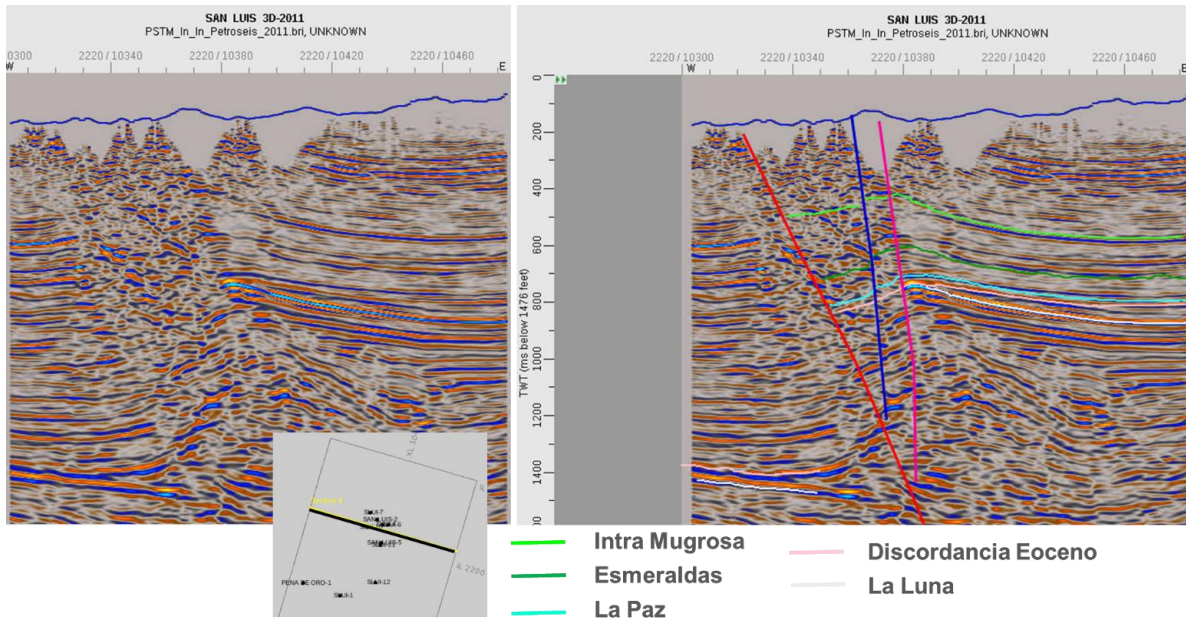


Figure 8. Dip seismic section at the north of the San Luis Field in the area of the producing wells. Left: without interpretation Right: with interpretation.

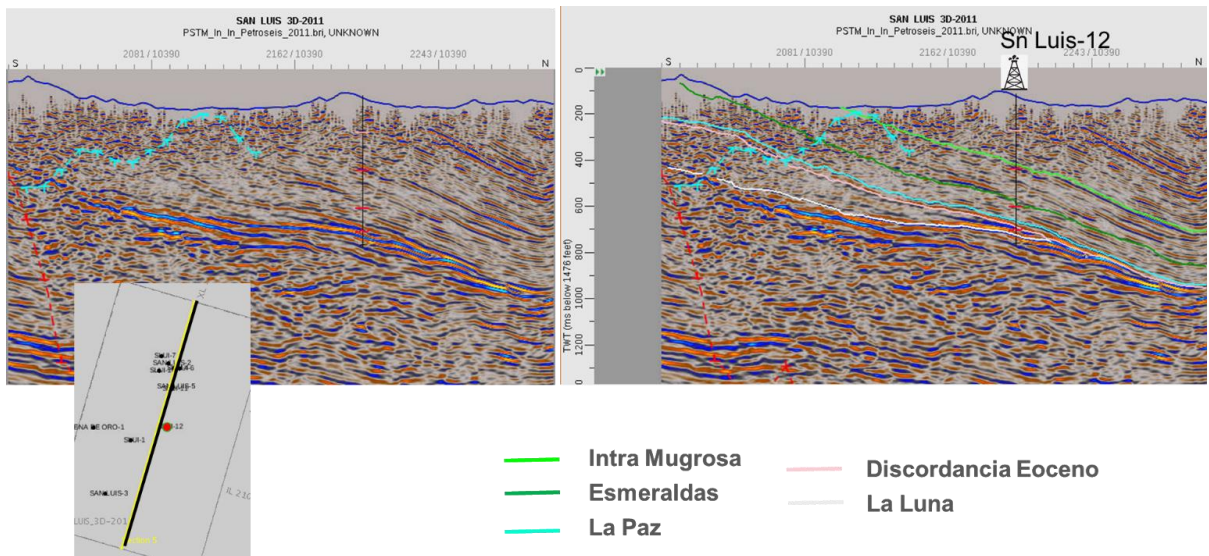


Figure 9. Strike seismic section Through the San Luis Field. Left: without interpretation Right: with interpretation.

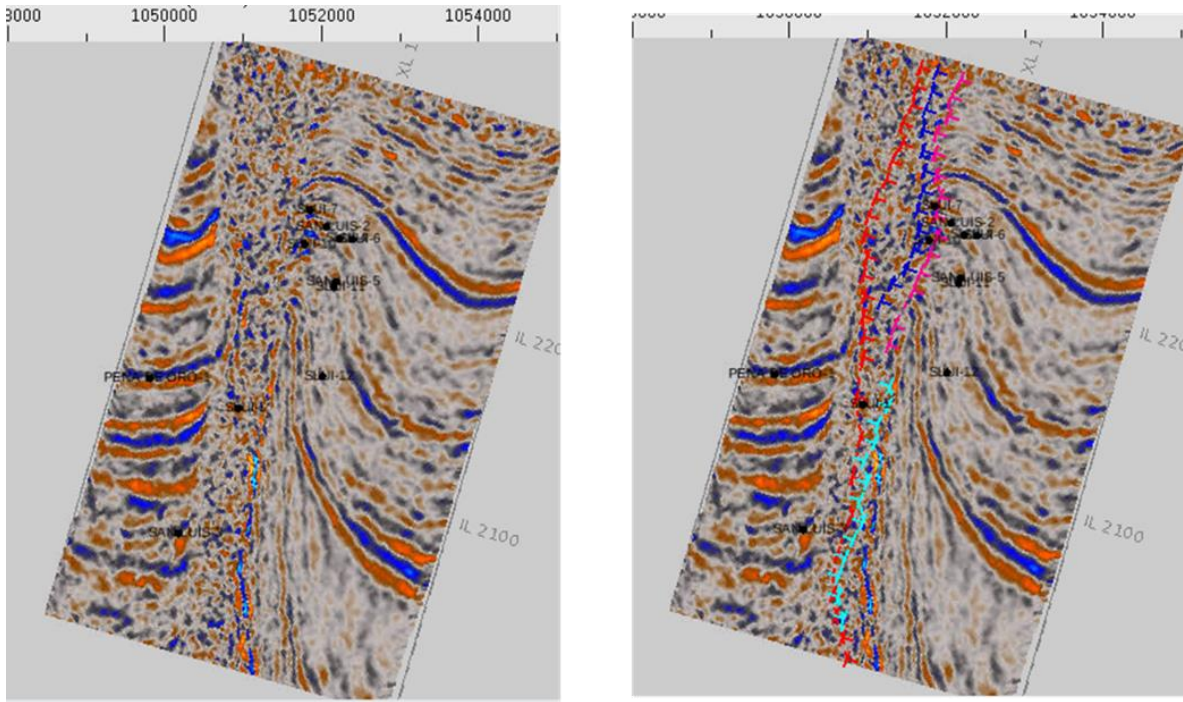


Figure 10. Time slice at 650 msec, showing the main interpreted faults. Left: without interpretation Right: with interpretation.

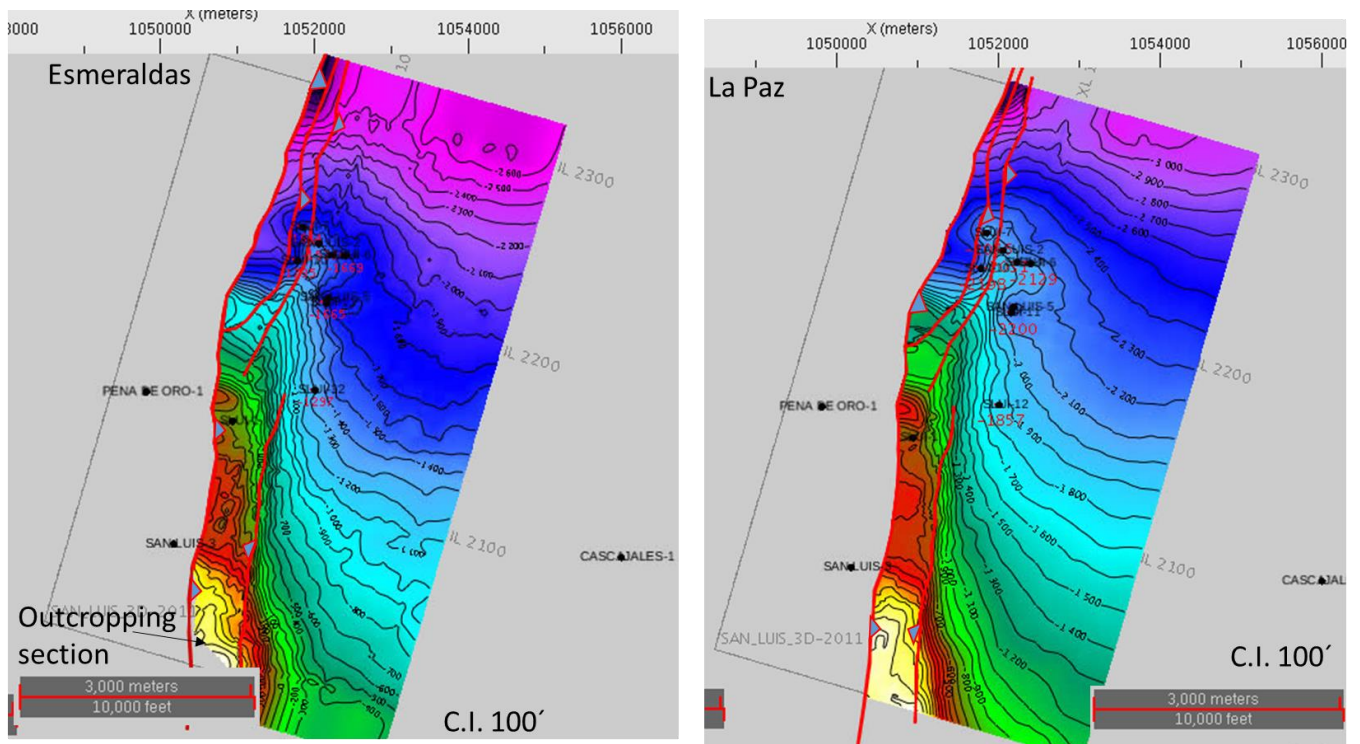


Figure 11. Structural maps to the top of Esmeraldas and La Paz Formations.

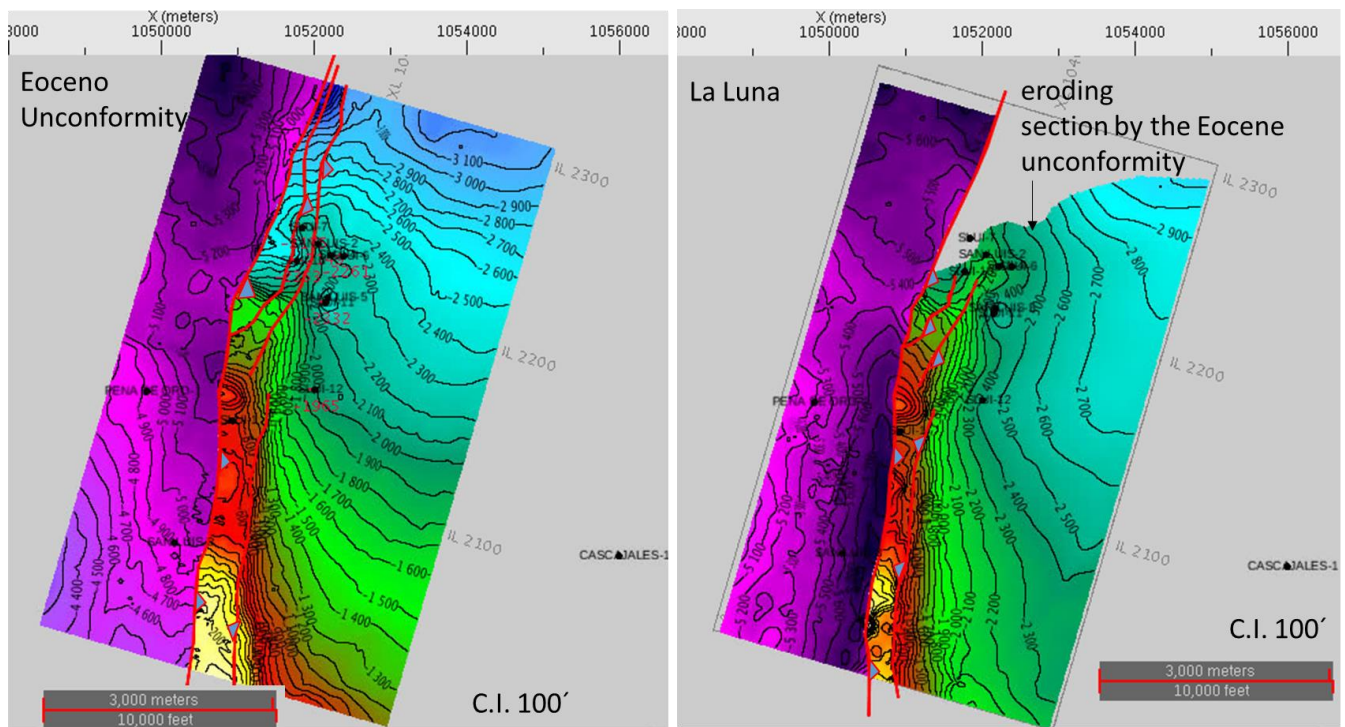


Figure 12. Structural maps to the top of Eocene Unconformity and La Luna Formation.

Based on what has been previously shown, there is great potential in areas up dip from the two oil producing wells to the west and south of the structure at level of Esmeraldas and La Paz formations as primary targets and as a second target the Umir Formation, which in the San Luis-12 well tested oil too. One advantage of this targets is its relatively shallow depths (less of 3000 feet). La Luna Formation is also a potential target as a Non-Conventional reservoir. A level of play the foot wall of the Peña de Oro Fault offers a potential opportunity to explore the same reservoirs intervals. The Figure 13 shows the areal and vertical potential of development and exploration in this forgotten field.

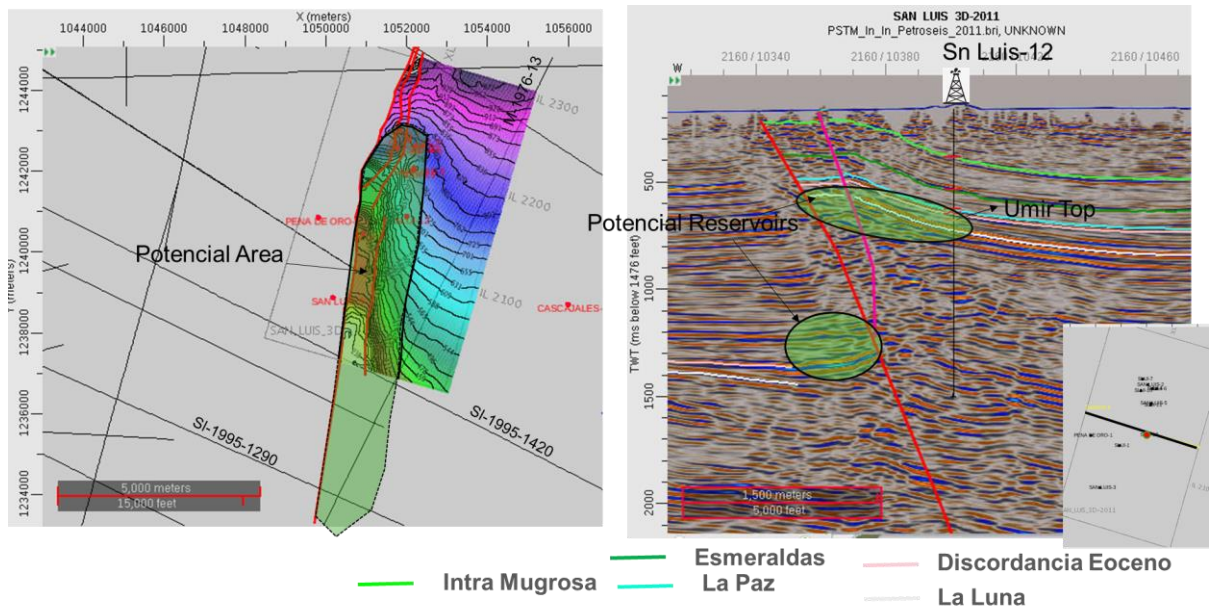


Figure 13. Potential areas of development and exploration in the San Luis field.

Preliminarily, a deterministic Oil in place was estimated in the area of the seismic interpretation and a level of Mugrosa, Esmeraldas and La Paz formations using average petrophysics, lowest known oil levels from the wells and areas, the Table 1, shows that there is potential of 257.6 MM barrels of Original Oil in Place (OIP); note, that is not estimated the area to the south outside of the 3D seismic survey.

Formacion	area (acres)	pay(feet)	poro	Sw	Bo	OIP (MM bls)		Lkos
Intra Mugrosa	2.47E+03	1.45	0.19	0.3	1.08	3.427	Intra Mugros	-502
Esmeraldas	3.91E+03	28	0.23	0.23	1.08	139.3	Esmeraldas	-1767
La Paz	4208.6874	19.75	0.26	0.26	1.08	114.9	La Paz	-2300
Total						257.6		

Table 1. Petrophysical parameters and estimated OIP in the 3D seismic area.

Conclusions

There is a potential of new oil reserves in up dip direction of the structure and from the oil producing wells at level of Mugrosa, Esmeraldas and La Paz Formations as primary targets and as secondary targets Umir and La Luna Formations.

An advantage is the shallow depths (less than 3000 feet) especially for the primary targets.

Acknowledges

The author expresses his acknowledging to Ecopetrol S.A. -Vicepresidencia de Desarrollo for allowing to present this work.

SESSION TITLE: Theme 1: Petroleum Systems, Geochemistry, New and Emerging Plays

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Characterization of a Triassic Presalt System Between the Eastern Cordillera and the Andean-Amazonian Foreland of Peru and Brazil

AUTHORS (FIRST NAME, LAST NAME): Emilio Carrillo¹

INSTITUTIONS (ALL):

1. Servicio Geológico Colombiano

ABSTRACT BODY:

Abstract Summary: Siliciclastic and carbonate presalt units in salt giants form part of prospects with low risk for hydrocarbon and underground storage industry. However, there are many salt giants which their presalt units are still to be discovered and characterized and waiting to be analyzed their potential as reservoirs. This fact is due to: 1) existence of offshore salt giants limiting outcrop observations; 2) uncompleted stratigraphic record of salt giants; and 3) poor quality of seismic images related to geophysical properties of evaporitic rocks. This work focuses on a siliciclastic presalt unit related to a Late Triassic salt giant located in a study area between the Eastern Cordillera and the Andean-Amazonian foreland of Peru and Brazil. This unit has been drilled in some wells and observed in seismic lines and outcrops. The main questions to respond in our work are: 1) when was this presalt unit deposited? 2) which were their depositional environments? and 3) is this unit a potential reservoir?

Observations of seismic lines and sedimentary features of outcrops and well-cores and well-log and stable isotopic analysis of samples were used to obtain a structural, thickness, lithological, sedimentological and chronological characterization. Also, a revision of petroleum features documented in previous works was carried on.

The following results were obtained in the study area: normal faulting with low throw (up to 100 m) controlled the sedimentation of the presalt unit; the maximum thickness of this unit is around 1300 m; it is formed by sandstones and claystone in areas with a relative low thickness and sandstones with evaporitic and carbonate intervals in depozones; cross-bedding and lamination in white and red sandstones is observed; and gypsum samples corresponding to the presalt unit have an average ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ of 0.707293. In a previous work, it is described the existence of porous sandstones which we associate to the presalt unit.

The results allowed us to interpret that: (i) the presalt unit was deposited during the ending of the Norian age in a fluvial system with local surrounding aeolian environments and marine salt pans in outer zones; and (ii) the studied presalt unit has a potential as reservoir. The Permian succession in north Germany and Netherlands, where important gas fields (Groningen field) have been discovered in a fluvial-aeolian presalt unit with evaporites, could be an analogue supporting the potential of the Andean case.

SESSION TITLE: Theme 1: Petroleum Systems, Geochemistry, New and Emerging Plays

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Paraná Basin (Brazil) - sills concentration and their influence on the petroleum system

AUTHORS (FIRST NAME, LAST NAME): Ana Júlia Raphael Lima¹, Marcelo Souza², Claudia Domingues Teixeira³, Farid Chemale Jr⁴

INSTITUTIONS (ALL):

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4. Universidade do Vale do Rio dos Sinos (UNISINOS)

ABSTRACT BODY:

Abstract Summary: The Paraná Basin, located in South America, records a large package of volcanic rocks interbedded with sedimentary rocks. This magmatism, named Paraná-Etendeka Province, is one of the largest Large Igneous Province (LIP) in the world and is related to the opening of the South Atlantic Ocean during the Gondwana Supercontinent fragmentation in the Early Cretaceous. The magmatism is characterized by tholeiitic and calc-alkaline basalts, with a minor amount of rhyolites and rhyodacites. In Brazil, these volcanic deposits as a massive amount and widespread volcanic layers. The LIP cross-cut the Paraná Basin as sills and dykes swarms that cut the Carboniferous to Lower Cretaceous sedimentary deposits. These sills cross the high Total Organic Carbon (TOC) content (max. 26%) rocks of the Iratí Formation. In the Paraná Basin, due to the high thermal activity induced by these igneous rocks and their structural framework, they could play a key role in the maturation and sealing of oil and gas deposits of the Iratí Formation. This work aims to study the effect of sill intrusions in the Iratí Formation and their influence on the petroleum system. We carried out an integration between well, gravity, and seismic data available for the Paraná Basin. The geophysical signature shows a high gravity zone related to The Paranapanema craton and the higher thickness of the Serra Geral Basalt. That high gravity zone contrasts with low gravity at borders associated with the Proterozoic metasedimentary rocks and flexures existing in this region. Our results indicate a large concentration of sills in the northeast and west of the basin, where the TOC of the Iratí Formation is 26%. We report a maximum 24.76% ratio of sills/sedimentary and a media is 8.65% in the Paraná Basin. We identify areas where this high ratio can strongly interfere in the petroleum systems.

SESSION TITLE: Theme 1: Petroleum Systems, Geochemistry, New and Emerging Plays

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Microthermometry of carbonate rocks of Hondita-Loma Gorda formations, Cueva del Tigre sector, municipality of Yaguará- Huila, Colombia

AUTHORS (FIRST NAME, LAST NAME): Ingrid Natalia Muñoz Quijano¹, Diego Loaiza², Camila Quevedo³, Camila Lozano⁴

INSTITUTIONS (ALL):

1. Universidad Surcolombiana
2. Universidad de Caldas
3. Surcolombiana University
4. Surcolombiana University

ABSTRACT BODY:

Abstract Summary: Colombia's limited oil reserves make it extremely important to find new extraction fields or to potentiate existing ones, thus affecting the production of the Upper Magdalena River Valley basin. In the oil industry, geochemical properties are used to understand oil systems, where one of the most important parameters is formation temperature.

Microthermometric measurements of fluid inclusions of carbonate rocks of Hondita and Loma Gorda formations were made, resulting in salinities that vary between 20.27% - 24.30% eq. weight of NaCl and an average homogenization temperature of 133.65°C, indicating that, at the time of trapping, the rocks were in the generation window of medium-light hydrocarbons for Loma Gorda and heavy-light hydrocarbons for Hondita; a regressive and transgressive evolution of the Cretaceous Sea is evidenced due to the variation of energy in the sedimentary environments.

SESSION TITLE: Theme 1: Petroleum Systems, Geochemistry, New and Emerging Plays

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Analyzing the Volatiles in Legacy and Fresh Cuttings Samples from the Delvina Gas Field (Albania) to Understand the Petroleum System, Assess Drainage due to Prior Production, and Plan a Path Forward for Field Appraisal and Development

AUTHORS (FIRST NAME, LAST NAME): Christopher Smith¹, George Vassilellis², Zamir Bega³, Timothy Smith⁴, Patrick Gordon⁵, Michael Smith⁶

INSTITUTIONS (ALL):

1. Advanced Hydrocarbon Stratigraphy
2. Energy Development Group
3. Energy Development Group
4. Advanced Hydrocarbon Stratigraphy
5. Advanced Hydrocarbon Stratigraphy
6. Advanced Hydrocarbon Stratigraphy

ABSTRACT BODY:

Abstract Summary: The Delvina gas field in Albania consists of a series of carbonate formations from the Eocene to upper Cretaceous which are thought to serve as a reservoir and sealed by an overlying flysch. Production began in 1987 and the field has a history of producing condensate. Production has historically been lackluster largely because of challenges with the tight matrix and presence of natural fractures. Furthermore, a lack of reliable petrophysical measurements and a poor understanding of the petroleum system hampered development efforts. Recently, Energy Development Group of Albania provided funding and technical leadership with a plan to acquire lacking information and to apply modern drilling and completion techniques. Two of the key wells, Delvina 9 and 12 (D9 and D12) were never logged with modern tools. The focal point is D12, which sits at the top of the structure and has one of the best production histories. To gain actionable subsurface data for D9 and D12 legacy cuttings from the flysch to TD of both wells were analyzed with Rock Volatiles Stratigraphy (RVS) by Advanced Hydrocarbon Stratigraphy (AHS). RVS developed by AHS extracts volatile chemistries from fresh and legacy rock samples (cuttings and core). RVS of the legacy cuttings allowed for evaluating water content, resource distribution, H₂S, fractures, and apparent cross field contacts in these wells that could not be re-entered. These data gave the operators a completion and targeting concept to attempt. A sidetrack of D12 (D12ST1) was drilled to provide fresh reservoir characterization and a chance to test modern completion techniques. Fresh cuttings from D12ST1 were collected and analyzed with RVS. These provided detailed information about resource concentration and composition in the present-day reservoir and detailed information about fractures, phase, and the mechanism of resource migration. In addition to providing important information that can be paired with traditional petrophysics to identify zones in the carbonate for further development, a major utility of RVS comparing the data from the legacy D12 cuttings to the D12ST1 cuttings. These comparisons allowed for a detailed appreciation of which portions of the carbonate were already drained from production, a key piece of information in the redevelopment of the field. Overall, the cuttings analysis supported a more definitive characterization of matrix, natural fractures and hydrocarbon distribution and opened a path to development.

SESSION TITLE: Theme 1: Reservoir Studies II

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Modelling Hydrocarbon Expulsion, Migration and Timing in The Corozal Basin of Northern Belize

AUTHORS (FIRST NAME, LAST NAME): Ashley Jones- Middleton¹, Trisha Garcia- Fitzpatrick², Mark Longman³, Douglas Waples⁴, Hans Axel Kemna⁵, Raymond Thompson⁶, Craig Moore⁷

INSTITUTIONS (ALL):

1. Geology and Petroleum Department
2. Geology and Petroleum Department
3. Sirius Exploration Geochemistry Inc.
4. Sirius Exploration Geochemistry Inc.
5. Sirius Exploration Geochemistry Inc.
6. Geology and Petroleum Department
7. Geology and Petroleum Department

ABSTRACT BODY:

Abstract Summary: Belize forms the eastern extension of the Peten Basin, a province with prolific oil fields in Mexico and Guatemala. The producing Spanish Lookout and Never Delay oilfields, the South Canal Bank discovery and numerous hydrocarbon surface seeps and subsurface shows, have proven the presence of a working petroleum system in the understudied Corozal Basin of northern Belize. While previous studies have identified the geochemical characteristics of different oils within the basin, the details of source-rock maturation, expulsion, migration and timing of hydrocarbon emplacement remain speculative. The objectives of this study involved better defining the basin's thermal history, estimating source rock maturity, determining the timing of hydrocarbon generation and expulsion, and determining the most probable vertical and lateral migration pathways for the migration of hydrocarbons within and into the Corozal Basin. A global and regional reconstruction of the geological history of Belize was conducted to establish a conceptual model for the tectonic and sedimentary history of the basin. The findings of which were used as an input into the Novva software to construct 1D burial and thermal history models for forty-five wells and nine pseudowells across the Mesozoic-Cenozoic sedimentary units of the Corozal Basin. Calibrated thermal history plots were then used to calculate the hydrocarbon generation from three hypothetical source rocks within the Corozal Basin. Finally, the most probable vertical and lateral pathways for migration and trapping possibilities were determined using map-based 3D modelling in the Trinity software. The constructed thermal and calculated hydrocarbon generation histories show that since Belize has had a cool temperature history, it would be difficult to develop strong exploration possibilities in the Corozal Basin without a contribution from hydrocarbons migrated into Belize from the Peten Basin, with generation occurring between 50-100 Ma and expulsion occurring shortly after. Modelling the occurrence of the two commercial fields and one discovery in the basin revealed that long-distance lateral migration along or through two separate formations must be postulated. In addition to significantly increasing the understanding of the geology of the Corozal Basin, these findings can contribute to the development of exploration strategies for the Corozal Basin by focusing future exploration efforts and resources in the most prospective areas.

SESSION TITLE: Theme 1: Reservoir Studies II

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Quantitative evaluation of the pore structure of tight sandstone reservoirs and implications for the genesis of reservoir inhomogeneity

AUTHORS (FIRST NAME, LAST NAME): Cunjian Zhang¹

INSTITUTIONS (ALL):

1. China University of Petroleum (East China)

ABSTRACT BODY:

Abstract Summary: Accurate assessment of the pore structure and inhomogeneity of tight sandstone reservoirs is essential to evaluate the reservoir quality and resource potential. The pore structure and sedimentation characteristics of the tight sandstone reservoir samples of the Xujiahe Formation from Yuanba area in the northeast portion of the Sichuan Basin were analyzed using experimental methods such as mercury intrusion capillary pressure, scanning electron microscopy, electron probe, etc. Analytic hierarchy process (AHP) was used to determine the weights of each factor in the reservoir evaluation system in order to quantitatively evaluate the pore structure of the tight sandstone reservoir as well as to identify the dominating factors leading to its inhomogeneity.

The rock mineral composition determines the pore structure of tight sandstone reservoirs. With most pore sizes of 10-200 nm and 7.5% of dominant connected pores (pore sizes larger than rapex) and a pore structure evaluation value of (Str) 1.04, the lithic sandstone reservoir is more susceptible to mechanical compaction, which leads to the near disappearance of primary pores, primarily developing pores between clay platelets and fracture pores. Chlorite between the particles of feldspathic lithic sandstone reservoir inhibits the cementation of siliceous cement and forms a channel for the flow of organic acid to promote the dissolution of the particles; there are mainly pores formed by the dissolution of cement and particles, as well as intraplatelet pores within clay aggregates, the size range of pores is large, and thus the inhomogeneity is stronger, most pores are 20-300 nm in size, the proportions of dominant connected pores is 42.7% and the Str is 3.32. The feldspathic lithic sandstone reservoir has a bigger Str than the lithic sandstone reservoir, making it a better favorable lithogenous facies for the high-quality reservoirs.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Assisted interpretation of core images with Deep Learning workflows: application to deep-water deposits of the Corinth rift (Greece)

AUTHORS (FIRST NAME, LAST NAME): Sébastien Rohais¹, Antoine LECHEVALLIER¹, Antoine Bouziat², Sylvain Desroziers³

INSTITUTIONS (ALL):

1. IFPEN
2. IFPEN
3. IFPEN

ABSTRACT BODY:

Abstract Summary: Deep Learning applications to unstructured data, such as images, provide means to optimize tasks that can be repetitive for technical experts. Meanwhile, the saved time would allow the expert to focus on more fulfilling tasks with important added values. In this paper, we confront Deep Learning workflows for the classification of images with tangible data used by geoscientist in their daily work. We highlight the main challenges in assisted interpretation of core images with Artificial Intelligence as well as some potential solution. Notably, we address how to handle situations where only few training data are available and how to choose and tune a model through Transfer Learning.

The dataset comes from an expedition of the International Ocean Discovery Program (IODP) in the Gulf of Corinth. It consists in 500 PDF files of core images from 3 wells already interpreted by geoscientist expert into 17 facies associations (FA). Facies associations primarily correspond to deep water deposits (>600-800 m water depth) of the Plio-Quaternary. We use the dataset in a feasibility study towards a digital tool automating the interpretation of core images based on a training selection that has been manually labelled. The workflow includes: (i) the data preparation, (ii) a parametric study on pre-processing and modelling parameters, (iii) a fine tuning and evaluation of the best model, and finally (iv) feedbacks from technical experts and recommendations.

Our study confirms the applicability of Deep Learning workflows to operational geological data sets, but also highlights that adapting these technologies to geological use cases is not straightforward. The core images extracted from the IODP report to describe the FAs are not enough in number to train an accurate model. There are specific configurations of the Sliding Window algorithm that generate image sets leading to more accurate models. Several data augmentation techniques also significantly improve the model accuracy, as well as fine-tuning techniques. Trained on 20% of the core length, the best-performing model shows a Top-1 accuracy of 70% and a Top-3 one of 90% when used to interpret the remaining segments. This promising result leads to practical recommendations for similar projects, potentially unlocking significant efficiency gains in the interpretation of geoscientific images.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Artificial Intelligence Technology Applied to Petroleum System Resource Assessment of the Undrilled Ultra-Deepwater Guajira Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Carlos Beisl¹, Marcio Rocha Mello²

INSTITUTIONS (ALL):

1. BPS/ Geospatial Petroleum

2. Brazilpetrostudies

ABSTRACT BODY:

Abstract Summary: The employment of Artificial Intelligence in the remote sensing technologies has enabled great advances in image interpretation including a better understanding of how to identify oil slicks from different sources on the sea surface using Synthetic Aperture Radar (SAR) images. Machine Learning (ML) algorithms have remarkably increased the ability to differentiate seepage slicks over the petroleum systems regions from oil spills. Oil detection in SAR images is only possible due to the reduction in backscattered energy intensity compared to the surrounding free water. However, the individualization of natural oil seeps from those of anthropic origin can only be obtained using circumstantial information of the oil slick itself. Until recently, the interpretation of seepage slicks was performed using only the Knowledge Driven approach. Nowadays, a powerful data analysis provided by machine learning methods has been employed to develop robust classification model to distinguish an oil slick source. For the Machine Learning approach used in this study a huge database with more than 3,000 features of oil slicks was built based on the long-term monitoring of: (1) different petroleum system regions associated of intense halokinesis basins, (2) oil platform zones, (3) and regions with intense maritime traffic. Hundreds of Sentinel-1 images acquired over very prolific seepage regions such as the Gulf of Mexico, Angola offshore region and Caspian Sea were interpreted to build an accurate database of reliable polygons seepage slicks and oil spills organized and stored in a Geographic Information System (GIS). Each feature of the database presents a several of radiometric (or physical), geometric and contextual attributes that are analyzed by applying statistical methods implemented in robust tools that allow defining standards and establishing models to support decision makes. Different ML algorithms were evaluated, including artificial neural networks (ANN), random forest (RF) and logistic regression (LR). Classification models using ANN obtained accuracy values greater than 92 and 90 for RF. These results of a well-established domains are very satisfactory, and the transfer learning approach have being applied in the interpretation of oil slicks features in the Ultra-Deepwater region of Guajira Basin with promising results.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Neogene Aquifers of the Middle Magdalena Valley: A new frontier for the use of “non-potable” water resources in the development of conventional and unconventional reservoirs

AUTHORS (FIRST NAME, LAST NAME): Felipe Cardona¹, Jorge Andres Sachica², Maria Florencia Segovia³, Jose Mario Martinez⁴

INSTITUTIONS (ALL):

1. Ecopetrol
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4. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The basins of the Magdalena River (Colombia) located between the Central and Eastern mountain ranges, share structures and a common geological history. The Middle Magdalena Valley (MMV) basin is located to the northwest of the Villeta anticlinorio where a pre-Cretaceous basement, composed of igneous and metamorphic rocks, is overlain by thick marine sequences where ductile shales predominate. These intervals have been outlined by a Molassic succession of conglomerates, sandstones and mudstones that appear to be a response to the thrust of more rigid structural units or blocks of the Central and Eastern Cordilleras. According to Morales et al.

(1958), the Real Group is a thick stratigraphic unit, formed at the base by 30 meters of conglomerates of black chert, quartz, sandstone pebbles, and overlaid by more than 3000 meters of pebble sandstones with cross stratification and intercalations of varicolored mudstones. Segovia and Cardona (2019) recognized vertical variations of salinity in the formations of the Real Group where fresh aquifers (2000 ppm) and brackish aquifers (7000 ppm) were identified without evidence of a transition zone between these units deposited accordingly. To plan for the development of Non-Conventional Reservoirs, innovative petrophysical analyzes have been carried out that, integrated with geological and geophysical interpretations, allowed to propose a flow induction test in a well close by to corroborate the quality of the water stored in these formations and estimate the transmissibility capacity by adapting specific tools and procedures. The result was promising and evidenced the presence of non-human consumable water resources that could be used for future industrial requirements, thus reducing the blue water footprint and allowing better use of the usable resource. The oil and gas industry in place at the MMV requires a high amount of water to operate; the conventional fields that are being operated under the technique of secondary recovery through water injection and the refining processes are industrial assets that require this resource for their operational continuity. The identification and sustainable use of the aquifers which are regionally continuous but with different productivity capacities, would support future development of operations with the objective of meet the goal recently proposed by Ecopetrol to reduce 60% of fresh water consumption by 2050.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Societal Preparedness to Volcanic Activity: Opportunities and Challenges Highlighted by the Geosciences Sustainability Atlas

AUTHORS (FIRST NAME, LAST NAME): Maria Angela Capello¹, Heather Handley²

INSTITUTIONS (ALL):

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2. Empty

ABSTRACT BODY:

Abstract Summary: The recent eruption of the volcano in La Palma (October 2021) raised questions and a debate in society at large, related to the preparedness of individuals to face geological hazards when geologic forces suddenly become disruptive and catastrophic. This article will showcase how the application of the new “Geosciences Sustainability Atlas” (2022, in press), enhances the understanding of the role of geoscientists and in particular volcanologists, in the following aspects of the readiness of the society:

- The comprehension of the role of geologists and geoscientists in the community and in sciences
- The understanding of what SDGs (UN Sustainable Development Goals) are impacted by the study of past and current volcanic eruptions
- The imperious need of assessing geologic hazards in sites of interest for communities, resource management or ecosystems.
- The relation between education and awareness in a community about the SDG framework and the Individual responsibility and participation in the reduction or mitigation of geologic hazards
- The active role geoscientists may play in providing technical support for development plans, construction norms, and even legislation.

The study done compiles statistics pertinent to volcanoes activities from the remote past to recent times, showcasing best practices in prevention loops, and disastrous gaps that resulted in mortality and economic losses related to volcano activities.

The authors used volcano-related relevant statistics and data, mapping it to the Geosciences Sustainability Atlas to the three Dimensions it clusters: People, Planet and Prosperity, identifying aspects relevant for each one. They also prepared a roadmap of potential actions to advance specific SDGs, grounded on their experience and knowledge of the particularities of this segment of the Geosciences.

Conclusions about the readiness of the society in relation to volcanism will trigger some reflections about the role geoscientists in general, and volcanologists in particular, are called to play.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Leveraging Subsurface Knowledge and Exploration Methodologies Towards the Energy Transition

AUTHORS (FIRST NAME, LAST NAME): Andrea Ortiz-Karpf¹, Eduardo Lopez-Ramos², Claudia Cardozo³, Lorena Suarez⁵, Cesar Patiño⁴

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
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ABSTRACT BODY:

Abstract Summary: Ecopetrol's knowledge base and capabilities will help the country transition to a low-carbon economy. For example, oil and gas exploration methodologies such as Play Based Exploration (PBE) are instrumental to map subsurface fairways for carbon sequestration, geothermal energy developments, and hydrogen. Play-based exploration (PBE) is a widely used methodology to assess the subsurface distribution of petroleum systems elements and it is the basis for the selection of exploration focus areas. In an analogous way, comprehensive PBE knowledge is key to assess Colombia's subsurface potential for emerging decarbonization technologies and the eventual selection of sites for carbon storage, geothermal energy, and hydrogen pilot projects. At Ecopetrol, we have adapted traditional play-based exploration methodologies to evaluate carbon capture and geothermal potential in the Middle Magdalena Valley and the Llanos basins in Colombia. We integrated existing regional geological models that were initially conceived for oil and gas exploration, with available subsurface data to quantify geothermal and CO₂ storage potential and assess geological risk. This methodology can be applied to other basins and to other resources like natural hydrogen. This is the first step towards ranking of prospective areas in Colombian basins and provides a foundation on which to further leverage the country's oil and gas infrastructure and electricity grid. As we illustrate, the Energy Transition brings a new era of subsurface exploration with the opportunity to broaden the application of oil and gas skills.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Hydrogeochemical Characterization of the Southern Cauca River and Possible External Pollutants.

AUTHORS (FIRST NAME, LAST NAME): Manuela Soto Marín¹, Felipe Gonzalez-Penagos²

INSTITUTIONS (ALL):

1. Universidad de Caldas

2. Water Research Group

ABSTRACT BODY:

Abstract Summary: The Cauca River is one of the two most important macro-basins of Colombia as part of the Magdalena-Cauca hydrographic area. Almost 1000 km length flowing northward to the Caribbean and lies between the Western and Central Andes Cordilleras of Colombia. In the department of Valle del Cauca, the southern portion, it becomes the most important source of surface water for the community, agriculture, and mining. Since the water of the Cauca River is widely used for human consumption, monitoring the river water quality is key factor to measure the concentrations of ions and heavy metals, to understand the origin and the pollution of industrial, urban and mining discharges. The understanding of the water quality allows us also to work together with the local community creating conscience of the importance of a water quality for human consumption and ensuring its treatment.

Hydrogeochemical and compositional historical parameters of the water of the Cauca River between 2016 and 2020 at different seasons of the year were compiled and analyzed. Additionally, 12 new samples were collected in 2021, in both the Cauca River and the creeks at the eastern sector of the Western Cordillera and the western sector of the Central Cordillera from Bolívar to La Victoria. In order to analyze and characterize the interaction and behavior of the bedrock with the composition of the Cauca River and to establish possible external pollutants that alter the initial composition of the river. Hydrogeochemical data of the creeks allow us to propose a natural rock-water interaction end-member reference for a meteoric water with low influence of industrial, urban and mining water. Parameters such as pH and electrical conductivity were determined in situ, while concentrations of nutrients (NO_3) majority ions (Na, Mg, K, Ca, Cl, SO_4 , HCO_3), trace elements (Fe) and heavy metals (Hg, Pb, Cd, Ni, Zn) were determined in laboratory. As a result, hydrogeochemical diagrams indicated that the waters are magnesium bicarbonate type with a tendency to mixed type with calcium chloride type, where the predominant cations were of type Ca^{2+} and the predominant anions were of type HCO_3^- , for the piper diagram. With regard to heavy metals, contamination is observed in (Pb, Cd, Ni, and Cr) since they present data above the maximum allowed values.

SESSION TITLE: Theme 2: Structural Styles and Kinematics II

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: The Role of the Cimitarra Fault and the influence of the basement highs in the configuration of the Middle Magdalena Valley Basin, Colombia. Implications for under-explored opportunities.

AUTHORS (FIRST NAME, LAST NAME): Leonardo Duerto¹, Jorge Acosta², Luz Marina Duarte³, Fabio Santamaria⁴, Sandra Anaya⁵, Diego Garcia⁶, Iván Camilo Higuera⁷

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol

ABSTRACT BODY:

Abstract Summary: In the past Middle Magdalena Valley (MMV) was believed to have a uniform geological history. However, new gravity and magnetic data shows a complex basement morphology. Several basement highs were formed when a Jurassic extensional episode shaped the Pre-Cretaceous rocks and affected the subsequent Cretaceous-Cenozoic tectono-stratigraphic layering.

The Cimitarra Fault Zone (CFZ) and the adjacent basement highs (La Cira in the south, San Rafael and San Alberto in the center, and Gamarra in the north) were marked by tectonic activity, giving the northern part of the valley a deformation history different than that of its southern part.

Onlap of Lower Cretaceous depositional sequences over tilted Jurassic sediments along these basement highs implies an active infilling sedimentation (Rosablanca/Tablazo Fm.). The Late Albian truncations seen at the top of the Simiti Fm. also indicate an incipient deformation along the Cimitarra fault and other similarly oriented fault systems in the region. Both events signal a shallowing along the basement high areas around the CFZ during the sedimentation of the Simiti and La Luna Fms.

A large-scale Maastrichtian age deformation along the CFZ, seen in the Umir Fm. growth strata, split the northern part of the basin from its southern part, reactivating normal faults along the main edges of the ancient Jurassic Horst and Graben system, and reversing them with a strong component of right lateral strike-slip motion. During Paleocene this deformation was followed by transpression, generating east vergence thrusts that fractured the Horst and Graben system in a short-cut fault style.

From the Late Cretaceous and through Eocene the San Rafael high absorbed the major part of the region's shortening, ca. 10 km, creating a thrust front with a NS axis. At this time all the crests of the basin's structural highs were also eroded. As the result, a piggy-back basin formed west of the thrust front, to the north of the Cimitarra Fault.

When the St. Marta-Bucaramanga fault system was formed during Eocene and Miocene, uplifting and displacement the Santander Massif, areas of the MMV adjacent to the Eastern Cordillera suffered a transpressional episode, resulting in additional folding and faulting producing structures with NW vergence.

MMV's Cretaceous sequences necessitate detailed exploration. The geological history of formation of this valley reveals its potential for being a significant oil province that is still under-explored.

SESSION TITLE: Theme 2: Structural Styles and Kinematics II

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Geometry and evolution of the Casabe Fault in the Middle Magdalena Valley Basin, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Mayra L. Vargas¹, Pedro A. Galindo²

INSTITUTIONS (ALL):

1. Universidad Nacional de Colombia
2. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The Casabe Fault is located in the western flank of the Middle Magdalena Basin, Colombia. Previous studies of the fault have shown structural information focused only on the reservoir level, then its evolution and deformation styles had not been analysed in detail as yet. This study integrates the 3D seismic interpretation of the two PSTM seismic volumes covering an area of 212 Km², providing a unique opportunity to visualize three-dimensionally the northern tip of a regional intra-plate strike-slip fault in the subsurface. As a result of the detailed seismic interpretation, 13 time-structural maps were generated covering all the sedimentary section. In addition, the calculation of time-thickness maps together with the construction of vertical and interval displacement diagrams help to analyse and characterise the structural styles and depositional patterns along the fault zone. Hence, the structural styles observed include fault reactivation processes and strike-slip deformation. Nine fault segments within the Cretaceous section are identified. These were reactivated and amalgamated by the strike-slip deformation during the Cenozoic. Evidence for strike-slip deformation includes the occurrence of en-échelon normal faults, pop-up and pull-apart structures, and horsetail terminations.

To summarise these observations, a schematic model of the Casabe Fault is generated for the study area. The model illustrates the three-dimensional variation of structures associated to the fault plane, and how these structures constitute the northern termination of a regional fault zone. Likewise, the analysis of the results, allows to identify a deformation stage prior to the Eocene Unconformity (Late Cretaceous – Paleocene), and to propose that the strike-slip deformation has been active since the Late Eocene to the Recent. The results of this study incorporate new knowledge to the interpretation of the regional geological evolution of the Middle Magdalena Valley Basin and provide new observations and analysis that contribute to the understanding of the evolution of strike-slip fault zones.

SESSION TITLE: Theme 1: Petroleum Systems, Geochemistry, New and Emerging Plays

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Where are the Reservoirs in the Colombian Caribbean Margin? Insights from Seismic Attributes

AUTHORS (FIRST NAME, LAST NAME): Roberto Aguilera¹

INSTITUTIONS (ALL):

1. RA GEOLOGIA E.U.

ABSTRACT BODY:

Abstract Summary: The Colombian Caribbean Margin has become an area of particular exploratory interest in recent years, however the knowledge of the depositional systems, in particular the distribution of potential reservoirs is a major uncertainty on the definition of traps at the area. This is further complicated by the complex and variable structural styles along the margin and the fact that most wells have been drilled on its continental shelf in close proximity to the shoreline, providing a limited view of the subsurface.

Considering this, and in order to tackle this uncertainty, a seismic attributes analysis of multiple 2D seismic transects covering more than 80000 squared kilometers on the Colombian Caribbean Margin and tied with some existing wells have been carried out. From this analysis an evolutionary model of the depositional systems showing the vertical and lateral variability of the likely reservoirs, their transitions among the different structural provinces and possible trapping mechanisms has been developed.

This model provides a better understanding on the petroleum systems in particular the distribution of their elements, and also on the geological risk of potential exploratory opportunities in this frontier area of Colombia.

SESSION TITLE: Theme 1: Petroleum Systems, Geochemistry, New and Emerging Plays

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Play Concepts and Play Based Exploration Applied to Colombia Caribbean Basin

AUTHORS (FIRST NAME, LAST NAME): Victor Ramirez¹, Juan Carlos Ramon², Fabricio Combata³, Andres Lozano⁴, Leonardo Moreno⁵, Andrés Fuenzalida⁶, María Cerón⁷

INSTITUTIONS (ALL):

1. Dirección Técnica de Hidrocarburos - Servicio Geológico Colombiano
2. SGC - Servicio Geológico Colombiano
3. Servicio Geológico Colombiano
4. Servicio Geológico Colombiano
5. Servicio Geológico Colombiano
6. Servicio Geológico Colombiano
7. Agencia Nacional de Hidrocarburos

ABSTRACT BODY:

Abstract Summary: Play Based Exploration is a methodology that allows to put together petroleum systems and prospective geological features in a basin framework. By identifying geological features of exploratory interest under the concept of play, explorers, decision makers and investors can rank geographic areas into the particular basin and allocate proper time, technical efforts and economic resources to those projects where higher return and portfolio growth is expected.

Caribbean Offshore basin of Colombia, with an extension of more than 250.000 km² and considered a frontier province in northern South America, is becoming an exploratory emerging region. Encouraging results from drilling campaigns in the last 7 years indicate the presence of working petroleum systems, with a hydrocarbon potential in the level of 35 to 90 TCFG, and fair to good chances of finding liquid hydrocarbons.

Exploratory efforts carried out by Colombia national oil company Ecopetrol and several players such as Petrobras, Anadarko, Shell, Repsol, Equion and ONGC among others during the 21st century in offshore Colombia, have been executed in a block by block (contract by contract) fashion, with state of the art concepts and technologies, although not necessarily systematic when proving geological concepts.

A systematic description of plays in the Caribbean has been proposed and published by some authors, such as Ramirez 2007, Vence 2008, Ardila and Diaz, 2015, Martinez et al, 2015, Ecopetrol 2016 and Carvajal et al, 2020. Despite the value of their contributions, these approaches were either restricted geographically (only referred to portions of the Caribbean basin) or limited by the data available.

Projects executed in 2020 by ANH with local universities have made use of play fairways methodologies, in an effort to cover three areas of Caribbean offshore with regional interpretations.

The present work presents the most recent attempt by Agencia Nacional de Hidrocarburos and the Dirección Técnica de Hidrocarburos (a division of Servicio Geológico Colombiano) to use play based exploration approach to analyze the Caribbean Offshore in a single systematic project. Several play concepts are reviewed, documented and updated. The summarized results, reported as play fair ways maps, constitute a technical basis for fostering the exploration and investment in this promising province.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences I

SESSION DAY & DATE: Wednesday, April 20, 2022

SESSION TYPE: Poster

TITLE: Hydrocarbon to Heat: Evaluating Geothermal Potential in Existing O&G Assets

AUTHORS (FIRST NAME, LAST NAME): Ivan Palacios¹, Gustavo Chacon¹, Maria Hurtado¹

INSTITUTIONS (ALL):

1. Schlumberger

ABSTRACT BODY:

Abstract Summary: The main objective of geothermal coproduction projects is to boost the generation of electrical energy by transforming the heat coming from the produced water of the oil wells through a generator. The geothermal resource operational scheme may vary depending on the water enthalpy: low (<90°C), medium (90°C-150°C) or high (>150°C). Many oil reservoirs represent only a low-to-mid temperature resource but taking advantage of oil infrastructure saves the high investments associated to exploration and development making these low temperatures resources profitable. Oil operators are realizing these benefits and since 2019 are intensifying their efforts to coproduce geothermal energy from their existing fields.

The objective of this work is to develop a workflow from volumetrics to simulation, allowing not only the quantification of the heat in place of a geothermal system but also the selection of the best development scenario in order to determine the viability of a field, area or wells to cogenerate energy. The workflow starts by calculating the resource potential using a volumetric estimation method introduced by the United States Geological Survey (Circular 790) and modified to account for uncertainties in key input parameters with Monte Carlo's probabilistic approach. The information required for this step and following ones, is depurated from subsurface and surface data and operating histories. The specific data evaluation includes logged formation temperatures, wellhead temperatures, formation depths, porosities, well schematics, and flow rates. In addition, related data such as distances to injectors and to on-site stations can be used in the analysis. Subsequently, advanced modeling techniques and numerical simulation can be carried out to land the opportunities identified and define if more flow, higher temperatures or both can be achieved by specific recompletion or perforation activities.

A case study of a mature oil field is presented. It was identified that most of the wells evaluated have wellhead temperatures that are within the theoretical range for at least kW-scale power generation, and a special Region is likely to support MW-scale generation. The results demonstrated a conservative resource potential of up to 11 MW and possible workover intervention operations to extend the life of the assets as geothermal producers for +20 years.

THURSDAY
21 APRIL 2022
ORAL PRESENTATIONS

SESSION TITLE: Theme 3: Recent and Potentially Untapped Deep-Water Petroleum Systems

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Regional effects of the Panama arc-South America collision and its controls on hydrocarbon distribution in Colombia and western Venezuela

AUTHORS (FIRST NAME, LAST NAME): Juan Pablo Ramos¹, Paul Mann¹

INSTITUTIONS (ALL):

1. University of Houston

ABSTRACT BODY:

Abstract Summary: Despite many previous paleoceanographic, paleontological and geologic studies in Panama, Colombia, and western Venezuela and their offshore areas, the debate continues on the the age of the initial collision of Panama with interpretations ranging widely from Oligocene (25 Ma) to Late Pliocene (2.8 Ma) along with how this event was manifested in the regional subaerial and marine geology. In order to address these questions, we present: 1) a regional depth-to-top crystalline basement map of both on- and offshore areas; 2) integration of thermochronologic data from the Colombian Geochronological Database (CGD); 3) updating of on- and offshore paleogeographic maps using recent data acquired in the past decade; 4) defining areas of angular unconformities and their ages; 5) generation of burial plots, sedimentary thickness and isopach maps from basins in Colombia and western Venezuela; 5) compilation of GPS data and late Quaternary fault zones; and 7) mapping of regional distribution of seeps, producing wells and giant oil and gas fields. Results from these compilations include: 1) collision of the Panama arc marked a regional event of uplift of basement blocks with thermochronology showing a main phase of cooling and exhumation during the late Miocene-Pliocene (12-4 Ma); 2) basement uplift and erosion in a tropical climate produced clastic wedges in on- and offshore clastic basins; 3) the development of the north-flowing and strike-parallel Cauca, Magdalena and Maracaibo river systems formed a continuous source of clastic sediments into the Caribbean sedimentary basins especially with the development of the Magdalena submarine fan; 4) the Panama collision creates a wave of Late Miocene to Recent (13-0 Ma) hydrocarbon maturation and migration that encompasses the Maracaibo, Llanos, Middle Magdalena Valley and Catatumbo basins; and 5) the Antioquia plateau areas of western Colombia, an area of thinly preserved sedimentary rocks is related to the presence of the inferred Panama indenter.

SESSION TITLE: Theme 1: Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Real Time Surveillance: An Eagle Eye View from Subsurface To the Office

AUTHORS (FIRST NAME, LAST NAME): Sandra Janeth Montoya Osorio¹, Juan Carlos Alzate²

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Hydrocarbon exploration involves many remote, challenging, expensive, and technically complex activities. Difficulties in drilling a wildcat prospect, related to abnormal pressures, lost circulation, and borehole stability, including washed-out hole, hole collapse, and major events such as stuck pipe and sidetracks, can lead to significant amounts of non-productive time (NPT) during drilling operations. Pre-drill analysis implies an early identification of the factors that influence well stability, reduce cost, save time and avoid future problems. A clear need for real-time surveillance is evident in exploratory wells, where it can make a significant contribution to the optimization and safety of the oilfield operations. The ability to remotely monitor operations reduces the need for experts or other non-essential personnel on location. The well is essentially under the supervision of several experts with different points of view, ensuring the delivery of a safe and efficient operation from office, home or even from your mobile device. Several other operational benefits can be realized from real-time monitoring: reduce operation costs by reducing NPT and improving operational efficiency, provide a platform for effective communication between the disciplines involved in well delivery and become more proactive than reactive, planning ahead and ensuring high quality well construction. This article discusses several of the noticeable advantages of having real-time support technologies through high quality communications and a clearly defined workflow involving collaborative work between staff in the rig, operations office team and the head office through communication protocols and decision trees together with the use of new technologies. The paper describes how this approach enabled the decision makers in the field to access the experience and support from the experts in the organization. These “on-call” teams ensured that the knowledge of the organization was leveraged, and experience shared. The approach enabled the team to provide resources to follow up the events and properly record results in lessons learned and best practices.

SESSION TITLE: Theme 1: Stratigraphy II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Genesis of “Bentonites” in the Upper Cretaceous of Colombia

AUTHORS (FIRST NAME, LAST NAME): German Bonilla¹, Duvan Garcia², Juliana Palacios³, Cristian Valencia⁴, Laura Redondo⁵, Javier Luque⁶, Alejandro Beltran-Triviño⁷, Manuel Paez-Reyes⁸

INSTITUTIONS (ALL):

1. Universidad EAFIT/inClay laboratories
2. inClay laboratories
3. inClay laboratories
4. Universidad EAFIT
5. Universidad EAFIT
6. Harvard University
7. Universidad EAFIT
8. Universidad EAFIT

ABSTRACT BODY:

Abstract Summary: Millimetric to metric layers of greyish claystone are found interbedded with the Coniacian-Campanian (84–74 Ma) hemipelagic limestones of the La Luna Formation in the Middle Magdalena Valley (MMV). These claystones are commonly termed “bentonites”, which presumably record volcanism in a back-arc domain. Despite having a wide distribution and being a frequent lithofacies in the Cretaceous rocks of the MMV, they have been largely neglected and their origin and the geologic processes that led to their deposition remains unclear. Here, we describe the mineralogical and geochemical composition of several “bentonitic” layers collected in the MMV basin, focusing on the identification and quantification of clay minerals and their elemental composition. The stratigraphic succession in which “bentonites” are present is consistent with the deposition of these rocks under the influence of currents on the bottom of a shallow ramp. However, our preliminary results suggest a more complex picture than that suggested by the sedimentological analyses. Some of the “bentonitic layers” are almost entirely made of kaolinite, while some others contain interstratified layers of illite/smectite and well-preserved amorphous materials (volcanic glass) and plagioclases. For the former, and based solely on geochemistry brackish or fresh-water environments would be needed. This interpretation contradicts the sedimentological evidence and suggests instead a different mechanism for the deposition of these layers. We hypothesize that episodic anoxia of the water column and abundant organic matter can provide an acidic geochemical environment that in turn leads to the development of tonstein-like (i.e., replete of kaolinite) layers. For the later, smectites are interpreted as the precursor of the I/S interlayers and thus were deposited with a predominant basic pH and under marine oxic/dysoxic conditions

SESSION TITLE: Theme 1: Petroleum Systems I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Integrated Basin Analysis and Play Fairway Evaluation of the Llanos Orientales Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Juan Carlos Ramon¹, ANDREA PABLOS², CESAR Mora³, Andrés Fuenzalida⁴, Yuliana Ramirez⁵, SARA RENGIFO⁶, MARIA MURILLO⁷, María Cerón⁸

INSTITUTIONS (ALL):

1. SGC - Servicio Geologico Colombiano
2. SGC - Servicio Geologico Colombiano
3. SGC - Servicio Geologico Colombiano
4. Servicio Geológico Colombiano
5. Servicio Geológico Colombiano
6. Servicio Geológico Colombiano
7. SGC - Servicio Geologico Colombiano
8. Agencia Nacional de Hidrocarburos

ABSTRACT BODY:

Abstract Summary: The Prolific Llanos Orientales Basin accounts for most of the historic oil production in Colombia. Mostly small-to-medium size oil companies have explored and produced oil from both the Cretaceous and Tertiary reservoirs since 1940. Although there are close to 8500 wells drilled in the area and more than 60.000 km of 2D and 90 3D volumes, very few have been published about the regional stratigraphy, structural, basin analysis and fluid flow dynamics.

This paper shows a regional integrated updated view of the basin from integrating and interpreting 6000-km of 2D seismic data with about 408 wells, and most oil available production data. Oil production comes from 8 different stratigraphic levels from Cretaceous to Oligocene. Oil seems to migrate to stratigraphically higher levels through faults or by leaking seals. Reservoir and seal distribution is controlled by the tectono-stratigraphic history of this foreland basin. Multiple trap types have been successfully tested and produced. API and oil biomarker data evidence the presence of at least 5 different types of crude oil groups suggesting complex fluid flow patterns resulting from several pulses of oil generation and migration. Water salinity indicates also a multiphase regional entrance of meteoric water into several stratigraphic levels.

Integrated data are summarized in regional basin analysis and play fairway maps to show basin-wide geological and fluid property distributions, petroleum systems and prospective geological features.

SESSION TITLE: Theme 1: Petroleum Systems I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: New Exploratory Vision of the Cretaceous Sequence in the Platform of the Llanos Orientales Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Edgar Chajid Kairuz¹, José María Jaramillo², Ruben Arismendy³, María Emilie Daroca⁴, Sonia López⁵, Fabio Cordoba⁶, Julián Garrido⁷, Laura Rojas⁸, Javier Peña⁹

INSTITUTIONS (ALL):

1. Gmas and Neoil Exploration
2. GMas Research Group
3. Neoil Exploration
4. Neoil Exploration
5. Gmas
6. Neoil Exploration
7. Empty
8. Neoil exploration
9. Universidad Nacional de Colombia

ABSTRACT BODY:

Abstract Summary: The review of more than 100 exploratory wells in platform area of the Llanos basin, which drilled the Cretaceous sequence, tied with seismic interpretation and attributes, allow us to see a detailed distribution of facies, structural characteristics, and new exploratory plays.

The Cretaceous sequence is made from base to top by:

Une Formation, base of the sequence, deposited because of a rise in sea level, it is a quartz arenite interval, with thin claystone intercalations. The unit was deposited over a paleo topography mainly of Paleozoic sequence present at the base of the stratigraphic sequence. The Une Formation is characterized by significant variations in thickness and facies, Gacheta Formation is the continuity to the east of the Cenomanian - Turonian - Campanian source rocks rocks, equivalent to the La Luna Formation (Middle and Upper Magdalena Basins) in a proximal position (without calcareous facies) and represent the maximum flooding surface. In addition to shale intervals with potential as source rocks and seals, it has sandy beds with good petrophysical properties to be reservoirs as can be analyzed in several fields that produce from this interval. Some sandstones intervals with high glauconite content are difficult to identify with electric logs as reservoirs.

Guadalupe Formation, deposited at the end of the Campanian and Maastrichtian, constituted by thick sandstone quartz and thin claystone intercalations and represent the end of the regressive - transgressive cycle. The sandstones are excellent reservoirs.

The regional recognition of the facies changes of these three formations will make possible to identify sectors in the basin with potential for stratigraphic, combined, and structural traps (several not explored yet, because many wells only drilled the tertiary sequence without paying attention to the Cretaceous potential) and will very possibly lead to discoveries of new fields in the basin associated with new or little explored plays.

The area where the Cretaceous sequence is located comprises more than 120 thousand square kilometers, has infrastructure, good 2D seismic coverage, many sectors already have 3D seismic focused on structural interpretation, producing fields in the Cretaceous sequence associated with structural plays and an appreciable amount of well to tie with seismic data. These can make easy to identify new structures to prospect and the new discoveries will be in production in short periods of time.

SESSION TITLE: Theme 1: Petroleum Systems II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Reservoir Fluid Prediction Methodology in Petroleum System Modeling by Calibration Based on PVT Data, Foothills and Llanos Foreland Basin in Colombia

AUTHORS (FIRST NAME, LAST NAME): Esteban Taborda², Felipe Gonzalez-Penagos¹, Linda Montilla³, Wilman Ramírez⁴, Raul Osorio⁵

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol

ABSTRACT BODY:

Abstract Summary: As part of the general exploration process, the petroleum systems modeling at different scales plays a fundamental role as a useful tool in the analysis of opportunities in the exploration portfolio. In this sense, is important to optimize the scope of the models to obtain predictions of the fluids according to the geological scenario of the different accumulations. Being predictive means correlating the source rock and the fluid. The source rock organofacies, level of maturity and preservation as precursor defining type of hydrocarbon associated with specific thermodynamic conditions, its physical properties, and the impact on the expected volumes of gas and liquid. Consequently, the most suitable or acceptable conceptual development model for the accumulation is designed, and the predictions related to the fluid should reflect the highest degree of certainty.

The Ecopetrol prospectivity groups has been carrying out integrated studies to correlate the petroleum system analysis and the presence of different fluid types in foothills and foreland Llanos Basin. A numerical regional basin model has been performed using a structural, facies and petroleum system modeling integrated with PVT fluid data from adjacent fields, to improve the knowledge about the processes (generation, migration, and accumulation of hydrocarbons) and nature of the fluids. However, the key factor that controls the composition of the fluid and therefore its physical properties from its origin, is the compositional petroleum generation kinetics, and often there is not enough information to define a specific compositional kinetic, unfortunately. For this reason, the proposed methodology seeks to calibrate the hydrocarbon generation kinetics using quality PVT data, considering the specific kinetics of the organofacies documented in the basin. The results obtained from the petroleum systems modeling must be evaluated in detail, regarding the coherence between the composition of the fluids and the physical properties obtained, otherwise it may incur in unwanted bias (increasing the uncertainty) in the fluid prediction of the model.

This methodology provides greater confidence to the results that aim to estimate the distribution of the different fluids in the basin, and can be applied to other basins, even in different geological contexts.

SESSION TITLE: Theme 1: New and Emerging Plays II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: A New Exploratory Concept Along the Castilla Field Trend: Paleocene Incised Valleys of the T2 Reservoir

AUTHORS (FIRST NAME, LAST NAME): Luis Ignacio Quiroz¹, Yudy Estevez², Johan Leonardo Ortiz Quiros³, Elena Torres⁴, Jaime Gelvez⁵, Oscar Sanchez⁶, Jaime Martinez⁷

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The T2 reservoir is a sandstone unit comprising three different chronostratigraphic intervals (Campanian, Paleocene and Early to Middle Eocene), separated by unconformities. We have integrated and correlated well cores, biostratigraphy and logs of 450 wells from the southern Llanos Basin (CPO-9 Block), which allowed us to predict the distribution of the T2 reservoir in this part of the Basin. The Cretaceous T2 is characterized by a series of estuarine channels and tidal flats, sharply overlaying deltaic parasequences of the K1. A major unconformity in the Paleocene truncates the Cretaceous sequence to the East of the Chichimene Field, eroding most of the Cretaceous T2 along the Castilla Field trend. The Paleocene is composed by amalgamated sandstone forming fining upward successions with minor muddy interbeddings, accumulated in a fluvial system by braided streams. The Eocene consist of conglomerates accumulated in more proximal braided streams, followed by a burrowed sandstone and shale of marine environments. A regional, tuffaceous paleosol separates the Eocene units and is used as a datum for the regional correlations. An Isopach map of the fluvial Tertiary units, limited by the Paleocene unconformity and the Eocene paleosol, shows the development of a NW-trending incised valley running across the northern part of the Castilla Field, which is mostly filled by Paleocene sandstone. The regional mapping suggests the development of other incised valleys along the Castilla Field trend, but the proper location of channels is unknown from conventional well-log mapping. By integrating seismic attributes, such as RMS and spectral decomposition, we can predict the position of the channels by analogy to the expression of the Castilla main valley. The amplitude anomalies correspond with wells that have good productivity in T2 reservoir along the Castilla Field, whereas the spectral decomposition shows linear features that mimics the expression of the Castilla incised valley. Similar features were identified in other areas, resulting in a complex mosaic of incised valleys along the Castilla Field trend. Accordingly, we have identified new exploratory areas to the NE and SW of the Castilla Field, consisting of a play concept that combines structural fault inversion and reservoir deposition within incised valleys.

SESSION TITLE: Theme 1: Petroleum Systems II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Pre-salt Petroleum Systems of the Campos and Santos Basins, Offshore Brazil: The Challenge of Predicting Fluid Phase

AUTHORS (FIRST NAME, LAST NAME): Cristina Solla-Hach¹, Luiz H Drehmer², T. Les Leith³, Sebastian Hinsken⁴, Gillian D. Dale⁵, Roar Krigsvoll⁶, Wayne Wright⁷

INSTITUTIONS (ALL):

1. Equinor
2. Equinor
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4. Equinor
5. Equinor
6. Equinor
7. Equinor

ABSTRACT BODY:

Abstract Summary: The Campos and Santos basins offshore Brazil are recognized as prolific oil provinces with most of the oil being generated by Early Cretaceous pre-salt lacustrine source rocks. Key questions raised by recent drilling results in the outboard areas of these basins, relate to the nature of the source rocks and the tectonic/thermal history of these areas. Elucidation of these uncertainties requires a multidisciplinary regional approach which considers changes in source rock character, tectonic development and its interaction with the thermal evolution of the outboard regions.

Regional evaluation of litho-facies development and geochemical data suggest significant changes in source rock character from inboard to outboard, likely related to variations in the infilling and geometry of the lacustrine/transitional depositional systems. Tectonism associated with the incipient break-up of the margin during Aptian times is a major driving force behind the regional changes and fit for purpose-scale reconstruction of pre-breakup geometry is essential in understanding the margin development. The oil-prone nature of the source rocks generating the oils of the prolific inboard oil province was assumed to extend to the outboard regions of these two basins.

Multiple tectonic scenarios were tested using tectonic forward modelling of selected 2D lines. The resulting heat flow scenarios were input into the development of a regional PetroMod model to evaluate the impact of the different tectonic models on the localization, timing and nature of expulsion from the pre-salt source rocks.

The combination and integration of mapping, tectonic modelling, petroleum system modelling, geochemical interpretation, and failure analysis permitted the development of a cohesive model for the prediction of phase across the Campos and Santos Basins, emphasizing the outboard areas. This approach permits the rapid integration and evaluation of new results at a regional scale and a more comprehensive suite of predictive scenarios.

SESSION TITLE: Theme 1: Petroleum Systems III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: The Thermal Effect of Emeishan Large Igneous Province to the Hydrocarbon Maturation in the Sichuan Basin, SW China

AUTHORS (FIRST NAME, LAST NAME): Xiaoyu Liu¹, Nansheng Qiu²

INSTITUTIONS (ALL):

1. China University of Petroleum (Beijing); University of Copenhagen
2. China University of Petroleum (Beijing)

ABSTRACT BODY:

Abstract Summary: The emplacement of the Late Permian Emeishan large igneous province (ELIP) in the Upper Yangtze craton, SW China, is considered to be not only a crucial factor that triggered the end-Guadalupian biodiversity crisis, but also implicated in the formation of the large-sized mineral occurrences. The Sichuan Basin (SCB) is a polycyclic superimposed sedimentary basin located to the northeast of the ELIP and is the main gas-producing region in China. Over the past decade, many Permian basaltic rocks were penetrated by deep industrial boreholes in the SCB as the hydrocarbon exploration of ancient marine strata progressed. However, the geodynamic mechanism of the Permian magmatism and its contribution to the hydrocarbon maturation in the SCB remain debated. Here we present the first geochemical variations of Late Permian basaltic rocks and rich zircon fission track (ZFT) and (U-Th)/He dating (ZHe) data of the Sinian-Lower Paleozoic clastic rocks from deep exploratory boreholes in the SCB. Whole-rock petrography and geochemistry demonstrate that the Permian basalts in the SCB were likely generated in response to plume-lithosphere interaction in which the weakness zones of the lithosphere may have had a significant impact on the distribution of these basalts, indicating that ELIP may extend over a substantially broader region than previously estimated. Coupling with Ro, ZFT and ZHe data, the reconstruction of thermal evolution history displays different elevation of thermal anomalies throughout the SCB during the Middle-Late Permian in consistent with the spatio-temporal scenario of the ELIP. Thus, based on the geochemistry and low-temperature thermochronology results, spatial distribution of the thermal effect of ELIP to hydrocarbon maturation in the SCB were classified, including two high thermal effect units in Liangping area and Jianyang-Santai area, a medium thermal effect unit in southwestern SCB and other normal thermal effect areas. The results will play an important role in understanding the controversial Sinian to Early Paleozoic thermal history and have important application value for the research and exploration of the conventional gas and shale gas in the SCB.

SESSION TITLE: Theme 1: Petroleum Systems I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Origin and Distribution of Hydrodynamic Traps in the Llanos Basin of Colombia

AUTHORS (FIRST NAME, LAST NAME): Carlos E. Macellari¹

INSTITUTIONS (ALL):

1. Consultant

ABSTRACT BODY:

Abstract Summary: More than 1.4 Bbls of heavy oil (11-15° API) have been discovered to date in hydrodynamic traps in the southeastern Llanos Basin of Colombia. The largest is the Rubiales Field, but other important accumulations such as Quifa, Caño Sur and Pendare are present in this area. The common element of these fields is that they are stratigraphic traps defined by the intersection of the top seal (the Miocene Carbonera C6 Unit) with an inclined oil-water contact (OWC) (dipping 0.3° towards the NW). The overall tilt of the OWC is fairly small (about 3.5 to 6 m/km), a value that is in the lower range of cases with documented tilted OWC due to hydrodynamics. In most cases the accumulations occur where there are minor inflections in the top seal formed by differential subsidence controlled by the underlying paleo-relief of the Paleozoic.

The area of stratigraphic traps coincides with the forebulge of the Llanos Basin as well as with a major gravity high. A striking feature is that the area of the stratigraphic traps, which is found south east of the Meta River, is being actively uplifted. This is evidenced in the different levels of terraces that are present south of the Meta River. These terraces have a concentration of iron concretions at the surface, probably indicating paleo-phreatic zones. The highest present-day terrace has an elevation of 287 m, (vs. approx. 140 m of the Meta River). This is evidence that this zone is actively being uplifted (at least 200 m) and eroded in contrast to the rest of the basin that is a zone of deposition.

All these stratigraphic accumulations have a very strong aquifer, and it has been proposed that the tilted OWC is related to hydrodynamic flow from the margin of the basin, or from areas with a higher hydraulic head. However, the orientation of the tilted OWC trend (NE-SW) is almost perpendicular to the hydraulic head contours for the basin but coincides with the orientation of the Llanos Basin forebulge. The OWC trend also coincides with the present-day strike and dip of the Carbonera Formation, which in turn is controlled by the deposition of the overlying thick Mio-Pliocene molasse sediments of the Guayabo Group. It is proposed that the tilting of the OWC is related to recent uplift in areas where the oil is biodegraded due to bacterial activity and did not have time yet to equilibrate. This model could be applied to the exploration of other areas of the basin.

SESSION TITLE: Theme 1: Stratigraphy I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Tectono-Stratigraphy of the Flamencos Discovery by Ecopetrol, Middle Magdalena Basin of Colombia

AUTHORS (FIRST NAME, LAST NAME): Ignacio Iregui¹, Lina Maria Maya², Iván Camilo Higuera³, Luis Gerardo Figuera⁴, German Rondon⁵, Susana Urrego⁶

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The Flamencos-1 is a recent onshore discovery of Ecopetrol (2019), in Mid-Eocene fluvial litho-arenites of the Middle Magdalena Valley basin (MMV) of Colombia, trapped in the downthrown block of a regional transpressive fault. The Flamencos discovery has been followed by two successful appraisal wells producing 25.400 barrels through well tests.

Integration of recently reprocessed 3D - seismic - that included well-tied inversion and extensive seismic attribute analyses - and well data from neighboring oilfields, allowed the identification of a combined nature trapping (structure / stratigraphy). The accommodation space generated by the kinematics of this transpressional fault system, was synchronically filled by the Mid-Eocene litho-arenites, in a continental, high energy environment of deposition (braided rivers?) having strong implications on its presence and geometry as first coarse-grained depositional systems above the middle Eocene unconformity. This understanding could improve predictability in the nearby areas. Further work is planned to better delineate the reservoir flow units, given the number of local discontinuities and unconformities that separate the stacked bars and sand bodies of slightly different age above the base of the reservoirs. The identification of this type of combined trap along with the reservoir geometries, represents an exploratory opportunity for potential analogs across the basin.

The Flamencos discovery validates Ecopetrol's Near Field Exploration strategy, that aims to find opportunities in relatively mature areas for rapid discovery-to-commerciality business cases. This implies thorough geoscience and engineering assessments to bring on low risk prospects out of by-passed opportunities during previous exploratory campaigns and proving new plays, giving high value to new ideas.

SESSION TITLE: Theme 1: New and Emerging Plays II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: The BSR Black Swan Effect

AUTHORS (FIRST NAME, LAST NAME): Karyna Rodriguez¹, Neil Hodgson¹, Julia Davies²

INSTITUTIONS (ALL):

1. Searcher
2. Discover Geoscience

ABSTRACT BODY:

Abstract Summary: Determining the geothermal gradient in undrilled regions remains one of the largest areas of uncertainty in frontier basin exploration. Bottom Simulating Reflectors (BSR's) occur at the base of a shallow gas hydrate layer in many of the world's deep-water basins and by calculating the geothermal gradient from the sea floor to the base of the hydrate, quantitative and qualitative inference of the deeper heat flow can be made. A global seismic dataset has been used in this study to identify BSRs and estimate the geothermal gradients in various frontier areas, resulting in important implications in the understanding of the petroleum systems.

One example is from a forearc setting commonly associated with a low geothermal gradient and a high risk in source rock maturity where the sediment overburden is relatively thin. Mainly for this reason, Peru offshore southern basins remain largely unexplored. A BSR- derived geothermal gradient was calculated throughout these basins yielding surprisingly high values of nearly 50°C/km, which agree with 47°C/km observed at the ODP 188 site, where methane hydrate was also recovered. The implications are very positive for future exploration as the Upper Cretaceous inferred source rock, buried under around 2 km of sediment, is modelled to be in the hydrocarbon generation window.

Another example comes from integrating the hydrocarbon evidence provided by the presence of BSRs, together with well data and satellite slick mapping studies. Offshore Mexico, outboard of the Mexican Ridges, clear BSRs have been identified which are also associated with oil seeps on the sea surface. The nearby mixed turbidite contourite system which has been interpreted in this area, could contain large untested hydrocarbon accumulations.

The use of BSRs is demonstrated using various seismic examples. In Peru the high geothermal gradient estimated in the forearc basin setting points to an active petroleum system in agreement with the numerous reported oil seeps. Offshore Mexico, the presence of BSRs supports a new play type associated with a hybrid turbidite-contourite system. In the Gulf of Papua, a high-quality seismic dataset enables the confirmation of a BSR that does not simulate the seabed. Nassim Taleb writes about "black swans" as events that appear to be anomalies but change the paradigms. The PNG "black swan" suggest BSRs may be even more useful in mapping variations in heat flow and geotherm than we had previously recognised.

SESSION TITLE: Theme 1: New and Emerging Plays III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: The largest unexplored Cretaceous and Tertiary delta – Pelotas Basin, Brazil

AUTHORS (FIRST NAME, LAST NAME): Neil Hodgson¹, Karyna Rodriguez¹

INSTITUTIONS (ALL):

1. Searcher

ABSTRACT BODY:

Abstract Summary: Along strike in Brazil's Pelotas Basin, we find a nice surprise at the Pelotas Delta – one of the world's great Cretaceous and Tertiary Delta which remains obviously unexplored. There are background reasons for the lack of drilling, questions of operational water depth and shared uncertainty on reservoir presence, source presence, hydrocarbon phase, as well as the dreaded up-dip leakage risk.

Frontier basin exploration requires a detailed petroleum systems evaluation to de-risk firstly and foremost the most critical elements, source rock presence and maturity but also to address the other three key elements, reservoir, trap and seal. With all the above-mentioned petroleum system elements defined and de-risked, a deep-water play fairway model has been generated for the Pelotas Basin.

The model predicts mature Aptian source presence. Additionally, using a BSR (Bottom Simulating Reflector at the base of a gas hydrate interval) -derived geothermal gradient, on the slope and within the Pelotas Delta Cone, gas is modelled to be the more likely phase, yet at the edges of the Pelotas cone – the source will more likely be in an extended oil maturity window. At the outward edges of the Pelotas delta lies a play of up-dip to sea stratigraphic closures that are perfectly situated to capture and trap the oil generating from this mature Aptian source.

Inhibitors to exploration of the Cretaceous plays below the basin floor from the Santos to Malvinas Basins have comprised a number of factors that with the advent of new technology and a revised approach, can be re-evaluated. The play has all the separate elements of a working hydrocarbon system, source, reservoir, seal and trap that can be found in areas along the margin where all risk factors will be aligned positively. This play is proven in the northern South Atlantic, in the oil discoveries of Sergipe.

In the Pelotas Basin of Southern Brazil, a combination of a thick sedimentary cone above a strongly subsiding crustal architecture has created an opportunity to explore the Cretaceous basin floor play in relatively accessible and amenable water depths. That there has been no exploration of Cretaceous basin floor fans south of the Santos Basin in Brazil, Uruguay and Argentina is itself remarkable. However, we suggest not as remarkable as the extraordinary potential of this play.

SESSION TITLE: Theme 1: Stratigraphy II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Modelling and Characterization of Facies Using MPS: Caipal – Palagua Field, MMV, Colombia

AUTHORS (FIRST NAME, LAST NAME): Mario Andres Pachon¹, Carlos Osorio², Enrique Gallardo³, Edgar Pineda⁴, Robinson Aguirre⁵, Claudio Larriestra⁶, Jesus Porras⁷, Mario Mallaviabarrena⁸, Horacio Verdur⁹

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Nova Energy
7. Nova Energy
8. Nova Energy
9. Nova Energy

ABSTRACT BODY:

Abstract Summary: An integrated workflow linking traditional hand drawn paleogeographic maps and state-of-the-art geostatistical techniques was applied to construct a 3D geocellular model at the Middle Magdalena Valley (MMV), Colombia.

Paleogeographic maps were constructed by a multidisciplinary team of sedimentologists, geologists, petrophysicists and geophysicists, integrating facies association derived from core data, log shapes and seismic attributes. These maps describe the heterogeneous reservoir distribution and the complex sedimentological environment of the MMV. Facies associations were derived from discrete inter-well facies correlation defined within a high-resolution sequence stratigraphy framework. Reservoir units are associated to Tertiary (Oligocene–Miocene) continental deposits, represented by alluvial fan deposits linked to the tectonic activity in the Central Cordillera and lateral connection with braided and meandering fluvial deposits spanning across the MMV.

Training images were then built aiming to reflect facies association geometries. Interpretative constraints were then drawn integrating facies association distribution and the paleogeographic zonation boundaries. Each boundary encloses a sand/shale distribution reflecting a computerized stochastic model distribution. The paleogeographic zonation boundaries were then used to locally supervise the Multi-Point Geostatistical Simulation (MPS) modelling.

This expert-guided workflow to condition stochastic models, favors and maximize the multidisciplinary interaction and information usage when dealing with multi-dimensional reservoir data. Concurrently, it is structured to permit the creation of multiple consistent static models that can eventually downscale to build dynamic models that evaluate different development strategies capturing the impact of geological uncertainties in the forecasts and business decisions.

SESSION TITLE: Theme 1: New and Emerging Plays II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: The Miocene Porquero Formation in the Lower Magdalena Valley basin of NW Colombia: from bypassed pay to four producing gas fields in 5 years.

AUTHORS (FIRST NAME, LAST NAME): Luz Rodriguez¹, Andrew Willis², Nilanjan Ganguly³, Stephen Hiebert⁴, Sean Johnston⁵, Patricia Gavotti⁶, Mark Teare⁷, Aurora Juan⁸

INSTITUTIONS (ALL):

1. Canacol Energy
2. Canacol Energy
3. Canacol Energy
4. Canacol Energy
5. Canacol Energy
6. Canacol Energy
7. Canacol Energy
8. Canacol Energy

ABSTRACT BODY:

Abstract Summary: The Miocene Porquero Formation in the Lower Magdalena Valley basin of NW Colombia is a thick (3400 Ft) marine shale that has historically been viewed as a regional top seal and potential source rock. There have been some gas shows and limited production in the adjacent Plato sub-basin, but sandstones within the thick shale in the San Jorge sub-basin have generally been regarded as poor-quality reservoirs.

The Porquero potential in the San Jorge sub-basin was identified by apparent bypassed gas pay in sandstones in two wells drilled in the Nelson gas field by Shona Energy, a company acquired by Canacol Energy in 2012. Those wells had the deeper Cienaga de Oro Formation as a main target. The analysis of gas shows, logs, and drill cuttings suggested the presence of 80 Ft of potential bypassed gas pay in the Porquero. This concept was tested by temporarily shutting in production from the deeper CDO reservoir in a well and testing the Porquero. The Porquero sandstone tested 13 MMscfgpd with no water. Following this proof of productive capability, a dedicated Porquero exploration well was drilled in the Nelson Field. It encountered 39 Ft of net pay with 19% porosity and produced 23 MMscfgpd of gas per day (4035 boed). Subsequent exploration wells discovered the adjacent Toronja, Arandala and Breva gas fields.

The main interval of interest in Porquero is interpreted to have been deposited during a sea level lowstand, leaving shallow marine shoreface sandstones encased in marine shale. The productive interval is characterized by good quality sandstones with an average porosity of 25% and an average water saturation of 45%. The sandstone reservoir exhibits low resistivity, making petrophysical interpretation challenging, particularly in legacy wells with older wireline log suites. Modern wireline log suites acquired in the wells have allowed calibration of seismic attributes and enable us to confidently map the distribution of gas-bearing sandstones on 3D seismic. Mapping indicates that gas is trapped in both structural and stratigraphic traps. The Middle Porquero Formation play in this area has rapidly evolved from bypassed pay identified in a deeper pool well in 2015 to four producing gas fields today. Cumulative production is 9 BCF and proven resource 73 BCF OGIP. Further exploration potential in the area is indicated by additional AVO anomalies.

SESSION TITLE: Theme 1: Petroleum Systems III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Current oil distribution associated to an Oligocene paleostructure in the Chichimene – Akacias – Lorito trend, a case study in Los Llanos basin, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Rodrigo Alejandro Claa¹, Franklyn Angel²

INSTITUTIONS (ALL):

1. Ecopetrol

2. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Chichimene Akacias and Lorito fields (ChiAkLo) have a complex structural and sedimentary evolution changing through geological history associated to different regional stresses that have generated the current reservoir configuration. The target of this study is the main producing unit, T2, which consists of 300 ft of clean sandstones deposited in a transition environment during 3 different periods: Maestrichtian, Paleocene and Eocene.

In this paper, we present a methodology that integrates geosciences to production data, to explain the current fluid distribution that supports an unusual prospective model and development plan. The workflow starts with a detailed structural and stratigraphic regional seismic interpretation to help understand the control of the different deformation stages on the deposition and charge of T2 unit. Then a petrophysical review tries to explain the original fluids distribution of the reservoirs; and finally, we integrate some production data to validate the whole model.

The structural mapping showed that at Lower Oligocene there was a regional SW-dipping homoclinal charged trap, then inverted during Miocene. This inversion resulted in the current reservoir geometry where fluids reaccommodation is still incipient due to the heavy oil high viscosity. The T2 sedimentary model defined by a stratigraphic seismic interpretation shows East-to-West variations, as well as changes in reservoir quality, from fluvial systems in Castilla Field to braided deltas and delta fronts in ChiAkLo, variations controlled by a fault system at Lower Paleocene that represented the limit of an asymmetrical hemigraben generated during Cretaceous.

The petrophysical model suggests 3 different FWL's, one for each geological period, meaning that the geological trap for ChiAkLo is not in equilibrium since the structural inversion occurred recently. On the other hand, the increase of Sw from NE to SW, observed by wells drilled at almost the same depth, suggests that the fluid distribution is not responding to the current inverted structure, but to a previous paleostructure.

This prospective model, validated by the production and logging of more than 300 wells, can explain the low production in the attic of Lorito, the transition zone in the flank of Akacias, and the high oil saturation in the footwall of Chichimene. Thus, this model has become an accurate tool to give technical support to the development plans for the ChiAkLo trend.

SESSION TITLE: Theme 1: Stratigraphy I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Basinwide Traceability of a Transgressive Systems Tract: the mid Vivian (Cretaceous) in the Marañón basin, Peru

AUTHORS (FIRST NAME, LAST NAME): Oscar Lopez-Gamundi¹, Cecilia Lopez-Gamundi²

INSTITUTIONS (ALL):

1. P1Consultants LLC
2. Rosenstiel School of Marine and Atmospheric Science, University of Miami

ABSTRACT BODY:

Abstract Summary: The Upper Cretaceous (Campanian-Maastrichtian) Vivian Formation, present mostly in the subsurface of the Marañón basin, consists of two sand-rich units (Lower Vivian or Vivian A and Upper Vivian or Vivian B) with an intervening thin, mud-prone interval (mid Vivian). The Vivian Formation is overlain by a 2nd order, transgressive, mud prone Cachiycu Formation toward the northwest and west. Regional isopach maps of the Vivian Formation show thinning northwest toward the Oriente Basin in Ecuador. Marine influence increases distally northwestward, particularly for the Upper Vivian, as inferred from distinctive changes in gamma-ray (GR) - based electrofacies. The tripartite lithostratigraphic subdivision of the Vivian Formation correlates with the 3rd order sequence stratigraphic framework proposed for the unit. This framework allows to discern a lowstand systems tract (LST) that corresponds to the fluvially dominated Lower Vivian interval followed by a mud-rich, transgressive systems tract (TST) for mid Vivian interval that in turn grades upward to the sand-rich, highstand systems tract (HST) of the Upper Vivian. This HST ranges from a proximal smooth blocky electrofacies along the basin margins to a dominantly funnel smooth or serrate GR electrofacies, interpreted as a shoreface-deltaic succession, dominant in the central and distal parts of the basin.

Regional, SE-NW – oriented, strike well sections in the distal medial and proximal sectors of the basin show minimum facies changes between wells. NW-SE – oriented, dip well sections illustrate the most drastic facies changes of the mid Vivian TST. In the northwestern, distal sector of the basin the TST is characterized by high GR log response interpreted as fine-grained, marine deposits. Distinct, thin maximum flooding intervals, with high (about 150 API units) GR log response, are identified only in this distal domain; they represent the turnaround point of the Vivian sequence. This TST electrofacies association grades laterally to a serrate, lower (50-60 API units) GR log response (medial TST) in central parts of the basin. The distal and medial GR electrofacies of the mid Vivian TST can be traced along the basin axis for at least 300 km. In the southeastern and eastern, proximal sectors of the basin there is no distinction of the TST from the underlying LST and overlying TST. The entire sequence is dominantly fluvial characterized by blocky, low (between 15 and 30 API units) GR log response

SESSION TITLE: Theme 1: Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Production optimization with numerical simulation through assisted adjustment and probabilistic analysis using workflows, case study Chachahuén Sur, Neuquén basin, Argentina

AUTHORS (FIRST NAME, LAST NAME): Mariela Gamboa¹, Lisandro Martínez Gasso², Nicolás Pena³, Daniel Varas⁴, Guadalupe Oviedo⁵

INSTITUTIONS (ALL):

1. YPF S.A.
2. YPF S.A.
3. YPF S.A.
4. YPF S.A.
5. YPF S.A.

ABSTRACT BODY:

Abstract Summary: The case study refers to the Chachahuén Sur Field. The development dates to mid-2013, after the exploratory and extension drilling campaign targeted at Rayoso Formation, a succession of early Cretaceous fluvial cycles. These cycles are truncated by the Intersenonian unconformity, which lies between the reservoirs of the Rayoso Formation and the shaly base of the Neuquén Group and works as a regional seal. The main production cycles correspond to cycles 2a, 3a and 1c, being the best properties and the largest areal development, the sandstone of cycle 2.

In the present, 395 wells have been drilled. 76 of them are injectors wells and 47 more are expected to be converted.

Although injection into the block began at the end of 2014, due to different factors, it has not been possible to inject water according to the required flow rates and stability. As a result of this and because of the global adjustment was insufficient to define specific actions, the project focuses on achieving optimization at well level. Consequently, have a simulation model that responded with that degree of detail was necessary.

Besides the large number of wells, this reservoir has different characteristics that make it complex when carrying out the analysis and modeling. The amount of data from the more than 300 wells together with the seismic interpretation allowed the identification of 24 regions with different water-oil-gas contacts. The presence of a gas cap at an intermediate level was also identified. Within the three reservoir cycles, three sedimentary facies were characterized through the analysis of nine core samples in conjunction with the geological environment understanding.

Given the huge flow of information, the project was worked on in a probabilistic way. The facies model analysis, petrophysical variables sets, their relationships, and the different water-oil-gas contacts were used in the iteration process in the assisted adjustment of the history production. In a first sensitivity analysis, workflows allowed to iterate more than 300 variables between limited ranges, to achieve 67 impact variables in the optimization process by objective functions with wells and sandstone cycles vectors.

Making use of this methodology, the historical adjustment reached was highly satisfactory and allowed to generate forecasts optimizing production according to the available injection.

SESSION TITLE: Theme 1: Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Production Optimization using Oil and Water Geochemical Fingerprinting

AUTHORS (FIRST NAME, LAST NAME): Jennifer Adams¹, Tim Ruble², Matt Flannery³, Mark A. McCaffrey⁴, Chris Laughrey⁵, Alan S. Kornacki⁶

INSTITUTIONS (ALL):

1. Stratum Reservoir
2. Stratum Reservoir
3. Stratum Reservoir
4. Stratum Reservoir
5. Stratum Reservoir
6. Stratum Reservoir

ABSTRACT BODY:

Abstract Summary: Low-cost production optimization through fluid-based monitoring using natural geochemical tracers is fast, does not disrupt production, and represents real-time fluid flow. Geochemical differences between fluids ("fingerprints") can be used to determine fluid origin, diagnose production problems, allocate commingled samples, monitor water injection, and estimate the drained rock volume (DRV). Combining initial (baseline) fluid characterization with regular time-series analysis and/or specific diagnoses of production problems can lead to effective field management and production optimization. These fingerprinting methods are applicable to oil, gas, and water across a wide range of production settings -- from deepwater fields to heavy oil reservoirs to unconventional reservoirs developed using horizontal wells. We describe the key elements and results of fluid fingerprinting programs from: (i) a heavy oil field with four commingled zones with highly variable contributions over time (where our results were used to inform completion strategies); and (ii) DRV estimates at Spraberry and Wolfcamp source-rock plays in the Permian Basin (to identify the amount of production coming from outside horizontal well landing zones). We also describe the use of samples obtained from cuttings using the new EZ-LTHP (EZ Low-Temperature Hydrous Pyrolysis) method to determine high-resolution liquid hydrocarbon fingerprints in source-rock plays. In a parallel production allocation study using High-Resolution Gas Chromatography, the EZ-LTHP extract end members quantified production from higher permeability non-target intervals which could not otherwise be identified using oil samples produced from the same pad. These results have major implications for well placement (landing zones and well spacing) to maximize performance of multi-well pads in stacked plays. Produced water studies are becoming more commonly used to identify mud contamination, to monitor water injection operations, to identify the source of excess water in key wells, and to determine flowback recovery in unconventional plays. We describe production allocation at an injected water operation intended to improve heavy oil recovery from Llanos Basin reservoirs that identified reservoir architecture and well orientation as key variables determining the effectiveness of the water injection program. Subtle geochemical differences between fluids can serve as natural tracers of fluid movement to optimize recovery.

SESSION TITLE: Theme 1: Petroleum Systems II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Prospects Assessment in Compressive Area: Example from the Bolivian Sub Andean Zone.

AUTHORS (FIRST NAME, LAST NAME): Frédéric Schneider¹, Luis Constantini², Stéphane Rousse³, Raul Giraudo⁴

INSTITUTIONS (ALL):

1. Beicip-Franlab
2. Beicip-Franlab
3. Beicip-Franlab
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ABSTRACT BODY:

Abstract Summary: Fold belts are estimated to hold significant untapped petroleum resources which could help supporting future O&G production. The exploration risk tied to the geological complexity and to the data scarcity in those regions may be mitigated using proper play-based exploration and basin modeling techniques. In this presentation, we will throw light on the added value of regional studies, advanced petroleum system technologies for fold and thrust belt provinces, and specific workflows, based on outranking algorithms and neural networks, for portfolio management and prospects assessment. An application case on the evaluation of the deep prospects of the immature Devonian play of the Bolivian Southern Andean foothills will be presented.

The regional integration allows reducing the uncertainties at the play level and consequently improve the risk assessment. In particular, the reservoir and seal properties as well as the source rocks characteristics are better prognosed when data has been gathered and processed at regional scale.

In these tectonic settings, the seismic is generally of poor quality in the areas of interest (anticlines). Acceptable trap definition is reached when seismic interpretation is carried out jointly with the structural interpretation.

Once calibrated with temperature, maturity and field data, 2D complex model gives insight on the timing for HC trapping with deformation. It also allows understanding faults impact on fluid flow, connecting or disconnecting reservoirs as the deformation progresses. It also allows defining new plays such as the upward truncation of syncline flank. Furthermore, the model predicts that the identified prospects are likely to be charged.

The filling of a trap can be estimated as a function of:

1. The surface of the fetch area which is a result of the seismic and structural interpretation.
2. The age of the structure which is estimated from regional knowledge and local deformation studies.
3. The remaining production of the source rocks at the time of structuring, which is derived from 1D basin modelling.
4. A local PSY (Petroleum System Yield) coefficient that is calibrated with the existing fields.

The results of the regional integration are integrated with those of the local studies to build an exploration portfolio. The dynamic management of the portfolio is carried out with an integrated and unbiased methodology based on outranking algorithms and neural network.

SESSION TITLE: Theme 1: New and Emerging Plays III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Influence of temperature, depositional environment and oil properties in hydrocarbon heterogeneity saturation: the Socha Formation in Buenavista block, Eastern Cordillera, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Andres De la hoz¹, Tomas Villamil², Omar Leal³, Juan Ospina⁴, Sergio Arturo Medina Díaz⁵

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4. Omega Energy Colombia
5. Omega Energy Colombia

ABSTRACT BODY:

Abstract Summary: Exploring in high topographic elevation settings is challenging as exemplified by the historical very low exploration success rate of the Eastern Cordillera inverted basin (approximately 5 % in exploration wells). Uplift is generally accompanied by significant structural deformation and compartmentalization, breaching of traps, change of pressure regimes, freezing of hydrocarbon kitchens as well as changes in reservoir characteristics by burial and exhumation. Elevation gain occasionally works in favor of accumulations, by bringing breached oil charged tilted reservoir panels into cool thermal regimes. Exponential increase in viscosity as cooling happens favors biodegradation rather than seepage and oil escape, to the point of formation of an effective seal by tar at the surface.

The Socha Formation in the Buenavista block was deposited as meandric fluvial channel system at the base of the formation, and changes upsection to a higher accommodation space setting in which sandstone bodies are floating within finer grained strata. The lower, sand-rich, part of the formation is the main reservoir of interest. It has been drilled by ten conventional wells in Corrales field and 1,540 feet of core have been cut in the southern part of Buenavista block. This formation also outcrops in the block and has been studied at surface. Electric logs, cores, and outcrops allow the construction of a new petrophysical model that shows very good reservoir qualities, 17.2% average porosity, 50ft net reservoir thickness, and 8-55% Sw. The variation of oil saturation is controlled by sedimentary structures such as cross stratifications and bioturbation zones, allowing better accumulations in zones of better reservoir rock quality. Testing data from Corrales-2, Corrales-3, Corrales-4, and Corrales-6 wells show that oil gravity varies from 17 to 9 degrees API (4,500 to 3,000 ft), to practically immobile oil at surface. In addition, the gravity measured in cores varies from 8-11 degrees API between 1,500 to 100 ft depth. The best wells flowed without stimulation an average of 44 barrels of oil per day. New mapping techniques combined with existing 3D seismic data calibrated by multiple wells show a significant oil in place accumulation, the current challenge is the definition of the most cost-effective and efficient development.

SESSION TITLE: Theme 1: Reservoir Studies I
SESSION DAY & DATE: Thursday, April 21, 2022
SESSION TYPE: Oral

Extended Abstract: The Permian Reef of West Texas and New Mexico: Ocean Stratification Provides Scaffolding, Internal Waves Provide Mixing for Carbonate and Organic Productivity

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ABSTRACT

The Permian Reef has been studied extensively and details of its stratigraphy are generally well established; however, the depth at which the reef formed, the depth of fastest carbonate production, and the factors responsible for its facies distribution and sustained growth are uncertain. Enigmatic facies trends and the extent to which collapse has contributed to the profile have resulted in conflicting models of platform geometry and thus an uncertain ecological setting. Of primary importance to the growth of any reef community is nutrient supply. Several nutrient models have been used to explain the enigmatic facies relationships within the Permian such as a phototrophic model similar to modern shallow water tropical reefs, terrestrial nutrient sourcing, and undefined upwelling. Recent oceanographic investigation of the vertical structure of modern oceans shows how density stratification, internal waves and tides, and contour currents shape the substrate, move sediment, and enable the cycling of nutrients. Recent investigation of modern mesophotic and deep-water reefs as well as ancient deep-water mounds indicate that it would be reasonable to invoke the interaction of stratified water masses with the substrate to explain many ancient reef settings. A model of nutrients being supplied by internal wave mixing along a pycnocline for Mississippian mounds can also accommodate facies trends observed in the Permian Reef Complex.

This model provides a mechanism and scaffolding for the reef system being the product of the oceanographic conditions created by a pycnocline and internal waves interacting with the substrate near the base of the photic zone. The transition from the base of the massive reef facies of the Capitan Limestone to the fore-reef breccias is the key interval in the reef system. New data from this transition include onlapping wedges of peloid rich coated grain grainstone, glauconite, oriented particles, several decimeter scale wave forms, and cross bedding dipping toward the platform. These data support this hypothesis. This model also impacts sequence stratigraphic interpretation because, in addition to changes in sea level and collapse of the reef front, the change in rate of growth to fill accommodation is partially driven by changes in water masses and pycnocline depth. The top of the massive reef facies disintegrates upward and is not hitched to the sea surface, but is dependent on carbonate and nutrients welling up from below.

INTRODUCTION

One of the key factors in understanding ancient marine carbonate reef and mound systems is the mechanism for enhanced productivity that resulted in localization and subsequent growth of the community. The objective of this study is to apply a nutrient model proposed for Mississippian bioherms of the Sacramento Mountains, New Mexico (Fig. 1) to the Permian Reef. The Sacramento Mountain bioherms have provided fertile ground to test hypotheses and examine effects of controlling parameters such as depth, seafloor topography, and ocean stratification because of excellent outcrops and well constrained stratigraphy along the homoclinal ramp (Stanton et al., 2000). Questions surrounding these and similar mounds worldwide have centered on the factors that control the localization of individual reefs (Stanton, 2006) and the depths at which they grew (Hebbeln and Samankassou, 2015). Stanton (2006) concludes that the modern photosymbiotic model for carbonate reef systems may be of limited use for ancient reefs and an alternative,

heterotrophic paradigm may be a more robust model for much of the Phanerozoic. He cites that significant nutrient sources could include terrestrial input, endo-up welling, cold seep hydrocarbon venting, and oceanographic factors such as upwelling, oxygen minimum zones, and internal waves. Numerous criteria that have been used to indicate shallow water growth in ancient reef systems are not diagnostic for water depth, and new data derived from modern deep-water reefs indicate that many ancient examples are just as likely to be bathyal (Hebbeln and Samankassou, 2015), so do not fit the oligotrophic model.

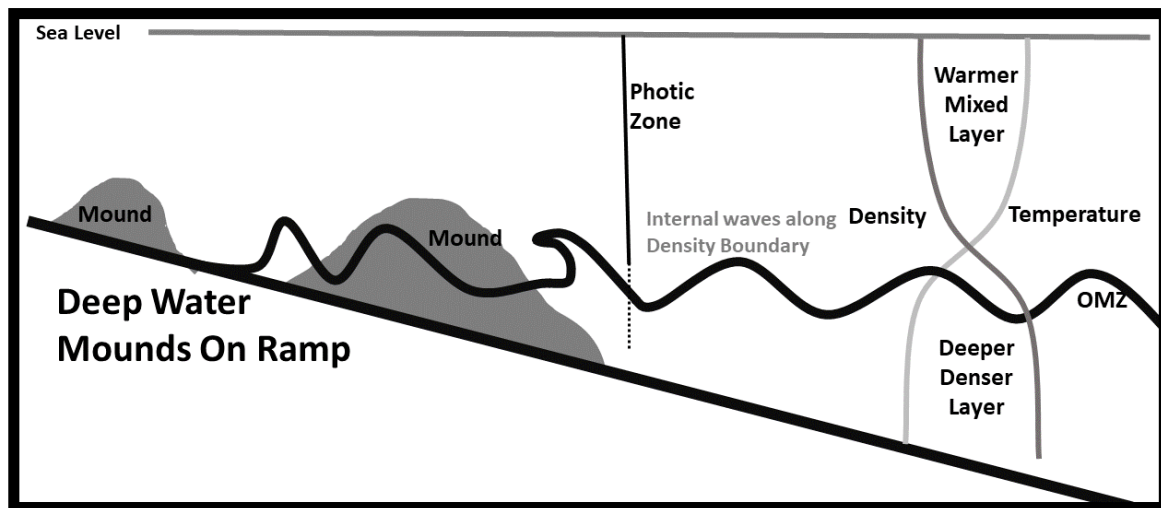


Figure 1. Model for Mississippian mounds as described by Stanton et al. (2000).

As an explanation for the mounds in the Sacramento Mountains, Stanton et al. (2000) propose that initiation and subsequent growth resulted from interaction between local topography of tectonic, depositional, and erosional origin with a stratified water mass. In this model, a nutrient-rich oxygen minimum zone (OMZ) at the pycnocline located at the base of the photic zone provides sustenance and mixing via internal waves, focusing the localization of biological and carbonate productivity (Fig.1). During the last several decades, the body of work concerning the stratified nature of ocean systems has advanced significantly with respect to nutrient cycling (Fiedler et al., 2013), and the resulting physical, chemical, and biological effects (e.g. Suits and Arthur, 2000; Droghei et al., 2016; La Forgia et al., 2018, 2019). These mechanisms are also being turned to more frequently for ancient systems (Stanton, 2006; Pomar et al., 2012, 2019).

The Permian Reef has been an enigma in terms of finding models to explain its sustained, prolific growth with the minor contribution of photosynthetic calcifiers (Wood, 1999), and its facies distribution with the fastest rate of carbonate production being at depth (Schmidt, 1977). A model for a stratified water mass interacting with the reef dominated by heterotrophic organisms would help answer key environmental questions about the depth at which the reef existed and about the mechanism that provided nutrients. Investigation of the Permian Reef has centered around several themes, including: to what extent reef front collapse contributed to the facies distribution and platform profile (e.g. Saller, 1996; Hunt et al., 2002; Rush and Kerans, 2010; Smith and Kerans, 2018); what contributed to the proliferation, structure, and diversity of the reef community (Babcock, 1977; Yurewicz, 1977; Wood, 1999; Weidlich and Fagerstrom, 1999; Kirkland, 1999); and to what extent organic and inorganic processes contribute to the reef framework and cement (Babcock, 1977; Yurewicz, 1977; Schmidt, 1977; Mazzullo and Cys, 1977; Grotzinger and Knoll, 1995). These questions can be approached from a perspective in line with the growing body of

work focusing on the vertical structure of the water column and nutrient flow fed by the interaction of a pycnocline with the substrate.

Ocean stratification

Stratification of the water mass is inherent to marine systems and investigations of ocean dynamics reveal the key role pycnoclines play in nutrient cycling and productivity. This boundary between shallow and deep water is the most important feature impacting the ecology and nutrient flow within the oceans between the surface and base of the water column (Longhurst, 2007; Fiedler et al., 2013). Longhurst (2007) summarizes the primary nutrient pathway being the result of the oxidation of sinking organic matter as it stalls at the base of the well mixed, warm, lower density surface water, and this gives rise to a nutricline, pycnocline, deep chlorophyll maximum, productivity maximum, and oxygen minimum that tend to occur vertically within a few meters. The depth of this interval may range to over 250m deep in the open ocean near the equator, breaks down toward the polar region, and may rise to as shallow as 25m at the eastern tropical ocean margins where it impinges upon the edge of the continent. The nutrient rich, oxygen poor water at density boundaries is the main source of nutrients in upwelling zones worldwide (Longhurst, 2007). Pycnoclines are also documented at the boundaries of different water masses created by density contrasts such as between Atlantic shallow water and Mediterranean water masses in the Straits of Gibraltar (e.g. Alvarez-Perez et al., 2005).

Documentation of interaction between the pycnocline and substrate can manifest and be preserved in sediments in several ways, including: 1) localized organic and carbonate productivity (e.g. Vercoeur et al., 1986; Longhurst, 2007; Cullen, 1982; Wienberg and Titschack, 2017; Fredericksen et al., 1992; De Mol et al., 2002; Freiwald, 2002; Freiwald et al., 2005; Alvarez-Perez et al., 2005; Freiwald and Roberts, 2005); 2) influence of anoxia and on chemistry and biology where an OMZ impinges upon the sea floor (e.g. Stanton et al., 2000; Pr  at et al., 2008; Bourque and Boulvain, 1993; Boulvain and Neuweiler, 2000; Suits and Arthur, 2000); 3) movement of sediment and formation of sedimentary structures caused by internal waves and tides along the pycnocline (e.g. Droghei et al. 2016; Zhang et al., 2019; La Forgia et al., 2018; La Forgia et al., 2019). Many modern deep, cold-water coral communities are also associated with even deeper water mass circulation and contourite deposits (Rebesco and Taviani, 2019; Wienberg and Titschack, 2017). Productivity in modern shallow water coral reefs may also be linked to nutrients transported upwards from pycnoclines (Roder et al., 2010).

Understanding the Ancient

Interaction of a stratified water mass is cited as a key environmental factor in numerous ancient ecosystems and is invoked as an under-appreciated mechanism for sedimentary structures otherwise interpreted as the product of beach, tidal, and storm processes (Pomar et al., 2012; 2019; Bidas et al., 2012). Pycnocline and internal wave processes are used to explain the localization and growth of ancient mound and reef systems such as in the Devonian (Boulvain and Neuweiler, 2000), Pennsylvanian, (van der Kooj, 2009), Jurassic (Alnaghah et al., 2013; Neuweiler et al., 2001), Upper Jurassic-Lower Cretaceous (Harchegani and Morsilli, 2019), and Eocene (Morsilli et al., 2012). The similarities between numerous Phanerozoic reef systems that were apparently not dependent upon autotrophic and photosymbiotic systems likely result from similarities in the structure of the nutrient system (Stanton, 2006).

Mississippian of the Sacramento Mountains, NM Prologue

This report is part of a broader study focusing on one of three sample sets. The other two sets are from the Mississippian of the Sacramento Mountains, NM (Fig. 2; Jeffery, 2021), the first of which documents fabrics of the early mound growth within seven Alamogordo Member mounds. Samples were collected in vertical transects from the base, upward through each mound. These

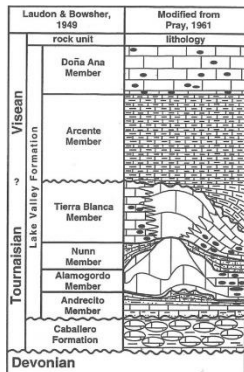


Figure 2. Stratigraphy (Jeffery and Stanton, 1996)

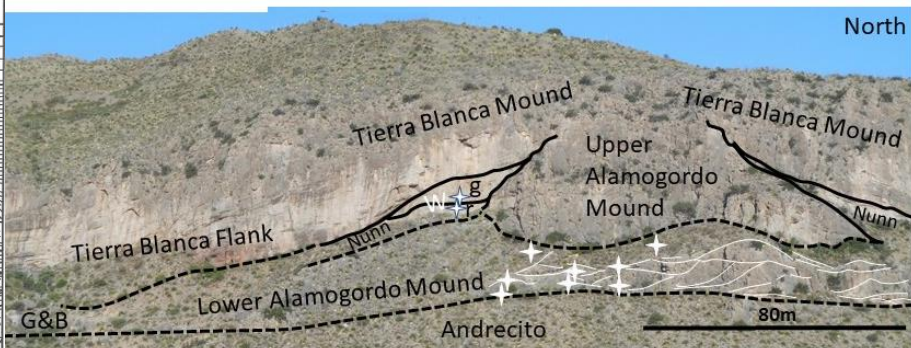


Figure 3. Sacramento Mountains mound exposure in Deadman Branch Alamo Canyon. White stars are sample locations.

data indicate that the mounds contain facies and facies patterns that are a successional accumulation of normal marine filter feeding organisms including mainly sponges, bryozoans, and crinoids, and do not contain fabrics or biota associated with oligotrophic or seep environments. This also concurs with carbon isotopic data showing slightly heavier values on mounds (Wu and Chafetz, 2002) than level bottom (Stanton et al., 2002) that indicate the mounds are not the product of a hydrocarbon seep from a deep source, but that there may have been anoxic fermentation occurring within the mound. The second sample set documents the fabrics forming the facies progression of onlapping flank between the Alamogordo Member and Tierra Blanca Member cores adjacent to the large mound in Deadman Branch, Alamo Canyon (Fig. 3 “W”). This second data set consists of a lower unit (Fig. 3 “r”) containing up-slope current orientated ripples interbedded with red biofilm laminae containing calcimicrobial fossils (Fig. 4), and an upper unit (Fig. 3 “g”), that contains hummocky bedded glauconitic peloidal and crinoidal grainstones (Fig. 5). Redbeds with biofilms are interpreted as the product of OMZ edge effects (e.g. Pr  at et al., 2008)

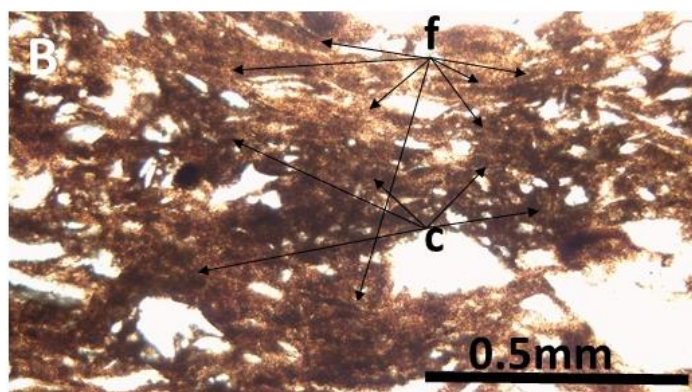


Figure 4. “r” redbed biofilm with hematite coated filaments (f) and clotted (c), areas in thin section.

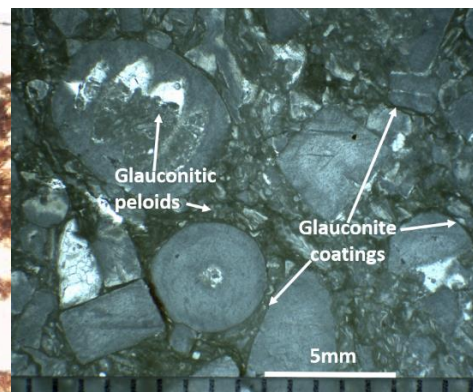


Figure 5. “g” glauconitic peloidal crinoidal grainstone in thin section.

and glauconite the product of concentration at the base of the OMZ (e.g. Suits and Arthur, 2000). These data, especially the biofilms, bedforms, and abundance of glauconite, provide independent

verification and support of the presence of an oxygen minimum zone with internal waves along a pycnocline that impinged upon the flanks of the mound. Stacking and onlap indicate a rise in the level of the OMZ, presumably corresponding to changes in accommodation (Jeffery, 2021).

Beyond The Mississippian

The model for the Mississippian relies on physicochemical characteristics observable in modern oceans that are independent of geologic time, and should be of relevance to other ancient systems. The Mississippian example contains many components and textures similar to those reported from the Permian Reef, including abundant marine cements, sponges, fenestellid bryozoans, and crinoids, and growth within mesophotic to oligophotic depths (Babcock, 1977; Yurewicz, 1977; Schmidt, 1977; and Grotzinger and Knoll, 1995), and growth patterns that were distinctly influenced by accommodation (Tinker, 1998).

PERMIAN REEF

The Permian reef complex of the Guadalupe Mountains of west Texas and New Mexico is one of the most well studied sedimentary successions in the world and was cited as a reef by Lloyd (1929). Strata (Fig. 6) consist of horizontally bedded back reef strata of the Seven Rivers (Smith and Kerans, 2018), Yates (Tinker, 1998), and Tansill (Mazzullo, 1999) formations, the massive reef facies that comprise the up-slope portion of the Capitan Formation (e.g. Babcock, 1977; Weidlich

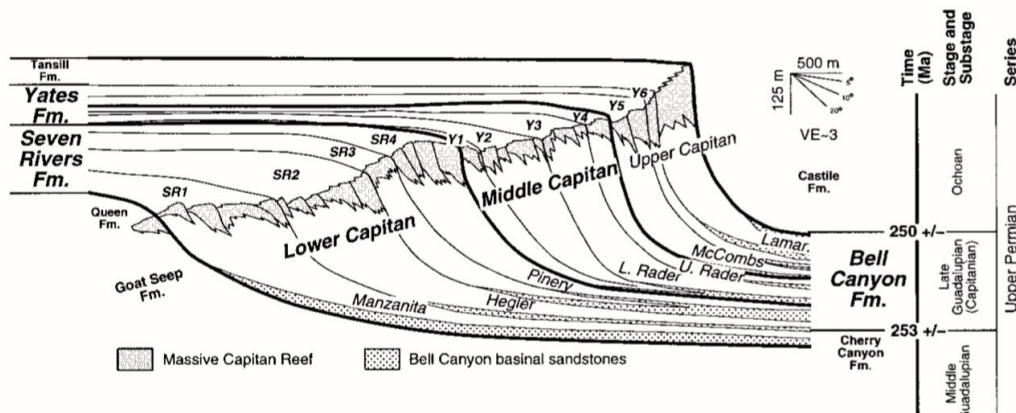


Figure 6 Stratigraphy of the Guadalupe Mountains (Tinker, 1998).

and Fagerstrom, 1999; Wood, 1999), and the steeply dipping fore-reef breccia facies that comprise the down-slope portion of the Capitan Formation (Playton and Kerans, 2017) and have been summarized in numerous publications (e.g. King, 1948; Hill, 1996; Saller et al., 1999). The keystone of this complex, the massive reef, flourished in moderately deep, low turbulence water with a diverse biota of sponges, bryozoans, and problematical organisms reinforced with tremendous amounts of aragonite and calcite cements and microbial precipitates (Newell et al., 1953; Babcock and Yurewicz, 1989).

One of the main focuses of investigation concerns the profile of the horizontal back-reef strata bending down toward the top of the reef facies and facies distributions interpreted by some to indicate that the reef did not grow to sea level and existed in deeper water (e.g. Lang, 1935; King, 1948). These observations have been key to formulating models for platform development that impact paleontologic and stratigraphic interpretations. The Permian Reef was interpreted as a shelf edge barrier reef at the margins of a stagnant basin by Newell et al. (1953) largely as a result of the models available, including examples such as the south Pacific and the Great Barrier Reef

after the second world war (e.g. Cloud, 1952). Dunham (1969) alternatively proposed that the pisolite facies associated with extensive exposure surfaces well behind the reef is the highest part of the platform, and facies progressively deepen basinward, curving downward to the reef or marginal mound (Tinker, 1998; Smith and Kerans, 2018; Rush and Kerans, 2010). This has become the predominant explanation along with some basin-ward roll or compactional flexing, slumping, and failure caused by edge-parallel fracturing accentuating the apparent basin-ward tilt of the shelf edge (Saller, 1996; Rush and Kerans, 2010). The extent to which compaction altered the apparent depth of the top of the reef and the platform profile and the extent to which the facies progression corresponds to depth continues to be equivocal (Hunt et al., 2002; Smith and Kerans, 2018). Details of the facies progression within the shelf, reef, and fore-reef, form an association distinct from modern shelf-edge barrier reefs.

Missing Mechanism

A nutrient model that provides a satisfactory explanation for facies trends and the onset and growth of the reef system remains to be proposed. The persistent onset of reef growth within a narrow depth range but within meso- or oligophotic depths must be linked to some persistent oceanographic feature. Basinal waters welling up from the deep have been implicated to explain the biological diversity, extensive cementation, and fastest growth of the reef being caused by proximity to the supply of rising carbonate and nutrients (Schmidt, 1977). Stratification of basinal waters has also been suggested (Newell et al., 1953; Schmidt, 1977; Grotzinger and Knoll, 1995), but it has not been linked to a mechanism that explains how the system sustained the reef's equilibrium or resulted in the problematical facies trends.

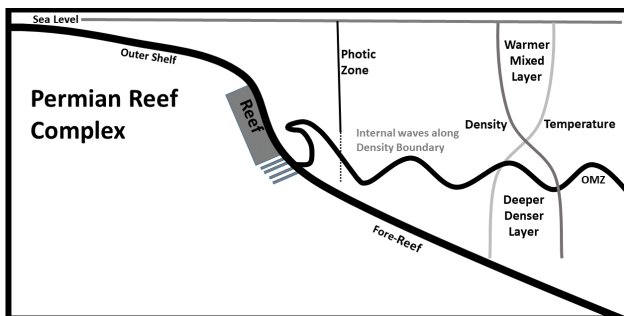


Figure 7. Model applied to Permian Reef

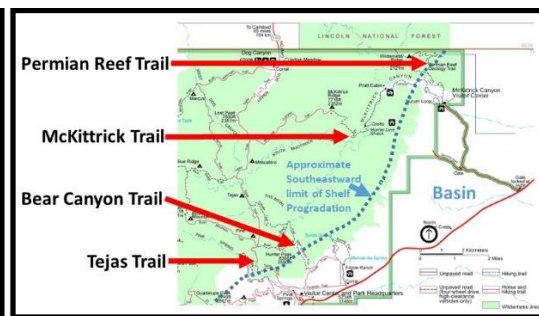


Figure 8. Location map: National Park Service

Applying the model from the Mississippian would provide scaffolding and a mechanism for long term proliferation of the Permian Reef while shifting the focus from the depth of the top of the reef to the vigorous growth closer to the base. It is proposed that the Permian Reef grew at depths near and above nutrient rich ocean water associated with a pycnocline near the base of the photic zone (Fig. 7). The Permian reef would have thus proliferated in the zone of mixing provided by internal waves at and above the intersection of the pycnocline and the slope. The profile of the reef system enables a hypothesis that the pycnocline impinged upon the slope at the boundary of the reef and fore reef facies. The inflection point at the top of the fore reef breccias where the angle of dip of the slope abruptly declines basinward (Brown and Loucks, 1993; Tinker, 1998) marks the boundary between active cementation and reef growth above, and the angle of repose of loose debris below, and thus indicates the position of the pycnocline.

Capitan Reef to Fore Reef Transition

Four exposures of the reef to fore-reef transition have been documented within the Capitan Limestone of the Guadalupe Mountains, each containing a similar succession of facies. The exposures are in Pine Canyon along the Tejas Trail, Bear Canyon along the Bear Canyon Trail, and McKittrick Canyon along the McKittrick Trail and the Permian Reef Trail (Fig. 8). The exposure along the Tejas Trail in Pine Canyon is the most continuous exposure and will serve for description. A west-east dip transect is exposed along two segments of the Tejas Trail that extend eastward both up-trail and down-trail from a westward pointing switchback (Fig. 9). The trail exposes the transition from fore-reef breccias (below and to the west) up into horizontally bedded, then

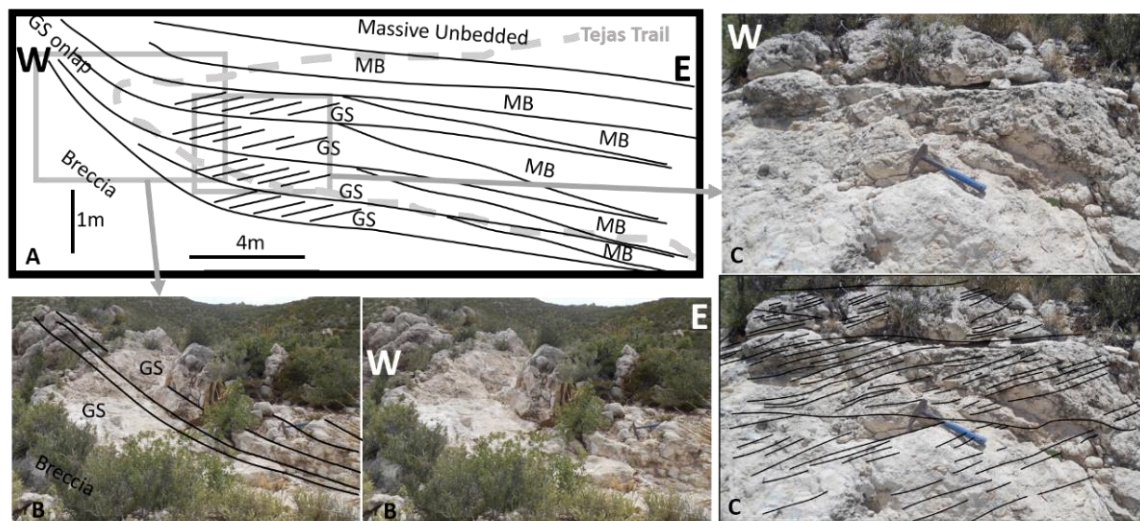


Figure 9. A is a rough sketch of the outcrop showing light shaded rectangles of locations of photographs B and C. There are two versions of each photograph B and C showing an interpreted and uninterpreted view. The light shaded dotted line is the Tejas Trail. GS=grainstone, MB=Massive, bedded accretionary reef facies.

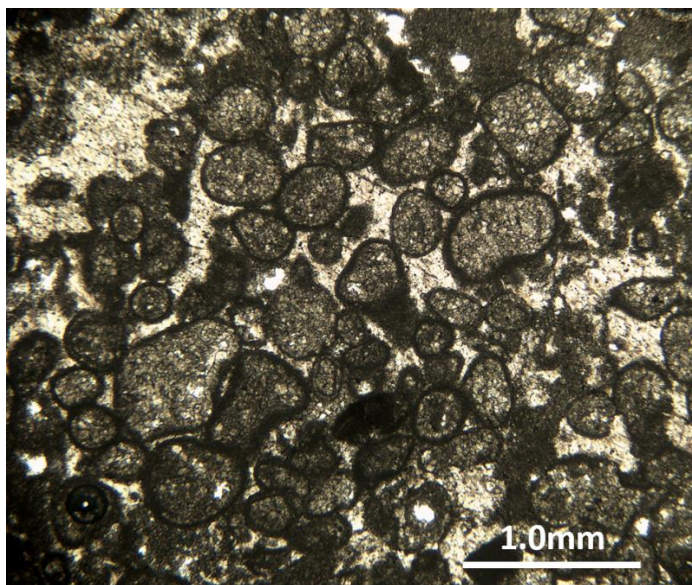


Figure 10. coated grain grainstone in thin section.



Figure 11. Weathered outcrop surface

massive reef facies (above and to the east). The exposure within the switchback is composed of

several stacked sigmoidal wedges of grainstone beds that onlap the slope westward onto underlying breccia beds and downlap and interfinger eastward (Fig. 9A). The western end of the sigmoidal wedge thins and sweeps upwards against the underlying, eastward dipping slope (Fig. 9AB). The beds can be traced laterally along strike for a short distance off the trail to the west and north in the weathered outcrop. The unit thickens within and to the east of the switchback to as much as 5 meters and consists of beds that are nearly horizontal, 0.3-0.5m thick bed sets with prominent, westward-dipping cross beds (Fig. 9c). Within several tens of meters to the east, the wedge thins and interfingers with the lowest reef strata that are nearly horizontal, composed of growth oriented encrusters, and on the order of 0.5 meters thick. The slope of the trail down and to the east of the switchback is roughly parallel to the dip of the sigmoidal wedge beds of grainstone. The bedded reef facies extend several tens of meters to the east, then grade into down-slope breccia. Additional offlapping wedges of grainstone with westward dipping cross beds are observed below and to the west of the wedge exposed along the trail.

The grainstone beds are composed of coated peloids and coated fossil fragments. Coated grains have an average size range from 0.25mm to 0.5mm (Fig. 10), but some beds contain concentrations of large fusulinids and crinoid stem segments up to several centimeters long as seen on weathered surfaces (Fig. 11). Cement between grains is recrystallized to chalky micrite and white and green clays, including glauconite in some of the most well preserved samples. More poorly preserved samples are composed of friable, sugary microspar with white clay, red hematite staining, and vague ghosts of the circular coated grains. The coatings in well preserved samples are consistently similar in thickness and fabric in most of the grains. Coatings consist of a dark micritic layer 5-10 microns thick, covered by a light layer of radial microspar 15-20 microns thick (Fig. 10). Molds of elongate particles of fusulinids and crinoid stem segments on weathered horizontal exposures have a preferred north-south elongate orientation (Fig 11).

DISCUSSION

The sigmoidal wedge of coated grain grainstone with large sand waves with westward-dipping crossbed sets and aligned elongate particles is the product of a sustained or periodic current. The sand waves are the result of a westward, up-slope directed current that was strong enough to winnow finer particles, concentrate grains, form large cross beds, and orient particles. The consistent thickness and fabric of the coatings on the coated grains indicates that, although the grains may be allochthonous, the coatings formed as a result of wave action at this locality. The abundance of peloids and presence of glauconite in better preserved samples may indicate proximity to the base of an OMZ. These features are present in close association with the depth at which the earliest phases of ecological succession of reef facies began its growth on the talus slope. All of these characteristics are consistent with a pycnocline, OMZ, and associated internal waves impinging the slope in the vicinity of the boundary between the reef and fore-reef.

The model for stratified Permian Basin waters with a pycnocline near the base of the photic zone helps make sense of these characteristics and provides a mechanism for the widespread and sustained proliferation of the reef system. Internal waves provide mixing and bring deeper waters from beneath the pycnocline to the shallower, productive zone, as is seen with modern deep and shallow reefs (Alvarez-Perez et al., 2005; Roder et al., 2010) and through modelling (LaForgia et al., 2018). The large cross bed sets are within the range of size and orientation of bedforms produced by internal waves from modern oceans, (Droghei et al., 2006; Zhang et al., 2019) and experimentally from solitary waves (La Forgia et al., 2019).

Previous authors describe the top of the reef being in 10-70 meters of water, with recent discussion centering around 30 meters (Smith and Kerans, 2018). If the reef is on the order of 100-150 meters thick, these estimates would put the base of the reef at 130-180m, well below normal sustained surface wave action, but consistent with the depth of the photic zone and pycnocline in normal, clear, tropical ocean water (Fiedler et al., 2013) and reported for sand waves documented in the South China Sea (Zhang et al., 2019).

Permian Reef Hypothesis

The nutrient model of a stratified water column within the Delaware Basin provides a mechanism and scaffolding for the proliferation and equilibrium of the Permian Reef. The critical interface is not the top of the reef facies, but the base (Fig. 5). The base of the reef, being on the order of 130m to 180m water depth, would have been near the base of the photic zone, chlorophyll maximum, thermocline and thus the position of the pycnocline and OMZ. The inflection point at the base of the reef marks the position at which internal waves and tides swept the uppermost fore-reef debris, winnowing and forming sand waves, precipitating calcite coatings on grains, and enabling the lowermost reef growth. This energy breaking against the shelf at the base of the reef provided upwelling currents and rising boluses of nutrient rich water. The fastest growth, as noted by Schmidt (1977), was focused within the steepest part of the reef front and can be explained by rising, depressurizing, warming masses of cool, dense, alkaline water being transported upward by internal wave mixing.

A bottoms-up rather than top-down view of succession of the reef facies makes sense of the enigmatic disintegration of reef facies upwards, and pivots the nature of discussion to the structure of water masses within the basin. If the depth of the pycnocline determined the depth of reef growth, then the processes that would have caused changes in its position, intensity or currents would have contributed to successional and sequence stratigraphic relationships.

The stratification of the Permian Basin water was likely more complex than this simple model. Additional boundaries within the water column likely resulted from vertical temperature and salinity variations, as well as inflow from beyond the Delaware Basin. A dynamic deep water circulation within and between water masses could have helped shape substrate and contribute to movement of deep sediments such as the development of contourites in deeper facies. These are conversations that align with investigations of modern deep-water reefs and ocean nutrient cycling.

CONCLUSION

Evidence supports a model incorporating ocean stratification that provides a mechanism and scaffolding for the proliferation of the Permian Reef. The system and its prolonged sustainability can be explained by upwelling of nutrient rich alkaline waters derived from the pycnocline by means of internal waves. In the process of developing the concepts for the Mississippian of the Sacramento Mountains, employing this model helps to populate the sequence stratigraphic template with data that expose facies trends documenting a shift of the OMZ during a change in accommodation. The marine redbeds and the glauconitic grainstones are evidence of shifting conditions during transgression, and reveal how changes at the ocean surface can affect sediments at depth. By employing this model for the Permian of the Guadalupe Mountains, data expose what could be the keystone to understanding how the equilibrium of the reef system was sustained. The association of up-dip oriented sand waves of coated grain grainstones with the initiation of reef growth demonstrate how the facies succession can resolve the vital relationship

between reef systems and the configuration of ocean strata; thus, enabling a model in alignment with recent oceanographic study.

In the spectrum of models for understanding ocean nutrient cycling and the evolution of reef or mound environments, the oligotrophic, photosymbiotic model paradigmatic of modern, shallow reefs is not representative of many ancient settings. The focus on ocean stratification and nutrient cycling for reef systems dominated by heterotrophic suspension feeders or autotrophs enables us to decouple from the limitations and assumptions of the oligotrophic model. The physical conditions that result in the vertical structure of the oceans have persisted throughout the history of life. Models for nutrient rich settings may be more representative of many Phanerozoic and earlier reefs and may help shed light on how reef communities developed.

ACKNOWLEDGMENTS

Many thanks to Bob Stanton for encouragement and thoughtful, productive discussion. The author is also grateful for long ago discussions with Paul Comet and some more recent ones with Steve Bachtel. Funding for this research was provided by the Gilde/Grose Professorship at Marietta College and the author is very grateful to the anonymous donor. Many thanks are extended to Guadalupe Mountains National Park and Park Geologist Dr. Jonena Hearst for permitting field work and sampling and numerous discussions.

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SESSION TITLE: Theme 1: Stratigraphy II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Three-dimensional Reconstruction of the Evolution and Infill of the Pliocene to early Pleistocene Tubará-Juan de Acosta Syncline, Northern San Jacinto fold belt, NW Colombia.

AUTHORS (FIRST NAME, LAST NAME): Josué Alejandro Mora Bohórquez¹, Luis Eduardo Santamaría², Cristhian Gómez³, Rigo Ramírez⁴, Mauricio Ibáñez-Mejía⁵, Germán Patarroyo⁶, Milton Rueda⁷, Gabriel Veloza⁸, María Cerón⁹

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ABSTRACT BODY:

Abstract Summary: The three-dimensional infill of the Tubará-Juan de Acosta syncline (TJAS) is studied through the integration of outcrop, drillhole and reflection seismic data. This asymmetric syncline was filled by three unconformity-bounded stratigraphic sequences, represented by four lithostratigraphic units. The lower, early Pliocene sequence is formed by two lithostratigraphic units, a basal unit comprising regressive sandstones deposited in wave-dominated deltas, overlain by a finer-grained unit, deposited in a transgressive middle to outer shelf. In the eastern flank of the syncline, the basal unit is 150-300m thick, whereas in the western flank it thickens to 450-570m. The second, late Pliocene sequence (third lithostratigraphic unit) was cored in the ANH Juan de Acosta-1 stratigraphic well, comprising 550m of fining-upwards, slope to outer shelf deposits and evidencing a transgression and deepening of the basin. The third and youngest stratigraphic sequence (fourth lithostratigraphic unit) preserved in the axis of the TJAS, comprises 300m of interbedded sandstones and fossiliferous mudstones deposited in estuarine channels, bars, and bays. This earliest Pleistocene unit evidences a change from fluvial environments in the south to shallow marine environments in the north. A combination of biostratigraphy and U-Pb detrital zircon geochronology allowed us to better constrain the age of the stratigraphic section in the TJAS as Pliocene to early Pleistocene (4.9-2 Ma), indicating that the arrival of the proto-Magdalena River occurred in early Pliocene times. Our observations suggest that the paleo-drainage of the Magdalena River changed from a SE-NW direction in early Pliocene times, to a S-N direction in early Pleistocene times. The infill and configuration of the syncline were controlled by the growth of the Cibarco Anticline to the E and by the contraction of deep structures located farther to the W. Such contraction inverted the flanks of the basin and probably caused the shift of the Magdalena River paleo-drainage to a S-N direction. Although the sandy units preserved in the TJDS have good reservoir properties, they are preserved at very shallow depths. Thus, their relevance for hydrocarbon systems lies on their role as overburden rocks for maturation of older units, and on the revealed tectono-stratigraphic evolution of the northernmost San Jacinto fold belt in the last 5 Ma, which is crucial for assessing timing and synchronism in petroleum system modeling.

SESSION TITLE: Theme 1: New and Emerging Plays III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Linking the geomorphology and stratigraphic record of three types of submarine canyons along a convergent tectonic margin. The Southern Caribbean of Colombia

AUTHORS (FIRST NAME, LAST NAME): Julian Naranjo-Vesga¹, Juan Paniagua-Arroyave², Andrea Ortiz-Karpf³, Lesli Wood⁴, Zane Jobe⁵, Pedro A. Galindo⁶, Lauren Shumaker⁷, Darwin Mateus⁸

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ABSTRACT BODY:

Abstract Summary: Submarine canyons are primary conduits for sediment transfer from the continental shelf to deep marine environments. They are of great interest to the petroleum industry because their sandy deposits can form major hydrocarbon reservoirs, and because the submarine currents and mass failures flowing through their conduits can be hazards for submarine infrastructure. Here we analyze high-resolution bathymetric and seismic data to characterize the morphological variability of submarine canyons upon the action of different sediment supply, shelf morphology, and seafloor topography along the convergent tectonic margin of the Southern Caribbean of Colombia. Mass failures, tectonic faults, and localized continental sediment supply play a key role in the initiation and evolution of submarine canyons along convergent tectonic margins. We propose three end-member types of canyons: Type I canyons exhibit direct connection to a major river associated with high sediment supply. These canyons are highly erosive and cut topographic barriers created by tectonic deformation. Type II canyons relate with faults at the canyon's head, where the location, orientation, and sinuosity are controlled by fault orientation. Also, faults increase the occurrence of mass failures from the steep canyon borders, increasing the depth and width asymmetry. Finally, Type III canyons evolve toward the continental shelf edge from retrogressive mass failures. These mass failures produce erosional scars that merge downslope to become submarine canyons in early stages of development, which evolve to wider but shallower canyons due to progressive basinward merging. We argue that the morphology of each canyon results mainly from the interaction of continental sediment supply, mass failures, shelf width, and fault occurrence. These results can be used to understand the evolutionary framework of submarine geomorphology that can be applied to other convergent tectonic margins.

SESSION TITLE: Theme 1: Stratigraphy II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Update on the Paleogene Water-Level Drawdown Hypothesis, Gulf of Mexico

AUTHORS (FIRST NAME, LAST NAME): Stephen Cossey¹, Joshua Rosenfeld², Mark Bitter³, James Pindell⁴

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ABSTRACT BODY:

Abstract Summary: We provide an update on the Gulf of Mexico Paleogene water-level drawdown hypothesis by revising and augmenting the original observations to provide new grounds for the continuing assessment of this concept, which has important implications for hydrocarbon exploration. This paper assimilates information on 7 issues from a variety of sources that suggests attention should be focused on the 56 Ma sequence boundary as the most likely time of drawdown, just before the Paleocene-Eocene Thermal Maximum, rather than mid-Paleocene as was first thought. The younger timing downplays the possible association between the Paleocene “Whopper Sandstone” and drawdown, and provides the time necessary for the Cuban arc to begin collision with the Bahamas Platform and close the Florida Straits, a necessary part of the hypothesis. We highlight data from other authors that appear to show that the fastest rate of clastic deposition for all Wilcox time was at about 56 Ma. We also focus on evidence that there may have been Paleogene evaporative conditions in the Gulf, and whether evaporites are even necessary for the viability of the hypothesis. We highlight and discuss evidence from a selection of more than 33 paleo-canyons around the Gulf rim, most of which could have been formed at ~56 Ma given current dating, and we consider the apparent formation of a Gulf-wide unconformity at this time, just before the PETM. The magnitude of the proposed drawdown is estimated from evidence along the thalweg of the Chicotepec paleo-canyon in eastern Mexico. Evidence for subaerial exposure and erosion along the margins of western Florida and northern Yucatán, including at Chicxulub, is also reviewed. Finally, the enigmatic Georgia Channel System is highlighted, and we call for detailed work to confirm if short-lived interruptions in circulation between the Gulf and the Atlantic Ocean during the Paleogene might have occurred, particularly at ~56 Ma. Another good thesis topic would be to deconstruct the last stages of the Cuban orogen and further test the required continuity of a land bridge from southern Florida to Yucatán at ~56 Ma, using comprehensive seismic and well databases in the Yucatán and Florida Straits and the western Bahamas.

SESSION TITLE: Theme 1: Stratigraphy I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Rethinking the depositional profile for Late Cretaceous in NW south America; implications for exploration in conventional and unconventional hydrocarbons.

AUTHORS (FIRST NAME, LAST NAME): German Bayona¹, Camilo Montes², Agustín Cardona³, Sebastian Zapata⁴

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ABSTRACT BODY:

Abstract Summary: Upper Cretaceous rocks, important constituents of the petroleum system in Llanos and Magdalena Colombian basins, accumulated on a west-deepening marine platform formed under a passive-margin setting that covered a former back-arc basin. Following results from different recent studies indicate that these interpretations must be revised: (1) subaerial exposure and relative shallow deposition of both the siliciclastic and the carbonate successions, (2) localized deformation and magmatism of Upper Cretaceous successions, (3) diachronous onset of deposition of Upper Cretaceous rocks upon former horsts structures, (4) contractional tectonism along the western continental margin that reincorporated Early Cretaceous backarc basins, (5) construction of continental magmatic arcs along the continental margin, and (6) farther to the west, the destruction of a double-subduction oceanic plate previous to the collision of the Caribbean plate and associated oceanic volcanic arcs. We locate all these new results in our palinspastically restored margin at Late Cretaceous to explore new tectonic models. We propose a wavy-like ramp profile with three depositional highs and two depocenters. Depositional highs located above former extensional uplifted structures where very shallow deposition with subaerial exposure took place on siliciclastic, mixed and calcareous settings from east (Llanos) to west (Magdalena), whereas shaly deposition took place in the depocenters where pyroclastic ashes supplied from the west accumulated. This depositional profile was flooded by rapid sea level rise since Turonian time. Changes in the subduction regime produced contraction and onset of continental magmatism along the former extensional margin, whereas slight deformation with very localized magmatism took place on the former interior extensional basin. From Turonian to early Campanian, post-rift shallow-marine (< 100 m depth) deposition took place in anoxic conditions. This new basin configuration explains the input of sandy terrigenous material from coastal to shallow marine conditions by hyperpycnal currents, forming possible stratigraphic reservoirs. Similarly, the development of shallow-marine mixed ramps to the west favored accumulation of reservoir units adjacent to the former horst structure. The wavy ramp profile changed westward to the submarine contractional basins, where deposition took place in deeper marine conditions as the basin deepened toward the subduction zone.

SESSION TITLE: Theme 1: Petroleum Systems II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: The utilization of high-resolution Petroleum Systems Modelling to characterize seafloor seepage systems –the Vestnesa Ridge case.

AUTHORS (FIRST NAME, LAST NAME): Matthias Daszinnies¹, Andreia Plaza-Faverola², Øyvind Sylta³, Stefan Bünz⁴, Rune Matningsdal⁵, Are Tømmerås⁶, Jochen Knies⁷

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ABSTRACT BODY:

Abstract Summary: Present-day methane seepage off the coast of Svalbard is evidenced by active gas flares in the water column and precipitation of methane-derived authigenic carbonates (MDAC) over the past 160 000 years. Whilst MDAC deposits document the submarine discharge of methane well over time, considerable uncertainties persist on the geological history of past leakage. Particularly, seepage trigger mechanisms and initial free gas sources are the virtually unconstrained. We will present results from a high-resolution 3D petroleum systems model (PSM) assembled to evaluate the charge impact from potential thermogenic hydrocarbons on the seafloor seepage system of the Vestnesa Ridge, NW Svalbard. Our results demonstrate that gaseous hydrocarbons, originally derived from Miocene age terrigenous organic matter, can accumulate largely in ~2-million-year-old (Ma) sedimentary sequences underneath a pockmark system observed along the ridge's crest. Those traps are subjected to a continuous gas charge until present day. Furthermore, our results argue for a supply of free gas to a paleo-gas hydrate stability zone which initiated gas hydrate formation already ~3.0 Ma ago. Instead, will our model results indicate that seafloor gas leakage and pockmark formation is governed by fault corruption of hydrocarbon traps and not by excess pore fluid pressure nor a continuous gas charge to the surface. The onset of episodic seafloor seepage on Vestnesa Ridge can be associated with the first shelf edge glaciation of the Svalbard-Barents Sea ice sheet (SBIS), ~1.5 Ma ago. The obtained PSM results are consistent with the notion that repeated forebulge uplift and subsidence, due to cyclic SBIS build-up and decay, can be advocated as a mechanism that repeatedly caused extensional fracturing of the eastern Vestnesa Ridge segment. This fracturing damaged the modelled gas accumulations and spawned hydrocarbon migration pathways towards the seafloor. We will present a seepage history concept where recurring tapping into thermogenic gas traps fostered by fracture formation due to glacial isostatic adjustments and fracture re-activation could explain recent observations of multiple seepage events on Vestnesa Ridge during episodes of intense cooling over the past 160.000 years.

SESSION TITLE: Theme 1: Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Reservoir allocation of commingled production in the Chipiron field, Colombia using a cost-efficient alternative to production logging

AUTHORS (FIRST NAME, LAST NAME): Mark A. McCaffrey¹, Arli Páez², Manfredo Kleber³, Fernando Grajales⁴, Alvaro Solano⁵, Balmore Duran⁶, Yuly Ramirez⁷, Jeremy E. P. Dahl⁸

INSTITUTIONS (ALL):

1. Stratum Reservoir
2. SierraCol Energy
3. SierraCol Energy
4. SierraCol Energy
5. SierraCol Energy
6. SierraCol Energy
7. Stratum Reservoir
8. Stratum Reservoir

ABSTRACT BODY:

Abstract Summary: The Chipiron oil field was discovered in 2011 in the Northern Llanos Basin (Arauca department) by Sierra Col Energy (previously called Occidental de Colombia) when the discovery well encountered oil in two horizons (Carbonera Fm) while drilling Pleistocene-Cretaceous sediments. The discovery well was drilled from the basin edge, was highly deviated (75°), and was completed in both oil-bearing sands. Governmental regulations required quantitative allocation of the contribution from each sand to the commingled production. However, operational and logistical complexities rendered conventional production logs cost prohibitive. Therefore, the operator selected a more cost-effective technology to monitor the contribution from each sand to the production. The method used (i) gas chromatographic analyses of oil samples to allocate the oil production and (ii) compositional and isotopic analyses of water samples to allocate the water production.

When a field contains multiple oil-bearing horizons, an efficient production strategy is to complete each well in more than one flow-unit, commingling production. Naturally occurring differences in the composition of the fluids from each flow-unit then can be used as natural tracers to quantify their respective contributions to the commingled production. Before implementing this technique in the Chipiron field, the operator performed a “blind test” of artificial mixtures of oils from the two zones. The results of the blind test demonstrated the accuracy of the technique. As a result, a multi-year monitoring program was begun using that technique to allocate the contribution of each of the two flow-units to the commingled production. That monitoring program demonstrated that the oil production from one of the flow-units progressively decreased until 100% of the oil production came from the other sand. The water production was also allocated using naturally occurring tracers. Based on the high degree of confidence in the results obtained through this technology, the operator concluded that this innovative and extremely cost-effective allocation methodology is particularly valuable in wells where logistical complexity renders production logging impractical: fields such as Chipiron. The analysis cost represented ~ 1% of what a single production log would have cost in this type of highly deviated well. Understanding the fluid origin helped the operator to reduce costs by making timely zone isolations and rig interventions.

SESSION TITLE: Theme 1: New and Emerging Plays III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Formation and Destruction of a Giant Stratigraphic Trap in the Táchira Depression, Southern Venezuelan Andes

AUTHORS (FIRST NAME, LAST NAME): Carlos E. Macellari¹

INSTITUTIONS (ALL):

1. Andes Energy Consulting

ABSTRACT BODY:

Abstract Summary: Even though the first oil field of Venezuela (La Petr6lia, 1882) was discovered in the Táchira Depression, located at the junction of the Venezuelan Andes with the Cordillera Oriental of Colombia, no liquid hydrocarbon discoveries have been made in the area ever since. However, since 1960 a major oil seep impregnating mio-pliocene conglomerates of the La Cope Formation has been exploited intermittently as asphalt mostly for road construction. (La Gotera Asphalt Mine).

La Cope Formation was deposited as a product of the first uplift of the Andes. The unit was deposited unconformably on the nose and flanks of a large-scale anticline oriented N40° and plunging to the SW (Uribante High). However, this unit extended over a much larger area but was later affected by the main Andean orogeny and was partially eroded. A detailed analysis of the petrography of the sandstones and conglomerates as well as paleocurrents, indicate that these sediments were derived from the Uribante High.

The La Cope Formation has a fluvial origin and is arranged in two members. The Lower Member is mostly conglomeratic and was deposited by braided rivers. The Upper Member is mostly composed by sand and clay and was deposited by high sinuosity meandering rivers. The asphalt accumulations are present in the northeastern portion of the Táchira Depression, where the Lower Member of the La Cope Fm rests directly above the unconformity on top of the Cretaceous Aguardiente Fm, which at the time was part of the Uribante High. It is believed that the conglomerates were charged with oil derived from the Cretaceous La Luna Formation that was generating oil at the time of deposition of the unit. This oil migrated directly into the conglomerates and moved for a short distance updip also impregnating the sandstones of the underlying mid Cretaceous Aguardiente Fm. The seal of the accumulation was formed by lateral facies changes, overbank shales, or eventually the muddier Upper Member.

It is difficult to establish the ultimate size of this paleo-accumulation. The EUR reserves of the La Gotera mine are approximately 6.3 MMBO. A rough estimate of the total hydrocarbons in the outcrops of the La Cope Fm is in the order of 90 MMBO, however the original accumulation was orders of magnitude larger. This breached trap was probably the focus point for charge in the Táchira Depression, thus suggesting that a large portion of the hydrocarbons generated in the area have been lost.

SESSION TITLE: Theme 1: Stratigraphy II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Virtual Field Trips with Remote Collaboration as a Better Way to Communicate and Understand Geological Processes

AUTHORS (FIRST NAME, LAST NAME): Claudia Ruiz-Graham¹

INSTITUTIONS (ALL):

1. Imaged Reality

ABSTRACT BODY:

Abstract Summary: Fieldtrips help geologists to understand the 3-Dimensionality and lateral variations of earth processes from basin to pore scale. The reality is that many times natural processes hide their secrets in inaccessible and dangerous locations. Even in roadcuts, safety risks can prohibit a close-up investigation of an outcrop. On the other hand, even in the friendliest environments, geologists are called to understand the large-scale tectonostratigraphic complexity of a geological site only by looking at a small “window” at the base of an outcrop. Too many times in the past geologists have been asked to understand geological processes on an outcrop by reviewing 2D diagrams on pre-reads and verbal descriptions from instructors. There is no doubt that Geology is 3D and that the brain also understands space in 3D. Virtual reality places geologists in an immersive 3D digital space where they are surrounded by data whilst they experience the field in ways that in real life they cannot. Either by investigating and combining data at real scale or being able to study a geological site in the palm of their hand, geologists dramatically increase their understanding of geological processes in 3D. Immersion increases cognition and knowledge retention, improving decision making. Virtual reality also improves knowledge capture, by creating the option of field trip repeatability.

Flying off a cliff in VR at real scale to examine the entire stratigraphic column or rotating a 3D outcrop model in order to restore the pre-collisional setting allows geologists to have a better visual understanding of the field before and after visiting an outcrop. This practice has the advantage of more detailed geological observations in real fieldtrips and a robust knowledge retention of the outcrop locations.

In this talk we will take you to a virtual fieldtrip, to depositional systems with examples across the globe using Stratbox, the first virtual reality platform for Geoscience.

SESSION TITLE: Theme 1: Petroleum Systems I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Lessons from the Corrales and Bolivar oil fields, exploring the Eastern Cordillera of Colombia.

AUTHORS (FIRST NAME, LAST NAME): Sergio Arturo Medina Díaz¹, Tomas Villamil², Sofia Santodomingo³, Juan Ospina⁴, Andres De la hoz⁵

INSTITUTIONS (ALL):

1. Omega Energy Colombia
2. Independent Consultant
3. Omega Energy Colombia
4. Omega Energy Colombia
5. Omega Energy Colombia

ABSTRACT BODY:

Abstract Summary: The Eastern Cordillera Inverted Basin, defined as the Early Cretaceous depression limited east and west by rift shoulder extensional faults that separate relatively thin upper Cretaceous rocks from thicker and older Cretaceous packages has only two proven commercial hydrocarbon accumulations. The Corrales field is the largest accumulation of the basin, it is a 1,700 acre fault-bound compartment of the eastern flank of the Beteitiva syncline. Proven commercial reservoirs are quartz arenites of the Late Cretaceous Tierna Formation of the Guadalupe Group. The Corrales field is primarily a gas accumulation with an oil rim, with critical lateral seal being a footwall fault. Original oil producing mechanism was gas cap drive and late-stage current production is drainage of remaining gas. The Bolivar field is composed of smaller fault-bound compartments on the crest of the transpressive San Antonio pop-up anticline, the main reservoirs of this field are low porosity, possibly fractured, La Luna Formation that produces 18.3 API gravity oil, and the Tierna Formation at only 1,000 feet depth that produces gas.

3D seismic interpretation of the Buenavista Block integrated with results of existing wells and reservoir engineering data, allow a modern redefinition of the structural model and thus help in the establishment of best practices for the exploration in this very low chance of success (approximately 5% historical success rate) and complicated basin. Exploratory efforts should focus on traps in synclinal flanks pursuing good quality Tierna in large fault-bound compartments rather than chasing highly compartmentalized constricted anticlines. New exploratory opportunities have been identified using this approach, one of them -Macaravita- is a west-dipping structural compartment isolated from others by faults of different characteristics: the eastern boundary of the trap is the footwall of a west-verging reverse fault, the northern boundary is the hanging-wall of a north-verging thrust fault, the west boundary is the footwall of an east verging reverse fault and the south boundary is structural dip to edge of 3D data.

SESSION TITLE: Theme 1: New and Emerging Plays II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Where is the reservoir? Challenging the geological uncertainty in the new era of exploration of Colombian Llanos Foothills

AUTHORS (FIRST NAME, LAST NAME): Paola Castano Giraldo¹, Yvonne Ramirez Castro², Luis Enrique Soto³, Maria P. Perdomo⁴, Juan Carlos Alzate⁵, Guillermo Rodriguez⁶, Erich Caballero⁷, Alejandro Gonzalez⁸, Diego A Millan⁹

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol
8. Ecopetrol
9. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The discovery of a new gas condensate accumulation by the well Liria YW-12 in the Colombian Llanos Foothills represented a significant milestone in the new era of the basin exploration led by Ecopetrol.

Despite being a proven petroleum system and the availability of information from development wells, the poor quality of seismic image did not allow mapping structures with confidence and propose a single structural model. The area is highly complex since it exhibits a structural style of stacked thrust sheets and isolated floating structures. This structural complexity leads to geological uncertainties in finding repeated and stretched sections that are not evident on seismic, which therefore, could not be predicted.

Under this context, predicting the stratigraphy of the wellbore path while drilling was the biggest challenge. Thus, the workflow included the analysis of geological and drilling data as well as the natural borehole tendency as a part of the dataset used in the generation of multiple structural models. This methodology was successfully proved on decision making which had a positive impact on the economic results of the project.

From an operational point of view, any abnormalities could have compromised the outcome of the project. For instance, the formation above the main reservoir was found to be stretched than expected. As a result, there was a risk of concluding operations at the wrong depth, where finishing the well section (10 5/8") at a shallower depth would have made drilling and subsequent reservoir evaluation extremely challenging. On the other hand, drilling deeper through the main reservoir could have resulted in massive mud losses and the drilling of a sidetrack.

A further anomaly was encountered in the formation above the deepest target, where an unexpected stretched sequence was observed due to an increase in structural dip. This was interpreted as a fold within the structure. Appropriate understanding of such geological scenario guided the team while drilling through a highly challenging operation, leading to the prediction and subsequent discovery of the secondary reservoir.

The methodology and following good practices not only contributed to reaching the objective, but also resulted in the optimization of drilling operations and mitigation of operational risks, time/cost efficiency, all while delivering one of the few wells in the area without any geological or technical sidetracks.

SESSION TITLE: Theme 1: Petroleum Systems III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Assessing Charge Risk in the Perdido Fold Belt Through Petroleum System Modeling Techniques

AUTHORS (FIRST NAME, LAST NAME): Patrick Wojciak¹, Fernando Rodriguez¹, Marie Callies², Felipe Medellin³

INSTITUTIONS (ALL):

1. BHP
2. Beicip-Franlab, Paris, France.
3. Beicip-Franlab, Houston, TX, United States.

ABSTRACT BODY:

Abstract Summary: A kinematic petroleum system model based on the structural restoration of a 2D section in the Perdido Fold Belt was generated with the objective of modelling hydrocarbon charge across shale detachments into shallow reservoirs. The basin model was built accounting for salt deformation and the large amounts of shortening observed in the area from Early-Late Oligocene times. The shortened complex mechanical stratigraphy is manifest in complex faulting and folding at different wavelengths and on different stratigraphic levels, generating several structures favorable for the trapping of hydrocarbons. Reservoirs are comprised Eocene and Oligocene sandstones in turbiditic deposits, sourced by the prolific Tithonian source rock from which hydrocarbon expulsion starts in Paleocene. Calibrated to known discoveries and well data available in the area, the model was used to test multiple scenarios on migration losses and the behavior of faults using a dedicated basin simulator able to handle complex geometries with faults treated as real volume objects. Several shale retention parameters were tested, as well several faults scenarios, considering them individually as closed, or open; open while active and then closed while inactive. Fault continuity across reservoirs was also tested, allowing a better understanding of migration mechanisms and their impact on charging different prospects. Other classical basin modeling outputs were also analyzed, such as the reservoir pressure, temperature and the effective stress at the seal levels through time.

This presentation will introduce the applied workflow and technologies before focusing on 2D scenario testing and a discussion of key results. This kind of approach, although in 2D, drastically contributes to the understanding of the petroleum system, particularly where uncertainty is high in such a complex area.

SESSION TITLE: Theme 1: Petroleum Systems III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Detection of High-Maturity Seeps in the Caribbean

AUTHORS (FIRST NAME, LAST NAME): Jeremy Dahl¹, Michael Moldowan²

INSTITUTIONS (ALL):

1. Stanford University
2. Biomarker Technologies Inc.

ABSTRACT BODY:

Abstract Summary: Discovering oil seeps is one of the oldest and still one of the most effective techniques of oil exploration. Offshore seep studies are usually based on piston cores acquired from sediment grabs over a selected area of interest. In a typical piston-core study, the samples are acquired, then frozen, taken to a lab and extracted and the extracts analyzed for any sign of petroleum residue. Analytical techniques include fluorescence, UV-Vis, IR, GC, GC-MS and GC-MS-MS. Positive indications of seeps include (1) visible oil in the core, (2) dark colored, oily extracts, (3) fluorescence, (4) GC traces indicating oil and (5) GC-MS traces containing oil biomarkers.

While these methods are sometimes effective, they do not work for high-maturity seeps of gas and condensate many of which occur in the Caribbean, offshore Colombia. The reason is that there is: (1) no visual evidence of petroleum in the piston cores, (2) any extractable material is colorless, (3) extracts do not fluoresce due to the small size of condensate aromatic molecules, (4) the GC may show no evidence of oil since light condensates are very easily biodegraded, and (5) due to the high maturity of the escaping fluids, biomarkers will be absent.

Although conventional techniques are generally useless for high-maturity seeps, mapping diamondoid concentrations in piston-core extracts provides an excellent method. Basically, cores are dried, weighed and extracted and the extracts run by GCMS to determine diamondoid concentrations. The concentrations are mapped based on piston core grab locations and from these maps, high-maturity seeps are easily recognized from positive anomalies of diamondoid concentrations. For example, diamondoid concentrations in one Caribbean piston core study, offshore Colombia, go from a background concentration of around 1-5 parts per trillion by weight of sediment extracted to over 100 ppt at seep locations. This is true even though there is no other indication of seepage in these cores derived from conventional detection methods. Diamondoid concentrations are effective whereas typical seep indicators are not because: (1) diamondoid concentrations increase with increasing maturity, (2) they are present in fluids associated with even dry gases, (3) they drop out at the ocean sediment interface due to a drop in pressure and temperature, (4) they are highly resistant to biodegradation and (5) using the right methods, they can be quantified extremely accurately.

SESSION TITLE: Theme 1: New and Emerging Plays II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Aguas Vivas Field – A Significant New Gas Discovery Hidden for Over 70 Years of Exploration History in the Lower Magdalena Valley Basin, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Patricia Gavotti¹, Ryan Aquilini², Andrew Willis³, Nilanjan Ganguly⁴, Luz Rodriguez⁵, Sean Johnston⁶, Mark Teare⁷, Aurora Juan⁸

INSTITUTIONS (ALL):

1. Canacol Energy
2. Canacol Energy
3. Canacol Energy
4. Canacol Energy
5. Canacol Energy
6. Canacol Energy
7. Canacol Energy
8. Canacol Energy

ABSTRACT BODY:

Abstract Summary: The most important gas reservoir in the Lower Magdalena Valley (LMV) basin onshore NW Colombia is the Oligocene to Lower Miocene Cienaga de Oro (CDO) Formation, a thick section (up to 5000 Ft) of fluvial, estuarine and shallow marine sandstones, shales and coals resting on basement and overlain by a thick regional marine shale top seal (Porquero Fm.). Most of the historical CDO gas discoveries in the basin have been in structural traps associated with extensional faults which were identified by mapping the top CDO horizon. In the Aguas Vivas area, first gas was discovered by the Jobo-1 well in 1947. Five pools (Jobo, Cañaflecha, Cañahuat, Arianna and Katana) have been discovered and produced a cumulative 110 BCF. Historical practice was to drill the crest of a structure and continue through gas bearing sandstones until the first wet sandstone was encountered and call TD. 3D seismic data was acquired over the area in 2007-2012 and reprocessed with an AVO compliant workflow in 2015. This new reprocessing coupled with a reevaluation of the legacy well data demonstrated that previously unrecognized structural closures existed at horizons deeper than the historically productive uppermost CDO. These closures are spatially offset from the top CDO accumulations due to the dip of the bounding faults. Fault dip and structural crest migration with depth, coupled with numerous legacy contract boundaries present challenges for completely testing stacked reservoir sandstones through the thick CDO section. In 2021, the prospect was tested by two wells drilled on opposite sides of a contract boundary: Cañahuat-4 was drilled on the Esperanza block to test upper CDO sandstones as mapped at top CDO closure and encountered 72 Ft. (22 m) of net pay. Later the same year, the Aguas Vivas-1 well was drilled on the VIM-21 block to test deeper CDO Sandstones on an offset structural crest and encountered 412 Ft. (126 m) of net pay, the largest ever encountered by a single well in the basin. The combined net pay of both shallow and deep zones encountered in the two wellbores was 484 Ft. (148 m). The application of detailed mapping on 3D seismic has led to a new significant gas discovery overlooked by several previous operators over a period of 70 years.

SESSION TITLE: Theme 2: Andean Structural Styles I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Several Oil Water Contacts and Different Hydrocarbon Types in the Capachos Anticline, Why? What Does It Mean for the Prospectivity in the Structure? A Perspective From the Analysis of the Deformation Timing.

AUTHORS (FIRST NAME, LAST NAME): Isaid Quintero Arévalo¹, Luis Enrique Soto², Felipe Botero³, Eliseo Teson⁴, Maria Isabel Dussan⁵, Luz Jeny Navarro⁶, Carolina Quintana⁷

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The structural setting of the Capachos Anticline shows a tear faults system that compartmentalizes into four blocks. Each block has a different hydrocarbon-water contact (HWC) for the Cretaceous and the Paleocene reservoirs in the anticline. In order to understand the current HWC configuration and find new exploratory opportunities it was necessary to study how the anticline deformation evolved taking into account: (1) the deformation timing by a growth strata analysis and (2) the restoration of the compartmentalization associated to the tear faults activity. To generate the isopach and structural maps, this study used a seismic cube and eight wells data. As a result of these analysis, it is unraveled that at least four deformation stages produced the current structural setting. Three growth intervals were found in the middle and late Miocene stratigraphic section. The oldest corresponds to the Middle Miocene León Formation and it is in the southern block, showing that a first deformation stage was acting in this block at this time and was restricted by a tear fault and a backthrust. The second growth interval corresponds to a late Miocene lower Guayabo Formation and it is present at least in the three northern blocks, showing that the deformation of the Frontal Capachos Fault and its backthrusts was extended to the north as it was deposited. The third growth interval is present in the late Miocene middle Guayabo Formation and it is located in the northern part of the anticline, defining the onset of the northern closure configuration of the anticline by the deposition time of this interval. Since this time the three northern blocks were able to capture hydrocarbons, however, the tear fault slip restoration along the anticline hinge shows that the restored HWCs share the same structural level for every reservoir, suggesting that the hydrocarbons' charging process in the crest stopped once the structure was compartmentalized. This charging interruption must be related to the connection of the tear fault system with the previously formed backthrusts, which acted as a seal not only in the crest but also for configuring a deeper HWC in the western flank of the anticline, opening a new exploratory perspective. Additionally, the structural restoration reveals that the restored HWC in the southern block is higher than in the northern block, which could be explained by the isolation of this block by the tear fault and the backthrust since the middle Miocene.

SESSION TITLE: Theme 2: Andean Structural Styles I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Structure and Orogenic Evolution of the Madre de Dios Fold and Thrust Belt, Southern Peru

AUTHORS (FIRST NAME, LAST NAME): Christian Hurtado¹, Patrice Baby², Calderon Ysabel³, Brusset Stephane⁴, Viveen Willem⁵

INSTITUTIONS (ALL):

1. Universidad Nacional Mayor de San Marcos
2. IRD
3. PERUPETRO
4. Toulouse University
5. PUCP

ABSTRACT BODY:

Abstract Summary: The Subandean Zone of Perú is considered as a fold and thrust belt system causing during its development an important interaction between subsidence zones of the foreland, sedimentation-erosion, and deformation rates. The Madre de Dios basin has part of this segment and is located in the southern Peruvian Amazon basin with a recognized gas potential of 2 TCF drilling by Candamo 1-X well. In recent years, the combination of methodologies involving balanced cross sections and lower temperature thermochronology allowed dating and reconstruction of important deformation phases that coincide with the development of the Andean relief and the migration and deformation of the Subandean front. The references of the deformation and propagation record in the Madre de Dios basin are delimited to a Miocene-Pliocene period, however, the seismic sections show important indicators such as folds formed by faults, growth strata and duplex structures forming during the Late Cretaceous-Paleogene and sealed by an early Miocene unconformity that could represent a compressional stage that affects the Madre de Dios basin long before its configuration. This work attempts to show the role of deformation in the Madre de Dios basin during the development of the Andean Orogen. To understand this process, it is intended to establish a lateral structural control and to reconstruct the kinematic deformation of the Eastern Cordillera and Subandean Zone. To achieve this objective, we generate three balanced regional structural sections and the representation of different stages of deformation by means of the recognition of important erosion surfaces and the compilation thermochronology ages. The results identify 3 types of structural styles controlled by the variation of detachment levels (Cabanillas, Chonta, and Cachiyacu formations) and the presence of basement indenters that control the propagation of the Subandean front (Example Madidi Arc). A total shortening has been measured that varies from 35 to 65 km that progressively increases from north to south. It is important to emphasize for the first time a shortening control measured for Upper Cretaceous-Paleogene deformation ranging from 12 to 24 km with the development of a significant passive roof duplex deformation with controlled propagation through basement structures (Madidi Arch).

SESSION TITLE: Theme 2: Andean Structural Styles I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Thin Skin Fold Belt Structural Style in the Argentinean - Bolivian Subandean Foothills the Madrejones anticline example

AUTHORS (FIRST NAME, LAST NAME): Juan Iñigo¹, Alfredo Disalvo¹, Martin Iribarne², Juan Reynaldi¹

INSTITUTIONS (ALL):

1. Pluspetrol

2. Geopark

ABSTRACT BODY:

Abstract Summary: The Subandean Belt System of Bolivia and Argentina constitutes one of the main hydrocarbon provinces of South America, with associated giants gas and condensate fields. These elongated anticlines and synclines, extending hundreds of kilometers into Bolivia and northern Argentina, are associated with a thin skin fold and thrust structural style, characterized by a series of complex structures, where outcropping anticlines can be displaced from subsurface hydrocarbon-bearing structures. Subsurface structural interpretation is a major challenge in this region, as a result of extremely poor seismic data quality, and the existence in some areas of ductile shales that cause displacement between shallow and deep structures. The Madrejones anticline, located in the foothills of the Bolivian Subandean belt, constitutes one of the few examples where seismic, well and outcrop data allow a more reliable interpretation of the subsurface structural configuration. For this structure, a fault propagation fold transported by an out-of-sequence thrust was interpreted. In addition, two minor sub thrusts, with no surficial expression, can be defined, associated with fault bend fold kinematics. The existence of these subthrust sheets is usually inferred in many other structures of the Subandean Ranges and the fact that these can be interpreted in Madrejones makes this a reference case for areas with poorer data quality.

SESSION TITLE: Theme 2: Andean Structural Styles I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Challenges in Finding Structured Fractured Reservoirs in Complex Thrust Belts Systems: a Drilling Case in the Southern Subandean Belt in Bolivia.

AUTHORS (FIRST NAME, LAST NAME): Olivier De Mena¹, Daniel Peña², Massimo Bonora³, Jose Olaya⁴, Willy Gil⁵, Rodrigo Limachi⁶, Goitia Antezana Victor Higo⁷, Tomas Zapata⁸, Gonzalo Zamora⁹

INSTITUTIONS (ALL):

1. Repsol
2. Repsol
3. REPSOL SERVICES COMPANY
4. Former REPSOL - Now TBI COLOMBIA SAS
5. Consultant
6. REPSOL BOLIVIA
7. REPSOL BOLIVIA
8. Repsol
9. Specialists, Repsol, Madrid, Spain.

ABSTRACT BODY:

Abstract Summary: High relief, mountainous jungle conditions, outcropping formations ranging in age from Quaternary to Upper Devonian in the core of the structures, and an effective petroleum system make the southern Subandean region of Bolivia a prolific Fold Thrust Belt with giant gas fields and one of the most challenging areas for the definition of hydrocarbon drilling prospects.

In these complex geological settings, topographic and geological maps and their correlation with existing well data is the only hard data available. Therefore, it is important that this information (stratigraphic columns, thicknesses, and lithological descriptions) must be accurate as it will constitute the basic input for geological and structural models. The topography, the structural complexity, and the variability in the mechanical stratigraphy makes the acquisition and processing of geophysical seismic data challenging. Nevertheless, despite the initial low quality, careful geophysical processing and observations help to constrain interpretations and capture the range of structural uncertainties.

Here we present an interpretation workflow along a W-E seismic line from a recent 3D seismic survey that combines all the available data to build a comprehensive structural model for one of the south Subandean ranges of Bolivia. This workflow begins with the analysis of the surface geological information as direct constraints that must be honored and followed with observations of the subsurface data that become indirect constraints for the structural interpretation. This workflow was validated through forward modelling honoring as much as possible the time constraint to reduce the number of possible structural models and quantify uncertainties in prospects definition. This workflow has demonstrated that in order to be successful in such complex settings all the information need to be considered, analyzed and integrated. The close collaboration between exploration geologists and processing geophysicist is fundamental to obtain a good seismic image quality in areas where traditionally the image is very poor. This approach allowed the multidisciplinary team to define exploratory prospects, manage most of the associated uncertainties and risks, and helped to take the right decisions during drilling and avoid operational problems.

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Artificial Intelligence Approach to Predict Mineralogy of Shales: An Example from Qusaiba Shale, Rub' al Khali Basin, Saudi Arabia

AUTHORS (FIRST NAME, LAST NAME): Ayyaz Mustafa¹, Zeeshan Tariq², Abdulazeez Abdulraheem³, Mohamed Mahmoud⁴, Mohamed Omar Abouelresh⁵

INSTITUTIONS (ALL):

1. King Fahd University of Petroleum & Minerals (KFUPM) - Saudi Arabia
2. King Fahd University of Petroleum & Minerals (KFUPM) - Saudi Arabia
3. King Fahd University of Petroleum & Minerals (KFUPM) - Saudi Arabia
4. King Fahd University of Petroleum & Minerals (KFUPM) - Saudi Arabia
5. King Fahd University of Petroleum & Minerals (KFUPM) - Saudi Arabia

ABSTRACT BODY:

Abstract Summary: The Qusaiba Shale is a proven source rock for the Palaeozoic petroleum system of the middle east and it is targeted as a potential source of unconventional shale gas in Saudi Arabia. Mineralogy of shale plays a key role in the successful design and performing the hydraulic fracturing operations and in turn evaluating the production potential. There is limited research available in the literature on the application of artificial intelligence for mineralogical prediction, which motivate us to perform this research on the Qusaiba Shale. The study aims to predict the Qusaiba Shale mineralogy, specifically clay and quartz minerals using readily available conventional logs, where both minerals are the major constituents of shale and help in assessing the brittle and ductile zones within the shale formation. Three lithofacies were defined in the Qusaiba Shale based on different geological and sedimentary features of core samples. Predictive models were developed for two utmost important minerals present in Qusaiba Shale formation including clay and quartz using artificial intelligence techniques. An adaptive neuro-fuzzy inference system (ANFIS) and artificial neural networks (ANN) were employed to precisely predict the two major minerals contents in Qusaiba Shale formation. All four models were found to have good accuracy. ANN-based models exhibited minimal errors with AAPE and RMSE of 2.53 and 1.45 for quartz and 3.43 and 2.01 for unseen data points for clay prediction models respectively. ANFIS-based prediction models presenting the AAPE and RMSE 2.67 and 1.83 for predicted quartz values and 3.59 and 1.89 for the clay content respectively. The applied artificial intelligence predictive model for major minerals in Qusaiba Shale i.e., clay and quartz would be a viable and useful approach to achieve valuable information about minerals content in shale for prospective evaluation of shale gas reservoirs. The results of this work would be useful in prospect evaluation and optimizing the production from unconventional shale gas reservoirs in Saudi Arabia. Moreover, the approach used may provide insights into replacing traditional mineralogy determination methods to save cost and resources in the absence of cores and mineralogy logs in the unconventional Qusaiba Shale resource. Furthermore, applying the same artificial intelligence approach and steps could be used for the field development of other shale gas and oil fields around the world.

SESSION TITLE: Theme 6: Subsurface Energy Systems Beyond Traditional O&G: Hydrogen and Geothermal Energy

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Medium Enthalpy Caloric Risk Assessment in Une Formation of the Llanos Basin - Colombia **AUTHORS (FIRST NAME, LAST NAME):** Eduardo Lopez-Ramos¹, Cesar Patiño², Felipe Gonzalez-Penagos³, ALBEIRO LOPEZ⁴

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The Llanos Orientales is the most prolific petroleum basin of Colombia. In this region, oil industry data is used to evaluate the caloric potential of deep aquifers, which is a necessary step to assess the feasibility of medium-enthalpy geothermal energy projects. One important geothermal aquifer of interest is the Une Formation, a middle Cretaceous deltaic to shallow marine quartzitic sandstone unit. With further integration of hydrogeochemical and hydrology information, we use the Une to illustrate the elements that compose a medium-enthalpy geothermal system, which we name the “Mesozoic primary porosity, middle temperature” play.

The “Mesozoic primary porosity, middle temperature” play can be considered as proven as knowledge exists about its subsurface distribution, temperature, reservoir properties, fluid production, and average energy recovery. Along the Llanos foredeep, the Une Formation is a strong semi-confined aquifer, which reaches depths of 3 km and temperatures of more than 100 °C. The average thickness is 200 m and primary porosity is greater than 10%. With these properties, the estimated total recoverable energy resources for the play amount to 13,7 GWe, using an energy recovery factor of 5%. This energy magnitude is approximately 5 times the installed capacity at Hidroituango, the largest hydroelectric plant built in Colombia.

Thanks to the characterization of the “Mesozoic primary porosity, middle temperature” play, a portfolio of geothermal opportunities has been built in the Llanos basin. Part of this portfolio comprises heavy oil fields at the economic boundary of production due to their high-water productions. There is an opportunity to extend their useful life, initially by co-production of energy for self-consumption. It is envisioned that some of these fields will evolve into geothermal sites for generation of electrical energy, adding to the national energy grid.

SESSION TITLE: Theme 6: Subsurface Energy Systems Beyond Traditional O&G: Hydrogen and Geothermal Energy

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Subsurface H₂ Storage: The Role of Understanding Salt Dome Caprocks

AUTHORS (FIRST NAME, LAST NAME): Lorena Moscardelli¹, Oliver Duffy¹, Jinyu Zhang¹, John Andrews², Mark Shuster³

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: Hydrogen will play a crucial role as part of the ongoing energy transition and subsurface hydrogen storage will be part of the equation. Hydrogen storage in salt domes is a proven concept with three commercial hydrogen storage sites operating in Texas. Estimates suggest that if hydrogen gas were to replace 10% of natural gas supply in the United States, the current hydrogen storage capacity would need to be increased 200x. Salt domes within the Texas Gulf Coast can host multiple salt caverns but the design and placement of salt caverns requires subsurface geological input. Intra-salt deformation during salt dome evolution can lead to the development of boundary shear zones (BSZ) that can pose a risk to salt cavern construction and operation. Placing and operating salt caverns in close proximity to or within BSZs can increase the risk for (1) casing deformation of wells, (2) deformation and collapse of caverns and (3) the encounter of weak and porous salt zones that can lead to product loss and contamination. Mapping caprock irregularities in salt domes can reveal the presence of BSZs in the shallow sections of a dome, the integration of well data and the analysis of salt cavern morphology using sonar imaging can then inform the interpretation of BSZs at depth within the dome. Caprock characterization is a useful approach to understand intra-salt deformation given that onshore seismic data usually does a poor job at imaging intra-salt structures. In this work, we will talk about the importance of documenting and understanding caprock geometries to predict BSZs and how these predictions can assist in the better placement of salt caverns. We will also provide an update regarding our ongoing efforts to update the salt dome inventory of Texas.

SESSION TITLE: Theme 6: Subsurface Energy Systems Beyond Traditional O&G: Hydrogen and Geothermal Energy

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Can native hydrogen become the new extractive industry for the 21st century?

AUTHORS (FIRST NAME, LAST NAME): Gonzalo Zamora¹, Rubén Loma², Antonio Martin Monge³, Andre Vayssaire⁴, Massimiliano Masini², Antoni Olaiz⁵

INSTITUTIONS (ALL):

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5. Repsol

ABSTRACT BODY:

Abstract Summary: The need to curtail CO₂ emissions at a global scale has triggered search for new energy resources as part of the so-called energy transition. Since hydrogen produces minimal pollutants when combusted, it is being regarded a key pillar on this transition. Hydrogen is a fundamental industrial feedstock, and at present is mostly derived from fossil fuels via steam reforming of natural gas, partial methane oxidation and coal gasification. Although hydrogen is the most abundant element in the universe, it has received little attention in terms of exploration. However, hydrogen-rich gas seeps are common in nature. These emanations were first detected in mid-oceanic ridges in 1970 but have been afterwards identified in a large variety of geological settings. These seeps can be regarded as the proxies of an active hydrogen generation system in the subsurface, much in the same way as oil seeps prove the existence of a working petroleum system. There are several mechanisms that are known to produce molecular hydrogen in nature (i.e. native hydrogen) including mantle degassing, microbial activity, and metagenetic generation from organic matter, among others. However, abiotic ferrous iron oxidation is proven as major natural sources of native hydrogen. This oxidation is common during the process of serpentinization, where hydrogen is a by-product in the hydrous alteration of ultramafic rocks. Thus, the Olivine, which is a predominant mineral in mantle rocks, reacts with water to produce serpentine and free Hydrogen in complex reactions. The estimated large volumes of hydrogen generation from geological sources, together with the amount of new evidence that are emerging due to more detail analysis, and the presence of what seems to be a large hydrogen accumulation in Mali, are showing that native hydrogen is much more widespread in nature than was previously thought. In this study, we set out to tackle the question whether natural hydrogen can be explored and produced. The challenge is to understand the “hydrogen system”; which are the main sources and the sinks of hydrogen in nature? How does it migrate and where can it be trapped? Which seal do we need to trap the smallest molecule? In this contribution, we will discuss if proven approaches in the petroleum industry, where most of these questions find an equivalent, can help us gain further insights into the inner workings of native hydrogen systems.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Geoscientists are Fundamental to the Energy Challenge

AUTHORS (FIRST NAME, LAST NAME): Max Brouwers¹

INSTITUTIONS (ALL):

1. Getech

ABSTRACT BODY:

Abstract Summary: Society needs more energy that is affordable, reliable and clean. Geoscientists play a crucial role in solving this triple challenge. They understand the earth, its processes and resources better than any other discipline. Geoscientists can thus improve the environment and help society while also ensuring the required capital is provided by shareholders.

This presentation outlines the shifting role for geoscientists. It highlights the new skills required and makes recommendations on how to support the geoscientists of the future to ensure they can step up to the energy triple challenge. As the world diversifies its energy sources, the role of geoscientists diversifies and expands too.

The shifting landscape for six geoscience sectors will be described, ranging from petroleum to nascent areas such as geo-engineering. In addition to sector specific trends, the aggregate direction for the discipline will be discussed.

What this means on a more personal skill and capability level will be examined too. This includes topics such as the need for a deeper understanding of artificial diagenesis, to strengthened business acumen for geoscientists. Next to considering skills, geoscientists should nurture their ambition and entrepreneurship to ensure they have impact. This includes stepping up to inform strategic decision makers and public at large objectively and comprehensively of the pros and cons of alternative choices.

Given the critical role of geoscience, suggestions are made how the decline in geoscientists can be halted, in order to address the world's energy challenges in the future. Because, geoscientists are core to the energy solution.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Creating a Sustainability Atlas for Geosciences

AUTHORS (FIRST NAME, LAST NAME): Maria Angela Capello¹, Emer Caslin², Iain Stewart³, Miriam Winsten⁴, Ludvine Wouters⁵, Denise Cox⁹, Heather Handley⁶, Anna Shaughnessy⁷, Estella Atekwana⁸

INSTITUTIONS (ALL):

1. Red Tree Consulting, LLC
2. Empty
3. Empty
4. Empty
5. Empty
6. Empty
7. Empty
8. Empty
9. Storm Energy

ABSTRACT BODY:

Abstract Summary: Interest, capability and capacity in Geosciences is enhanced and supported if the value it adds to society, the environment, and economic development is appraised, communicated, and understood.

One way to enhance the value proposition of geosciences is to map its activities, applications, and practices to the United Nations 17 Sustainable Development Goals (SDGs). The SDGs are a global framework adopted in 2015 to analyze the progress achieved to address urgent challenges of humanity. The Atlas developed shows how geosciences play a pivotal role in advancing the SDGs. The journey to generate the first Geosciences Sustainability Atlas included the following working loops:

- The shaping of a multi-national, multi-ethnic, and multi-disciplinary team of professionals, aimed to cover most geographical areas.
- The establishment of timelines, workflows, and goals for the project that ensured an alignment of all professionals involved.
- The envisioning and selection of the audience to whom the Atlas was to be directed, as this shaped the length, depth and focus of the work at stake.
- The implementation of communication strategies to ask for examples of the utilization of geosciences to advance SDGs, in a worldwide consultation
- The selection of an open access publishing platform non-associated with single affiliations.
- The active seeking of endorsement of relevant geosciences-related professional associations and organizations.
- The activation of promotional activities to raise awareness of the geosciences community to the creation of the Atlas, inclusive of podcasts, articles, social media posts, and webinars.

The Atlas involves mapping geosciences to the SDGs, a process that was done by defining three Dimensions: People, Planet, and Prosperity.

Selected case studies, initiatives and projects in which geosciences play a fundamental role are being used for each Dimension. The examples are selected to facilitate the representation of all disciplines in geosciences, private and public initiatives, and geographical distribution, with the purpose of enlightening the understanding of the prime role geoscientists have.

The Geosciences Sustainability Atlas has been endorsed by the UNESCO and aims to be a platform for communication, able to reach large audiences with an inspirational message and showcase the tremendous contribution Geosciences makes in achieving the SDGs, and subsequently, inspire younger audiences to pursue careers in geosciences.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Energy Transition: Cognitive Bias and Scientific Reductionism (Faith, Facts and Fake News)

AUTHORS (FIRST NAME, LAST NAME): John Londoño¹

INSTITUTIONS (ALL):

1. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Often, the discussion about energy transition focuses on personal ideologic concerns, derived from one's own cognitive evolution, that regularly categorizes reality according to certain intrinsic hierarchy of order or chaos, or good and evil, that prevails in each individual. Thus, any phenomenological fact is judged according to a subjective discriminatory approach that embraces those realities supporting its own value system and rejects those realities contrary to it. This epistemic process, known as cognitive bias, pervades almost every single public (and maybe private) discussion about earth's decarbonization. Unfortunately, under this condition, each stakeholder takes an argumentative position neglecting any measurable fact that does not support its own narrative. This vision could lead us to avoid sensible holistic solutions. As in many past world trends, these days climate change appears to be a new culprit for almost every significant problem affecting modern society and nature, in today's global cosmovision of the world. The debate about global warming and the world's decarbonization-path has so many perspectives and subjective trues, that finding a unique undebatable, inflexible solution, results almost impossible. Another prevalent epistemological problem derived from such approach (the search for a binary solution), the scientific reductionism, or trying to establish simple linear correlations between nature's two or more complex processes, results in considerable loss of resources, focus and time, deviating the discussion towards dubious or nonconclusive paths, instead of real multivariate analysis more in line with phenomenological reality. From presidents and law-makers to multi spectrum activism, all over the world, and particularly, within mainstream and sensationalism media, where most population learn the news from, and thereafter an ethical position is assumed, most discussion about energy transition regularly appeal, even unconsciously, to these epistemic phenomena to represent a reality that rarely conveys the whole complexity of natural and societal processes.

SESSION TITLE: Theme 6: Subsurface Energy Systems Beyond Traditional O&G: Hydrogen and Geothermal Energy

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Natural hydrogen superficial emissions in a Brazilian craton. A quantitative assessment

AUTHORS (FIRST NAME, LAST NAME): Isabelle C. Moretti³, A. Prinzhofer¹, Joao Françolin²

INSTITUTIONS (ALL):

1. Geo4U
2. Georisk
3. UPPA

ABSTRACT BODY:

Abstract Summary: In many basins, hydrogen-emitting structures are now observed, but the estimation of the H₂ flow leading to their formation remains poorly constrained since all data show that the H₂ emissions are variable in space and time. We present here the data of a long-term monitoring campaign with a high density of permanent hydrogen detectors installed in 2 structures in the Minas Gerais State (Brazil). Results show that two kinds of signals are recorded, large sporadic pulses that affect the H₂ content of the soil for one or two days and smaller ones, with a daily periodicity, that last 6 hours and during which the near surface soil concentration usually does not exceed 200 ppm. This last signal is very regular in frequency, less in amount, and the daily maximum happens around noon or in the early afternoon. We interpret the large pulses, which may reach 1% as evidences of a deep hydrogen flux, leaking either from a reservoir located in the subsurface, from an aquifer which is degassing or, although it seems unlikely, directly from the H₂ generation area. The time correlation between the pulse and the increase of the daily signal suggests that this last one corresponds to the slow release of the gas that has been captured by the soil during its transport towards the surface. This daily signal is most likely influenced by external factors such as atmospheric pressure variations and sub-surface bacterial activity. In map view, the lack of correlation between the highest hydrogen concentrations over time suggests that the soil is very heterogeneous and that preferential pathways exist. Even if quantification of leakage doesn't represent the deeper hydrogen flux, these new data allow a more precise evaluation of the quantity of H₂ released in surface by these structures, more than six hundreds of kilograms per day. Globally this basin contains hundred of structures similar to the ones which has been monitored, 86 in the surrounding small hill and more than 600 within a distance of less than 100 km. It suggests that the leakage of H₂ in this area is more than 300 t/day and confirm the high H₂ prospectivity of this basin

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: How Geoscience Educational Programs to Increase Confidence in the Relationship Between Society and O&G Industry: ACGGP Study Case in Colombia

AUTHORS (FIRST NAME, LAST NAME): Laura Alejandra Becerra Silva¹, Linda Cárdenas Ramírez², Valentina Henríquez Avilez³, Flover Rodríguez Portillo⁴

INSTITUTIONS (ALL):

1. ACGGP
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ABSTRACT BODY:

Abstract Summary: The gap between geological knowledge and Colombian society has negatively impacted the perception of the geologists' work, the development of energy and mining projects, studies of geological threats, and geodiversity in planning and ordering of the territory in Colombia.

The Oil&Gas industry is not left out of this scenario, historically in the municipalities where seismic acquisition and hydrocarbon E&P processes are carried out, scenarios of opposition to the activities by the communities and some governmental and non-governmental entities are assembled. This opposition arises from a constant concern about the effects that these activities can have on resources such as water. But it is asserted by misinformation, lack of knowledge of the geology of its environment, and the activities that are developed for E&P projects.

On this context, the ACGGP created its own Regional Pedagogy Program (PPR) to democratize geological knowledge and contribute to overcome these barriers. Within the framework of the PPR in 2020, and in collaboration with a natural gas exploration and production company, a social perception study was accomplished about the concepts of seismic acquisition and the water cycle in communities of San Benito Abad, Sucre, to quantify the impact that pedagogical methodologies have on communities.

Five communities were selected in the area of direct influence of a gas prospecting project, a two-phase methodology was implemented: (1) Data collection to obtain statistical values of social perception, implementation of regional pedagogy workshops and (2) Statistical data analysis.

Based on the results, it was concluded that the implementation of the Regional Pedagogy workshops supports the understating of the processes and the geological knowledge of their territory with percentages between 88% and 97% of correct answers, which confirms that the methodologies are effective to reduce the lack of geological knowledge among communities.

The PPR that were developed throughout 18 departments of Colombia have fostered communication between companies, institutions and communities, allowing to overcome the gap between governments, science and society, and also serving as a bridge for the conversation and sustainable development of the territories in Colombia, granting the viability of energy and mining projects but specially causing recognition of the geologists' and geophysicists' profession in Colombia.

SESSION TITLE: Theme 6: Subsurface Energy Systems Beyond Traditional O&G: Hydrogen and Geothermal Energy

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Seismic Reservoir Characterization to De-Risk Geothermal Play in Denmark

AUTHORS (FIRST NAME, LAST NAME): Esben Dalgaard², Adriana Gordon¹, Kenneth Bredesen³, Anders Mathiesen⁴, Niels Balling⁵, Raul Cova⁶

INSTITUTIONS (ALL):

1. Qeye
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6. Qeye

ABSTRACT BODY:

Abstract Summary: A 2D seismic AVO inversion and well log analysis was completed in 2019 as part of the multidisciplinary research project GEOTHERM developed by the Geological Survey of Denmark and Greenland (GEUS) with the INNOVATION FUND of Denmark's support. The objective of this case study is to help characterize a geothermal reservoir in northern Zeeland, Denmark. Seismic AVO inversion has been widely applied as an effective procedure for reservoir characterization in the oil and gas industry. Hence, the use of seismic AVO inversion to characterize geothermal reservoirs seems valid as the aim is to identify different lithologies while estimating the porosity at the zone of interest. It is possible to invert for different elastic properties such as acoustic impedance (AI), P-wave and S-wave velocity ratio (V_p/V_s) and density from seismic data. Typically for sedimentary rocks, AI is often correlated to the porosity while both V_p/V_s and AI can act as a good lithology discriminator.

The target of this case study is the Gassum formation dominated by fine to mid grain sandstones that alternate with mudstones at an approximate depth of 2 km below the surface. The Gassum formation has proven excellent reservoir quality at several locations and is also the geothermal reservoir for two other geothermal plants in Denmark. The closest well to the study area was used to establish the link between the subsurface properties and the seismic through a wavelet extraction and a background model. From the seismic inversion results, it was possible to interpret different lithologies and estimate porosities. The results revealed several layers of porous and clean sandstones as potential high-quality reservoirs for geothermal energy development within the Lower Jurassic unit and the Gassum formation. Even though the limited data available for the study caused some challenges, the obtained predictions seem generally reasonable when compared to existing regional well data, seismic interpretations, and geological expectations. Ultimately, this study demonstrates the applicability of quantitative interpretation workflows for reservoir characterization as a tool for de-risking geothermal resources.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

EXTENDED ABSTRACT: Potential for Underground Hydrogen Storage in the Uruguayan Continental Shelf

Bruno Conti¹, Pablo Gristo¹, Juan Tomasini¹, Santiago Ferro¹, Rodrigo Novo¹; 1. E&P, ANCAP, Montevideo, Uruguay

Abstract

In this work, the potential for underground hydrogen storage in porous media, offshore Uruguay, is assessed by identifying play elements and their competence. General conditions for geological storage are similar to those of hydrocarbon accumulations: a stratigraphic, structural or mixed trap, a suitable reservoir and an adequate seal to prevent fluids to escape from the trap. This analysis is restricted to shallow waters of Punta del Este and Pelotas basins, where bottom fixed or floating wind turbines could be placed for renewable energy generation. The main geological storage play identified, consists of Late Cretaceous stratigraphic pinch-out traps of the postrift sequence, composed by shoreline-shelf, estuary or delta sands, sealed by thick marine shales related to a transgressive regional event in the Paleocene. The Late Cretaceous sequence can be observed on seismic to pinch out in a shoreward direction against a basement high (Polonio). In addition, the play shows lateral closure associated with differential compaction of sediments on depocenters, located on both sides of the high, which generates gentle drape structures. Those structures appear all along the shelf, in a NE-SW direction, from 50 up to 200 meters of water depth. In terms of competence, nearby exploratory wells data evidence satisfactory properties for the potential Cretaceous reservoirs with good porosity values. Moreover, the effectiveness of the Paleocene shale seal, a key factor, is evidenced by the abrupt change in the fluid inclusions population detected in the wells, comparing Cretaceous with Cenozoic sequences.

Key words: Hydrogen, Underground Storage, Play, Uruguay, Offshore

Introduction

The offshore of Uruguay is located in the South Atlantic Ocean between 50° 00' and 55°60' west longitude and 33°75' and 37°80' south latitude. Its exclusive economic zone extends up to 200 nautical miles, covering an area of approximately 125,000 km² with bathymetries up to 4000 m. No hydrocarbon discoveries have been made yet, in an underexplored area with only three exploratory wells drilled over 40 years. However, the continental shelf of Uruguay, in the context of the South Atlantic Ocean, shows an interesting potential for the generation of renewable energy, taking into account the high wind speeds and capacity factors (Global Wind Atlas, 2022), currents and solar irradiance. In anticipation of a future global market for hydrogen, Uruguay, through its National Oil Company is planning to tender offshore areas for the production of green hydrogen from offshore renewable sources (Buljan, 2021). Moreover, from the perspective of a global energy transition, it is expected that oil and gas companies take advantage of their offshore skills and gradually incorporate the production of renewable and low carbon energies. On this framework, geological and geophysical data from offshore oil and gas exploration, including 40,000 km of 2D, 43,000 km² of 3D seismic, 130 seabed samples and metocean and environmental data, can be of value to address various challenges, including the long-term storage of hydrogen.

Geological setting

The Uruguayan continental margin comprises three sedimentary basins: Punta del Este Basin to the southwest, Pelotas Basin to the northeast and Oriental del Plata Basin, that develops in deep-waters over oceanic crust. These basins were generated during the process of fragmentation of the Gondwana supercontinent and later opening of the South Atlantic Ocean in the Late Jurassic-Early Cretaceous. Punta del Este Basin has a funnel shape with a NW-SE trend, constituting a failed arm (aulacogen) of the rifting process (Stoakes et al., 1991). The main features of this basin is the development of large half-graben structures that, in some cases, reach thicknesses of more than 4 km. Pelotas Basin extends through offshore Uruguay and southern offshore Brazil with a NE-SW trend, representing the flexural margin of the rifting process that evolved into a passive margin (Conti et al., 2017). It is characterized by thick wedges of seaward dipping reflectors (SDRs) in its central segment. Punta del Este and Pelotas basins developed over continental crust and are separated from each other in shallow waters by a basement high, the so-called Polonio High, which played an important role as sediment source area. In deep and ultra-deep waters these two basins become a unique depositional setting, called Oriental del Plata Basin (Soto et al., 2011), that overlays oceanic crust with a NE-SW orientation.

The evolution of these offshore sedimentary basins can be divided into three main tectonic phases (Soto et al., 2011): a) Prerift phase (Pre-Jurassic deposits), represented by sedimentary and igneous rocks deposited in the area previous to the breakup of Gondwana. This sequence includes Paleozoic continental to marine sediments, as well as Proterozoic and older crystalline basement rocks), b) Synrift phase (Late Jurassic-Early Cretaceous), constituted by volcanic rocks and continental sediments deposited in grabens and half-grabens structures during the Gondwana fragmentation process, and c) Postrift phase (Aptian to Present Day), corresponding to the sedimentation associated with the development of marine conditions and eustatic changes. These three phases are represented in Punta del Este and Pelotas basins while, Oriental del Plata basin infill is constituted only by Cretaceous and Cenozoic postrift marine deposits.

Due to the fact that these are passive margin basins, the sedimentary package has suffered little deformation, with most of the large faults associated to the synrift phase. For this reason, most of the hydrocarbon traps that developed in these basins are of a stratigraphic origin.

Method

General conditions for geological storage are similar to such of hydrocarbon accumulations: a stratigraphic, structural or mixed trap, a suitable reservoir and an adequate seal to prevent fluids to escape from the trap. The seismic data acquired offshore Uruguay in the last 15 years allowed the interpretation in detail of different sequences that compose the sedimentary infill of the basins and also the identification of numerous hydrocarbons plays in the prerift, synrift and postrift sequences, most of them associated with stratigraphic and mixed traps such as turbidites, submarine channels and pinch-outs. More than 40 prospects, with varying size, volume, reservoir properties, overburden, bathymetries and geological risk, have been mapped (Gristo, P. et al, 2021). By seismic-stratigraphic analysis of the 2D and 3D data, and the geological data from wells, ANCAP identified plays with specific characteristics that could potentially be used for geological storage.

The first criteria established to restrict suitable storage plays is related with bathymetry, only selecting plays located in water depths below 200 meters. This analysis is restricted to shallow waters of Punta del Este and Pelotas basins, taking into account the high wind speeds and capacity factors of these regions (Global Wind Atlas, 2022), where bottom fixed or floating wind turbines could be placed for the renewable energy generation, notwithstanding that floating technology

would allow large-scale renewable energy generation in deep water settings, in the near future (DNV-GL, 2019).

The second criteria established is associated to the depth of the reservoir that should be over 1,500 m. According to Hassanpouryouzband et al. (2021), suitable offshore hydrogen storage reservoirs should be at depths over 1500 m to ensure that hydrogen densities of $10 \text{ kg}\cdot\text{m}^{-3}$ are achieved. In addition, the geological target should have good porosity and a high permeability to allow the migration of the injected gas and pressure dissipation (Sainz-García, 2017). For this reason, the storage area should not be located at very high depths that could compromise the reservoir quality. The third criteria is related to the efficiency of the seal and overall effectiveness of the trap. The reservoir must have an impervious overlaying and lateral seal to prevent the upward migration of hydrogen. Finally, the fourth criteria to select a suitable play is related to the volume of the prospect. Accordingly, the reservoir must have a large potential capacity (hundreds of Mm^3) to store the produced hydrogen during seasonal periods. Additional information (e.g., core data) is required for properly addressing some other challenges associated with underground storage of hydrogen such as the interaction between H_2 with minerals and microorganisms of the reservoir and seal (Reitenbach et al., 2015).

Results and discussion

Three different plays for geological storage of hydrogen were identified in shallow waters, associated with the prerift, synrift and postrift sequences (figure 1). The main geological storage play identified that meet the established criteria, consists of Late Cretaceous stratigraphic pinch-out traps of the postrift sequence. This play is distributed over a large area of the continental shelf (figure 1).

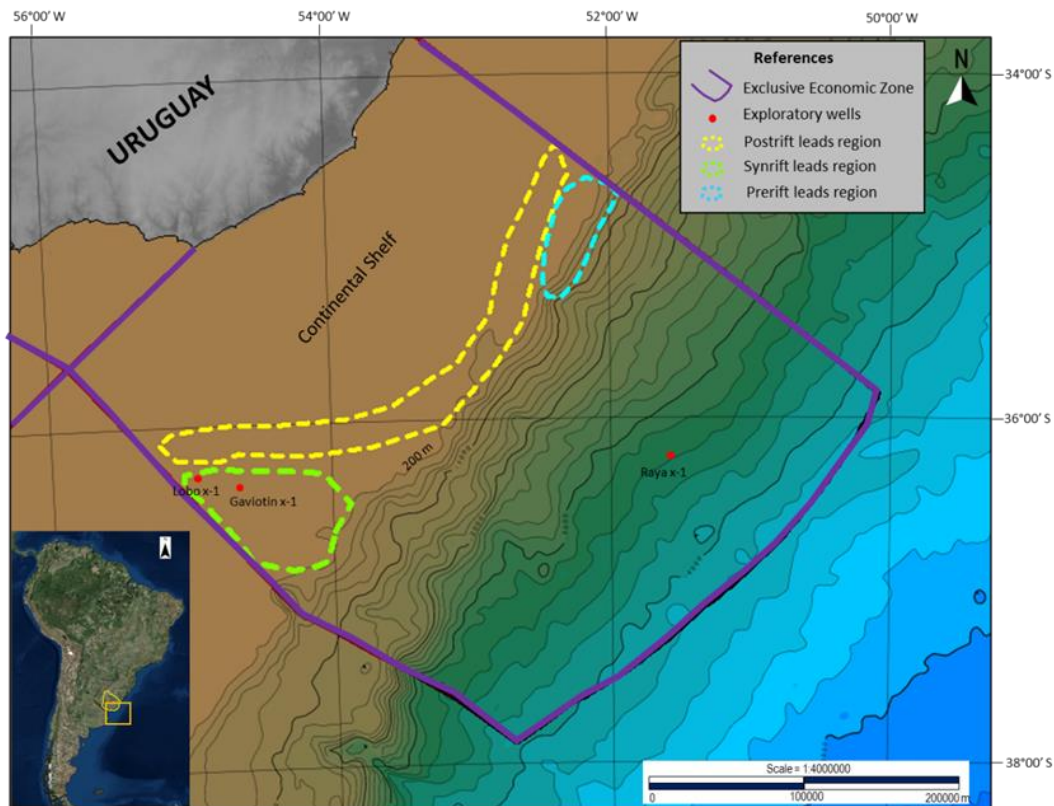


Figure 1- Distribution of potential storage plays in shallow waters, offshore Uruguay.

The reservoir is composed by shoreline-shelf, estuary or delta sands, sealed by thick marine shales related to a transgressive regional event in the Paleocene. The Late Cretaceous sequence can be observed on seismic to pinch out in a shoreward direction (figure 2) against a basement high (Polonio). In addition, the play shows lateral closure associated with differential compaction of sediments over the Punta del Este and Pelotas depocenters, located on both sides of the high, which generates gentle drape structures. This pinch-out play appears all along the shelf, in a NE-SW orientation, in bathymetries ranging from 50 up to 200 meters at sediment depths between 1800 to 2000 meters. In terms of competence, nearby exploratory wells data (Lobo X-1 and Gaviotín X-1 wells) evidence satisfactory properties for the potential Cretaceous reservoirs with good porosity values. Moreover, the effectiveness of the Paleocene shale seal, a key factor, is evidenced by the abrupt change in the fluid inclusions population of oil and gas detected in the wells, comparing Cretaceous with the Cenozoic sequences (Soto et al., 2016). Finally, the capacity of storage for some of the leads associated to this play appear to be very large (thousands of Mm³), taking into consideration the extension and thickness of the reservoir. However, a volume estimation from a selected prospect was not made for this particular study.

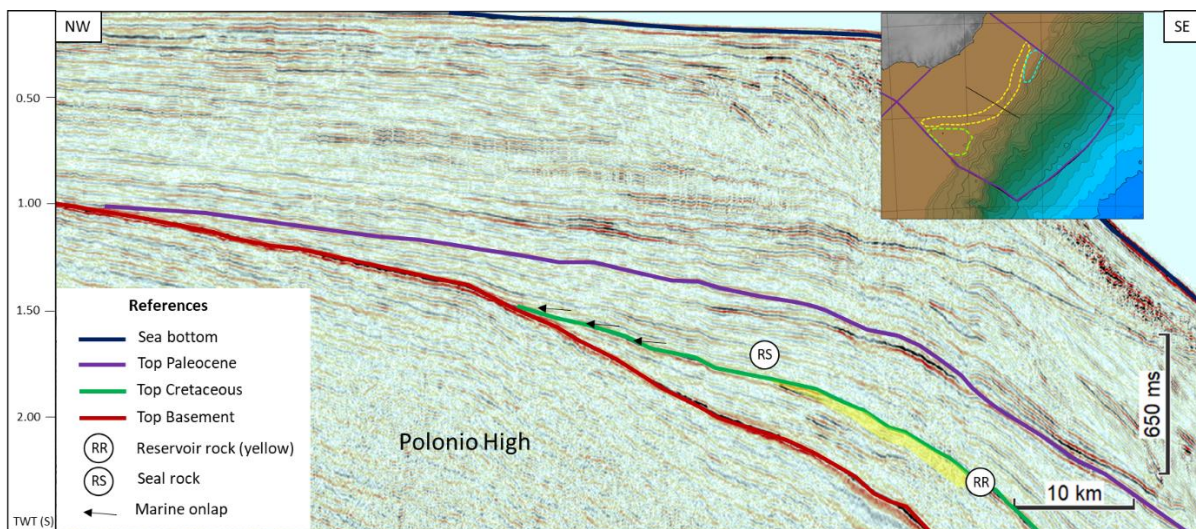


Figure 2- Seismic section showing the Late Cretaceous pinch-out play.

Conclusions

A preliminary evaluation of the potential for geological storage of hydrogen was made in the offshore basins of Uruguay, taking advantage of the knowledge and data, both geophysical and geological, generated in the last 15 years of hydrocarbon exploration.

Based on different criteria including bathymetry, sediment depth, competence and capacity of the reservoir, and trap and seal effectiveness, a candidate play was selected for potential geological storage of hydrogen. This play is represented by a Cretaceous postrift sequence composed by shoreline-shelf, estuary or delta sands located in shallow waters (below 200 m) of the continental margin of Uruguay in a SW-NE direction. The trapping mechanisms consisting of stratigraphic pinch-out sands over a basement high that develop drape structures, sealed by thick marine shales related to a transgressive regional event in the Paleocene. This study is a first approach to the subject of geological storage offshore Uruguay to identify potential play candidates. In a future work specific leads and prospects for this particular play can be characterized in detail and an estimation of storage capacity can be performed.

Acknowledgements

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SESSION TITLE: Theme 3: Offshore Reservoirs: Characterization and Optimization

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Dalmatian North Case History: The Importance of Regional Context in Stratigraphic & Depositional Model Workflows for Deep-Water Reservoir Characterization

AUTHORS (FIRST NAME, LAST NAME): Stan Stanbrook¹, Fadjar Budhijanto², Aleksander Armstrong³, Mike Staines⁷, Shariffah Alawiyah⁴, Brian LeCompte⁵, Gordon Fielder⁶, Bel Sennour⁸, Kelly Haizlip⁹, Douglas Leyden¹⁰

INSTITUTIONS (ALL):

1. Murphy Oil
2. Murphy Oil
3. Murphy Oil
4. Murphy Oil
5. Murphy Oil
6. Murphy Oil
7. Murphy Oil
8. Murphy Oil
9. Ecopetrol-America Inc
10. Ecopetrol-America Inc

ABSTRACT BODY:

Abstract Summary: In this case-study we outline the importance of regional and sub-regional depositional system interpretation in development projects. We detail stratigraphic and sedimentological analysis workflows for deep-water reservoir characterization and how this impacted reservoir performance and aquifer support expectations.

The Dalmatian North Field, operated by Murphy Oil in Block 4, Desoto Canyon, produces oil from two Miocene turbidite 'Big Hum' (BH) sands; A & B (lower & upper respectively) through two producers. DC4-1 is located structurally down-dip and DC4-2 updip. The wells are in pressure communication within each interval as well as between intervals, the latter revealed when DC4-2 found the BH-B as slightly depleted. Dalmatian North lacks aquifer support; therefore, it became important to improve the understanding of reservoir architecture to optimize plans for injector and producer placement.

Careful mapping of top & base BH-A & B and deeper Top Oligocene and salt-structures was undertaken on two different seismic surveys i.e., ION WiBand PSDM (2012) & WesternGeco Broadband NAZ (2015). Multiple amplitude extractions and spectral decomposition maps were generated for each interval as well as isochores between all levels. Each product was interpreted for stratal discontinuities, depositional features, and architectures. The wells were interpreted with petrophysics, image log and biostratigraphy to estimate degree of relative confinement (sensu Stanbrook & Bentley, 2021) and resultant architectures. Derived well architectures utilised the same definitions used in the mapping, allowing direct comparison of these architectural interpretations; these were cross referenced with depositional concepts and analogue databases.

Through understanding the regional context, we establish that depositional fairways, strongly controlled by salt structure, were derived from the NE from the Oligocene through to the Miocene BH level. The rapid deposition of sand immediately down-dip of salt structures improves the probability of stratigraphic continuity making successful placement of additional injectors & producers the BH more likely. Concurrently deep-water systems were derived from the NW and ran along the front of the same salt-structures; these eroded the down-dip extension of NE derived BH sands which explains the lack of aquifer support.

Stanbrook, D., & Bentley, M., 2021. MPG <https://doi.org/10.1016/j.marpetgeo.2021.105372>

SESSION TITLE: Theme 3: Brazil Atlantic Margin E&P

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Libra Beyond the Mero Field: Geologic and Stratigraphic Aspects, Santos Basin – Brazilian Pre-Salt Province

AUTHORS (FIRST NAME, LAST NAME): Mikael Arnemann¹, Eliane Petersohn², Rodrigo Morelato³, Julio Cesar Vital⁴

INSTITUTIONS (ALL):

1. ANP Agência Nacional do Petróleo, Gás Natural e Biocombustíveis
2. ANP Agência Nacional do Petróleo, Gás Natural e Biocombustíveis
3. ANP Agência Nacional do Petróleo, Gás Natural e Biocombustíveis
4. ANP Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

ABSTRACT BODY:

Abstract Summary: Libra is a giant prospect, identified in the Brazilian Pre-salt province. The Libra structure is located in the NE part of the Santos basin, in the Brazilian SE margin. Libra exhibits a huge structural closure > 500 km². The Libra structure is individualized in three different compartments with distinguished characteristics limited by important fault zones: (a) the northwest compartment, which became the Mero field; (b) the central compartment, which is still under evaluation; (c) and the southeast area, which was returned. The main goal of this study is to present a preliminary analysis of the remaining compartment of the Libra block, based on 3D seismic data and publicly available exploration wells. The 2-ANP-2A-RJS well was drilled in 2010 to test the northwest compartment of Libra. This well revealed 327 m of oil column in carbonate reservoirs from K38 to K48 sequences, corresponding to the Itapema and Barra Velha formations (Aptian). The central compartment of Libra was investigated by two exploration wells. The 3-BRSA-1267-RJS well was drilled at the structure apex. This borehole identified the same stratigraphic sequences of Mero, with different reservoir characteristics. The reservoir in the 3-BRSA-1267-RJS well exhibits intense intercalation with igneous rocks. This intercalation is less evident in the wells drilled in the Mero field. Measured pressure gradient data analysis performed in this well revealed gas condensate as the main fluid in the reservoir. There is a lack of fluid contacts in this well due the presence of igneous rocks in the base of the borehole. On the other hand, the 3-BRSA-1310-RJS well was drilled in a saddle between the Mero field and Libra central compartment. This well identified the K44, K46, and K48 stratigraphic sequences, correspondent to the Barra Velha formation. The carbonates are interlayered with igneous rocks, and exhibit intense recrystallization – thermal effect of the adjacent igneous rocks? The analysis of this well dataset reveals absence of interconnectivity between the Mero field and Libra central compartment. The well 4-BRSA-1346-RJS had been drilled on the flank of the south/southeast compartment and it has identified rocks from the same stratigraphic sequences. However, it exhibits a predominance of laminites/mudstones, and there is an absence of hydrocarbons shows. Even though Mero is the main target for exploration & development in the Libra block, other opportunities are certainly worth pursuing.

SESSION TITLE: Theme 3: Brazil Atlantic Margin E&P

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Unravelling the Gigantic Oil Potential of the Brazilian Coast beyond the pre-salt play

AUTHORS (FIRST NAME, LAST NAME): Eliane Petersohn¹

INSTITUTIONS (ALL):

1. ANP Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

ABSTRACT BODY:

Abstract Summary: The discovery of giant and supergiant oil fields in the pre-salt reservoirs has made Brazil one of the most important oil provinces worldwide and it will place it among the top 5 oil producers and suppliers in the world. However, the huge pre-salt discoveries have put a shadow in other promising oil-prone basins, which still are barely explored and can leave a gigantic wealth beneath the subsurface. From the extreme north of Brazil to the extreme south there are 10 thousand km of coastline and 2.5 million km² of sedimentary area distributed through 17 basins. In the north, the Brazilian Equatorial Margin (BEM) has great potential to become a new oil and gas production hub, reinforced by the exploration success in neighboring Suriname and Guyana. In the latter, recoverable oil resources are estimated at more than 10 billion boe. From West to East, the BEM is constituted by Foz do Amazonas, Para-Maranhao, Barreirinhas, Ceara and Potiguar basins. These basins share tectonostratigraphic evolution with the South American coast, suggesting that similar petroleum systems may occur across the Brazilian margin. Studies carried out on the BEM suggest active petroleum systems in deep and ultradeep water with potential for light oil discoveries in the Upper Cretaceous turbidite reservoirs. The Eastern Margin of Brazil (EMB) extends from the Pernambuco-Paraiba Basin in the northeasternmost part of Brazil to the southernmost Pelotas Basin, bordering with Uruguay. From North to South, the EMB is constituted by the Pernambuco-Paraiba, Sergipe-Alagoas, Jacuipe, Camamu-Almada, Jequitinhonha, Cumuruxatiba, Espirito Santo, Campos, Santos and Pelotas Basins. The EMB is highly known to the international petroleum industry due to its prolific pre-salt reservoirs. However, the large petroleum potential of the EMB is not restricted to the pre-salt play. SEAL basin is a new reference in deep and ultra-deepwater oil exploration and will become one of the main offshore natural gas poles in Brazil. The oil and gas play identified in SEAL extends to PEPB and JAC basins. ES basin has potential for sub-salt discoveries associated with allochthonous salts and, in PEL basin has potential for discoveries in stratigraphic plays associated with late cretaceous/paleogene turbidites and cretaceous marine source rocks. Therefore, there is still a huge oil potential to be unlocked on the Brazilian coast and these opportunities will be explored in a case by case scenario throughout this work.

SESSION TITLE: Theme 3: Recent and Potentially Untapped Deep-Water Petroleum Systems

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Untapped Stratigraphic Trap Definition in the Sureste Basin, Offshore Mexico

AUTHORS (FIRST NAME, LAST NAME): Karyna Rodriguez¹, Neil Hodgson²

INSTITUTIONS (ALL):

1. Searcher
2. Searcher

ABSTRACT BODY:

Abstract Summary: The Mexican Gulf of Mexico (GOM) is a proven world class hydrocarbon province. With 56 BBOE cumulative production and proven 1P, 2P and 3P reserves of around 80 BBOE, it is estimated to still hold prospective conventional resources of around 52 BBBOE (www.pemex.com). Despite this significant potential, since 2007, production began to decline from the mature fields and new fields were slow to come on stream.

The 2017 Zama discovery, operated by Talos Energy, is a great example of the importance of utilizing modern, high fidelity seismic processing to realize the potential of the extremely prolific Sureste Salt Basin. Other similar more recent examples from the Sureste Basin, are the Cairn Saasken and Repsol Polok and Chinwol discoveries, where seismic imaging played a key role in revealing the potential associated with these plays.

For this study the objective was to merge and reprocess 3 legacy 3D volumes in order to improve the post salt & subsalt imaging through a comprehensive broadband PSDM workflow, create a contiguous 3D volume via a pre-migration merge and support future salt-related prospectivity evaluations.

Sureste basin depositional geometry has been largely influenced by salt tectonics with reactive, passive and active salt structures all present. In order to identify possible stratigraphic hydrocarbon traps in this type of environment, seismic imaging is a critical element. In 2017 the merging and reprocessing of the 3 legacy Pemex 3D seismic volumes, resulted in enhanced imaging observed in both KPSDM (Kirchoff Pre-stack Depth Migration) and RTM (Reverse Time Migration) volumes.

High confidence in salt body imaging allowed the interpretation of all salt bodies over the 15,000 km² area covered by the merged volume. These were then used to constrain the automatic tracking of over 200 horizons. Attributes extracted over these horizons revealed detailed information on sand deposition at the different stages of salt movement. This in turn led to the identification of significant stratigraphic traps with clear AVA response.

With recent success stories around the globe associated with stratigraphic traps defined with modern seismic data, this area holds huge future potential as it is clearly underexplored in this trap type and it now has the required seismic image to uncover significant accumulations.

SESSION TITLE: Theme 3: Offshore Reservoirs: Characterization and Optimization

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: The search for the remaining resources in offshore oil fields - how redevelopment experience can lead to better decisions in exploration

AUTHORS (FIRST NAME, LAST NAME): Sidnei Rostirolla¹, Vitor Abreu², Andre Picarelli³

INSTITUTIONS (ALL):

1. 3R Petroleum
2. Abreu Consulting and Training ACT-GEO
3. 3R Petroleum

ABSTRACT BODY:

Abstract Summary: The main tasks of a petroleum geologist are to find hydrocarbons at the exploration scale, oil sweet spots during redevelopment of fields, and to define more efficient strategies to revitalize remaining reserves during later stages of the life of a field.

Modern methods in geological/geophysical interpretation and computational data analysis are used to search for hydrocarbons and optimize producing operations during the different stages of a project: (1) pre-drilling exploration, (2) appraisal; (3) development feasibility and (4) front end engineering and design (FEED). This implies that the petroleum geologist not only builds geological models of producing fields, but also needs to find oil sweet spots not yet produced.

Two case studies are presented from a geological/geophysical perspective. The first is a review of the geological characteristics that control heavy oil and water flows in turbiditic, lobe-dominated reservoirs in the Papa-Terra Oil Field. The understanding of sedimentology, reservoir architecture and structural configuration have a strong impact in the modeling on the 3D distribution and leakage pathways, baffles, and barriers. The second case study focus on the understanding of hydrocarbon flow units in channelized, deep-water reservoirs in the Peroa Gas Field, as a good example of how reservoir heterogeneities influence the pressure drawdown and hydrocarbon drainage in the field. In both cases, advanced reservoir architecture and structural analysis of the reservoirs were carried out, resulting in better prediction of remaining resources in the fields.

Lessons learned in both fields exemplify the importance of detailed structural and stratigraphic architectural analyses in defining producing strategies that may have left isolated pressure cells which redevelopment is now being assessed.

On the exploration side, knowledge gained from redevelopment is being applied to near-field exploration, evaluating deeper targets and similar analogue areas, to be added in the current company's exploration portfolio. Accurate calculation of in-place volumes and recovery ranges learned during redevelopment are key guidelines to prioritize exploration opportunities, for more accurate predictions and derisking of new accumulations to be found. This strategy made a strong difference in the discussed cases, which used these guidelines to reduce reservoir uncertainty and optimize static and dynamic factors that allowed better recoverable predictions.

SESSION TITLE: Theme 3: Offshore Reservoirs: Characterization and Optimization

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Suggested methodology for modeling karst zones in carbonate pre-salt fields, Brazil.

AUTHORS (FIRST NAME, LAST NAME): Fernando Coelho¹, Antonio Velasquez², Lizbeth Calizaya³, Ricardo Jahnert⁴, Lara Neves⁵, Marcia Maria Pinheiro da Silva⁶, Wendel Araujo⁷, Alexandra Baez⁸, Helman Duque⁹, Eliseu Kinoshita¹⁰

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol Brasil
3. Ecopetrol Brazil
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8. Ecopetrol
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10. Ecopetrol Brasil

ABSTRACT BODY:

Abstract Summary: The pre-salt reservoirs in Santos Basin (Brazil) are comprised by thick packages of carbonates that were significantly obliterated by diagenetic processes, such as karstification and hydrothermalism. Usually, the karstification processes played an important role by generating secondary porosity (vugs) and permeability that may have significant impact (positive or negative) on the dynamic behavior.

The karsts could influence the development in different ways, from the operational side (well stability, mud loss, risks of kicks and blowouts) to the oil production due to premature production of injected fluids, ultimately affecting economics of the project.

In summary, karsts influence the recovery factor and the profitability of the projects, so it is very important characterize them in order to generate more predictive models.

This work proposes a methodology to identify karstification zones and represent them in the static models by the integration of multiples data such as: well logs (density, Sonic and NMR), sidewall core, thin sections, borehole images, DST well data and seismic data. Karsts systems can be epigenetic or hypogenic. Both systems with dissolution of the rocks formed vugs and caves.

The methodology defines karstified zones based on the distinction of them, characterizing, for instance, the sea base level to obtain a framework to correlate the carbonate intervals under sub-aerial exposure in epigenetic systems.

In addition, the workflow applies a logical decision make process, in order to represents them in a 3D model. Due to the characteristic of each karst systems, epigenetic or hypogenic, the methodology is adapted and calibrated to honor the conceptual models.

Interestingly, modeling karsts systems allowed to obtain more reliable history matching with production (dynamic) data. Therefore, this method, totally repeatable, seems promising to quantify the impact of the karst zones in cumulative oil and water production.

SESSION TITLE: Theme 1: Petroleum Systems II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Peru Unexplored Onshore and Offshore Petroleum Systems

AUTHORS (FIRST NAME, LAST NAME): Neil Hodgson¹, Karyna Rodriguez², Julia Davies³, Lauren Found⁴, Dennys Uyen⁵

INSTITUTIONS (ALL):

1. Searcher
2. Searcher
3. Discover Geoscience
4. Discover Geoscience
5. Searcher

ABSTRACT BODY:

Abstract Summary: Hydrocarbon fields both on and offshore the north coast of Peru, in the Tumbes-Progreso and Talara extensional basins, have accumulated over 1.8 billion barrels of oil production. Peru has a huge variety of basins both onshore and offshore. Onshore, there are fields and wells that have been producing for more than 100 years whilst offshore, to the south, lie 5 additional offshore basins where little to no exploration activity has been undertaken.

Offshore Peru has proven hydrocarbon systems and ample evidence of significant untapped hydrocarbon potential. For example, with only 4 exploration wells, the Trujillo and Salaverry Basins have proven source with significant oil shows encountered during drilling. Also, hydrocarbon samples recovered from natural slicks on the sea surface, indicating an active petroleum system in these basins. Numerous significant undrilled structures in a variety of trap types have been identified on recently rectified legacy seismic data, which provides a consistent regional dataset enabling understanding to unlock this potential.

Onshore Peru, the first oil exploration well East of the Peruvian Andes was spudded 83 years ago, on a large surface anticline near the Pachitea River in the Ucayali Basin. The feature drilled was remarkable for the presence of hot springs and boiling rivers, giving the area, the well, and subsequently the oil field its name: Agua Caliente (Hot Water). Today we have excellent quality seismic data over the Agua Caliente field, where east west lines crossing the dome show not only why the structure is expressed as an anticline at outcrop, but also reveal a deep east verging thrust in front of the Andean ranges. Exciting prospectivity can be found below the thrust that formed the Agua Caliente anticline. The sub-thrust play is a common target in other foreland basin regions along the East Andean margin, often referred to regionally as the play of the “triangle zone”. Located in open acreage next to infrastructure, this sub-thrust play is not tested in the Agua Caliente structure. In a system where source, reservoir and structure lead the way for the oil industry east of the Andes, it is a remarkable opportunity.

Enhanced seismic datasets are providing insights into unexplored onshore and offshore petroleum systems, allowing us to start uncovering the “elephant in the room”.

SESSION TITLE: Theme 3: Brazil Atlantic Margin E&P

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Ultra-Deep Exploration Potential in Sergipe Basin, Brazil

AUTHORS (FIRST NAME, LAST NAME): Yermek Balabekov¹, John Cramer²

INSTITUTIONS (ALL):

1. PGS

2. PGS

ABSTRACT BODY:

Abstract Summary: Abstract

Ultra-deep-water areas of the Sergipe-Alagoas Basin are known for recent light oil, gas and condensate discoveries such as Barra, Farfan, Muriú, Cumbe and Moita Bonita. The exploration success rate for this recent campaign is very high at approximately 80%. This is thanks to the exploration campaign led by Petrobras and its partners since 2010 which applied advanced seismic acquisition and imaging technologies. Outcomes of a recent amplitude versus offset (AVO) analysis of multi-sensor seismic data in the area will be presented in this paper.

Methodology

AVO-based pre-stack seismic inversion was utilized for estimating relative P-impedance (rel. I_p) and the relative ratio between P and S wave velocities (rel. V_p/V_s). Over the past years, this approach has proven to be a quick and reliable way of scanning big areas for potential leads (amplitude anomalies). Given the broadband nature of the current dataset where there are rich recorded low and high frequencies present in the data, the match at the wells is usually good. This gives hope that amplitude response away from the wells can be trusted when looking for new prospects.

The analysis of seismic data helped to highlight well-known discovery intervals at Barra, Farfan, Muriú, Cumbe and Moita Bonita. The dry wells on the other hand did not have good anomalies. Thus the methodology was validated at the known discovery and dry wells. Next, 3D seismic adjacent to the ultra-deep-water sectors (A, B, C and D) indicated extension of the prospective interval towards the sectors as well as presence of AVO anomalies nearby.

Conclusions

A set of arbitrary lines was designed to tie the existing discoveries to most remote parts of the survey such as areas close to the edges of Sectors A, B and D. Further interpretation and analysis of the attributes generated from data, suggests that the Upper Cretaceous turbidite play may extend to the ultra-deep waters of the Sector C as well as to the southwest (Sector A) and northeast (Sectors C and D). Currently, Sector C is covered by the 3D and promising amplitude anomalies have been identified in it. There will be new broadband surveys acquired in zones A and D in 2021-2022. Thus, the Sergipe-Alagoas basin represents important exploration potential in the years to come.

SESSION TITLE: Theme 3: Recent and Potentially Untapped Deep-Water Petroleum Systems

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Evidence for clastic sediment input into Trujillo Basin, key element for de-risking exploration targets

AUTHORS (FIRST NAME, LAST NAME): Karilys Castillo¹, David MacConnell², Amanda Ulincy³, Eduard Maili⁴

INSTITUTIONS (ALL):

1. OXY, Occidental Petroleum
2. OXY
3. OXY
4. OXY

ABSTRACT BODY:

Abstract Summary: The Trujillo Basin, offshore Peru, is a frontier basin that remains unproven despite the hydrocarbon potential observed from piston core, slick data and well shows. To date, five wells have been drilled, mostly in basement highs testing the Cenozoic sequence; however, most of the Mesozoic and older rocks have not been penetrated. The riskiest element, from well results, is reservoir presence and quality. Therefore, finding evidence for reservoir presence and sediment influx into the basin is key for exploration campaigns.

The dataset used in this project consisted of 1600km² of 3D seismic data and more than 3500-km of reprocessed 2D seismic lines. From this interpretation, seismic facies consistent with turbidite deposits were identified with vertical stacking-patterns and lateral migration. This suggests the presence of sediment input into the basin since the Cretaceous. These seismic facies are restricted to basin center locations and flanks, rather than the basement highs targeted by prior exploration wells. Detailed mapping of these depositional elements allows for the identification of sediment fairways, and ultimately sediment entry points into the basin.

Examples from 2D and 3D seismic data will be discussed that expose the occurrence of potential reservoir/seal pairs, that combined with the presence of a working thermogenic petroleum system, exalt the hydrocarbon potential of the area.

SESSION TITLE: Theme 3: Recent and Potentially Untapped Deep-Water Petroleum Systems

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Go Deeper: The Forgotten Southern Santos Basin Post-Salt Oilfields

AUTHORS (FIRST NAME, LAST NAME): Marcio Rocha Mello¹, Michael Moldowan², Jeremy Dahl³, Pedro Parra⁴

INSTITUTIONS (ALL):

1. Brazilpetro studies
2. Biomarker Technologies Inc.
3. Stanford University
4. GEMS

ABSTRACT BODY:

Abstract Summary: For the last 30 years since their discoveries, the Cavalo Marinho, Estrela do Mar, Coral, Caravela and Tubarão gas, condensate and light oil fields in the shallow water of Southern Santos Basin have had their origin attributed to the Albian marine source rock systems of the Guarujá Formation. The origin classification was based on biomarker distributions and source rock richness studies. The oils are pooled in the pos-salt Albian carbonate reservoirs ranging in depth from 4,745m to 5,042m. In this study, we applied diamondoid nanotechnology (QDA and QEDA) in oil samples recovered from Tubarão and Caravelas fields and compare them with pre-salt oils sourced from the Rift, upper Barremian lacustrine saline Itapema Formation system responsible for charging the supergiant Tupi Field located a few kilometers away.

The QDA together with the QEDA data played a critical role in determining pre-salt lacustrine organic facies charging the post-salt marine oil fields, and potentially increase the accuracy and success rate of future oil exploration in deeper pre-salt reservoirs in the area.

SESSION TITLE: Theme 3: Brazil Atlantic Margin E&P

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Roncador Strategic Partnership - Implementing the IOR business model in Brazil

AUTHORS (FIRST NAME, LAST NAME): Henrique Araujo Cotrim¹, Dagrun Kjønsvik²

INSTITUTIONS (ALL):

1. Petrobras - Petroleo Brasileiro S.A.

2. Equinor

ABSTRACT BODY:

Abstract Summary: The Roncador field is a giant deep-water oil field located in the northern Campos basin in Brazil. In 2018, Petrobras and Equinor established a strategic partnership to exchange knowledge on mature petroleum fields, exploration and exploitation, and to further develop the Roncador field. The partnership ambition is to increase the reserves of the Roncador field with 500 to 1000 million boe. To reach this ambition, several partnership projects are established.

The Drainage Strategy (DS) project aims to optimize the drainage of the Roncador sandstone reservoir, providing a subsurface fundament for increased oil recovery (IOR). The project applies work methodology and IOR experience from mature fields at the Norwegian continental shelf, introducing a long-term vision on infill drilling.

The Roncador field had an initial hydrocarbon in-place volume of 10,557 million boe and by the end of 2020 approximately 1,606 million boe are produced. Key factors for increased oil recovery in the Roncador reservoir are successful infill targets based on a long-term drainage strategy, low well costs and adequate subsea and topside facilities.

The starting point for the project was a multi-disciplinary review of available subsurface data to achieve a common understanding of the reservoir recovery status and potential, including the uncertainties and challenges involved. The next step was target identification and simulation studies optimizing the pattern of infill producers and injectors within drainage areas. The infill wells are further evaluated based on geological and geophysical input, defining a priority/risk factor to each target. These tasks are followed by a field level optimization of reserves and field oil production, resulting in a recommended mid-to-long-term drilling schedule. The latter involved iterations with partnership D&W cost reduction and future subsea solutions projects.

Currently there are 54 active producers and 25 active water injectors on the field. A new drilling campaign started in January 2021 with 18 new wells (including replacement wells). The DS project has identified 11 additional infill targets plus 16 immature infill target ideas to feed into a continuous drilling schedule. Considering all new DS infill wells (mature and immature), as well as Lifetime Extension to 2055, shows a potential increase near 500 million boe compared to current reserves. This is the first step towards realizing the Roncador IOR ambition.

SESSION TITLE: Theme 3: Brazil Atlantic Margin E&P

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Exploratory Potential of the Equatorial Brazilian Basins: The Barreirinhas basin case

AUTHORS (FIRST NAME, LAST NAME): Juan Carlos Mondragon Castillo¹, Ivan Rodriguez², Leandro Barros³, German Rondon⁴, Mario Suarez⁵, Martha Serrano⁶

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol Brasil
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The Brazilian Equatorial Margin (BEM) includes the Foz do Amazonas, Pará-Maranhão, Barreirinhas, Ceará and Potiguar basins. It covers an area of approximately 520,000 km², most of which is located offshore. The genesis of these basins is closely related to Pangea break-up which took place during early Cretaceous times.

Brazil is currently one of the top-ten largest oil-producing countries in the world. Exploration and production activities have focused in the pre-salt play in the Santos and Campos basins located in the South Atlantic region, while the Brazilian Equatorial Margin (BEM) remains a frontier area. However, recent regional studies performed in the Brazilian equatorial basins, suggest that large oil/gas accumulations could be present in the deep to ultra-deep waters associated to turbiditic reservoirs.

The geological history of Barreirinhas is highly linked to the Romanche Transform Fault. Two distinctive structural styles have been identified in shallow areas; towards the south, flower structures associated to the Romanche Fault occur, while to the northwest a gravitational fold and thrust belt linked to an extensional-compressional system developed. Only three wells have been drilled in those areas; only one of them tested reservoir facies (Average porosity 14% and gas shows). Beyond this area, an underformed acreage remains truly frontier. The play is represented by Late Cretaceous turbidite reservoirs which could have been charged by the Cenomanian-Turonian source rocks. Because there are no geochemically proven correlations between source rock and fluids in the Barreirinhas basin, this petroleum system remains speculative.

The data set used consists of 16,000 Km of 2D seismic, 17 wells, and satellite-gravity data. A petroleum system model was constructed, and a play-based exploration methodological approach was adopted, taking into account petroleum charge, reservoir and seal elements. Results show that the Cenomanian-Turonian speculative source rocks have reached the gas window. The main risk in the underformed area is hydrocarbon charge due to the long vertical migration required from the deepest Cenomanian-Turonian speculative source rock to the Upper Cretaceous reservoirs. However, fault systems could have acted as migration pathways.

Although there is sparse data to constrain this regional evaluation, our results suggest that there is a promising exploratory potential to be tested in deep waters of the Barreirinhas basin.

SESSION TITLE: Theme 4: Geophysics in Colombian Hydrocarbon Exploration

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Using Seismic Attributes and Wells Data in a 3D Reservoir Characterization of a Mature Heavy Oil Field for Optimal Horizontal Wells Placement; Llanos Basin, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Lino Castillo¹, Angel Dasilva², Bolivar Villacres³, NYLIAN QUINTERO⁴, CESAR MORALES⁵

INSTITUTIONS (ALL):

1. Frontera Energy
2. Frontera Energy
3. Frontera Energy
4. Frontera Energy
5. Frontera Energy

ABSTRACT BODY:

Abstract Summary: Llanos Basin has some of the most important oil fields in Colombia, supporting more than 50% of the oil production in the country. Facies changes, structural framework, and hydrodynamics, are among the high-geological impact elements, and surprises in well-positioning during the execution of the development plans are common even in well-developed areas. Quifa Southwest is a mature Heavy Oil field discovered in 2008 in the Llanos Basin with a current gross oil production of over 25000 bopd between 12°-14° API. Big challenges are faced in terms of facies heterogeneities due to the depositional environment where the target unit was deposited. From 2008 to 2016, about 480 wells were drilled in areas with better net pay thickness, reaching a Recovery Factor close to 12%. During the execution of this first development stage, it was concluded that improvements in the reservoir models would be possible, targeting better wells with operational and cost efficiency improvements. From 2017, a range of classic post-stack seismic attributes such as amplitude, curvature, discontinuity were run in the field to enhance the well-placement. This seismic data was calibrated with well logs and used as an input to generate a geo-cellular model to extrapolate sedimentary facies, rock types, and petrophysical properties, obtaining a 3D reservoir characterization of the area. Additionally, geo-steering tools are being used to achieve good precision and rapid decision-making while drilling lateral sections of horizontal wells. As a result, over 280 horizontal wells have been placed on areas with different levels of heterogeneity, obtaining a positive performance in the horizontal sections, a reduction of sidetrack activities by 50%, and operational costs. Other attributes based on elastic seismic inversion were also used. However, post-stack attributes based on amplitude, frequency, and phase combined with a good well log tie are still helpful for well placement activities during the development of the field targeting a final recovery factor close to 20%.

SESSION TITLE: Theme 4: Seismic Data Acquisition/Processing and QI

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Iteratively Applied CNNs for Fault Tracking

AUTHORS (FIRST NAME, LAST NAME): Jesse Lomask¹, Samuel Chambers²

INSTITUTIONS (ALL):

1. IHS Markit
2. IHS Markit

ABSTRACT BODY:

Abstract Summary: In recent years, 3D Convolutional Neural Networks (CNNs) have been shown to be very effective for seismic fault interpretation. To combat overfitting, these methods often augment field data with synthetically generated datasets to train models. These synthetic datasets attempt to model the enormously wide variety of seismic data resulting from different acquisition and processing parameters, and geological complexity. Despite these measures, 3D CNNs models often still create results that suffer from both false positives and false negatives. We present a novel solution to address these problems by applying multiple CNNs sequentially. In this way, each inference of a CNN is considered a feasible solution that is then tested on the original data to essentially measure a goodness of fit. On the first iteration, we apply a CNN that generates fault locations and orientations from seismic amplitude. In subsequent iterations, the CNNs operates on a seismically derived fault-oriented semblance attribute designed to measure the goodness of fit by calculating semblance along planar elements oriented parallel to the faults of the previous iteration. As we iterate, the sharpness, continuity, and sensitivity of the resulting fault attribute gradually increases while the noise decreases. This method has shown significant improvement on a variety of 3D field datasets, thus increasing the scope of application of 3D CNNs.

SESSION TITLE: Theme 4: Geophysics in Colombian Hydrocarbon Exploration

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Integrating time preserving tomography and geological modelling for accurate updates of velocity model in complex Colombian foothills

AUTHORS (FIRST NAME, LAST NAME): Flor Vivas¹, Sergio Ibanez², Lina Medina³, Elive Menyoli⁴, David Garcia⁵, Erick Estevez⁶, Carlos Becerra⁷

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Emerson Exploration and Production Software
4. Emerson Exploration and Production Software
5. Emerson Exploration and Production Software
6. Halliburton Latinoamérica
7. Halliburton Latinoamérica

ABSTRACT BODY:

Abstract Summary: The geology of the Eastern Foothills of Colombia involves complex interactions of folded imbricate thrust sheets, popup sedimentary mini basins, detachments, sub- and intra thrust folds, eroded rugous topography, and foreland basin.

During exploration and development of a field in such settings, questions arise about the reliability of seismic volumes to accurately predict trap styles with very high dips, fault patterns and geometries, formation thickness, etc. Because of the seismic low signal-noise ratio in the Eastern Colombian Foothills, a data driven approach for velocity model building and updating is not sufficient.

The solution to this type of seismic data and structural challenges must integrate geologic modeling and concepts in the anisotropic velocity model building workflow.

Using a dataset from the Andean Foothills of Colombia, we illustrate the joint use of time preserving model-based tomography to iteratively update velocity models and the corresponding structural geologic models.

We model the perfectly sealed complex 3D multi-z imbricate structures ensuring geological consistency. The result of the entire sequence is improved depth migrated seismic image quality, minimized well marker misties, updated structural model and updated anisotropic parameters.

Because the generated velocity parameter models are kinematically equivalent, they produce flat seismic gathers after prestack depth migration. Therefore, this methodology synchronizes geophysical tomography (anisotropic velocity update) and geomodelling (structural framework) through the project life cycle, thereby guarantying the update of the structural model and generating a geologically plausible velocity model.

SESSION TITLE: Theme 4: Geophysics in Colombian Hydrocarbon Exploration

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: First Airborne Full Tensor Gravity Gradiometry for Hydrocarbon Exploration in the Llanos Foothills, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Leandro Barros², Fabio Santamaria¹, Angi Aparicio³, Eliseo Teson⁴, Mario Patino⁵, John Rico⁶, Sergio Ibanez⁷, Luis Gerardo Figuera⁸

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol Brasil
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol
8. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The Llanos Foothills are a fold and thrust belt of complex, multi-phase structuration and one of the most prolific hydrocarbon provinces in Colombia. Duplex zones result in multiple trapping configurations where it is often difficult to obtain a good seismic image due to structural complexities such as steep bedding and high angle faults, and exploration in these areas has relied heavily on structural models which are built integrating additional information. Therefore, it is important to apply geophysical methods that provide new information to improve the interpretation of subsurface structures.

Potential fields methods have recently gained importance within the exploration process, especially airborne full tensor gravity gradiometry methods, such as iFTG "Integrated Full Tensor Gravity", which is an innovative technology that measures both the vertical component of the gravitational field and the rate of change of gravity in all spatial directions, thereby detecting variations caused by density contrasts associated to stratigraphic and structural changes in the subsurface.

We share results of the first iFTG and magnetic survey carried out in the Llanos Foothills in an area of more than 6000 km² where seismic acquisition has not been possible in recent years due to social and environmental restrictions. Direct and inverse modelling was performed for the analysis of proposed geological models, in addition to combining the different gravity tensor components acquired in this campaign (T_{zz} , T_{xy} , T_{yy} , T_{xx} , T_{xz} , T_{yz}). Particularly, curvature analysis allowed us to find a good correlation between the structural geology and the gravity and magnetic anomalies. This results in improvements to the geological interpretation in areas without seismic information.

Application of potential field methods does not mean to replace conventional seismic data; on the contrary, the integration of different geophysical measurements provides more robust data sets for better interpretation and to reduce uncertainty in identifying prospects in frontier areas. Airborne full tensor gravity gradiometry enables rapid data acquisition, covers large areas at low cost and provides better resolution than conventional gravimetry. It has been shown that this method can significantly improve hydrocarbon exploration results. Therefore, we recommend its application as a complement to other techniques in the exploration of different areas of interest.

SESSION TITLE: Theme 4: Geophysics in Colombian Hydrocarbon Exploration

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Quantitative Interpretation: Applications for Hydrocarbon Exploration in Deepwater Offshore Colombia

AUTHORS (FIRST NAME, LAST NAME): Eduard Maili¹

INSTITUTIONS (ALL):

1. OXY

ABSTRACT BODY:

Abstract Summary: This paper discusses the application of QI and rock physics to hydrocarbon exploration in offshore Colombia, one of the last unexplored deep-water basins of the world. Within blocks COL-1, COL-2, COL-6 and COL-7 of the Colombia Basin, a substantial dataset, containing 29,360 KM² of 3D seismic data, 5,319 KM of 2D seismic data, 25,000 KM² of high-resolution bathymetry data, 250 piston cores and 27 heat-flow measurements, has been assembled. Detailed interpretation of these data reveals the presence of four prospective hydrocarbon play types: 1. the “wrinkle” play, comprising low-relief four-way structural closures, 2. the channel-complex play, 3. the sub bottom-simulating reflector (BSR) play, and 4. the thrust-belt play.

Seismic data were processed through PSDM and are of excellent quality. Direct hydrocarbon indicators (DHIs), including bright-spots and flat-spots, occur on well-defined four-way closures. As there are no wells inside the survey, (the nearest well in the basin is about 350 km away), uncalibrated AVO and other attributes were used initially to characterize the potential hydrocarbon-charged reservoirs, possible source rocks (class IV AVO), oil and gas migration pathways and top seal. To further improve the predictions, and assess uncertainties in reservoir characterization, a new method that considers depth trends from wells outside of the survey, combined with joint impedances and facies inversion, was applied. The results of this method, including most likely facies and hydrocarbon probabilities, are discussed. Reverse rock physics modeling was used to predict reservoir properties from elastic properties derived from inversion. Finally, inverted velocity and density data, were used for pore pressure prediction.

The advantage of this new method is that it can be used in other exploration areas where there are no wells within the seismic survey area or where wells are limited in number, or in cases where the available wells do not have the necessary measured logs for seismic reservoir characterization.

SESSION TITLE: Theme 4: Geophysics in Colombian Hydrocarbon Exploration

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Enhanced Reservoir Quality Prediction Based on Seismic Inversion and Rock Physics Analysis in a Deep Llanos Field - Colombia

AUTHORS (FIRST NAME, LAST NAME): Bolivar Villacres¹, Angel Dasilva², Mario Di Luca³, Lino Castillo⁴

INSTITUTIONS (ALL):

1. Frontera Energy
2. Frontera Energy
3. Frontera Energy
4. Frontera Energy

ABSTRACT BODY:

Abstract Summary: The Llanos basin in Colombia is a prolific oil basin, with several target levels and different types of trapping mechanisms. Facies changes involved in the depositional environment where stratigraphic sequences were deposited are a key problem for some of the accumulations. Predictability of these facies is crucial to improve field development plans and proper estimation of hydrocarbon volumes. This is the case for one field, located in the foredeep of the Llanos foreland basin. This field has two reservoir targeted levels with facies associated with a fluvial estuarine environment in a complex interrelation of distributary and tidal channels, delta plains, and tidal flats (mud and sand-rich). The morphological complexity of these types of environments accentuates the importance of lithology 3D estimation. Spatial information obtained from wells and seismic should be used to create models that help with lithology estimation. Limitation in seismic resolution caused by the depth of the reservoirs is a big challenge in facies prediction in this field. For this reason, a workflow based on rock physics properties and elastic seismic inversion volumes was applied to improve predictability. In terms of wells logs, there is a good response with density and V_p/V_s which allows discrimination. Good rock quality shows low density and V_p/V_s , decreasing in quality when increasing the density and V_p/V_s , the fluid effect is negligible due to fluid characteristics. A 3D pre-stack seismic inversion was carried out and several elastic properties were obtained. Based on rock physics properties, elastic volumes derived from seismic inversion, and detailed well calibration focus inside the reservoir, a new methodology using cross plot Density vs V_p/V_s was applied to get a new quantitative indicator of rock quality and petrophysical properties. The indicator can be also used as a probability cube to populate a 3D geo-cellular model. The last well drilled in the area showed excellent results in terms of facies prediction using this methodology, finding good quality rocks. Even though the predictability of this attribute is high, it will be fine-tuned by a detailed sedimentological model including information from cores and well logs. It also will reduce uncertainty for future wells proposed in the field development plan.

SESSION TITLE: Theme 4: Seismic Data Acquisition/Processing and QI

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Correcting for Near-Surface Velocity Variation in Seismic Depth Imaging Using Model Moveout (MMO)

AUTHORS (FIRST NAME, LAST NAME): Tim MacArthur¹, Rob Vestrum², Greg Cameron³

INSTITUTIONS (ALL):

1. Thrust Belt Imaging
2. Thrust Belt Imaging
3. Thrust Belt Imaging

ABSTRACT BODY:

Abstract Summary: In complex-structure environments like the Andes mountains and foothills, outcropping rocks generate a significant velocity variation in the near surface. In time processing, we intend to correct for these near-surface fluctuations with weathering statics corrections, however, this solution assumes vertical raypaths through the weathering layer, and this assumption is violated when we have high-velocity rocks outcropping at the surface. With depth imaging, we have an opportunity to include the weathering velocities in the PSDM velocity model and raytrace through the weathering layers to get a more accurate correction for near-surface velocity variation.

But then, what do we do with the weathering correction we calculated in the time processing? The weathering velocities from the refraction tomography are now in the PSDM velocity model, but the reflection statics calculated in the time processing are coupled to the refraction statics and time-processing velocities. These statics are therefore decoupled from the PSDM velocity model. Calculating new reflection statics using the PSDM velocity model resolves this issue. We propose a method where we discard all weathering statics from the time processing and perform all near-surface velocity corrections in the depth domain—including reflection statics.

We applied this workflow to a seismic dataset from the foothills of the Colombian Andes, which shows significant imaging improvements below the mountainous areas of the seismic survey.

SESSION TITLE: Theme 4: Seismic Data Acquisition/Processing and QI

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: FWI and RTM to Improve Seismic Imaging in Colombias Sinu San Jacinto Basin

AUTHORS (FIRST NAME, LAST NAME): Thomas Fieseler¹, Eliakim Schuenemann², Sandra Arevalo³, Horacio Acevedo⁴, Pablo Heredia⁵

INSTITUTIONS (ALL):

1. TEECsolutions GmbH
2. TEECware GmbH
3. TEECsolutions LLC
4. Exploration, Hocol S.A., Bogotá, Bogota, Colombia.
5. Hocol S.A.

ABSTRACT BODY:

Abstract Summary: Seismic exploration in Colombias Sinu San Jacinto basin is a difficult task due to its complex subsurface geology and often fast or highly variable near-surface velocity. Often times the surface conditions do not allow for a seismic acquisition design that fits the needs of the imaging challenges arising from these complexities. Consequently, seismic processing strategies that provide good results in simpler settings fail in the Sinu San Jacinto basin: many datasets were reprocessed several times without much improvement. However, assuming that there is no more information in the acquired data is often not true. In this work we present a processing strategy that aims to overcome the described challenges.

Seismic data from the Sinu San Jacinto basin usually has a low signal-to-noise (S/N) ratio. The Common Reflection Surface (CRS) processing technology offers a successful way of improving the S/N ratio. This method analyses for dip, depth and curvature of subsurface reflection elements. It collects energy from within the Fresnel zone and forms CRS traces that contain more reflection content and less noise. The CRS traces can be used for subsequent velocity analysis and pre-stack migration.

Key to successful depth imaging of land data is the near -surface velocity model. The Sinu San Jacinto basin is characterized by laterally highly variable velocities due to outcropping or eroded layers. To deal with these near-surface complexities we combine First Break Tomography (FBT) with Full Waveform Inversion (FWI) and Reverse Time Migration (RTM) imaging.

FBT uses travel time information from the first break picks to derive a near-surface velocity model which is usually employed for statics calculation. However, this tomographic model is also well suited for depth migration from topography.

FWI is an iterative approach to find the best sub-surface model to simulate seismic data that matches the observed waveform, i.e. amplitude and phase in a dedicated frequency band. FWI is used to update the FBT near-surface model.

It is well known that ray based depth migration techniques such as Kirchhoff are unable to correctly solve the travel times associated with complex velocity models. To overcome this drawback we use Reverse Time Migration (RTM) for imaging. Furthermore, RTM surface-offset gathers are used to update the deeper velocity model.

SESSION TITLE: Theme 4: Seismic Data Acquisition/Processing and QI

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Does seismic source size matter? A seismic source analysis case study from the Magdalena Valley, Colombia and Alberta, Canada

AUTHORS (FIRST NAME, LAST NAME): Andrea Crook¹, Shane Bossaer², Mostafa Naghizadeh³, Stephanie Ross⁴, Cameron Crook⁵

INSTITUTIONS (ALL):

1. OptiSeis Solutions Ltd.
2. OptiSeis
3. OptiSeis
4. OptiSeis
5. OptiSeis

ABSTRACT BODY:

Abstract Summary: For optimal, cost-effective imaging, a seismic acquisition design should be an integrated solution that in addition to geometry parameters, also considers the seismic energy source and its role in spatial sampling. In the past, seismic surveys for deeper targets (>2 km depth) used large explosive seismic sources (2-4 kg of explosives) deployed in deep shot holes (12-18m) with sparse spatial sampling. In areas where drilling deep shot holes was difficult, multiple shallower shot holes with smaller charges were used to generate the equivalent energy of a single large, deep source, but these were still deployed at the same spatial sampling interval as the larger charges. What if better seismic data could be acquired via better spatial sampling, without sacrificing deep imaging? This has been a successful approach with Vibroseis sources where surveys are now acquired with a single Vibroseis and single sweep at a much smaller spatial sampling interval than was used when multiple Vibroseis and multiple sweeps were used at each shot location. This case study examines methodologies for implementing this technique for explosive surveys.

While often explosive source performance is analyzed on shot records, a more statistically relevant analysis can be done by comparing fully processed seismic lines, as used by interpreters. However, a challenge in comparing different sources this way is that not only are the source parameters different, but often the acquisition parameters (source interval, receiver interval, recording channels) and the processing flow are different. This can complicate comparisons of source charge size and depth analyses as differences in these other parameters will affect results. In order to accurately compare just the changes in sources, seismic lines can be decimated to matching acquisition parameters and reprocessed. This is the approach taken in this case study, where four 2D seismic lines from the Magdalena Valley, Colombia with various source parameters were decimated to the same acquisition geometry, and then reprocessed to accurately compare and identify the best cost/benefit source options.

Furthermore, new developments in miniaturizing seismic sources are enabling smaller spatial sampling on surveys with explosive sources without negatively affecting costs. In Canada, several field trials have been conducted utilizing new miniaturized sources that can be deployed as shallow as 1m and still provide good energy at depth (Crook et. al., 2021, Brost, 2021). By reducing cost per source, more source points per km² can be recorded, resulting in a smaller station interval and better subsurface sampling. We will show a comparison of miniaturized sources vs. conventional sources in Canada to illustrate how improved subsurface imaging can be achieved with miniaturized seismic sources.

Acknowledgements

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References:

Brost, D. 2021, Tactics for Explosive Deployment Deep Basin Seismic Exploration: GeoConvention, Technical Program Abstracts.
Crook, A. et. al., Case Study: The use of miniaturized seismic sources for reduced environmental impact 2021, 82nd EAGE Annual Conference & Exhibition, Expanded Abstracts.

SESSION TITLE: Theme 4: Seismic Data Acquisition/Processing and QI

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Application of the in-house PSDM + VMB Methodology at the Colombian Eastern Foothills: case study and lessons learned based on recent well drilling results

AUTHORS (FIRST NAME, LAST NAME): Sergio Ibanez¹, Flor Vivas², Paola Castano Giraldo³, Erick Estevez⁴, Carlos Becerra⁵

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Halliburton Latinoamérica
5. Halliburton Latinoamérica

ABSTRACT BODY:

Abstract Summary: The Eastern Colombian foothills continue to be a relevant onshore play with great potential in exploratory projects., besides the gigantic fields already discovered. The area is characterized by a complex structural style related to folds and thrust belts, varying from single frontal structures to imbricates of several stacked thrust sheets in triangular zones.

Despite the importance of the area, it's very challenging to obtain an adequate seismic image of the main fields, and exploration prospects. Poor seismic acquisition parameters, combined with low signal-to-noise ratio coming from complex geology, weathering layer with extreme lateral velocity variations and highly irregular topography, are the main aspects that need to be tackled to decrease the uncertainty in the zones of interest.

A PSDM (PreStack Deep Migration) + VMB (Velocity Model Building) in-house methodology was implemented with the purpose of improving the seismic image on several prospects in the Colombian foothills. This methodology uses a general initial "Data Driven" velocity model, followed by tomographic updates based on attributes of dip, azimuth, continuity of velocities or seismic. Best evaluated PSDM Data Driven result (fairly good seismic image) is interpreted and used to build the initial "Model driven" velocity. Such a model driven solution is updated based on PSDM interpretations after isotropic well tie, and final anisotropic iterations.

In this work we present the application of the Methodology in a 3D seismic area covering one of the most prospective structural trends in the foothills (previously undrilled), and with successful results in the first exploratory well. PSDM quality controls are required to validate the reliability of the Model Driven velocity field, and include: seismic image enhancement showing the structural model confirmed with the well, decrease in well marker misties with each iteration, main velocity inversions represented in the model; and good match with checkshot velocities and VSP image.

Updates and sensibility analysis in the velocity model and PSDM results, during and immediately after finishing the well ; allowed us to decide the most likely structural model in the new discovered trend, had a significant impact in updated estimation of discovered resources, location of appraisal wells, and better prospect definition in the vicinity of the discovery.

SESSION TITLE: Theme 4: Seismic Data Acquisition/Processing and QI

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Seismic In Over Thrust Environment; Bolivia Example

AUTHORS (FIRST NAME, LAST NAME): Jose Olaya¹, Olivier De Mena², Amr Elsabaa³

INSTITUTIONS (ALL):

1. Former REPSOL - Now TBI COLOMBIA SAS
2. Repsol
3. Schlumberger

ABSTRACT BODY:

Abstract Summary: Advances in Seismic acquisition, processing and imaging have been associated with the need to develop new oil reserves in the Andes, where the exploration journey started in the 80's with 2D and low fold 3D seismic surveys, later on higher fold sparse 3D provided improved signal to noise but at the expense of poor near offset coverage, which needed for reliable model building and imaging. Denser single sensor acquisitions aimed at improving the near offset distribution required more integration between acquisition and processing to address the well sampled noise prior to group forming in the processing shop. Variations in seismic data quality sometimes associated with the two different acquisition within the same survey could hinder the interpretation and reservoir characterization efforts by introducing non-geological discontinuities and variations in amplitudes. In addition to the dependency on the acquisition parameters, seismic surveys are rarely acquired as planned due to rough topography, constructions or other environmental causes.

We present a holistic seismic imaging approach used in Bolivian foothills to overcome the adverse effects associated with merging multiple acquisitions in the presence of acquisition holes and irregularities. We describe the challenge and show a solution developed to merge data from irregular sparse 3D with data from 3D High Density acquisition seamlessly using 5D data reconstruction. The obtained uniform and denser coverage enabled an accurate earth model building. Because of the improved model accuracy and the high complexity of the foothills reverse time migration played an instrumental role in obtaining accurate structural maps and assisted in reservoir delineation.

SESSION TITLE: Theme 1: Stratigraphy I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Process Stratigraphy: Key to Unlocking the Depositional Architecture of the Guyana-Suriname Basin

AUTHORS (FIRST NAME, LAST NAME): Casey Meirovitz¹, M. Shane Long²

INSTITUTIONS (ALL):

1. ExxonMobil
2. ExxonMobil

ABSTRACT BODY:

Abstract Summary: Since hydrocarbons were first discovered at Liza-1 in 2015, the Guyana-Suriname Basin has challenged explorers globally to revisit long-held assumptions relating to the distribution and risk profile of stratigraphic traps. One key to the unusually high success rate observed in the Stabroek Block has been the ability to understand and predict the processes which result in successful stratigraphic architectures within this play type. Further, post-discovery development planning and execution requires detailed reservoir characterization, largely based on the marriage of limited data and conceptual geologic models. The stratigraphic architecture of deep-water sediments in the Guyana-Suriname Basin are closely tied to the style and evolution of feeder systems delivering sediment across the shelf and into the basin. Though a multitude of sediment entry points exist along the shelf edge, the architecture and evolution of the basin is dominated by the long-lived (Late Cretaceous) Berbice shelf-incised valley and, to a lesser extent, Essequibo sourced entrenched valleys. Existing depositional models, based on global subsurface and outcrop analogues, largely focus on endmember styles (confined channel levee vs distributive fan) and assume a singular, relatively narrow, fixed sediment entry point. In contrast, the deep-water Guyana-Suriname Basin is characterized by a wide, and tangled array of depositional styles, bedforms, and building blocks, directly related to the character and evolution of the Berbice incised valley and overlapping simultaneous deposition from multiple sediment entry points. By viewing the basin through the lens of process stratigraphy, relying on the integration of physics, hydraulics, and sedimentology, we are better able to prognose outcomes, evaluate the applicability of legacy concepts, and guide the creation of new geologic models. Here we present the Guyana-Suriname Basin as a case example for utilizing process stratigraphy to build upon existing depositional models and successfully explore the spectrum of depositional styles and architectures which exist in the space between currently explored endmember conditions.

SESSION TITLE: Theme 3: Recent and Potentially Untapped Deep-Water Petroleum Systems

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: ExxonMobil and the Guyana/Suriname Basin: Prospecting and Exploration in a Prolific Play

AUTHORS (FIRST NAME, LAST NAME): Mark Widmer¹, Luke Wilson²

INSTITUTIONS (ALL):

1. ExxonMobil
2. ExxonMobil

ABSTRACT BODY:

Abstract Summary: A highly successful exploration campaign was kicked off with the discovery of the Liza field offshore Guyana in 2015. The discovery challenged paradigms and helped to unlock new opportunities in what has become the most prolific resource discovery in the last decade with approximately 10 billion recoverable oil-equivalent barrels discovered.

Key calibration from by-the-bit exploration was critical in a play where traditional Direct Hydrocarbon Indicator (DHI) attributes are difficult to measure due to low dip, as well as ambiguous sealing mechanisms and locations. Skipjack, drilled after Liza, looked similar in geophysical signature and trap geometry to the Liza field. The Skipjack-1 well, in failure, provided important geophysical calibration of the 'wet trend'. This data was instrumental as exploration shifted further to the SE where seismic facies indicated a higher seal risk.

Seal risk and seismic geometries were further calibrated by additional exploration in the SE portion of the block. The initial seal risk predicted by the seismic facies was proven to be pessimistic by subsequent well results. Data from key wells provided additional key hydrocarbon calibration and tuned reservoir limits/parameters in different Environments of Deposition (EOD) leading to a string of successes in SE Stabroek.

Courage of conviction by team members and management enabled the exploration group to push past the perception of high risk. This has now proven to be instrumental to the shared success of the exploration team. The insights and data gained with this exploration strategy are continually being expanded by drilling results as we step out from the current discovery trend.

SESSION TITLE: Theme 1: New and Emerging Plays III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Paraguay Carandayty Sub-Basin Regional Geology and its Hydrocarbon Potential

AUTHORS (FIRST NAME, LAST NAME): Javier Angulo¹, Raul Gonzalez², Diego Timoteo³, Ignacio De Barros⁴, Giuliano Franco⁵

INSTITUTIONS (ALL):

1. Zeus Energy
2. Zeus Energy
3. Zeus Energy
4. Zeus Energy
5. Zeus Energy

ABSTRACT BODY:

Abstract Summary:

The Exploration for Oil and Gas in Paraguay began in 1949 with the drilling of the Santa Rosa 1 well in the Paraguayan Chaco region, almost 20 years after the first exploratory wells in the Chaco region (Argentina-Bolivia-Paraguay). The development of the Chaco Basin in the nearby countries of the region increased the access to goods and services for the oil and gas industry. Nevertheless, in the Paraguayan Chaco, most of the services and workforce had to be imported. Consequently, exploration activity has been intermittent by periods with exploratory campaigns with multiple drilled wells and others with no activity at all.

At this date, Paraguay has fifty-eight (48) exploratory wells in the Paraguayan Chaco, where thirty-One (31) are in the Carandayty sub-basin (a continuation of the Bolivian Tarija basin). Most of the producing units from Bolivian fields also presented gas and oil shows in the Carandayty sub-basin. In addition, one well has produced natural gas with positive well tests from Carboniferous and Devonian sands.

The Paraguayan sub-basins are still under-explored due to the low exploration activity. Still, new information obtained in the latest exploration campaigns in the Carandayty sub-basin confirms the existence and quality of the main elements of the petroleum system. The latest exploratory data and information obtained for regional correlation has been through the investment of Zeus Energy in new 2D Seismic surveys, historic regional seismic acquisition, correlation of all the historical data in the region and the drilling of 2 exploratory wells.

The results from the regional analysis confirmed the presence of the same regional source rocks found in Bolivia and northern Argentina. The source rocks of the Los Monos and Icla formations have similar TOC ranges and generation potential, and are present at shallower depths in Paraguay. A third deeper source rock, the Kirusillas formation, which is less known in the region, was drilled through and analyzed, with excellent organic-rich TOC values and thermal maturity within the dry gas generation window. Source rock properties of the Kirusillas formation make it also a candidate for an unconventional shale gas play. The findings point to most petroleum system elements, with a higher uncertainty regarding the subtle structural traps due to a lower degree of deformation in the sub-basin and insufficient seismic information coverage.

SESSION TITLE: Theme 3: Offshore Reservoirs: Characterization and Optimization

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Provenance and diagenesis of the sandstones of the Lower Eocene Play Fm. Wilcox, Perdido area **AUTHORS (FIRST NAME, LAST NAME):** Ma. de los Angeles Rodriguez¹, Karla Castillo¹, Olga Hernandez¹, Luis Rosas¹

INSTITUTIONS (ALL):

1. Petroleos Mexicanos (PEMEX)

ABSTRACT BODY:

Abstract Summary: The study area comprises the eastern part of the Subsaline Belt and the southern portion of the Perdido Folded Belt, where hydrocarbons associated with oil and gas-condensate have been discovered in sandstone sequences from the lower Eocene Play Wilcox main play established in the Perdido area.

The analysis focused on integrating the geological information that supports the origin of the sandstones and the main diagenetic events that impact porosity. By means of the analysis of sequence stratigraphy, the Lower Eocene Play Wilcox has been subdivided into 5 sequences of the Ypresian: 51.05, 52.18, 53.15, 54.60 and 54.80 Ma; the main reservoir rocks are found in facies of channel fillers (amalgamated, semi-amalgamated, and non-amalgamated), proximal overflows, lobes, and stacks of sand sheets with petrophysical properties of good to moderate.

The origin of the sediments for the sandstones in the northern portion has affinity with the paleodeltas of Rio Grande and Houston, and are classified as litarenites and feldspathic litarenites, towards the southern area there is a possible origin from the Burgos Basin, making a difference in composition, with higher lithic content. Diagenesis is one of the main factors that altered both the porosity and permeability of the reservoir rock.

The main diagenetic processes that altered the petrophysical properties of the storage rock are compaction, alteration of feldspars, different episodes of cementation (carbonate and silica), as well as different types of autigenic clays. The quality of the reservoir rock was improved by dissolution processes generating secondary porosity that was preserved at the time of the hydrocarbon placement, a characteristic feature in the production sequences of this play. The best quality of rock is found in the sequences 51.05 and 52.18 Ma, which is lost in the oldest sequences due to the deepening of these.

The seal rocks correspond to shales and bentonites from the Lower Eocene and allochthonous Jurassic salt, which have good thicknesses and cover the lower Eocene Wilcox play regionally. During geopressure analysis, pressure variations were detected at sequence levels, indicating different intraformational seals and compartmentalization in the sequences.

Keywords: Provenance, Diagenesis

SESSION TITLE: Theme 3: Offshore Reservoirs: Characterization and Optimization

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Understanding the lower Pliocene shallow marine evolution of the Southern Gulf of Mexico under an integrated methodology

AUTHORS (FIRST NAME, LAST NAME): Humberto Torres-Sastre¹, Javier Cortazar-Velazquez¹, Simeon Oseguera-Hernandez¹, Filiberto Alejandro-Torres¹, Alejandro Ortega-Nieto¹, Francisco Javier Martinez-Torres¹, Rolando Heberto Peterson¹, Ulises de Jesus Rodriguez¹

INSTITUTIONS (ALL):

1. Petroleos Mexicanos (PEMEX)

ABSTRACT BODY:

Abstract Summary: There are several producer oil and gas fields in the Mesozoic and Neogene sequences of the Salina del Istmo Basin in the Southern Gulf of Mexico. Light oil is the main type of hydrocarbons found in this sector of the basin. Recent exploration activities for new reservoirs are increasing understanding of the Neogene sequences of the salt tectonics basin. Using an integrated approach for biostratigraphic analyses in the study of old and new exploration wells, it is possible to interpret and correlate in salt-dominated province and reconstruct a depositional and structural evolution of hydrocarbon plays.

As a result of these analyses, it is presented an updated chronostratigraphic framework using different biostratigraphic markers for well-to-well seismic correlation. Determination of microfossil extinctions, seismic interpretation of candidates to sequence boundaries, construction of stratigraphic sections and sedimentary models were prepared to characterize features and distribution of reservoir sandstones.

Rock type and sediment provenance were used to know the features and distributions of the different sandstones identified. In addition, thin sections were available to understand distribution, quality and risk assessment associated to different depositional systems of reservoir rocks.

According to the chronostratigraphic chart of Hardenbol et al. (1998) top of the lower Pliocene is related to the extinction of *G. margaritae* at the age of 3.58 Ma. Key wells used to determine this peak are the B-1 well in the western and the A-1 well in the central part of the area, where top of the lower Pliocene was correlated to wells in the eastern portion. Both wells have been related to the shallower horizon with the extinction event of this organism. Considering that area between the C-1 and D-1 wells shows the development of a large thickness of sandstones in paleobathymetries of middle-internal Neritic associated to the progradation of the edge of the shelf can be difficult preservation of index organisms. Therefore, dating the top of lower Pliocene in the area, it would have to correlate from A-1 and B-1 wells, contributing to the understanding of depositional systems in the area.

SESSION TITLE: Theme 1: Petroleum Systems III

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Structure Thrust Tectonics and Hydrocarbon Evaluation of The Sierra Madre Oriental Fold-Belt in Southern Mexico

AUTHORS (FIRST NAME, LAST NAME): Irasema Olvera-Barroso¹, Luis Enrique Salomon¹, Rolando Heberto Peterson¹, Mario Aranda-García², Verónica I. Ramírez-Soria¹

INSTITUTIONS (ALL):

1. Pemex
2. Independent Consultant

ABSTRACT BODY:

Abstract Summary: This study aims to update the structure of autochthonous and allochthonous models and the understanding of stratigraphic and structural evolution through seismic interpretation and 2D sequential restoration of the buried tectonic front of the Sierra Madre Oriental, to identify areas of opportunity with hydrocarbons potential in the stratigraphic column composed of Upper Jurassic basin rocks, Cretaceous platform rocks and Tertiary turbidites.

PEMEX has discovered oil, gas and condensate plays in Upper and Lower Cretaceous rocks in allochthonous blocks; as well as an oil play in Eocene conglomerates at the foreland Tertiary frontal basin; and numerous gas bearing plays in Neogene turbidites. In the autochthonous of the thrust structure, condensate and gas Plays were recently found in Lower Cretaceous platform carbonates and a Jurassic Play in marine dolomites. Currently, oil play fields continue to be found in Cretaceous carbonates in thrust blocks.

Structural interpretation of thrust system has evolved according to the improvement of the PSTM seismic imaging of subsurface at different times in last century, to PSDM seismic in the last decade. Structural models have also evolved from unbalanced sections with PSTM seismic to models with balanced sections from PSTM and PSDM seismic, demonstrating the complexity of thrust fault arrangement.

Balanced structural models are presented for the first time that quantify the tectonic transport of stacked thrust front with reconstruction data of the Cretaceous Cordoba Platform rim and slope facies compared to an undeformed zone 35 km to the north. It is interpreted undeformed carbonated platform and slope seismic facies adjacent to the tectonic front in the southern portion that document separation with the Cordoba Platform. Transfer of shortening in fault systems along a thrust belt of previous models is applied to this work, but in addition different thrust wedges with variable thicknesses and mechanic stratigraphic models different from those published are documented.

Tectonic deformation evaluated of three balanced cross sections indicates that southern section has 45 km of middle Eocene transport while shortening of central and northern sections decreased from 32, to 24 km, respectively, with a late Eocene age of deformation. Models document that boundary between allochthonous blocks, and traps of the producing plays in the area, are in central and northern sector, where new exploratory opportunities were mapped.

SESSION TITLE: Theme 1: Stratigraphy I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Oral

TITLE: Predicting the heterogeneity in deepwater fans: integrating insights from outcrops, subsurface, and computational analogs

AUTHORS (FIRST NAME, LAST NAME): Fabien Laugier¹, Ali Downard¹, Ryan Wilson¹, Megan Stearman¹, Tao Sun¹, Ashley Harris¹

INSTITUTIONS (ALL):

1. Chevron

ABSTRACT BODY:

Abstract Summary: Deepwater fans represent the terminus for continentally derived sediments; as reservoirs, they are increasingly targeted for conventional and unconventional development and more recently a critical focus for CO₂ injection. These systems are commonly conceptualized as sand-rich, laterally extensive, and homogeneous based on qualitative analyses of outcrop, sparse well data, and low-resolution seismic data. However, continued efforts focused on characterization of key outcrops as well as conventional and unconventional production data has highlighted significant vertical and spatial heterogeneity can exist within deepwater fan reservoirs.

For effective characterization and performance forecasting, it is critical to develop predictive models for spatial heterogeneity and the impacts on connectivity. To address this, we conducted an integrated quantitative stratigraphic analysis across numerous outcrops, subsurface data, and physics-based numerical process models. These models effectively simulate stratal development of deepwater fans through forward simulation of transport, erosion, and deposition by sediment gravity flows, and result in digital analogs which can be quantitatively assessed. This integration permits us to quantitatively analyze trends in stratigraphic heterogeneity and develop a robust framework to predict internal complexity and connectivity within these critical reservoir types.

A first step was defining the organization of heterogeneity in a fan by testing the rates of variation in properties such as Net-to-Gross, Amalgamation Ratio, and facies trends at varying stratal orders. We observe scale-dependency in these properties, indicating hierarchical rather than fractal (scale independent). This implies that the 3D extent of heterogeneities observed in 1D must be linked to hierarchical order for accurate predictions away from well control. We further assess the 3D connectivity from proximal to distal architectures within a deepwater fan and link to 1D stacking patterns and developed a prediction framework based on this hierarchical analysis. This framework has been tested on conventional and unconventional reservoirs and leads us to conclude that at large hierarchical scales, complexity is lumped, homogenizing the reservoir; however, by considering the hierarchical nature of these systems, flow- and frac-impacting heterogeneities across multiple levels of hierarchy can impact development-strategy optimization and performance forecasting.

THURSDAY
21 APRIL 2022
POSTER PRESENTATIONS

SESSION TITLE: Theme 1: Stratigraphy & Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Prediction method of vuggy carbonate reservoir based on PR probability fusion model and genetic control

AUTHORS (FIRST NAME, LAST NAME): Kang Qiangqiang¹, Hou Jiagen², Liu Yuming³

INSTITUTIONS (ALL):

1. China University of Petroleum (Beijing)
2. China University of Petroleum (Beijing)
3. China University of Petroleum (Beijing)

ABSTRACT BODY:

Abstract Summary: Vuggy carbonate reservoir plays an important role in oil and gas development. Due to the complicated tectonic movement, denudation and leaching, the vuggy carbonate reservoir has high heterogeneity. Conventional reservoir prediction methods have no good ability to predict the reservoir architecture. In this paper, a fusion modeling method is proposed to improve the problem by combining seismic data, wells data and geological knowledge. Firstly, the development probability bodies between vuggy and the distance from surface water system and fault are established. By this way, we can control the modeling process by vuggy development mechanism (the nearer from fault and groundwater system, the more vuggy are found). Secondly, the development probability bodies based on the correlation of vuggy and a variety of seismic attributes are established; Thirdly, all probability bodies are fused to a fusion probability body by PR(permanence of ratios) probability fusion method. Finally, the fusion probability body is used as a soft conditional data to control the multi-point geostatistics modeling. The results show that models generated by the method we proposed have high quality architecture and accurate reservoir distribution. It proves that the multi-information fusion method improves the availability of data, and the constraint of geological knowledge makes models more reliable.

SESSION TITLE: Theme 1: Stratigraphy & Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Quantification of Reservoir Rock Properties (Porosity, Permeability and Vshale) in the Reservoir Rock Units of South Lake Albert Basin, Albertine Rift, Western Uganda.

AUTHORS (FIRST NAME, LAST NAME): Wilson Mbile Tumushabe¹

INSTITUTIONS (ALL):

1. Ministry of Energy and Mineral Development, Uganda

ABSTRACT BODY:

Abstract Summary: The study area, South Lake Albert Basin (SLAB) is part of the Albertine graben. The Albertine graben is the northernmost part of the western arm of the East African Rift System (EARS). The study majorly focused on interpretation of three-dimension (3D) seismic and suites of wireline log datasets, construction of 3D models, facies analysis, surface geological mapping and integrating both subsurface and surface data to assess reservoir rock properties. Petrel 2016.3 and Techlog 2015 softwares were used in this study. From previous studies, low to moderate reservoir quality (porosity, permeability and Vshale) was realized, and most of the drilled wells encountered 2 or more separate stacked oil accumulations (complex reservoirs) whose lateral extent had not been well understood that was attributed to poor reservoir property distribution. Thus, the major aim of this study is to quantify the reservoir rock properties and integrating both subsurface and surface data in order to evaluate the reservoir property distribution within the study area, with specific objectives of (1) interpreting subsurface and facies modelling data and (2) field (surface) data sampling, analysis and interpretation (3) integrating both subsurface and surface data. The study involved construction of three-dimension (3D) facies and reservoir property models, that were used in the assessment of facies and reservoir rock properties. The modelled results were integrated and interpreted together with field geological mapping data to assess and quantify the reservoir rock properties of the reservoir rock units. From the obtained results, it was deduced that the lithology from facies modelling (subsurface results) and field geological mapping (surface results) data were matching, and the reservoir rock properties in both Kaiso Tonya and Kingfisher areas have good values for all the interpreted reservoir rock properties that were quantified however, the section under Lake Albert has better values.

SESSION TITLE: Theme 1: Stratigraphy & Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Modern beach sediments characterization as a proxy for evaluating quality of Neogene reservoirs in offshore frontier basins of Colombia.

AUTHORS (FIRST NAME, LAST NAME): Victor Ramirez¹, José María Jaramillo², Miguel Ramirez³, Camilo Dongo⁴, German Moreno⁵, Paula Ordoñez⁶, Andres Vásquez⁷, Fabian Molina⁸, John Delgado⁹, Daniel Figueredo¹⁰

INSTITUTIONS (ALL):

1. GMas Research Group
2. GMas Research Group
3. GMas Research Group
4. GMas Research Group
5. GMas Research Group
6. GMas Research Group
7. GMas Research Group
8. GMas Research Group
9. GMas Research Group
10. GMas Research Group

ABSTRACT BODY:

Abstract Summary: This research project is financed with resources from the Agencia Nacional de Hidrocarburos (ANH) through the Ministry of Sciences with the main objective s to improve the understanding of the quality of siliciclastic hydrocarbon reservoirs, in the Caribbean and Pacific offshore basins of Colombia.

Predicting the reservoir quality constitutes a key aspect of hydrocarbon exploration risk. To make such predictions, geologists usually construct models that aim to identify supply areas and paleo drainage systems. Other approaches include interpretation of the subsurface data such as seismic images and rock quality prediction using geophysical techniques. These indirect methods rely on the quality and type of the data and often require calibration with wells and outcrop data. To provide elements of judgment in decision-making, additional tools are needed to understand the quality and distribution of offshore reservoirs.

This project postulates that the study of modern sediments in beach areas and river mouths provide data for predicting reservoirs quality in the subsurface. The study uses the mineralogy and the texture of the beach sediment samples as an input to model the distribution and diagenesis of the sands once they are deposited and buried offshore. The diagenetic models and experimental essays should result in a prediction of the sandstone porosity and permeability once the sediments are buried.

The methodology proposed contemplates the systematic collection of samples in 21 sites on the Caribbean coast and 10 on the Pacific coast. These samples will be studied using analytical and experimental techniques: Optical and digital petrography, quantitative mineral composition by X-ray diffraction, major and trace elemental composition by X-ray fluorescence, high resolution analysis of minerals and the diagenetic products using scanning electron microscopy - EDAX, cathode luminescence and petrophysical measurements at different confining pressures and temperatures. The results of the diagenesis experiments and computer simulation models will be calibrated with petrographic and petrophysical analysis of samples from wildcat wells already drilled in both the Pacific and Caribbean offshore basins of COLOMBIA-

A key contribution will be the mapping of reservoir quality as a fundamental element of the petroleum system in these frontier areas, along with the geological and morphologic description of beach localities along the coastal margins of Colombia.

SESSION TITLE: Theme 1: Stratigraphy & Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Paleo-valley Identification in a Glacio-Fluvial Depositional

AUTHORS (FIRST NAME, LAST NAME): Sihai Zhang¹, Thamer Almahamidh², Anren Li³

INSTITUTIONS (ALL):

1. Saudi Aramco
2. Saudi Aramco
3. Saudi Aramco

ABSTRACT BODY:

Abstract Summary: Glacio-fluvial depositional environments create lateral stratigraphic and lithological variations, which can produce a variety of valley-fill traps. The glacio-fluvial sandstone in paleo-valleys is an important type of hydrocarbon reservoir, and better understanding of such facies distribution is crucial for exploration. The aim of this study is to identify paleo-valley edges and characterize valley geometry by developing a practical geophysical technique. In this study, inversion-based spectral decomposition and RGB blending are employed to recognize paleo-valley geometry and characterize sandstone filled valleys distribution. A constrained least square spectra analysis (CLSSA) is utilized for its uniqueness of explicit formulation of spectra decomposition as a constrained inversion problem, and mitigates the contradiction of temporal and frequency resolution from an inversion perspective. RGB blending is a powerful technology to visualize multiple frequency volumes generated by CLSSA and demonstrates geological features clearly. Based on the two technologies above, the paleo-valley mapping workflow includes four steps: 1) implement cascaded conditioning of median filter and structural smoothing on seismic volume to improve data quality; 2) perform spectral decomposition using CLSSA to generate a number of frequency cubes; 3) analyze and build the relationship between geological feature and frequency components, and RGB blend the selected three frequency cubes; and 4) interpret and recognize paleo-valley on the RGB blended volume and slice.

The workflow based on CLSSA and RGB blending is applied to recognize paleo-valley in a glacio-fluvial depositional environment in the study area. The cascaded conditioning enhances the edges and prepares a high-quality dataset while the unique CLSSA provides high-resolution frequency cubes due to the mitigation of temporal and frequency resolution. Finally, the paleo-valleys are delineated by RGB blending and contribute to an improved characterization of paleogeography.

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Fine-Scale Lamination/Bedding, an Important Factor that Improve Hydrocarbon Productivity In Unconventional Reservoirs. A Case Study from The Woodford Shale, OK.

AUTHORS (FIRST NAME, LAST NAME): Carlos Molinares-Blanco¹, Daniela Becerra², Henry Galvis² **INSTITUTIONS (ALL):**

1. SierraCol Energy
2. Univ. of Calgary, Calgary, AB, Canada.

ABSTRACT BODY:

Abstract Summary: The fine-scale lamination/bedding is an important feature commonly neglected in the characterization of unconventional reservoirs. Self-sourced mudstone deposits are described as layered, or Vertical Transverse Isotropic (VTI) bodies, assuming the absence of significant vertical discontinuities (faults, fractures, cracks, etc.) Fine lamination/bedding is below the standard well log tool's resolution (~30 cm, 1 ft) and that affect reservoir petrophysical properties calculated from logs, such as porosity, net pay, oil saturation, and geomechanical properties calculated based on sonic and density logs, such as Brittleness, Young's Modulus or Poisson's Ratio. In this study, organic-rich Late Devonian Woodford Shale samples from outcrop, core-based ultrasonic pulse velocity analysis (UPV), and well production data from Grady County, Oklahoma, were compared to evaluate the potential effects of fine-scale lamination/bedding in the hydrocarbon productivity. The results show that the most productive intervals targeted by the horizontal wells, correlate with intervals that at lab tests exhibit higher acoustic anisotropy for P and S waves, or high Thomsen' coefficients (ϵ and γ). Brittleness in these rock intervals is characterized by low tensile strength, low fracture toughness values and more variable hardness measurements. This anisotropy is explained by the compositional variability observed in the low spaced (~5 cm, 2 inches), X-ray fluorescence (XRF) measurements and thin section descriptions. In outcrops, these intervals displayed a more frequent bedding and lamination (i.e., higher anisotropy) and are characterized by high fracture densities in the scanlines. The understanding of lamination/bedding is a key element to define the best intervals for hydraulic fracturing, because rock fabric may significantly improve productivity due three main reasons. First, more laminae within brittle intervals may act as weak planes that help to reduce the effective minimum horizontal stress. Second, the multi-layered reservoirs have a better storage capacity (thickness and porosity), commonly underestimated in conventional well logs. Third, the interbedding between organic-rich ductile beds (i.e., source rock) and organic-lean brittle beds (i.e., reservoir) may facilitate the hydrocarbon expulsion, because of a higher contact surface between the carrier-reservoir and the organic rich, source-rock intervals.

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Use of Neural Networks in the Calculation of Total Organic Carbon (TOC) Through the Relationship of Gamma Ray and Sonic Well Logs - A Case Study of the Pimenteiras Formation, Parnaíba Basin

AUTHORS (FIRST NAME, LAST NAME): Caio Diego Faustino Soares¹

INSTITUTIONS (ALL):

1. Eneva

ABSTRACT BODY:

Abstract Summary: The Devonian shales of the Pimenteiras formation are the main source rocks in the Parnaíba basin. Because of their organic richness, they are extremely important for both conventional and unconventional plays. The calculation of total organic carbon (TOC) is an important tool in understanding and extrapolating the geochemical characteristics of shales to intervals where there is no laboratory data. Consolidated techniques in the literature such as delta logR do not apply in most wells of the basin, where resistivity well logs are affected by highly conductive minerals, as in the case of pyrite. This study presents a workflow using neural networks, through the SOM (Self Organizing Maps) module of the Interactive Petrophysics (IP) software, to predict a TOC log from the relationship of gamma ray, sonic well logs and calibration with laboratory data. The results present satisfactory correlation between calculated TOC curves and laboratory data, turning this technique an alternative method for calculating TOC.

SESSION TITLE: Theme 3: Offshore Reservoirs: adding E&P value

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Mass-transport complexes in the Sureste basin, offshore Mexico: Seismic expression and implications for exploration and drilling hazards

AUTHORS (FIRST NAME, LAST NAME): Jonathan Hernandez¹, Clara Rodriguez²

INSTITUTIONS (ALL):

1. Schlumberger

2. Petronas

ABSTRACT BODY:

Abstract Summary: In this study, we integrate 3D seismic and well dataset to characterize a variety of submarine mass-transport complexes (MTCs) from offshore Mexico including local slumps associated with salt-related highs and a regional MTC, caused by shelf and/or upper slope failure during the Lower Miocene. This analysis forms part of a wider exploration assessment including the interpretation of 71,000 km² of 3D wide-azimuth seismic data to understand the tectonostratigraphic evolution and exploration potential of the Sureste Basin and associated sub-basins, offshore Mexico. The presence of submarine MTCs have both favorable and challenging implications for reservoir presence, seal potential, migration pathways, development and the presence of shallow drilling hazards. We evaluated a regional submarine MTC covering an area of at least 12,000 km² and thickness up to 700m, which we interpret to be associated with a catastrophic, gravitational failure of the shelf and/or upper slope during the Lower Miocene. The regional MTC is characterized by a matrix consisting of chaotic seismic facies. Thickness variations of the interval containing the MTC highlights lateral and frontal confinement by preexisting salt-bounded elongated depocenters. Wells penetrating the MTC indicate this regional feature is heterogeneous, translated into a chaotic facies as observed from seismic.

The interval overlying the MTC is characterized by highly reflective and more continuous seismic reflections, which we interpret as Mid to Upper-Miocene confined deep-water turbidites. Observations are supported by several wells that penetrate this sandstone-rich interval, which is also characterized by amplitude anomalies or direct hydrocarbon indicators. Our analysis suggests that MTC are found associated with turbidites presence generated just after the emplacement of the MTCs, controlling the initial deposition of Miocene deep-water turbidites, main Tertiary reservoir intervals in the Sureste basin. Local MTCs are recognized at shallower intervals and along the present-day seafloor associated with failure of the crest of salt-cored highs. Local submarine slumps and slides possess drilling hazard (wellbore instability); these features are commonly overcompacted so that drilling through, can significantly reduce operational time. Understanding of MTCs is key because they constitute important aspects of deep-water sediment fill and could lead to unprecedented exploration opportunities in the region.

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: The influence of physical, biological, and diagenetic processes on pore networks characteristics: Analysis of organic-rich mudstones of the Duvernay Formation, Canada.

AUTHORS (FIRST NAME, LAST NAME): Henry Galvis¹, Per K. Pedersen²

INSTITUTIONS (ALL):

1. Univ. of Calgary, Calgary, AB, Canada.

2. University of Calgary

ABSTRACT BODY:

Abstract Summary: The Late Devonian Duvernay Formation of Western Canada is among the few unconventional reservoirs where prolific organic-rich mudstones were developed adjacent to carbonate reef margins. Resulting from this shale-to-reef configuration, reservoir heterogeneity in the Duvernay appears strongly related to the spatial distribution and type of carbonate sedimentation. Remarkably, several sedimentary processes (e.g., physical, biological, or diagenetic) seem to have influenced the preservation or degradation of primary pore networks. Therefore, in this work, we illustrate that understanding the nature of sedimentary processes is critical to the characterization of mudstone fabrics and their associated pore characteristics. Using detailed core descriptions and outcrop analogues, the regional stratigraphic framework is subdivided into facies dominated by physical, biological, or diagenetic processes. Further, microfabric observations made under the SEM for each facies are tied to porosity, permeability, and pore size distribution data. Results suggest that mineral interparticle pore networks are best preserved in facies dominated by physical processes, where abundant silt-size grains of detrital origin are poorly sorted and may have sheltered the pore spaces between grains. On the other hand, diagenetic facies present the smallest porosity and permeability values –twice lower compared to facies dominated by physical processes–. Pore-filling calcite cement is the most typical expression of diagenesis in the Duvernay mudstones; although this cement prevented significant mechanical compaction, it occurred at the expense of a reduction in the interparticle pore volumes and an obstruction of pore throats. Finally, facies dominated by biological processes (bioturbation) presents a broad diversity of pore types and pore size distribution due to variations in burrow fill types and bioturbation intensities. However, the mottled-like burrows generally tend to preserve the mineral interparticle porosity better than discrete, isolated traces. The variety of identified mudstone microfabrics and associated pore networks provides the basis for predicting reservoir qualities in the Duvernay Formation and analog mudstone reservoirs where physical, diagenetic, and biological processes operate similarly.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Corrosion Inhibitors and Lubricants Characterization using The Rock-Eval® Shale Play™ Method: Case Studies to Determine the Origin of Geothermal Scales

AUTHORS (FIRST NAME, LAST NAME): Maria Romero-Sarmiento¹, Herman Ravelojaona², Nicolas Maubec³

INSTITUTIONS (ALL):

1. IFP ENERGIES NOUVELLES
2. IFP Energies Nouvelles
3. BRGM

ABSTRACT BODY:

Abstract Summary: The main idea of this work is to propose a quick analytical methodology to define the origin of geothermal scales via thermal degradation experiments using the Rock-Eval® Shale Play™ method. The methodology consists of recording the specific Sh₀, Sh₁ and Sh₂ parameters measured during both the vaporization and pyrolysis steps between 100 and 650°C. Measurements are first performed on solid geothermal scales to better quantify the bulk total hydrocarbon compounds released during the thermal degradation, and then analyses are performed on both corrosion inhibitor and lubricant samples. Rock-Eval® Shale Play™ parameters obtained for each investigated sample are then compared to determine if the corrosion inhibitor or the lubricant can be considered as the main cause of the scale formation in the investigated geothermal power plants. Results indicate that there is no apparent correlation between the corrosion inhibitor and the solid scale (case study 1). However, it seems that the use of lubricants could be associated to scale formation processes in the surface installations of geothermal power stations (case study 2).

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Nano-RPM technology for source water control.

AUTHORS (FIRST NAME, LAST NAME): José Cárdenas¹, Rodrigo Torres², Cesar Cáceres³, Ivan Valdivieso⁴

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Ecopetrol's technology strategy for Integrated Water Management identifies new opportunities for the nearly 2,000 million barrels of production water per year, which represent a cost of 400 MUSD per year. In this framework, the innovation and technology process identifies the control of water at the source, the treatment of surface water and the valorization of water as levers of this strategy. NanoRPM is a relative permeability modifier (RPM) that is based on the synthesis and formulation of a fluid based on silica nanoparticles functionalized with highly hydrolyzable polymers in an aqueous medium, to modify the mobility ratio of oil and water in reservoirs with high water influx (water cuts from 80% to 98%), reducing the production of water at the source and improving the efficiency of hydrocarbon recovery. Last year, a rigless pilot test of NanoRPM technology was carried out in a well with a water cut greater than 97% and 4000 barrels of fluid per day, with satisfactory results after 12 months of testing. To date there are incrementals of 12,000 barrels of oil and 400,000 barrels of water without producing approximately. In addition to this, the energy impact on the pump that works at lower frequencies and the decongesting of the production facilities are added to enable production input from other wells shut down due to high water production.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Detection of oil spill by satellite images, case study: LISAMA-158

AUTHORS (FIRST NAME, LAST NAME): Shaired Vergel Navarro², Cesar Eduardo Herrera Quintero¹, Valentina Moreno³, Jaime Santos⁴, Sharon Gamarra⁵

INSTITUTIONS (ALL):

1. Universidad Industrial de Santander
2. Universidad Industrial de Santander
3. UIS
4. UIS
5. UIS

ABSTRACT BODY:

Abstract Summary: In 2018, the Lizama 158 well suffered failures causing a migration of fluids to a site near the well, due to this accident, large volumes of hydrocarbons affected water sources from the Quebrada Lizama and Caño La Muerte to the mouth of the Sogamoso River. The spill caused serious damage to the environment and damage to the inhabitants of the area. The company in charge of the operation of the well, together with the Von Humbolt Institute, used containment measures and preventive monitoring. As well as the seal to avoid new outcrops of hydrocarbons. Since oil pollution can influence the state of the vegetation, Landsat 8 and Sentinel 2 images were used to identify the affected area and appreciate through multitemporal analysis the state and recovery of the vegetation from NDVI vegetation indices. ARVI₂, SAVI, G-SWIR, G-NIR and NDMI. Obtaining that during 2018-2019 there is a significant impact on the vegetation and by 2020 a recovery, as a result of the environmental remediation techniques used.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Preparation of graphenic material filters for reducing pollution in industrial waters and wastewater: a case in Colombia (Phase I)

AUTHORS (FIRST NAME, LAST NAME): Tatiana Milena Juliao Lemus¹, Maria Florencia Segovia², Jorge Andres Sachica³, Patricia Alvarez⁴, Marcos Granda⁵

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. INCAR
5. INCAR

ABSTRACT BODY:

Abstract Summary: In Colombia, the oil and gas industry are one of the most important for the country's economy, representing the 8 % of the GDP (Unidad de Planeación Minero Energética, 2015). Ecopetrol is making a big effort in turning oil and gas projects sustainable with time, according to the "Paris Agreement" and the reduction of gas emission for 2030. The VNC (Ecopetrol's Unconventional Vicepresidence) expect with this filters project, to produce a triple impact: Reduce CO₂ emission, by recycling the coke generated in the refinery, Reduce water footprint, by reusing 1) industrial waters or "flow back" water and/ or 2) brackish and salty waters obtained from deep aquifers, that are not appropriated for human consumption. In addition to this, Ecopetrol has expectations in developing filters for improving people's quality of life in the Middle Magdalena Valley, as in example, for sewage waters, which have been disposed in swamps without an appropriate treatment generating a big impact in the environment. INCAR (Institute of Carbon Science and Technology of Oviedo, Spain) has been working on the development of graphene substances from petroleum coke at low cost, a study that allowed the award of patent ES2507415A1. Based on this knowledge, and coupled with the need raised by Ecopetrol, this research has been proposed aimed at the development of graphene substances, which will be incorporated into other types of adsorbents (such as activated carbons), they promise to improve the effectiveness of filters currently existing for the cleaning of flow back water, groundwater not suitable for consumption and wastewater.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Enhanced weathering and carbon mineralization. A cheap, environmentally friendly and economically profitable carbon removal solution to mitigate global warming under a circular economy approach.

AUTHORS (FIRST NAME, LAST NAME): Juan Carlos Silva-Tamayo¹, Wendy Rondon²

INSTITUTIONS (ALL):

1. Testlab Laboratorios

2. Testlab Laboratorios

ABSTRACT BODY:

Abstract Summary: If we think back on our introductory geology and sedimentary geology classes we kind of remember a term that we barely heard while falling sleep during those classes, "chemical weathering". If several years after graduation, a group of geoscientist get together, in a congress like this, and we ask them about this term, they usually tend to relate it to the process that transform rocks either into sediments or into soils. If we ask the same group of geoscientists about how often they use this term during their professional career, we find that only a small fraction use it with some frequency. A similar conclusion is reached when one ask them about how important is the chemical weathering process in their career. What the majority of geoscientist forget from the GEO 101 or SED 501 classes is that this apparently simple process has the ability to regulate the Earth's climate and thus, may be the main solution to achieve the international goal of keeping global warming at 1.5 degrees Celsius above the pre-industrial era. The role that chemical weathering plays as the "Earth's Thermostat" relies on its ability to remove carbon dioxide from the atmosphere and perpetually store it, through inorganic mineralization, into soils. This role is complemented by its ability to generate and deliver the necessary alkalinity to promote carbon mineralization in the global oceans by through carbonate precipitation. Although chemical weathering effectively regulates the Earth's climate in geologic time scales, i.e. from thousand to millions of years, such a long term effectiveness can be reduced to human time scales if we speed up the chemical weathering processes. In this contribution we will show how innovations based on enhanced weathering of diverse geologic materials can be used, under circular economy approaches, to remove atmospheric carbon dioxide at Gigatone scales. These innovations have been designed not only to contribute to reach our goal to keep global warming at 1.5°C, but also to speed up our race towards a carbon neutral world. Initial estimates suggest that these innovation can help Colombia to reach negative net carbon emission within 3 years. These estimates also suggest that these innovations will impact the global carbon bonus market and generate the necessary royalties to contribute to a rapid and smooth energy transition worldwide.

SESSION TITLE: Theme 3: Offshore Reservoirs: adding E&P value

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: One Team to Deliver the T&T Growth Dream (Learnings from a Trinidad Near Field Exploration Campaign)

AUTHORS (FIRST NAME, LAST NAME): Ronnie Ameeralli¹, Avinash Ramroopsingh², Gabriella Kokoram³, Thomas Gan⁴, Sheldon Ogeerali⁵, Ryan Ramnath⁶

INSTITUTIONS (ALL):

1. Shell, Houston, TX, United States.
2. Shell plc
3. Shell plc
4. Shell plc
5. Shell plc
6. Shell

ABSTRACT BODY:

Abstract Summary: Trinidad and Tobago has a mature oil and gas industry that dates back to the early 1900s. A pillar of the local energy industry is the Atlantic LNG export terminal where natural gas has been processed and exported globally since 1995. With the drive for continued production comes the challenges of finding new backfill opportunities against the backdrop of geological complexity, competitive economics and challenging operations.

The Columbus Basin, forming the easternmost part of the Eastern Venezuela Basin, is situated along the obliquely converging margins of the Caribbean and South American plates. Shell is the owner of multiple licenses which includes the Dolphin field, associated platform and multiple smaller fields that are tied into it via subsea developments. With a recently acquired OBN came the opportunity to not only improve characterization of the existing fields but also untested plays and concepts.

In 2021, two near field prospects were matured for exploration drilling. Despite having multiple exploration and production wells in the area, they challenge the conventional seismic response expected for hydrocarbon accumulation and if successful, could challenge the way we explore in this and other basins globally. The well design here is also challenging due to high drilling angles, navigating through depleted reservoirs, pressure ramps and pick uncertainty. An emphasis has been placed on each casing section, understanding the uncertainty in the interpretation of the available data and the impact on well design and drilling scenarios. Given the volume potential and need for accelerated gas production, these wells seek to pursue joint exploration and appraisal objectives. With this comes the tension of defining a competitive well that delivers the information required to take an investible decision for a development.

This project has highlighted the criticality of multi-disciplinary collaboration to deliver maximum value which is significant in multiple dimensions. In either success or failure cases, the wells polarize these untested geological concepts which will impact the remaining portfolio and next plays to be interrogated. Furthermore, the work aims to reduce the cycle time from exploration to development to achieve accelerated 1st gas. This is a success factor which is increasingly critical for all developments globally. Finally, backfilling gas supply in Trinidad is a major win for all stakeholders involved.

SESSION TITLE: Theme 4: Time Lapse, Other Applications and Social Considerations

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Time-Lapse Seismic Acquisition: A Critique of Successes, Challenges and Future Prospects for Petroleum Operations

AUTHORS (FIRST NAME, LAST NAME): Bassey Bassey¹

INSTITUTIONS (ALL):

1. CRANFIELD UNIVERSITY

ABSTRACT BODY:

Abstract Summary: Increasing available knowledge reveal that time-lapse or 4D seismic survey is successful in locating bypassed pay to improve reserves and improves drilling efficiency with fewer, better-placed wells, resulting in a positive impact on near-term profitability in an uncertain oil and gas market. Despite expanding applications including CO₂ storage monitoring, time-lapse seismic is yet to fully attain full potential on an industry-wide basis. It remains a smaller sector than the original 3D seismic exploration that it was developed from. This paper thus examines major applications and methods of time-lapse seismic acquisition, evaluates pros and cons of the various methods of acquisition with a view to improving them for better reservoir characterization, and suggests frontier areas for adoption in deepwater petroleum operations across the globe.

Case studies are cited to support the arguments, performance metrics from the literature are critically analysed and reflections articulated into learning and action points to guide the industry moving forward. A proposition is made for improved acquisition using a modified system architecture of the conventional towed streamers method of time-lapse seismic shooting. It is believed that such innovation, upon trial and qualification, would facilitate more accurate data acquisition by optimizing the signal-to-noise ratio, which has remained a major challenge in seismic survey results especially offshore. A key recommendation is that the petroleum industry plans seismic data acquisition from ground up with 4D in mind. This involves understanding baseline data and planning acquisition to optimize history matching with previous survey data.

Lessons learnt from this work should provide useful insights to aid the industry 'fail fast', while improving recovery from mature fields and optimizing return on investment in new fields. Reviews exist on time-lapse seismic processing and interpretation, but none found on acquisition, where data inputted into geophysical and reservoir models are generated. It is vital to get this right for integrity and reliability of results used for decision-making. This paper therefore fills a significant knowledge gap, melting several works in silos into a mix and objectively analysing the real picture from a critical standpoint that would benefit professionals in both academia and industry.

SESSION TITLE: Theme 4: Seismic Data Interpretation and Simulation

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Prediction method of braided fluvial facies reservoir based on PR probability fusion model and multi-point geostatistics

AUTHORS (FIRST NAME, LAST NAME): Kang Qiangqiang¹, Hou Jiagen², Liu Yuming³

INSTITUTIONS (ALL):

1. China University of Petroleum (Beijing)
2. China University of Petroleum (Beijing)
3. China University of Petroleum (Beijing)

ABSTRACT BODY:

Abstract Summary: Predicting the spatial distribution of braided fluvial facies reservoir is of paramount significance for oil and gas exploration and development. Seismic data has significant advantages in dense spatial sampling, in recent years, many methods have been proposed to predict the reservoir distribution based on different seismic attributes. However, different seismic attributes have different sensitivity to reservoirs, and the information redundancy between them makes it difficult to integrate effectively. To address this problem, an effective method about how to integrate multiple seismic attributes effectively become a largely important research question. PR probability fusion model (permanence of ratios) is a method to effectively integrate multi class and multi-scale data sets, which can solve the problems addressed. In terms of reservoir modeling, multi-point geostatistics can effectively characterize target distribution characteristics, but how to construct high-quality training images has always been a problem. In this paper, we propose a braided river reservoir prediction method based on PR probability fusion model and multi-point geostatistics. Firstly, we collect statistics on similar modern sedimentation and paleo-outcrops, and build high-quality reservoir training images under the guidance of the deposition pattern; Secondly, We calibrate each linear combination of selected seismic attributes, calculate the principal component value and calculate the basic conditional probability. Thirdly, the PR probability integration approach is employed to combine all conditional probabilities and calculate the joint probability. Finally, we establish the reservoir distribution model through multi-point geostatistics and the joint probability. The results show that models generated by the method we proposed have high quality architecture and accurate reservoir distribution. It proves that the multi-information fusion method improves the availability of data, and the constraint of geological knowledge makes models more reliable.

SESSION TITLE: Theme 4: Seismic Data Interpretation and Simulation

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Fault Shadow Zone Mitigation via PSDM Imaging – Entrerrios, Llanos Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Dan Negut¹, Goran Cotra², Alex Negut³, Trino Salinas⁴, Carlos Duran⁵, Jose Araujo⁶, Rafael Guatame⁷, Gabriel Alvarez⁸

INSTITUTIONS (ALL):

1. Z-Terra North
2. Z-Terra North
3. Z-Terra North
4. Z-Terra North
5. Petroleos Sudamericanos
6. Petroleos Sudamericanos
7. Petroleos Sudamericanos
8. Petroleos Sudamericanos

ABSTRACT BODY:

Abstract Summary: Introduction

The Entrerrios Block is located in the Llanos Orientales Basin in Colombia, with an area of six thousand thirty-eight (6038) hectares. There are three producing formations in the field: Mirador, Gachetá and Ubaque. The main one is the Mirador Formation, which corresponds to continental and transitional deposits of fluvial sands. The Gachetá Formation is made up of punctual sand intercalations with variable content of organic matter. Its depositional environment represents coastal bars and lagoon environments. The Ubaque Formation represents a set of sandstones deposited on the Cretaceous sequence within coastal marine environments with fluvial and deltaic influence. Geologically the field is part of the Llanos Orientales basin and structurally its configuration was a smooth NE-SW monocline initially. The trap is a combination of structural and stratigraphic factors.

While time domain processing could not solve these issues, anisotropic PSDM processing, as described in this paper, was successfully used to alleviate the fault shadow effects, even though the offsets were too short to accurately estimate the anisotropy parameters.

Methodology

The Entrerrios-2007 and Entrerrios-2014 3D surveys were processed as a merged 3D, through to PSTM.

Upon successful PSTM completion, the interpretation process identified 5 main target horizons (Leon, Carbonera 1, Mirador, Ubaque, Basement) and 7 wells (tops and VSP/Sonic for Entrerrios #1, #2, #3, #5, #6, #7, #8) which formed the “skeleton” of the PSDM initial velocity model.

The initial isotropic PSDM interval velocity model was built starting off with the final PSTM velocity model calibrated with the VSP/Sonic velocities and using 3 passes of isotropic and 3 passes of anisotropic Tomographic Kirchhoff Velocity Model updates.

Conclusions

The Results of the PSDM processing and its subsequent interpretation permitted correcting in a very good way the effect of the fault shadow, allowing to observe and interpret the field as a monocline compartmentalized by faults of preferential direction SW-NE of greater size and quite different configuration; this has brought a strong benefit in finding a larger area of the field, which is reflected in an increase in on-site reserves and the possibility of drilling new development and advanced wells in better structural positions than the well previously drilled in the field.

SESSION TITLE: Theme 4: Geophysical Data Integration and Novel Methods

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Integration of geophysical data in imaging subsurface geology of Torres Arch in the Pelotas Basin, Southern Brazil

AUTHORS (FIRST NAME, LAST NAME): Claudia Domingues Teixeira¹, Henrique Serratt², Tiago Girelli³, Leticia Mallmann⁴, Farid Chemale Jr⁵

INSTITUTIONS (ALL):

1. Universidade do Vale do Rio dos Sinos (UNISINOS)
2. Universidade do Vale do Rio dos Sinos (UNISINOS)
3. Universidade do Vale do Rio dos Sinos (UNISINOS)
4. Universidade do Vale do Rio dos Sinos (UNISINOS)
5. Universidade do Vale do Rio dos Sinos (UNISINOS)

ABSTRACT BODY:

Abstract Summary: Pelotas Basin is located in the passive margin on the South America Continent. Related to an intense volcanic activity occurred during the South Atlantic rifting and breakup. This magmatism is more pronounced in the north of Pelotas Basin, reaching 17 km thickness. A volcanic dome, known as Torres Arch, was identified as a seaward dipping reflection (SDR) in this region. This work presents a regional geological-geophysical model across the Torres Arch. Gravity and magnetic methods are powerful tools for imaging volcanic units due to their strong magnetic signature and high-density contrasts. Gravity and magnetic data show good lateral resolution; however, defining the extent in depth remains a challenge. Seismic data showing low-resolution images in volcanic rocks, in contrast, can provide a reliable stratigraphic structure above volcanic rocks, thus improving the vertical resolution of gravity and the magnetic method in geophysical modeling. Magnetic, gravity, well, and seismic data have been compiled to understand better the complex processes that occur during the evolution of this segment of the South America passive margin. Firstly, the stratigraphic limits were obtained from seismic data. Then the residual gravity and the magnetic anomalies produced by volcanic rocks were recovered based on a dip seismic-derived structure. In addition, a 3D gravity inversion was performed based on density recovered from wells and an initial 3D regional density volume from the seismic surface to constrain basement densities. Magnetic amplitude inversion was also carried out to recover the physical properties information. The results reveal remarkable changes in the density and magnetic susceptibility, where distinct compositions of SDR also were observed in the variation of the geometry of the reflectors in the same package. Additionally, the integrated interpretation of geophysical data could significantly decrease the uncertainty associated with any single dataset and has produced more reliable images of the lateral and vertical distribution of volcanic rocks.

SESSION TITLE: Theme 4: Seismic Data Interpretation and Simulation

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Seismic facies analysis and depositional interpretation applied in a pre-salt carbonate field, Brazil

AUTHORS (FIRST NAME, LAST NAME): Wendel Araujo¹, Marcia Maria Pinheiro da Silva²

INSTITUTIONS (ALL):

1. Ecopetrol Brasil
2. Ecopetrol Brasil

ABSTRACT BODY:

Abstract Summary: Brazil began oil production from its pre-salt carbonate reservoirs in 2008 and at the end of 2021 represents the largest exploration and production target in Santos and Campos Basin (Brazil), currently accounts for more than 74% of the country's oil and gas production (ANP, 2021). The Brazilian presalt carbonates reached an incredible output of 2.85 million barrels of oil equivalent (boed) surpassing the post-salt production in July 2021 representing more than half of the country's daily production. The presalt carbonates reservoir are present in rift super-sequence and the Sag sequence covered by a giant salt layer of Aptian age. The Rift super-sequence is composed of continental siliciclastics, talc-stevensite ooids with interbedded lacustrine coquinas and organic-rich shales of the Piçarras and Itapema formations (Szatmari and Milani, 2016). The sag phase is represented by the Upper Barra Velha Formation, which is characterized by shrubs, spherulite, laminate and reworked facies (Gomes et al., 2020) precipitated nonmarine carbonate successions (Wright & Barnett 2015). This geological environment naturally presents a complexity facies (homogeneous and heterogeneous) that naturally generate distortion in the seismic signal during the data acquisition process.

The study presents the benefits of the LSRTM in an OBN seismic acquisition to carbonate reservoirs. Highlighting the reduction of migration artifacts, swing noise, better signal-to-noise ratio and lateral continuity. The high-quality data allows work with different frequency bands to optimizing attributes and seismic facies analysis to increase reservoir characterization. A good seismic data quality together with the analysis with seismic attributes as: cosine of phase, coherence, spectral decomposition and other attributes can improve the accuracy on the identification and delimitation process of Presalt carbonates facies.

Taken it account through this analysis was possible to identify some seismic facies correlated with some carbonate bodies, for example: Carbonate build-ups controlled by faults, pinnacles carbonates, carbonate terrace or platform, debris flow and low energy lakes deposits. As is known carbonate sedimentation processes are extremely sensitive to climatic factors, hydrodynamics, basin tectonics and morphology. These differences might cause vertical and lateral heterogeneity effects in seismic facies (Porta, 2015).

SESSION TITLE: Theme 4: Geophysical Data Integration and Novel Methods

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Structure and Geometry of the Pelotas Basin (onshore), Southern Brazil and Uruguay, from magnetotelluric imaging

AUTHORS (FIRST NAME, LAST NAME): Aline Menezes¹, Farid Chemale Jr², Patricia Lugão³

INSTITUTIONS (ALL):

1. Universidade do Vale do Rio dos Sinos (UNISINOS)
2. Universidade do Vale do Rio dos Sinos (UNISINOS)
3. Strataimage

ABSTRACT BODY:

Abstract Summary: Investigation of the deep structure is important for defining the tectonic evolution and geometry of a basin. The magnetotelluric (MT) method provided high-resolution two-dimensional (2-D) electrical resistivity models for the major deep-basement structures of the Pelotas Basin in the passive margin of southern Brazil and Uruguay. We obtained the resistivity models by applying mathematical inversion to 104 MT sites distributed along two profiles. The MT resistivity models show that the basin is deeper towards the sea. The MT models for Pelotas Basin show a conductive layer to depths of 4 km and resistivities 1 to 80 Ωm , intermediate rocks between the basin/basement and the zones of basement structures with resistivity ($< 500 \Omega\text{m}$) and basement rocks with resistivity ($> 500 \Omega\text{m}$). The resistivity contrast between basement and basin and lateral discontinuity between basement terranes were identified. This contrast outlines the basin geometry and the variations in physical properties of the terrane and of the basement. The resistivity information allowed us to characterize and delimit the main structures and the depth of sedimentary cover of the onshore portion of the Pelotas Basin along the coast of the state of Rio Grande do Sul (RS-Brazil) and Uruguay. The resistivity models extend 15 km deep, several kilometers below the top of the Precambrian basement. The top of the Precambrian basement varies from one profile to another from meters to kilometers and is covered in some places by packages of sedimentary rocks of different ages. Well data was used to calibrate the models, showing a good correspondence. The passive basin sediments of the onshore portion of the Pelotas Basin can reach expressive depths in the central portion with control from structures inherited from basement lineaments. The MT data combined with data from wells support a tectonic model for the Pelotas Basin that provides more reliable images of the distribution of the main lateral and vertical structures.

SESSION TITLE: Theme 4: Seismic Data Interpretation and Simulation

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Sinu and San Jacinto Basins, Recent Advances that Could Make this Area the Next Supplier of O&G Discoveries in Colombia

AUTHORS (FIRST NAME, LAST NAME): Karyna Rodriguez¹, Andres Mesa²

INSTITUTIONS (ALL):

1. Searcher
2. Horizonz Consulting

ABSTRACT BODY:

Abstract Summary: It is common within a basin's history that the lack of data, appetite for a neighbouring area, or outdated geological models, send the basin to ostracism. This is the case of Sinu and San Jacinto basins, in the Northwest of Colombia, some of the first to be explored in the first half of the 20th century, with good light oil indications and some small discoveries. During the last 15 years, the national government has acquired new seismic and well data, further geological studies have challenged previous geological models, and reprocessed seismic using advanced algorithms have exposed new insights about the type of structures present. All these combined, indicate that these basins have great potential to become a flourishing area for new hydrocarbon discoveries.

The exploration history dates to the 1900s. Small discoveries between the 20s and 50s, showed that there was potential for oil and gas. However, commercial discoveries moved attention to the Lower Magdalena Basin. Sinu and San Jacinto have about 1 exploratory well per 820Km², on the contrary, the Lower Magdalena basin has 1 per 350km². Seismic data is spread and poor in quality, which hasn't helped to unravel key aspects of the subsurface. Recent regional studies have come to several conclusions in terms of the basin evolution that can change the perception of the area. There is a major unconformity associated with deformation and erosion which took place during the Early to Middle Eocene, equally to what occurred along Magdalena basins. The Romeral Fault does not have a major influence after that erosional event. There is a marine Cretaceous sequence with good source rock characteristics that explains liquid hydrocarbons found in oilseeps and wells. There are shallow and deep marine reservoirs in the whole Tertiary sequence, recently proved by the Bullerengue discovery.

Seismic reprocessing using state-of-the-art technology, focusing on critical aspects including static calculation, cross spread noise attenuation, model building, and Pre- Stack Time/Depth Migration enable imaging of the trap systems related to mud diapirs, possible inversion structures, as well as a thick Cretaceous sedimentary sequence.

In conclusion, new data have unravelled key aspects of the petroleum systems of Sinu and San Jacinto basins, indicating a great potential to become a new prolific area for new hydrocarbons discoveries, which should encourage more exploration activity in the near future.

SESSION TITLE: Theme 4: Time Lapse, Other Applications and Social Considerations

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Depth Domain Seismic Interpretation Workflows an Applied Case for Structural Modelling: Caipal – Palagua Field, MMV, Colombia

AUTHORS (FIRST NAME, LAST NAME): Mario Andres Pachon¹, Jhonny Calderon²

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Pre-stack depth migration (PSDM) workflows are up-to-date technology solutions for seismic data processing. This process to obtain the seismic image in the depth domain, considering lateral velocities variations, has reached such a state of maturity that may display significant contrasts with the conventional seismic image obtained through time migration processing. The purpose of this work is to compare and highlight the differences between traditional seismic interpretation in the time domain (TWT) versus seismic depth domain PSDM, and their impacts on assets development and decision making.

Updating the structural model of the Palagua field, located in the Middle Magdalena Valley (MMV), was possible mainly due to the readily available new seismic volume generated by a Kirchhoff-type depth migration, including an inclined anisotropic correction (TTI). A new seismic interpretation, including post-stack seismic attributes analysis, was carried out on a depth domain data PSDM, leading to a new frame where the reservoirs levels reached a better adjustment with the available well data. Additionally, the optimized imaging of the fault system in a compartmentalized field allows interpreting a better-defined geometry and ensures a more accurate fault plane position that favors the well completion strategy.

Finally, a more realistic structure grants new seismic quantitative analyses and volumetric assessments based on a more detailed understanding of the field, lowering structure uncertainties and increasing the precision degree of optimal target locations in future drilling campaigns and Enhanced Oil Recovery projects (EOR).

SESSION TITLE: Theme 4: Geophysical Data Integration and Novel Methods

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Reducing Exploration Uncertainty by Unravelling Seismic Velocities and Statics

AUTHORS (FIRST NAME, LAST NAME): Jose Olaya¹, Tim MacArthur², Rob Vestrum³, Alejandro Gallo⁴

INSTITUTIONS (ALL):

1. TBI COLOMBIA SAS
2. Thrust Belt Imaging
3. Thrust Belt Imaging
4. TBI Colombia SAS

ABSTRACT BODY:

Abstract Summary: When imaging complex structures of sub-Andean Basins with seismic data, the shape and size—indeed, the existence or not—of an imaged geologic structure is dependent on the seismic-imaging velocities and the statics used to correct for near-surface weathering effects. These two parameters—velocities and statics—are intricately intertwined. Unravelling and optimizing these parameters will reduce structural uncertainty at the target level and reduce exploration risk.

We investigated a variety of industry-standard statics algorithms and how they affect synthetic model data and field data from the foothills of the Colombian Andes. Carrying each statics solution through to the final prestack time migration showed us how each solution affected the final seismic image. Comparing these solutions with the application of different velocity fields shows the interplay between velocities and statics. As the shape of the target structure changes with these parameters, we have an opportunity to evaluate the high (P90) and low (P10) volumetric calculations. This is another step towards the goal of quantifying structural uncertainty based on imaging parameters.

The final seismic image is dependent on velocities, statics, and the interplay between the two parameters. Evaluating the different imaging solutions requires interpreter input so that the processor gains an understanding of which reflector corresponds to the main target reservoir and the interpreter gains an understanding of the structural uncertainties in the final seismic image.

SESSION TITLE: Theme 4: Geophysical Data Integration and Novel Methods

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Solving Complex Overthrust Features Using Magnetotelluric, Seismic, Geological Surface and Wells Data Integration: Case Study in Igüembe Anticline, Bolivian South Sub-Andean.

AUTHORS (FIRST NAME, LAST NAME): Ángel Leonardo Sanchez¹, Ana Maria Goncalves², Evanz Lázaro³, Jaime Soria Galvarro⁴

INSTITUTIONS (ALL):

1. YPFB Chaco S.A.
2. YPFB Chaco S.A.
3. YPFB Chaco S.A.
4. YPFB Chaco S.A.

ABSTRACT BODY:

Abstract Summary: The Bolivian Subandean region is characterized by a thin-skinned thrust fold belt with structures persisting for 50-100 km along strike in a broadly North-South direction.

The Igüembe anticline is located southwest of the Bolivian South Sub-Andean region and extends for about 80 km, with a north-south general trending, neighboring the Ingre Anticline to the west and the Sararenda Anticline to the east.

There is a high geological uncertainty in the Igüembe anticline, due to the strong disharmony in its core and high dips in the layers. For this reason, in 2018 a Magnetotelluric (MT) survey was acquired. The results of MT supported the analysis by providing new information that allowed identifying the interface between "Los Monos" and "Huamampampa" formations (Devonian) and improving the definition of the structure's geometry in depth.

The objective of this work was to integrate seismic data (470 km), surface geology and wells with MT data into a balanced structural model. With this integration, it was possible to evaluate the exploratory potential of the area, obtaining a reliable geological-structural model.

The interpretation process began with the construction of the geological model based on 2D seismic data, the geological map, dip and azimuth data from the surface geology and well data. Secondly, the MT - Resistivity sections were added to the interpreted sections to compare both responses. Then, the geo-electric and seismic sections were correlated. Finally, once the information was confirmed, it was used as the input for the constrained inversion.

The model generated for the Igüembe anticline corresponds to an antiformal stack with a lower detachment in the shales of the Silurian base. The shallow structure corresponds to a thrust belt with a lower detachment in the upper shale levels of the Silurian, caused by the shortening transmission of a fault bend fold that is generated below the Ingre anticline.

The result of the integration demonstrated the existence of a hydrocarbon prospect, and it was proposed an exploratory well for drilling the highest of the Igüembe structure.

SESSION TITLE: Theme 4: Seismic Data Interpretation and Simulation

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: La Creciente Block, Lower Magdalena Valley Basin, Colombia: Fluid Factor Attribute, a Predictor Tool for Gas Bearing Intervals in a Near Field Exploration Case

AUTHORS (FIRST NAME, LAST NAME): Mario Di Luca¹, Fredy Torres², Ana Bolaños³, Gustavo Bertorelli⁴

INSTITUTIONS (ALL):

1. Frontera Energy
2. Frontera Energy
3. Frontera Energy
4. Frontera Energy

ABSTRACT BODY:

Abstract Summary: La Creciente gas field was discovered in November 2006. The discovery well for the main field, LCA-1, tested commercial gas in Ciénaga de Oro (CDO) sands. The reservoir is made up of shallow marine massive, clean calcareous quartz sandstones with gross thickness ranging from 450 to 700 feet, porosities in the range of 15-20%, gas permeability ranging 70 to 100 mD and net thickness ranging from 100 to 220 ft. After this discovery, three 3D seismic surveys were acquired, 12 wells were drilled and four different gas pools were defined into the block, achieving a production plateau of approximately 60 MMscf/d (2010-2015) with a cumulative gas production of 206 BCF in 4Q-2021. In October 2021, average production was 4.7 MMscf/d, out of three active producer wells (two fields). The main field, La Creciente-A, is a structural trap in a footwall of a normal antithetic fault with favorable juxtaposition of CDO sands with Porquero shales. In this field an OGWC was defined at -10,542 ft TVDSS, downdip of this contact, Apm-1X well was drilled looking for a pre-stack seismic inversion anomaly, identifying a separated reservoir; the well accumulated 1.5 BCF and confirmed a stratigraphic trapping mechanism in the area. Recently, a new effort has been carried out to define additional exploratory opportunities in the block related to stratigraphic plays. After a deep correlation analysis of different attributes with the wells results, the Fluid Factor (FF) attribute was defined as the best gas-sand predictor in the area. The prediction capacity of FF attribute was validated in wells that identified massive gas-sands, shaly gas-sands or dry shale intervals in CDO, showing good calibration results; as example, well LCA-2ST1 showed poorly developed reservoir facies and did not exhibit FF anomaly, all the wells with good production have depicted strong FF anomaly. Four new exploratory opportunities were defined in the Block with a total prospective results of 96 BCF, all of them showing strong FF anomalies and a good match with geological model. FF anomaly has a high relation with AVO effect, gather analysis on different wells positions and new opportunities were performed. Bottom line is that the Fluid Factor attribute is a reliable predictive tool to identify potential gas bearing reservoirs in the Cienaga de Oro Formation in La Creciente Block, allowing to identify near field exploratory opportunities that might extend the economic life of La Creciente Block.

ABSTRACT

One of the biggest challenges that we have been facing in seismic exploration operations, beyond the technical issues, it is related to environmental fears, coming not only from local authorities, but also from communities in the areas of interest, that becomes in positions against field seismic operations.

ECOPETROL S.A. has been working in solving these challenges and has evaluated several alternatives to mitigate the effect of these issues, which have caused a great impact in the Exploration Portfolio, because of the lack of new data to identify new opportunities. Among different reasons that are affecting prospects and play definition, we may mention the following: drilling opportunities have decreased, there are some areas without or poor seismic coverage and there is a high risk in the quality of legacy seismic data.

Having these considerations into account, Geophysics team in ECOPETROL S.A. has been working in several strategies, to allow us to have an approach with communities and other stakeholders. The purpose of this action is to show them, in a very assertive way, how the seismic acquisition is carried out and the probable impacts on the environment.

In this poster, we want to show new strategies which are looking for an adaptation to the new reality of the industry and the relationship with the environment.

INTRODUCTION

During some of the last seismic acquisition programs, ECOPETROL S.A. faced several socio-environmental issues, causing some troubles that affected data quality. The following are some examples:

CPE-4 2D (2013): during the seismic acquisition, environmental authority increased restrictive distances to environmental ecosystems. Based on a caution principle, they increased a margin of 200 meters over maximum flood level, deep wells and artificial swamps. (Figure 1).

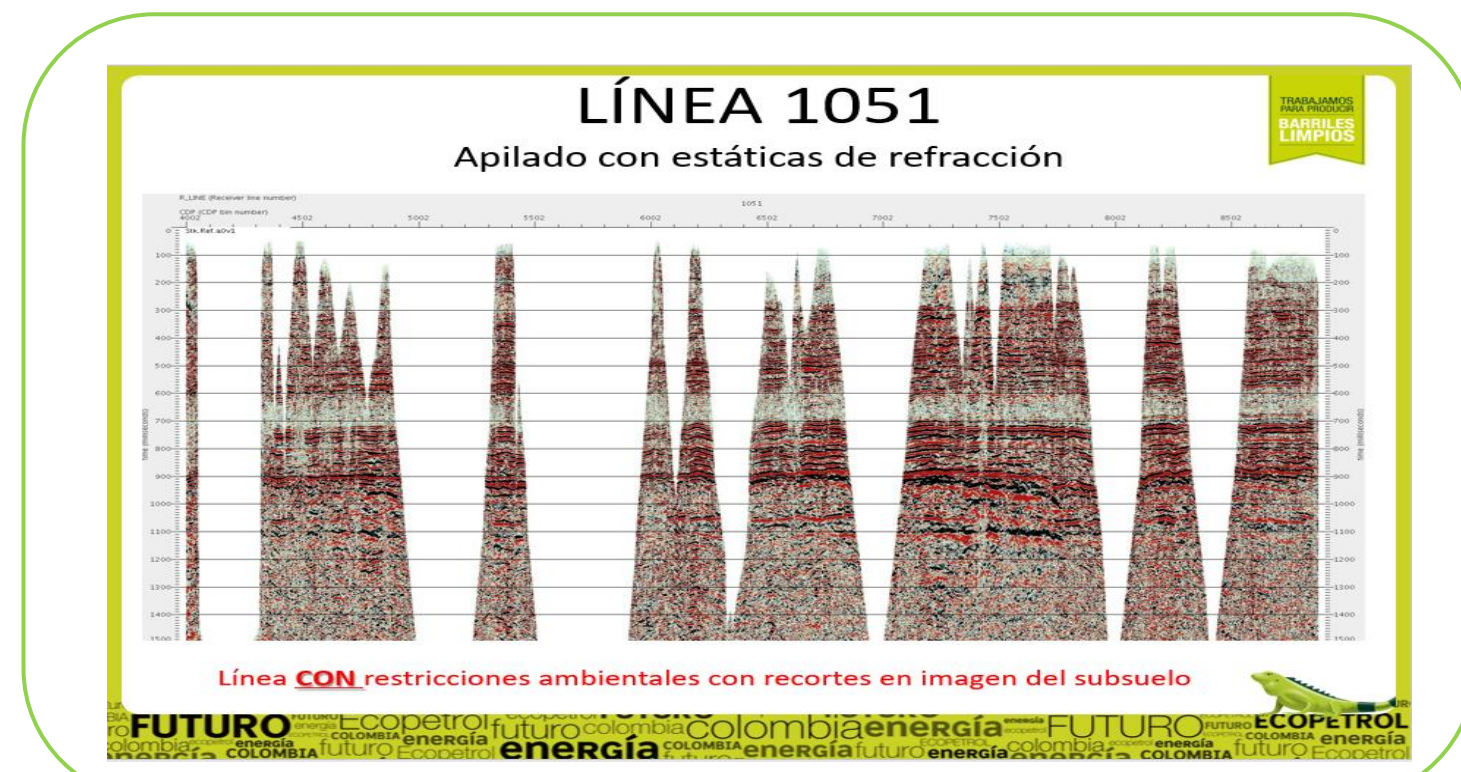


Figure 1. CPE-04 2D. LINE 1051. Brute stack. Refraction statics. Image effects due to environmental restrictions.

CARDON 2D (2016): due to social issues, acquisition lines were changed to crooked lines, considering several existing roads in the area. The seismic tie was not good enough because there were not lines to the west of the program. We acquired very good seismic data in this part of the Caguan-Putumayo basin. (Figure 2).



Figure 2. Cardón 2D 2016. Preplot 2D lines and post-plot crooked lines.

VMM-32 3D (2014): in the center of the polygon there is an environmental reserve area in which we could not enter with sources. There was a need to include infill outside of this area. With modeling and ray tracing we could illuminate the geologic targets on this area. (Figure 3).

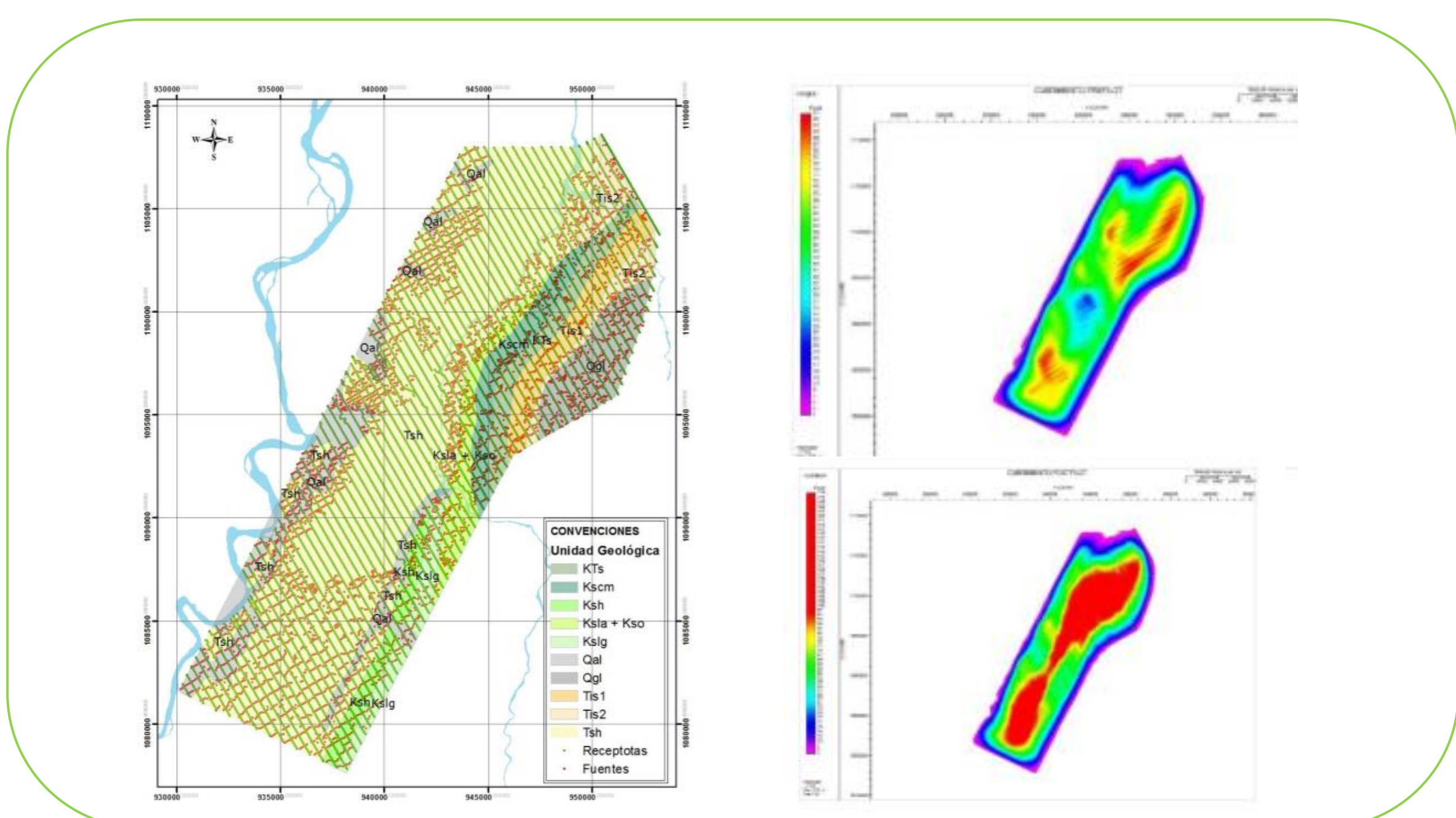
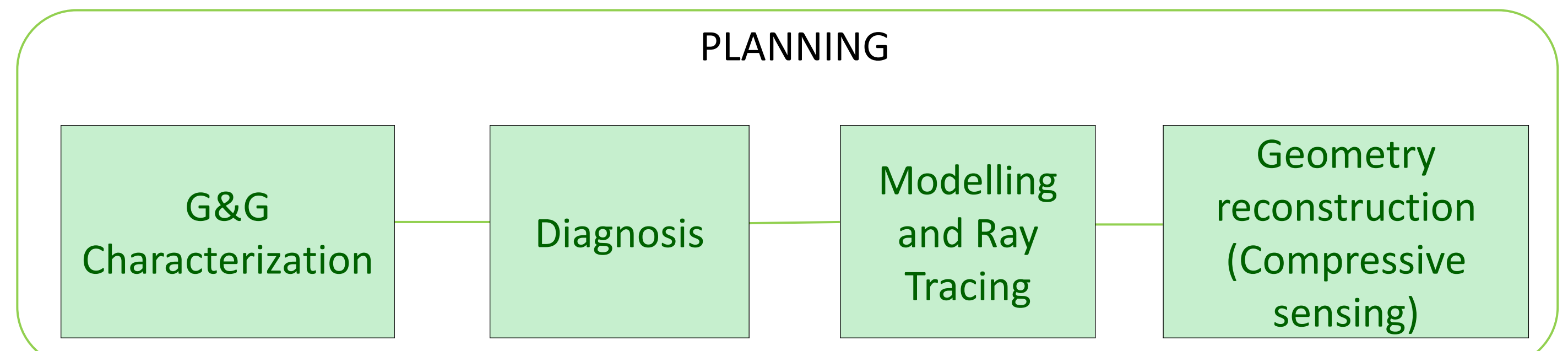


Figure 3. VMM 32 3D. Shot point location according to geology. Preplot and post fold map.

Because of all these issues, ECOPETROL S.A. has decided to look for a new strategy, where these concerns can be solved in early stages, doing characterization and effective diagnosis of the areas, in order to prevent later effects during the acquisition operation.

STRATEGY

The Geophysical team at ECOPETROL S.A. has identified that early work in the areas, helps to identify possible risks and issues that need to be considered before data acquisition. With this knowledge, we can implement the best work plan during field operations. We are using some technical tools and technologies, in order to help solving communities and environmental authorities concerns. We consider that this is the right way to start talking with these stakeholders and getting them as allied for the projects. Among the most innovating aspects that are being implemented, we can mention the following:



1. G&G characterization: early study in order to recognize main features (Figure 4), that are present in the surface area of the block. Identify geology, geophysics, logistics and socio-environmental more relevant issues, looking ahead possible restrictions for seismic acquisition operations.

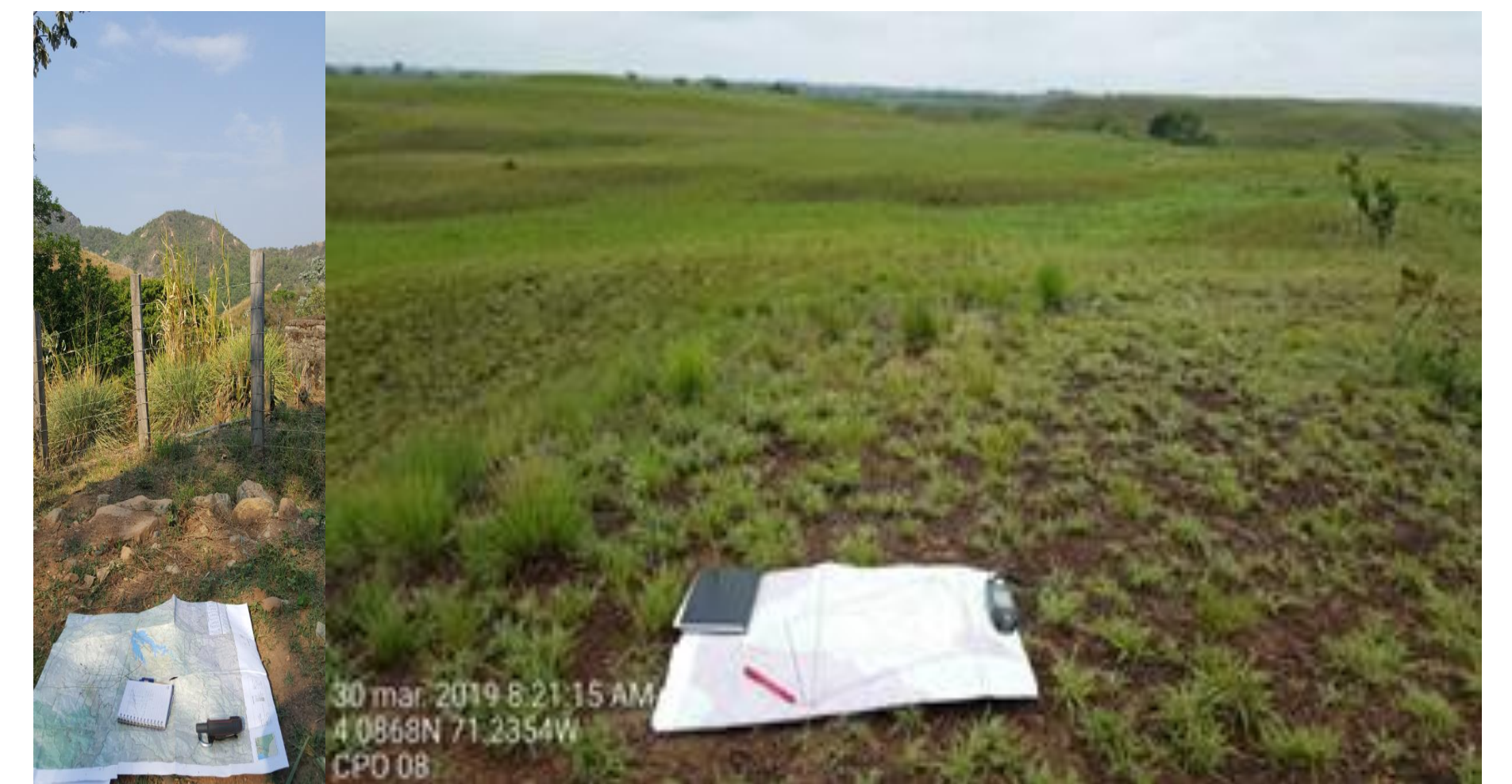


Figure 4. Identification of geomorphology and vegetal cover features for possible environmental restrictions.

2. Diagnosis per area: analysis of the situation in the block. It includes real estate (Figure 5), security, social, environmental, corporative and industry pending issues.

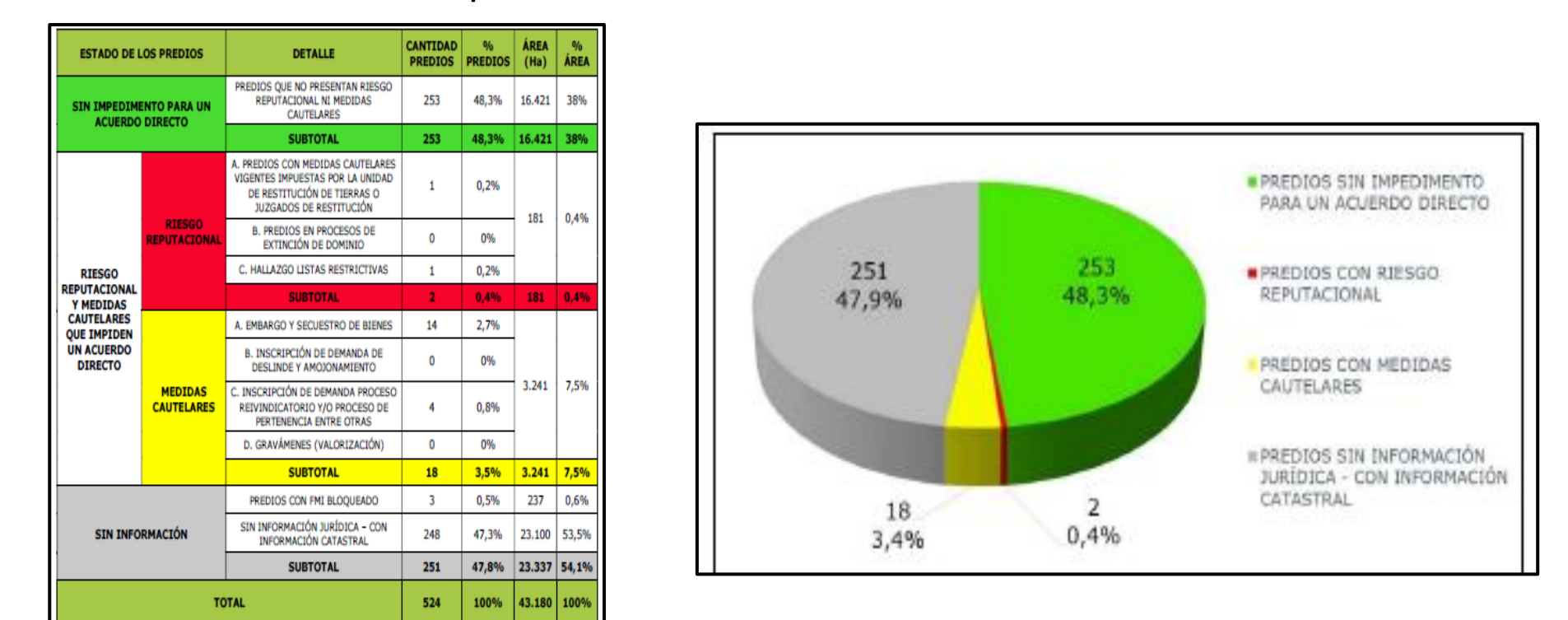


Figure 5. Real estate diagnosis.

3. Modelling and Ray Tracing: validate seismic design and acquisition area (Figures 6 and 7). During seismic operation, there is a real time control, to fulfill the requirements for an adequate target imaging.

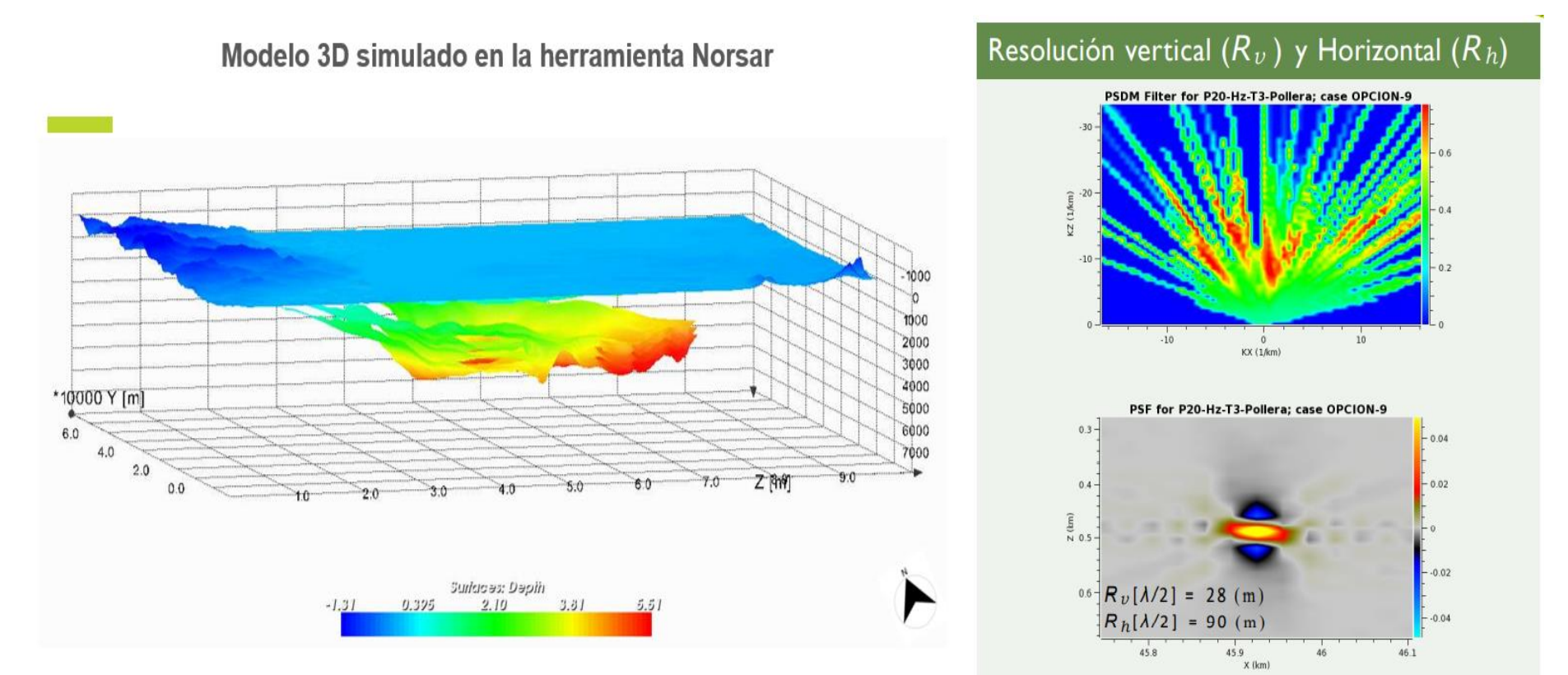


Figure 6. Modelling construction.

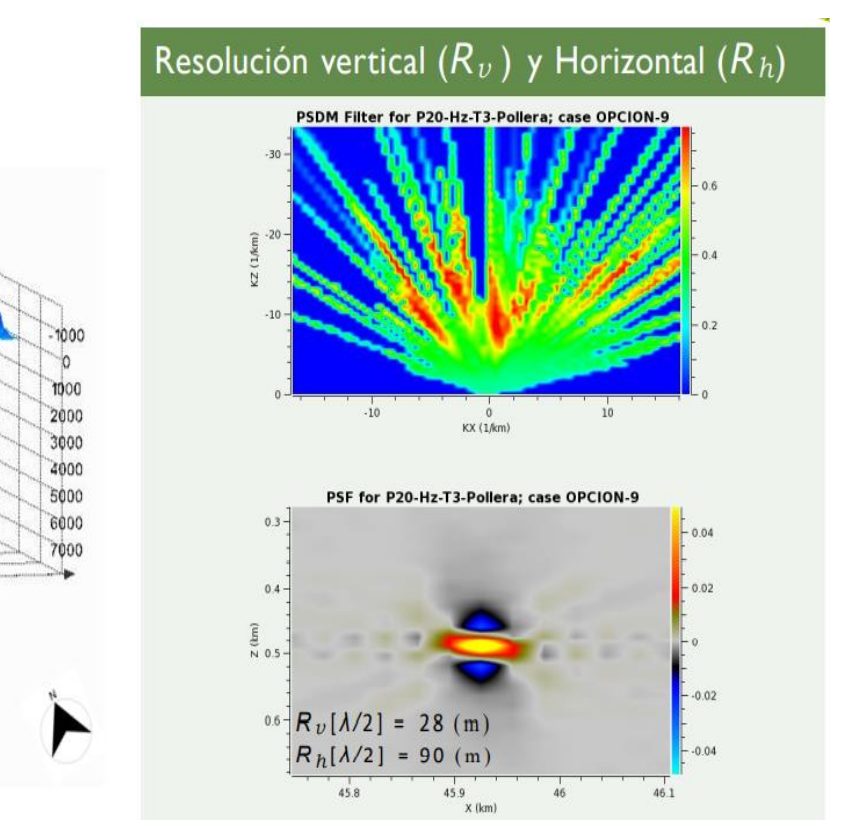


Figure 7. PSDM filter and their PSF associated.

4. Geometry reconstruction (Compressive Sensing): to fill some data gaps and get some reliable interpretable data (Figure 8).

The purpose of this technique is to use in the reconstruction of the acquisition geometry.

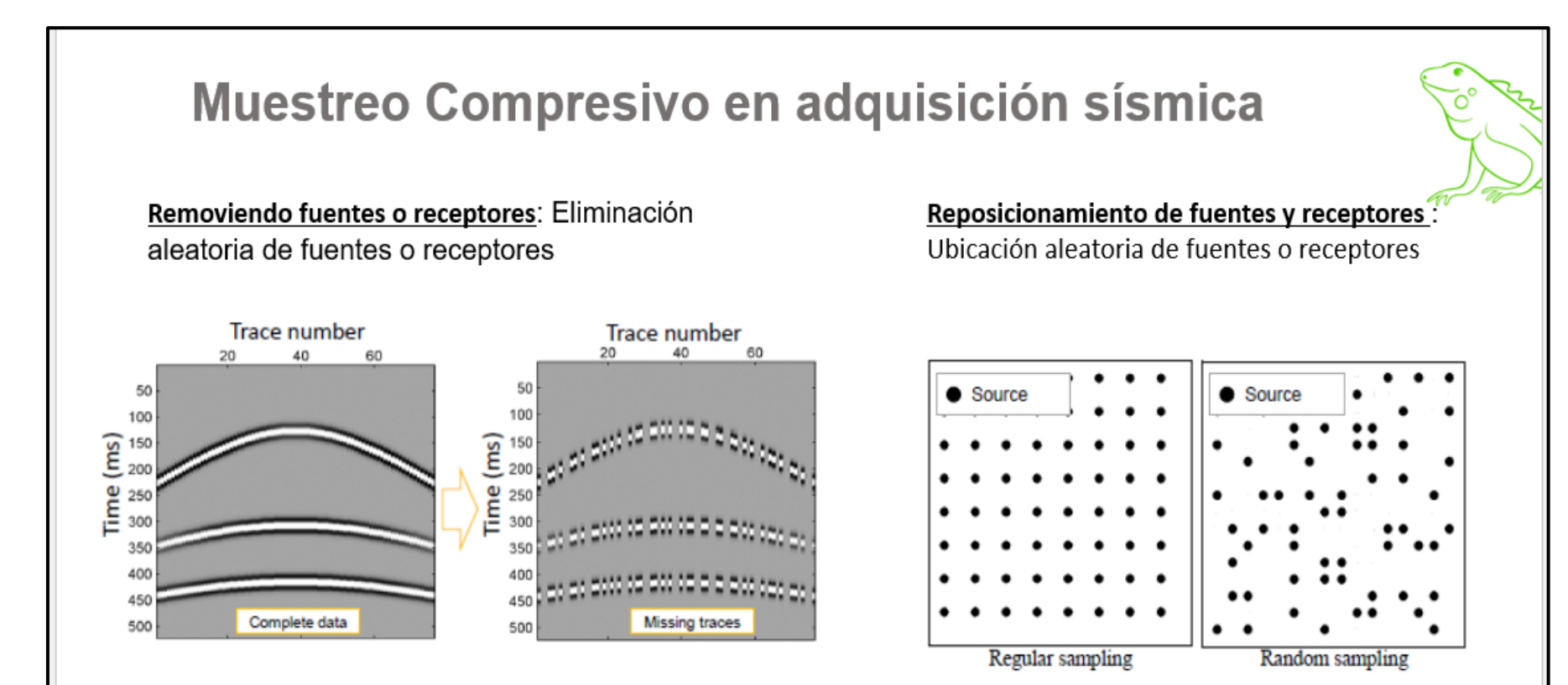
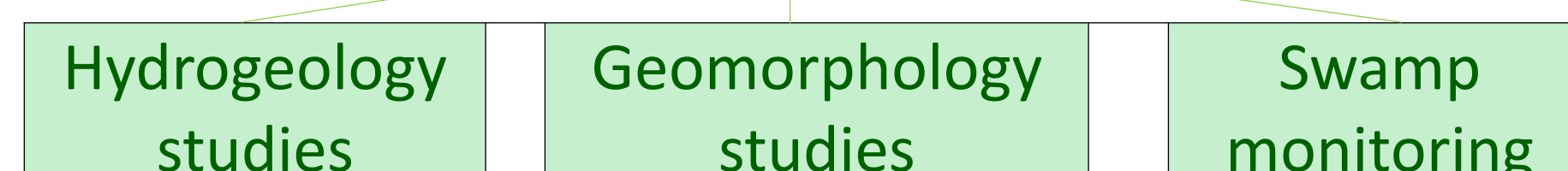


Figure 8. Compressive sensing sample in seismic acquisition.

SURVEY



5. Hydrogeology studies:

Characterize shallow aquifer zone and seal clay layers that must be considered in the shot point distribution. (Figure 9).

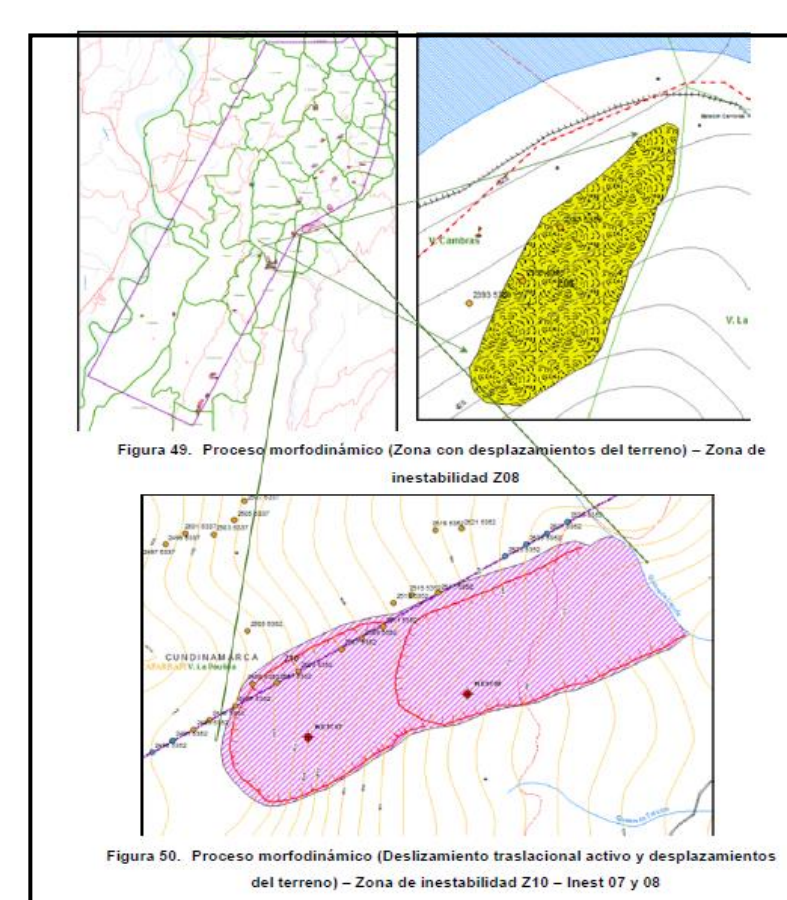


Figure 9. Conceptual hydrogeologic model. VMM-32 3D.

7. Swamp monitoring: evaluation of the environmental impact to be generated by seismic operations, the management and impact mitigation measures, control points and recommendations.



Figure 11. Examples of swamp monitoring.

STRATEGY

DECARBONIZATION

- Effective data storage.
- Usage of clean energy in the project.
- Environment-friendly supplies.
- Less document printing.
- Water usage.
- 3R campaign (reduce-reuse-recycle).
- Ecological reforestation.
- Lidar data integration with field topography, for preplot adjustment proposal before field phase (Figure 12).
- Wireless and nodal recording equipment.
- Electronic detonators.
- Use of drones.
- CS implementation (Compressive Sensing).
- Decrease in CO2 generation due to optimization of personnel and equipment transportation.

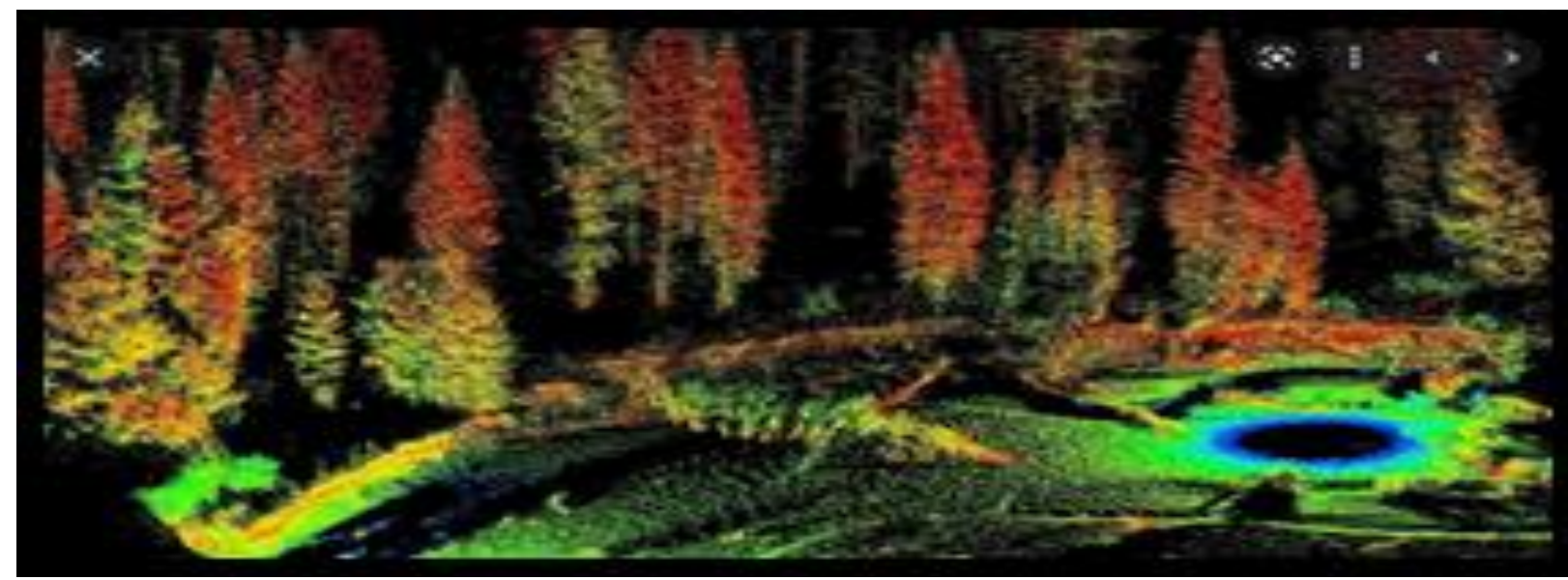
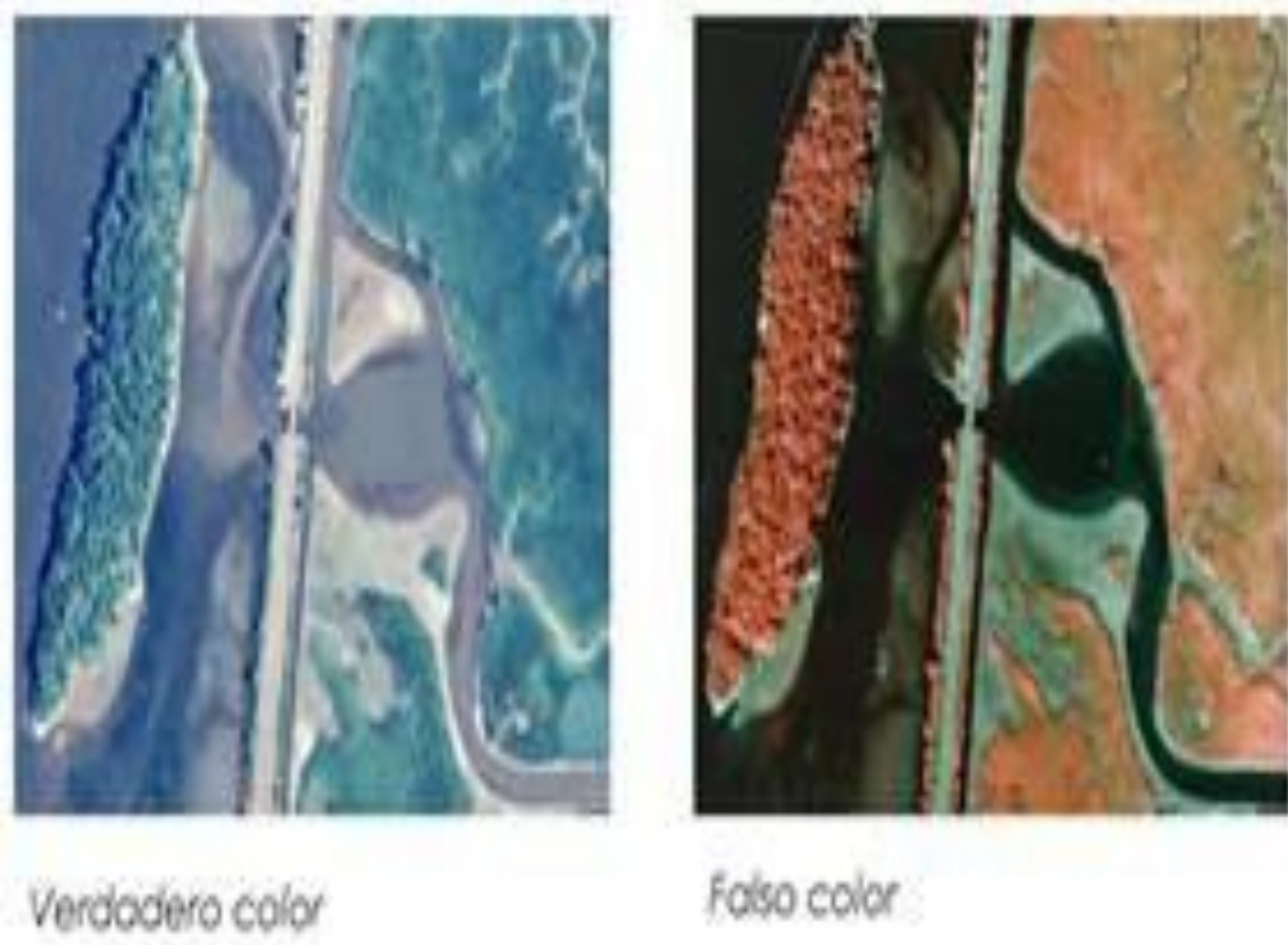


Figure 12. Lidar examples.

TECHNOLOGIES

- Drones:** they can be used in several activities (Figure 13):
 - Scouting of working areas.
 - Benefit in cost, time and opportunity.
 - Support in socio-environmental sensitive areas monitoring.
 - G&G scouting in areas with physical security problems.
 - Logistical support of the work areas in the execution of the seismic program (Figure 14).



Figure 14. Use and features drone in seismic operation activities. Fuente: <https://mundocontact.com/drones-que-ayudan-a-salvar-vidas/>

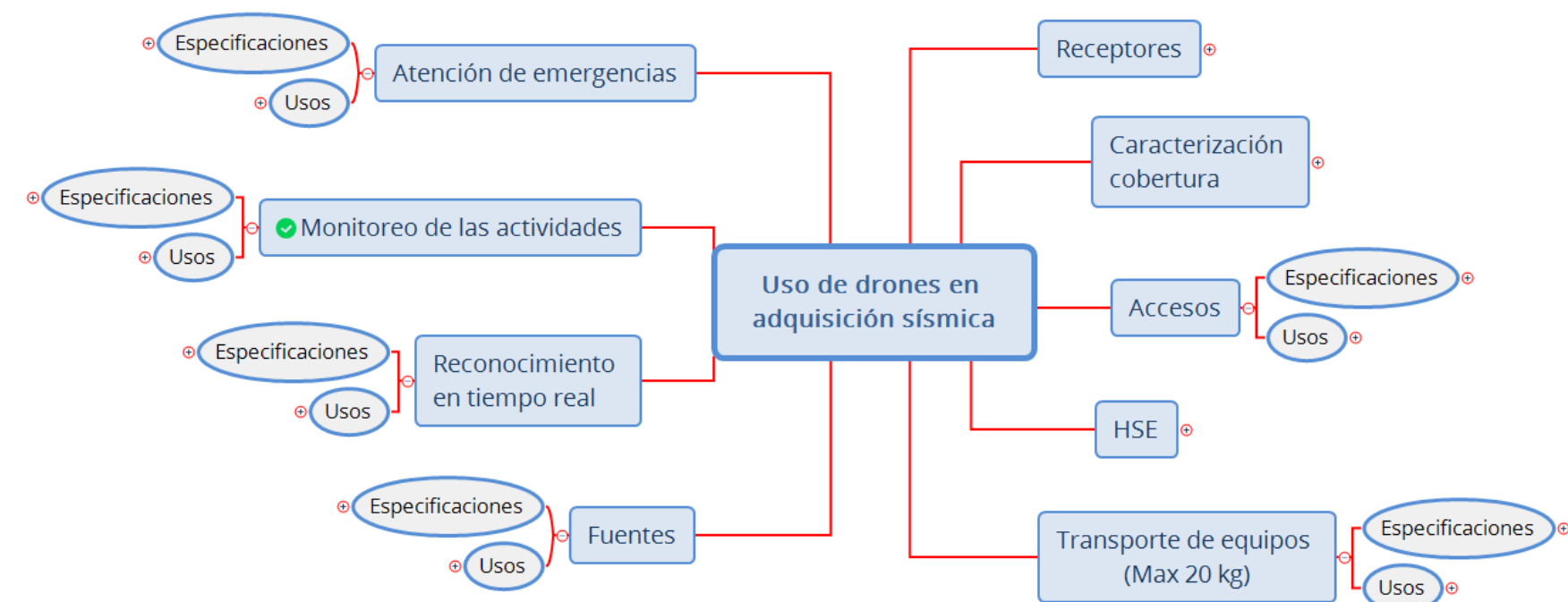


Figure 13. Use and features drone in seismic operation activities.

- Unique - nodal geophones:** it allows to minimize the impact on working areas (table 1), by reducing load size and good management of logistics (Figure 15).

No. Channels	32	
Equipment	Conventional	Wireless
Weight (kg)	320	21

Table 1. Comparison between conventional and wireless recording equipment.



Figure 15. Different types of wireless and nodal geophones. Fuente: <https://www.directindustry.es/prod/sercel-inc/product-137881-1920015.html>

SOCIO-ENVIRONMENTAL MANAGEMENT

Learning talks with environmental authorities and communities, starting from early times (Figure 16). We highlight the following:

- Close relationship among all the parties, provide trust in seismic operations, looking after of the environment and communities' concerns.
- Planning of early social investment, trying to support and help the needing of all communities, following Ecopetrol S.A. instructions.
- Being inclusive in labor participation, with training in the technologies to be used.

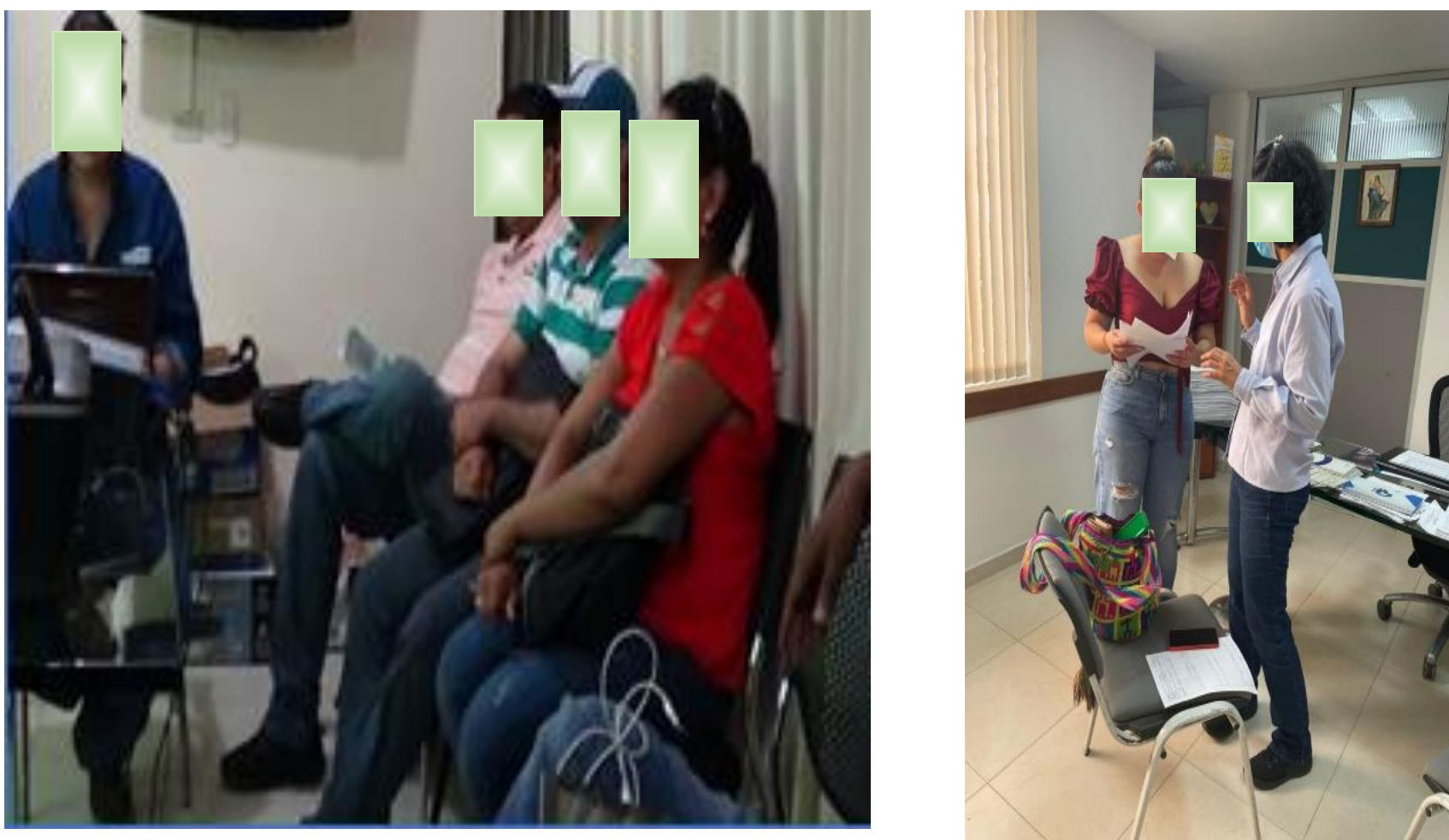


Figure 16. Learning talks with communities and local authorities.

DISCUSSION

Cost saving by parameters optimization, from modeling and ray tracing.

Seismic design option review and choose the best option from modeling and ray tracing results (Table 2).

DISEÑO	LINEAS FUENTE		
	Convencional, Fuente sísmica	Convencional, Fuente sísmica combinada	HD, Fuente sísmica combinada
INTERVALO ENTRE LINEAS (m)	480	480	320
INTERVALO ENTRE ESTACIONES (m)	80	80	320
DENSIDAD DE FUENTES / km²	42	27	10
TIPO DE FUENTE	Sismigel	Sismigel / Vibro	Sismigel / Vibro
PORCENTAJE, %	100	80 / 20	80 / 20
LINEAS RECEPTORAS	PATCH		
	Convencional	Convencional	HD
INTERVALO ENTRE LINEAS (m)	480	240	40
INTERVALO ENTRE ESTACIONES (m)	40	40	40
TRACE DENSITY	160000	275000	562500
NÚMERO DE LINEAS POR PATCH (Und)	40	40	240
NÚMERO DE CANALES POR LINEA (Und)	300	264	240
NÚMERO DE CANALES POR PATCH (Und)	4000	10560	57600
OFFSET MAXIMO (m)	3473.76	7040	7040
FOLD TOTAL	100	220	225
ARREGLO DE GEÓFONOS	3 / 6 / ÚNICO	3 / 6 / ÚNICO	3 / 6 / ÚNICO
ASPECT RADIO	100%	91%	100%

Table 2. Technical parameter options for a seismic project.

Geophysical model construction and ray tracing, to get illumination maps of the geological target horizons, used to optimize the area of the seismic acquisition and design geometry (Figure 17).

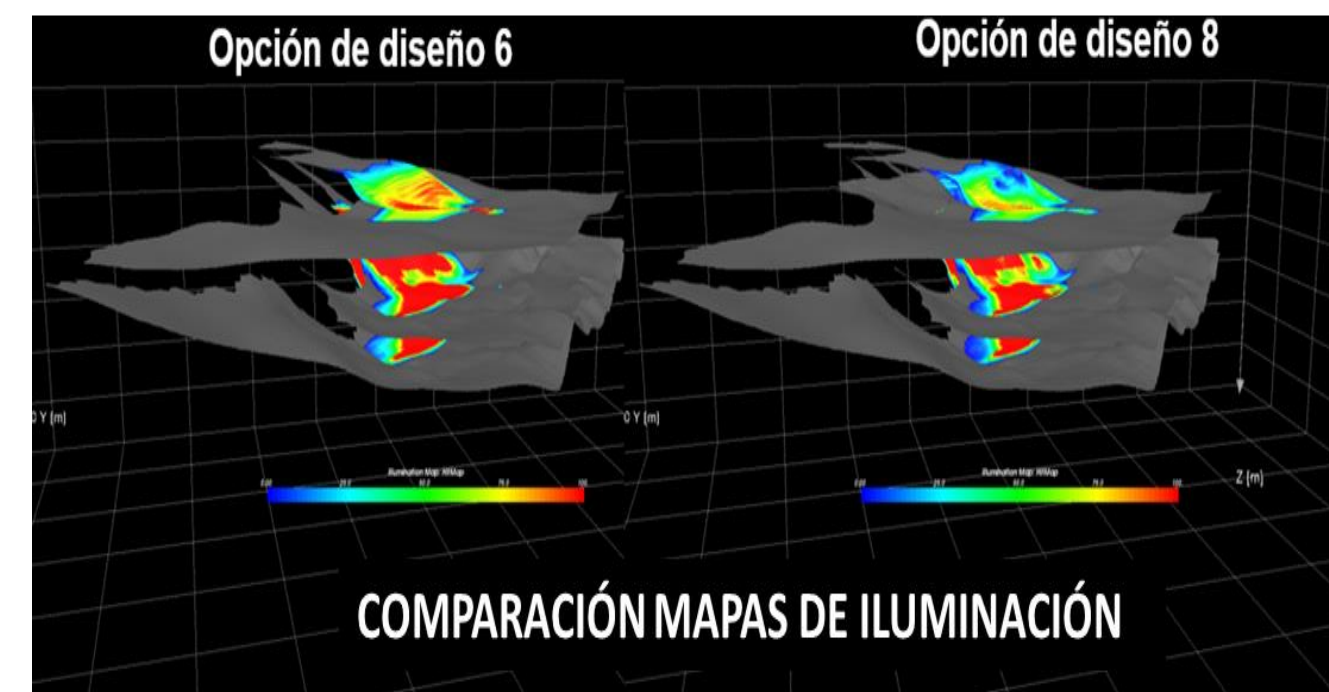
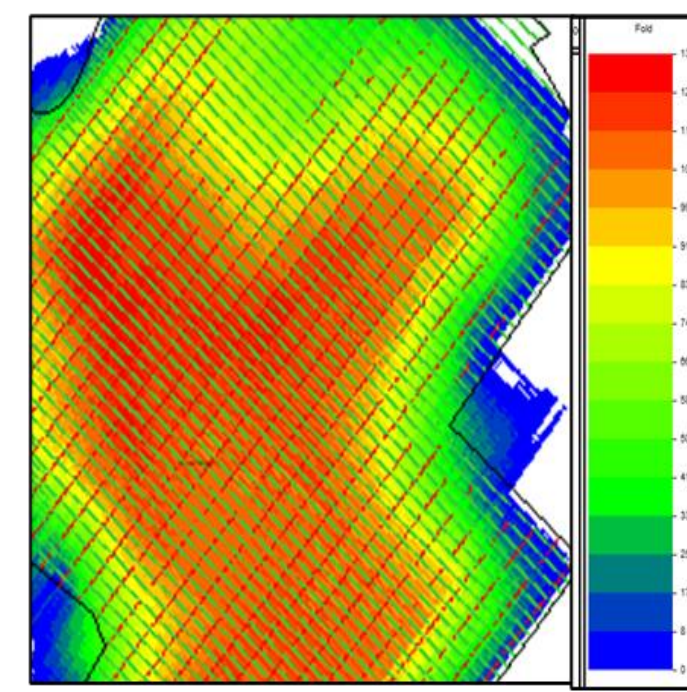


Figure 17. Fold and illumination maps from modelling.

Working with G&G characterization: how to optimize working area.

G&G scouting in early stages of a seismic project, let us not only seismic design adjustment, definition of technical and operative viability, but also helps in defining logistics (Figure 18).

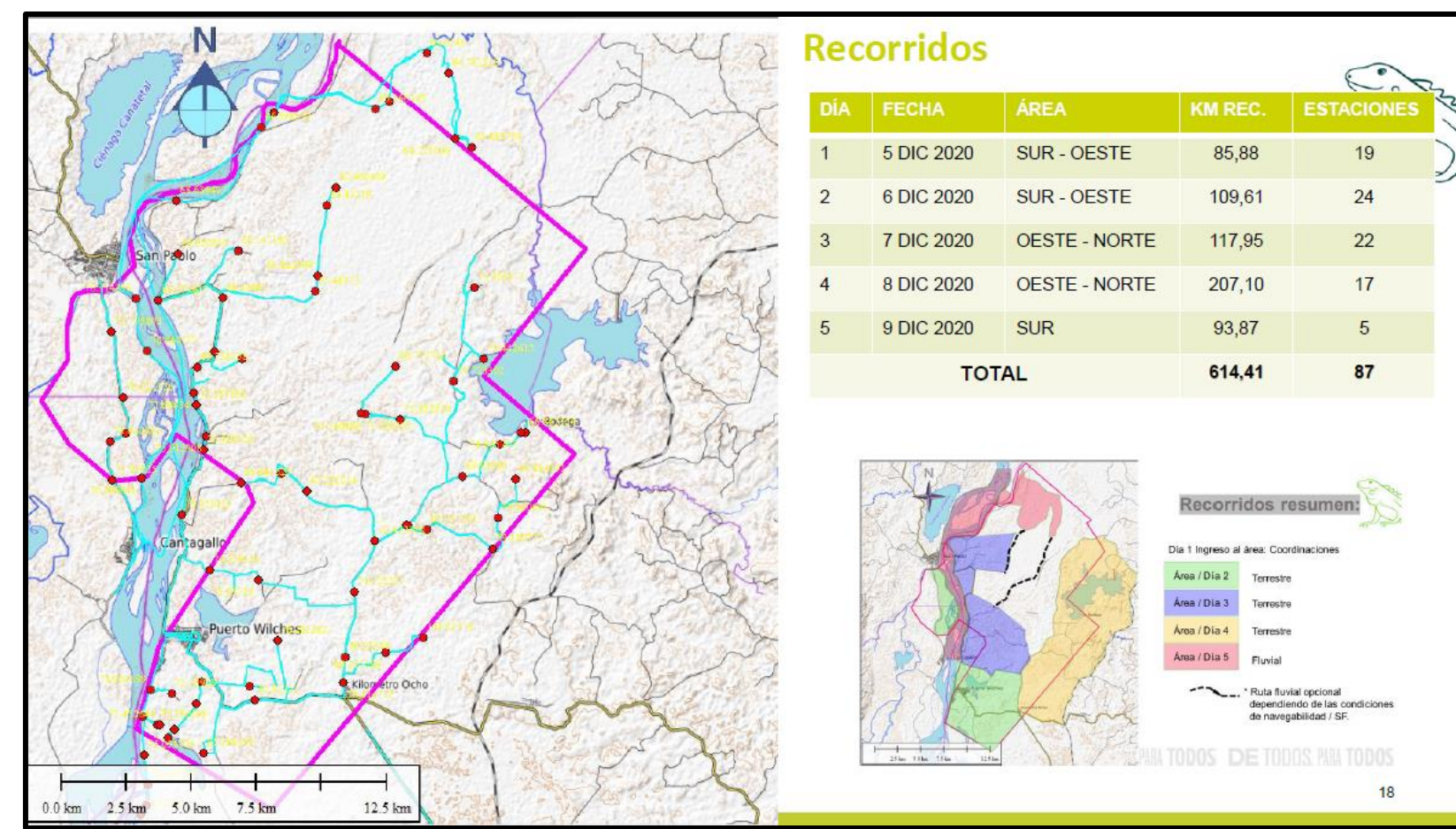


Figure 18. Scouting plan for logistics.

Socio-environmental impact.

Seismic design proposal is the result of a detailed geophysical analysis. It involves the following:

- Technologies available on the market that can benefit data quality of the seismic image and reduce environmental impact in the areas of restriction or exclusion, due to sensitive elements.
- Reduction in time of field operations.
- Monitoring of water bodies on surface and aquifers (Figure 19).
- Detection and prevention of unstable areas (Figure 20).

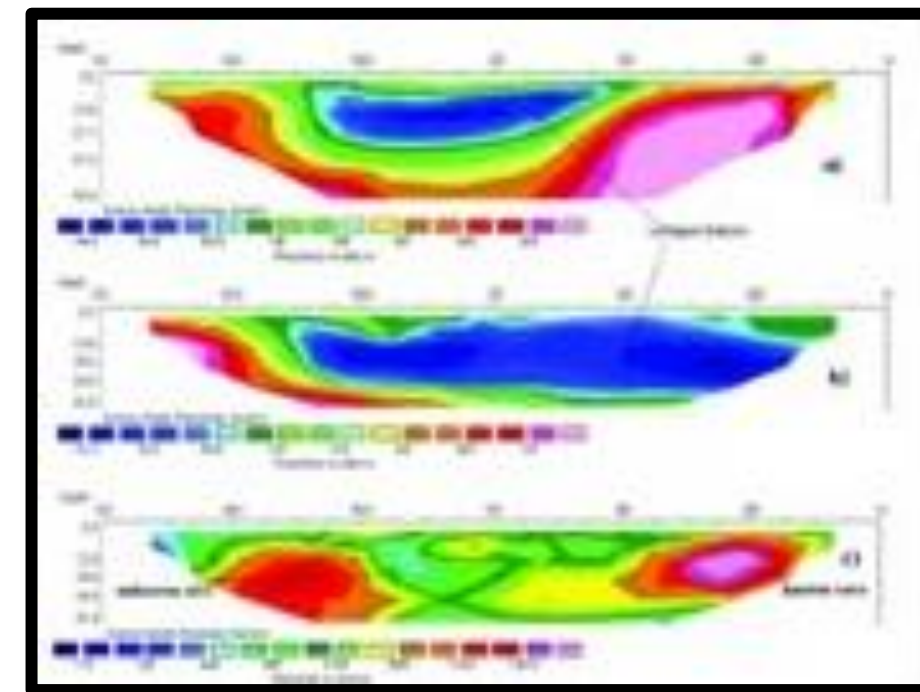


Figure 19. Aquifer identification.

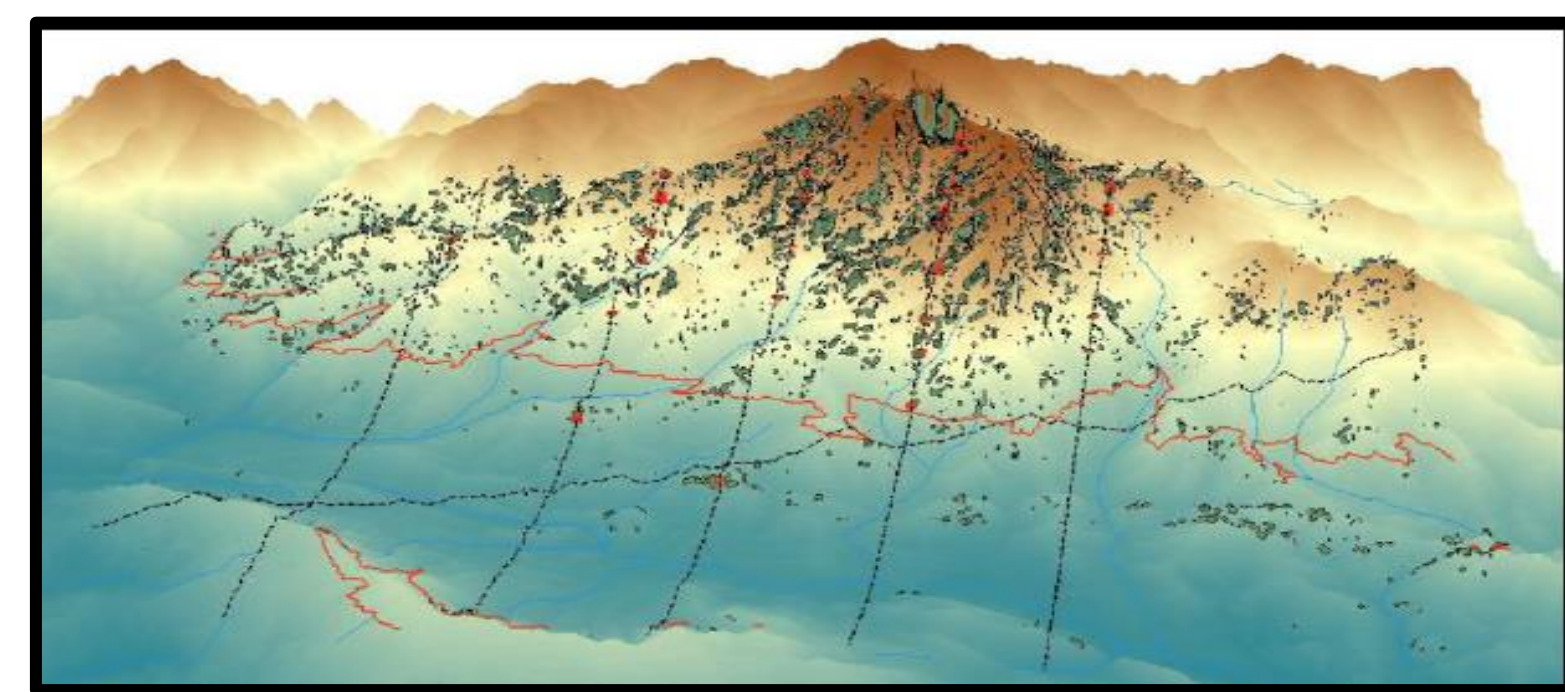


Figure 20. Slope map with 2D lines.

CONCLUSIONS

- Early identification of contingencies and solutions proposal.
- Agility in effective decision making (real time modeling and ray tracing), looking for the benefit of image data quality and Project Budget.
- Permanent communication with environmental authorities and communities.
- Cost savings associated with decarbonization activities and reduction in the generation of greenhouse gases.
- Analysis of benefits and feasibility in the implementation of new technologies in the different stages of the seismic project.
- Trust generation with communities, from training program and technology implementation.
- Seismic image with good data quality, according to chronogram and budget.

ACKNOWLEDGMENTS

The authors want to express their gratitude to Ecopetrol S.A. for the permission to produce this publication. Special thanks to the Exploration Vice-presidency (VEX), G&G Management, and the Acquisition Team.

In memory of Héctor Alfonso (1962-2020), who worked for more than 30 years at Ecopetrol. He gave us good advice in seismic design and imaging in order to assure the best seismic data quality. Finally, we are grateful to the Geophysics Team at the Instituto Colombiano del Petróleo (ICP), who worked very close to us in modeling and ray tracing.

SESSION TITLE: Theme 3: Offshore Reservoirs: adding E&P value

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Direct Hydrocarbon Indicators Support Prospectivity in Trujillo Basin Offshore Peru

AUTHORS (FIRST NAME, LAST NAME): David MacConnell¹, Karilys Castillo¹, Eduard Maili¹

INSTITUTIONS (ALL):

1. Occidental Oil and Gas

ABSTRACT BODY:

Abstract Summary: The Peruvian offshore Trujillo Basin is an under-explored frontier region with significant exploration potential. Many Eocene age low-impedance seismic anomalies, associated with apparent flat events, have been identified on 3D seismic volumes and, to a lesser extent, on sparse 2D seismic data.

Regionally, exploratory wells have been located on paleo-structural highs and have not targeted the Eocene turbidite facies which are focused in the basin centers. The amplitude anomalies strongly suggest the presence of hydrocarbons and, by extension, provide supporting evidence for the presence of reservoir and seal pairs as well as a working hydrocarbon system. Seafloor piston core data suggest the presence of both Cretaceous and Tertiary-aged oils and thereby contribute additional evidence and further reduce the risk of a discovery. In some prospects the (interpreted) fluid contact crosses both stratigraphy and faults, suggesting that the reservoirs may be relatively high net/gross.

The Miocene is not the most prospective sequence in the region – with high play risk for both reservoir and seal. However, in at least one instance, a high-impedance Miocene target exhibits dimming in an updip position and appears to conform to structure. This feature is interpreted to represent a well-imaged Miocene shoal complex. High-impedance reflectors typically represent highly compacted and/or cemented clastic rocks or other lithologies such as salt or limestones; however, if the rocks are porous, and pore spaces are filled with low-density fluids or gas, then the overall density can be reduced to generate a dim spot where hydrocarbons are present. Miocene targets could represent another new play type in the deeper offshore basins along the Peruvian margin. Future plans include the possible acquisition of new 3D seismic data which will add much needed data to develop these concepts across a broader area.

SESSION TITLE: Theme 1: Stratigraphy & Reservoir Studies I

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Comparing interpolation algorithms in hypothetical fluvial scenarios

AUTHORS (FIRST NAME, LAST NAME): Hector Campos², Paula Ataniya¹, Marcio Armisen²

INSTITUTIONS (ALL):

1. RFD

2. YPF

ABSTRACT BODY:

Abstract Summary: Paula Daniela Ataniya. RFD support.

Héctor Javier Campos. YPF EOR Development Geologist.

Marcio Raul Armisen. YPF EOR Development Geologist.

Making predictive 3D static-dynamic models for fluvial successions, in Golfo de San Jorge Basin (south of Argentina) can be a difficult work: mature fields with more than 500 wells each and more than 1000 mts of vertical stratigraphic column. Most of the time requires lots of modeling work, resources and time, for representing geological conceptual models that has to fits all the dynamic data. Populations of porosity are also important and tend to be strongly trended by the facies distribution, being the facies population the main question to be solved in a typical modelling workflow. Nowadays, we count with many property interpolation methods to represent facies distribution. For fluvial successions, interpolation methods are supposed to illustrates both, vertical and lateral heterogeneity, and its resultant connectivity. Trying to find the best interpolation method to populate fluvial facies can be something tricky. Uncertainty in the 2D subsurface fluvial facies distribution is by far the most important issue to be unraveled and quantified by static models. Main challenge for testing algorithms is they have to represent something that we actually don't know with certainty. The use of real field scenarios for testing population algorithms, in which "reality" is unknown, and worst, relative to the amount and type of data that is being used (well logs, core data, seismic) can leads to undesirable answers. But what if we had a real picture of the fluvial reservoir and its facies distribution: one that show us exactly what the model must represents. In that case we would bypass the uncertainty related to that, and we could actually know which algorithm fits bests to our picture/concept. In this analysis we assume that we know how our fluvial subsurface system looks like. We use different satellite images to represents the fluvial systems to be modeled and with a hypothetical vertical fluvial facies succession.

We design different field developments scenarios (varying density of wells, their location and interpolation interval dimensions) and compare the resulting different interpolation methods related to the hypothetical reality. We also test the prediction power of each interpolation method with proposal wells and, as we know how the reality is, we can determine which is the most accurate interpolation method.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences II

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Technical and Sustainable Waterflooding Solutions in a Mature Oilfield: Water Source Wells and Dumpflooding Solutions

AUTHORS (FIRST NAME, LAST NAME): Nestor Vasconez¹, Alba Meneses¹

INSTITUTIONS (ALL):

1. Schlumberger

ABSTRACT BODY:

Abstract Summary: Before the expansion to field level of a waterflooding project, a water injection pilot is evaluated to prove the concept, but this requires important facilities investments and construction time. With the objective of reducing investments and execution time, the current document describes technical and sustainable solutions for the expansion of a waterflooding project in a mature oilfield. The solutions cover the options for converting existing wells into water source wells and the application of a successful modified dumpflooding strategy.

The technical and economical solutions for this mature field, took advantage of a deeper low salinity aquifer with excellent water quality to produce the needed volumes of water from existing oil wells. Depending on the water rates needed, different fit for purpose alternatives are available to assure the volumes of water needed for the injection point. The plan also created a modification from the original Dumpflooding concept. A closed system was designed to produce water from the aquifer to surface through an ESP, designed to deliver a wellhead pressure up to 2,500 psi to be used also as injection pump. At surface, the water volume is measured by a flowmeter and then injected into the same well through a concentric string.

In parallel with the success and lessons learned from water source well options, six wells have been successfully completed using this novel dumpflooding design which allowed to accelerate the implementation of the waterflooding strategy where there are no water sources or pipelines to feed the secondary recovery strategy. The implementation time of waterflooding pilots decreased from around 3-5 years to 5-7 months. Engineering, procurement and construction of water treatment plants and long high-pressure lines were not needed resulting in minimum environmental and social exposure, and a reduction of surface facilities capital expenditure of 80%.

Any field operation independently from its location; jungle, desert or offshore, must have as one of its milestones the environment protection. This solution, in addition to achieving the technical requirement, brings a large environmental benefit by avoiding the need to build new pipelines and water treatment plants for the expansion of the waterflooding project.

SESSION TITLE: Theme 3: Offshore Reservoirs: adding E&P value

SESSION DAY & DATE: Thursday, April 21, 2022

SESSION TYPE: Poster

TITLE: Accelerated Field Development Plan – AFDP

AUTHORS (FIRST NAME, LAST NAME): Luis Mendoza¹, Pedro Ramirez¹, Oscar Quintero¹, Atahualpa Villarroel¹

INSTITUTIONS (ALL):

1. Schlumberger

ABSTRACT BODY:

Abstract Summary: Design of a digital solution based on an integrated workflow which allows to generate automated field development plan (FDP) considering any uncertainty regarding to modelling (Static and dynamic) and field management. This solution reduces the working time drastically (from months to weeks) and delivers probabilistic profiles ranked with an economic approach using net present value (NPV) at field level but also at well level using innovative tools.

This solution was created through an integrated process using workflow editor and uncertainty processes within a unified modeling environment software and comprises eight main components, such as: 1. Seismic Data & Interpretation 2. Geological Model & Probabilistic Volumetric 3. Reservoir Quality Index and Sweet Spot Screening 4. Well Placement & Trajectory Evaluation 5. Results Analysis & Selection Criteria 6. Production Forecasting 7. Probabilistic Well Ranking 8. Risk Identification & Mitigation Plan.

A flexible workflow which can be adapted to any condition of reservoir characteristics or economical constraints reducing the duration to generate FDP under uncertainty for brown or green field from months to weeks or days. This solution was applied in an extra heavy oil field with 3 producer zones, 128 Km² of area and 22 existing wells. It allows us to perform an uncertainty analysis with 100 realizations in a record time of 8 hours, sensitizing the cutoff of simulation opportunity index, maximum and minimum horizontal length, wells spacing, wells orientation and well trajectory type (horizontal, vertical, deviated). In average, 300 wells per case were proposed automatically by the workflow in the targets found; reducing the execution time (from months to weeks) using High-Resolution Reservoir Simulator (HRRS) was the most remarkable achievement because it combines domain expertise and advanced digital technologies (ADT). Additionally, NPV estimation and analysis helped to accelerate return of investment and profitability through a probabilistic well ranking based on economic variables and uncertainties. This solution has been applied in naturally fractured reservoir with excellent results in terms of profitability and execution time.

This methodology allows to quantify subsurface uncertainty and support business decision with hundreds of executions through a probabilistic approach. The integration with economic indicators (ROI and NPV) strengthens selection of best field development plan concept

FRIDAY
22 APRIL 2022
ORAL PRESENTATIONS

SESSION TITLE: Theme 1: New and Emerging Plays I

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Hydrocarbon Potential of the Bolivian Madre de Dios Basin

AUTHORS (FIRST NAME, LAST NAME): Frédéric Schneider², Raul Mayta¹, Stéphane Rousse³, Jorge Gutierrez⁴, Djowan Thomas⁵

INSTITUTIONS (ALL):

1. YPFB
2. Beicip-Franlab
3. Beicip-Franlab
4. YPFB
5. Beicip-Franlab

ABSTRACT BODY:

Abstract Summary: The Madre de Dios Basin, located in the northern subandean zone of Bolivia, is an under-explored basin. A complete stratigraphic revision including biostratigraphy, core description and seismostratigraphy has been carried out, suggesting some changes in the historical sedimentary models, and allowing the identification of several reservoir and seal pairs. The geochemical study indicates the existence of an Upper Devonian world-class source rock, in which, the Frasnian interval is characterized with a type I-II kerogen and an SPI higher than 6 t/m²; the Famennian interval has a type II kerogen, and its SPI reaches 3 t/m². The main challenge of the basin remains in finding traps.

3D simulations of stratigraphic and sedimentary processes provided maps of net sand thickness and seal distribution all over the basin. A subtle tectonic event was identified defining a new potential play in the Madre de Dios basin originating from a mild regional structuration inducing structural traps. Additionally, the model shows the existence of large stratigraphic traps within the Silurian and Devonian deposits.

A 3D dynamic model of the basin has been built. The thermal calibration of the temperature and maturity data is only possible considering an increase of the heat flux during Permian-Triassic time. Therefore, 90% of the hydrocarbons are expelled by the identified kitchen in the center of the basin, before cretaceous times. The remaining 10 % were expelled between the Oligocene and present time. Considering a Petroleum System Yield of 5%, the mean yet to find of the studied area is evaluated at 25 Bbbl of oil.

In order to mitigate the uncertainties, it has been designed a set of exploration activities including seismic acquisition, gravimetry, magnetometry, surficial geochemistry and stratigraphic wells.

The preliminary results of the first stratigraphic well are in good agreement with the prognosis and hence confirm the results of the stratigraphic and the basin modelling leaving the petroleum potential of this area unchanged and reducing the uncertainties.

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Overpressure in the Sinú Offshore basin, Knowledge and uncertainties

AUTHORS (FIRST NAME, LAST NAME): Darwin Mateus¹, Marcelo Garcia², Linda Montilla³

INSTITUTIONS (ALL):

1. Ecopetrol-ICP
2. Ecopetrol
3. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Pore pressure prediction is a critical issue for well planning in offshore operation due to the risks to cause both rig damage and oil spills to environment. Therefore, since 1950s, several methodologies for pore pressure and fracture prediction have been developed for the industry. Most of them consider the mechanism of compaction as the main cause of overpressure, ignoring other factors such as, tectonics stresses, boundary conditions, and pressure dissipation during geological evolution.

In the Colombian Caribbean margin, drilling operation have faced different pressure setting from hydrostatic condition (Chuchupa Field) to areas in which pressure reaches around 90% of the vertical stress (Fuerte-1 well). Overpressure conditions have generated additional costs greater than 50 MMUSD in the most critical cases. On the other hand, geological models for the Sinú offshore basin have not even established a relationship between overpressure conditions and geological characteristics such as sedimentation rates, Chrono-stratigraphic events or structural provinces. Therefore, pore pressure prediction is not a trivial assignment in this area.

The main objective of this work is to analyze overpressure occurrence in the Sinú offshore basin taking into account different scale tools. Well logs, seismic interval velocity and 2D basin modelling were used to identify overpressure zones. From those analysis it is suggested that the highest pressure accumulation is located in the youngest area of the Sinú deformed Belt, into units beneath Pleistocene - Pliocene. Likewise, the model suggests that overpressures are related to variation of compressive stresses associated with events of deformation from the Pleistocene to recent period. This work have been integrated into seal risk analysis in the Caribe Sur area.

SESSION TITLE: Theme 1: Reservoir Studies II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: An Approach to Integrate Petrophysical and Rock Physics Modeling for Hydraulic Stimulation

AUTHORS (FIRST NAME, LAST NAME): Jesus Pastor Salazar Rodriguez¹, Claudio Rabe², Andres Rodriguez Papa³

INSTITUTIONS (ALL):

1. Baker Hughes
2. Baker Hughes
3. Observatório Nacional

ABSTRACT BODY:

Abstract Summary: Currently, shallow and light-oil reservoirs can be difficult to find out and for this reason, oil and gas operators are exploring and developing complex, risky, and therefore costly reservoirs. This is the case of the Tamabra carbonate formation in México, which have gained relevance as potential reservoir for hydrocarbon production.

Petrophysics is one of the most fundamental tools for the industry of oil and gas exploration and production because its main objective is to estimate different petrophysical properties of the rocks to describe the potential of production of a hydrocarbon reservoir. Another important science behind is Geomechanic, which provides useful information for the best well location, drilling trajectory, optimum mud density, hydraulic stimulation design and to optimize well completion based on the stress field analysis, rock mechanical properties and formation pressure.

This study presents a strategy to assess the petrophysical and geomechanical rock properties to guarantee the optimal productivity from the Tamabra carbonate formation, located in the Tampico-Misantla basin in Mexico. This is based on the integration of petrophysical and rock physics models. The petrophysical model includes the determination of the pore throat radius, which defines the flow capacity through the pore space because it is an indicator of the connectivity between them. This pore throat radius is calculated using an equivalent Pittman equation corresponding to a mercury saturation of 50% (r_{50}) that is considered the best predictor for carbonate formations in general. The rock physics model includes the determination of Young's modulus and Poisson's ratio from acoustic and density log for brittleness estimation. This brittleness is integrated with fracture toughness and fracture gradient to generate the geomechanical model. Fracture toughness and fracture gradient are estimated from acoustic and density log as well as different petrophysical properties such as shale volume and porosity. The results of integrating the interpretation of the pore throat radius as petrophysical property to define the best zone for fluid flow is integrated with the geomechanical properties, improves the selection of the best zones for hydraulic stimulation and optimization of the strategy for sweet spot determination in the Tamabra Carbonate formation. This approach is validated with the results of the fracturing operation performed in different intervals.

SESSION TITLE: Theme 1: Reservoir Studies II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Tectono-Stratigraphic Modelling of Reservoir Rock Units: A case study of South Lake Albert Basin, Albertine Rift, Western Uganda.

AUTHORS (FIRST NAME, LAST NAME): Wilson Mbile Tumushabe¹

INSTITUTIONS (ALL):

1. Ministry of Energy and Mineral Development, Uganda

ABSTRACT BODY:

Abstract Summary: The study area, South Lake Albert Basin (SLAB) is part of the Albertine graben. The Albertine graben is the northernmost part of the western arm of the East African Rift System (EARS). The study majorly focused on interpretation of three-dimension (3D) seismic and suites of wireline log datasets, construction of 3D models and facies analysis to assess the tectonic and stratigraphic settings. Challenges and uncertainties of low to moderate porosity, permeability and high volume of shale i.e., poor reservoir parameters attributed to limited understanding of depositional and tectonic orientations had been highlighted in the study area. Thus, the major aim of the study was to investigate the tectono-stratigraphy of Early Miocene to Upper Pliocene section with specific objectives of (1) understanding the structural-stratigraphic-depositional setting orientation and (2) facies analysis. This study has discovered that the area is structurally complex with compartments and flower structures majorly in the Kaiso Tonya area. The study identified flower structures and different compartments which were separated by different normal faults and adjudged as highly compartmentalized. Also, the sedimentological interpretation conducted, identified that sediment deposition in area was highly intercalated (interbeds of different lithofacies i.e., there were thin lithofacies with different interbedded lithologies (clay, silt, fine and coarse sands) deposited at shorter intervals that was majorly attributed to the short changes in climatic (wet and dry) conditions that happened over time during the sedimentation process. The identified compartmentalization and intercalations of sediments has a very high effect on the reservoir rock properties.

SESSION TITLE: Theme 1: New and Emerging Plays I

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Guajira Interior Rift Basin and the Iguana Rift: Two New Prospective Petroleum Provinces Along the Offshore Caribbean of Colombia.

AUTHORS (FIRST NAME, LAST NAME): John Londoño¹, Eduardo Lopez-Ramos², Luz Marina Duarte³, Felipe Gonzalez-Penagos⁴, Oscar Marín⁵, Fredy Cañón⁶, Pablo Porras⁷

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Two likely Mid-to-Late Cretaceous rift systems have been identified along the northern Colombian offshore Caribbean waters. The Guajira Interior Rift Basin (GIRB), eastward from the Colombian Basin, a proto-Caribbean relict with a basement fabric resembling a continent-ocean transition, block-tectonics and depocenters exceeding 6000 meters of sedimentary-cover, appears to mark the initial separation between the north and south American blocks, where Triassic and Jurassic continental basement is found along both autochthons. Potential Late-Cretaceous world-class source rocks could be present along the deepest parts of the basin, where oil-prone thermogenic generation could be taking place since Late-Miocene. An over-pressure regime affecting upper Paleogene and deeper sedimentary successions is probably responsible for the lack of pervasive evidence of this petroleum system, from which only scarce evidence as fluid inclusions, mud volcanos and piston-cores have been recovered. Four-way closure structures and abundant evidence of coarsed-grain deepwater deposits, including bottom current reworked-sands, complete a set of potential plays that remain untapped along this promising frontier basin. The Iguana Rift System (IRS), along the Colombian Basin appears to be a Late Cretaceous – Early Paleogene lithospheric thermal event (a rift system?), whose crustal stretching factor β exceeds 3. It extends from the southernmost tip of the Beata Ridge southwards, hundreds of kilometers, in to Panamenian waters. This rather linear regional feature exhibits a thick sedimentary sequence, that according to some DSDP-well correlations could include Late Mesozoic potential source rocks with high TOC. Regional studies, as well, suggest that some deepwater feeders, including the northernmost part of the Cauca-Magdalena Fan, and recently the Aguja and Palomino canyon systems, have been transporting sand-prone sediments up to 300 km into the basin. Abundant MTCs, what appear to be four-way closure structures, and some DHIs complete a set of elements needed to conform a potential petroleum system along this intriguing new regional tectonic element. Water columns exceeding 3800 meters add a technical challenge to this unexplored area covering more than 180.000 km².

Although still uncertain, some tectonic models suggest a common genetic origin associated to the proto-Caribbean opening during Mid-Cenozoic time for these enthralling new features.

SESSION TITLE: Theme 1: New and Emerging Plays I

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Multi – basin look at the Oligo – Neogene carbonate play in the South Caribbean margin of South America

AUTHORS (FIRST NAME, LAST NAME): Juan Francisco Arminio¹, Carlos Giraldo¹, Marel Sanchez²

INSTITUTIONS (ALL):

1. U3 EXPLORE

2. Actus Veritas Geoscience

ABSTRACT BODY:

Abstract Summary: Look back studies help review exploratory concepts in light of recent advances. With a regional look focused on critical elements of the petroleum system, we present here a review of the Oligo – Neogene play of carbonates and related clastics present both offshore and onshore in the South Caribbean and hosts gas accumulations that range from small to medium and giant in five basins of Colombia and Venezuela.

The play forms in isolated basement highs with reservoirs found in Late Oligocene to Early Miocene carbonates and associated slope sands, sourced and capped by massive Miocene shales. Eight commercial accumulations and three discoveries had been registered, with approximately 21 TCF of gas in place distributed in five clustered Neogene basins: Lower Magdalena, Lower Guajira, and Upper Guajira in Colombia and Golfo de Venezuela, Urumaco, and La Vela in western Venezuela.

Play analogs were found in the exhumed Falcon basin of western Venezuela and the Guajira peninsula in Colombia. These Neogene basins are genetically related and likely formed by the tectonic collapse of Paleogene orogens. Basin subsidence initiated with pervasive normal faulting of the accreted substrate and continued in the Miocene when subsiding basins were filled with marine shales.

Renewed compression in Miocene–Pliocene caused tectonic inversion throughout the region. We estimate that an East-West right-lateral active strike-slip Oca fault is responsible for 30 to 40 km of total offset since the Middle Miocene. Primary sources for thermogenic hydrocarbons are marine Oligo – Miocene shales with significant terrestrial influence. Biogenic gas is also present in commercial volumes in some basins and light oil-proven source rock.

These Oligo – Neogene carbonates had been explored since the 1940s, with giant gas discoveries in the 1970s and more recently in 2009. When viewed in a multi-basin perspective, field size distribution and creaming curves suggest that important yet – to find volumes might be present in the region. This collaborative study from onshore to deep-water settings offers an updated framework for exploration plans for the play, honoring drilling results and highlighting critical risks of petroleum systems impacted by complex Caribbean plate geodynamics. In that sense, we think that exploratory risk could be reduced by a better understanding of controls on hydrocarbon migration and reservoir presence and/or quality.

SESSION TITLE: Theme 1: Stratigraphy and Processes

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Bottom Current Re-worked Turbidites of the Sinu Basin, Colombia Offshore, SW Caribbean

AUTHORS (FIRST NAME, LAST NAME): Nadeer Khan¹, David Reed², Neal Auchter²

INSTITUTIONS (ALL):

1. Shell - Trinidad and Tobago Limited
2. Shell Exploration and Production Company

ABSTRACT BODY:

Abstract Summary: In recent years, we've seen increasing examples of world class hydrocarbon discoveries in deepwater reservoirs that have been modified by bottom currents. One such example is the Plio-Pleistocene deepwater reservoirs of the Sinu Basin, SW Colombia, in which there are 2 multi-TCF undeveloped gas discoveries. This talk aims to describe the key seismic geomorphology characteristics of these reservoirs, the observed sedimentary facies from core, propose a depositional model for the reservoirs of interest and discuss the implications for Exploration and field development.

The Sinu Basin is in offshore SW Colombia where it is flanked on the east and west by accretionary prisms of Colombia and Panama respectively. Sediment supply through the Plio-Pleistocene is sourced primarily from the Central and Western Cordilleras and delivered to the basin via erosionally confined channel systems and gullies across the active fold and thrust belt.

Seismic mapping and attribute analysis suggest a gradation across the study area, from slightly modified sediment gravity flow geometries up-slope, near the deformation front (laterally compensating lobes) to completely re-worked bottom current geometries downslope (sediment waves stacked into composite bodies). Cores within the up-slope area show sedimentary characteristics that suggest re-working – rare normally graded sandstone beds, bed-top erosion overlain by mud, silt and scour based sands, complex stratification in sandstones including abrupt shifts between cross bedding, planar and ripple laminations and abundant scour in fine grained intervals with distinct bioturbation.

The proposed depositional model is that sediment gravity flows are re-worked by bottom currents oblique to sediment input direction. The zone of bottom current modification is laterally gradational where marginal positions appear to have only subtle modifications from lobe stacking patterns, whereas more central positions are completely reworked. The extent and spatial position of the BCMD zone changes vertically through stratigraphy suggesting a response to changes in depth, seafloor relief, and/or slope profile through tectonic evolution of the basin. The extent of re-working impacts the distribution of grain size and bed thicknesses on a sedimentary scale as well as composite body stacking and vertical connectivity on a seismic scale. Mapping these changes is key to field development planning, well placement and well performance prediction.

SESSION TITLE: Theme 1: Stratigraphy and Processes

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Defining submarine fan deposits from core data – An interpretation of the Paleocene-Eocene San Cayetano Formation, San Jacinto Fold Belt (SJFB), NW Colombia.

AUTHORS (FIRST NAME, LAST NAME): Juan Sebastián Carvajalino Pérez¹, Rigo Ramírez², Gabriel Veloza³, Josué Alejandro Mora Bohórquez⁴, María Cerón⁵

INSTITUTIONS (ALL):

1. Génesis Consultoría en Geología
2. Génesis Consultoría en Geología
3. Hocol S.A.
4. Hocol S.A.
5. Agencia Nacional de Hidrocarburos

ABSTRACT BODY:

Abstract Summary: The stratigraphic record between Upper Paleocene and Lower Eocene in the SJFB is grouped in the San Cayetano Formation. Tectonically, this lithostratigraphic unit was deposited in a forearc environment related with the normal subduction of the Caribbean “plateau” under South American plate. Although, this succession contains prospectus of source and reservoir rocks, their environment of deposition is still a matter of debate. This work presents a sedimentological study of 2190 ft drilling core in the ANH-SS-15-STR-S stratigraphic well; drilled by ANH in 2013, south of Montería, in the central part of the SJFB. We interpret ancient submarine fan deposits with the following sub-environments: lower slope, upper submarine fan, middle submarine fan, and lower submarine fan. The main sedimentary processes include slumps, debris flows and turbidity currents. The lower slope deposits (up to 15 ft thickness) are composed of slump-folded heterolithic facies. The upper submarine fan deposits (up to 170 ft thick) are constituted by sandstones (97%), mudrocks (2%) and conglomerates (1%). In the sandstones facies were identified massive beds, organic matter laminae, internal lamination (current ripples and syn-sedimentary deformation), floating clast, random clast fabric and erosional surfaces. The ichnodiversity is low; the only traces are Ophiomorpha, Thalassinoides and escape traces. The middle submarine fan deposits (up to 45 ft) are constituted by interbedded of sandstones (52%), mudrocks (47%), and conglomerates (1%). These deposits have laminated sandstones (current ripples, syn-sedimentary deformation, and mud drapes), injection structures and load casts. Overall, the deposits are slightly bioturbated and in some intervals with moderate bioturbation of Thalassinoides, Ophiomorpha, Nereites, Phycosiphon; locally associated to Scolicia and Chondrites. The lower submarine fan deposits (up to 45 ft) are constituted by interbedded of mudrocks (66%), sandstones (32%), conglomerates (1%) and limestones (1%). These deposits have laminated sandstones (current ripples, syn-sedimentary deformation, and load casts). The bioturbation index is medium to high, it is characterized by Thalassinoides, Ophiomorpha, Nereites, Phycosiphon; locally associated to Scolicia and Chondrites. Hydrocarbon shows are related to sandstones facies in the upper and middle submarine fans; these sandstones may have reservoir potential in the SJFB.

SESSION TITLE: Theme 1: Reservoir Studies III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Quantifying Reservoir Properties at Outcrops: Geometric Applications of DOM-Based Projections.

AUTHORS (FIRST NAME, LAST NAME): Mauricio Baquero², German Bayona¹

INSTITUTIONS (ALL):

1. Corporación Geológica Ares
2. Corporación Geológica Ares

ABSTRACT BODY:

Abstract Summary: Reservoir units have internal heterogeneities such as lithological, compositional, and structural complexities, that exploration and development teams need to understand for better oil recovery. Outcrop data supply relevant scale and dimensional geometric information that may be used as a link among diverse seismic and core data sets. This information is relevant in providing critical information in understanding changes in the heterogeneities. DOMs provide unique products to geologically interpret 2D and 3D bodies and structures in the outcrops while taking advantage of their full exposure. DOM-derived orthomosaics permit reliable and convenient measurements of distance, area, and angles, which in turn support interpretations susceptible to geometric quantifications.

Based on detailed interpretations in orthomosaic windows, we propose a methodology to quantify reservoir aspects that impact exploration and production activities. Field-derived lithological descriptions fed 2D sedimentary bodies and structural interpretations that are topologically processed to obtain indexes of presence, connectivity, lateral changes, and thick beds on lithofacies of interest. Vertical and lateral variations of fracture abundance measurements (density and intensity) calculated over the complete exposure are linked to the lithofacies to provide a better input to geomechanics analyses than traditional sampling-based methods. Changes in bed geometry allows for identification of regional surfaces in inaccessible exposures.

In this presentation we will illustrate the application of the indexes to examples from important reservoirs units in three Colombian basins with varied depositional and deformative environments. Additionally, we will demonstrate other applications that take advantage of the geometric advantages of orthomosaics.

SESSION TITLE: Theme 1: Stratigraphy and Processes

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Bottom Currents Cycles in the Coniacian-Campanian Galembo Formation, The Luna Sea (Colombia): Sedimentology and Ichnology as Response to Deposit Mechanisms for Reoxygenation of the Sediment-Water Interface in an Oxygen-Deficient Epicontinental Sea

AUTHORS (FIRST NAME, LAST NAME): Gabriel Mendoza-Rodriguez¹, Oscar Romero-Ballen², Alexandra Delgado³, Manuel Paez⁴, Camilo Dávila⁵, Andrés Fuenzalida⁶

INSTITUTIONS (ALL):

1. Servicio Geológico Colombiano
2. Servicio Geológico Colombiano
3. Servicio Geológico Colombiano
4. Servicio Geológico Colombiano
5. Servicio Geológico Colombiano
6. Servicio Geológico Colombiano

ABSTRACT BODY:

Abstract Summary: Organic-rich mudstones/wackestones of foraminifera and marls with a low bioturbation index are the dominant lithofacies in the Coniacian-Campanian Galembo Formation of the Middle Magdalena Valley (MMV). Sedimentological and geochemical observations are consistent with these rocks being deposited on an oxygen-deficient mixed carbonate-siliciclastic ramp. Conversely, the upper part of the Galembo Formation contains lithofacies with evidence of a more well-oxygenated sea bottom. In detail, the internal architecture of these facies consists from base to top of a) foraminifera-phosphates massive packstones; followed by b) parallel-laminated to cross-laminated wackestones; c) wave-ripple cross-laminated wackestones and packstones, and capped by d) siltstone with low bioturbation indexes. These successions are bioturbated to different degrees with *Thalassinoides*, *Planolites*, *Asterosoma*, and *Teichichnus* as the main trace fossils found in these rocks. The present work describes bottom currents successions, repeated in constant cycles registered in cores from wells and outcrops data from the south Middle Magdalena Valley Basin. This succession of facies can be interpreted as the record of bottom currents in a mixed ramp. In addition, the high index of bioturbation and the moderate diversity of ichnofauna is consistent with short periods of faunal colonization of the benthic zone driven by the action of bottom currents that, in turn, were responsible for the reoxygenation of the sediment-water interface. Finally, this oxygenation event in the Campanian marks not only the end of anoxic conditions that persisted during the middle Cretaceous in the La Luna Sea but also marks the end of the marine-dominated sedimentation in the MMV; the latter process resulted from a marine regression as a consequence of tectonic movements predating the Cenozoic Andean orogeny.

SESSION TITLE: Theme 1: Reservoir Studies III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Karst zones characterization in the Pre-Salt carbonate reservoirs - Santos Basin, Brazil

AUTHORS (FIRST NAME, LAST NAME): Lara Neves¹, Ricardo Jahnert², Lizbeth Calizaya³, Wendel Araujo⁴, Marcia Maria Pinheiro da Silva⁵, Helman Duque⁶, Fernando Coelho⁷, Antonio Velasquez⁸

INSTITUTIONS (ALL):

1. Ecopetrol Brasil
2. Ecopetrol Brasil
3. Ecopetrol Brasil
4. Ecopetrol Brasil
5. Ecopetrol Brasil
6. Ecopetrol
7. Ecopetrol
8. Ecopetrol Brasil

ABSTRACT BODY:

Abstract Summary: Epigenic and hypogenic karst systems within the Pre-salt comprehend intervals with high permeability reservoir. Both karst types are intrinsically related with faults, fractures and breccias creating high permeability zones. Recognition of these karst zones is important due to the high hydrocarbon volume productivity. The lacustrine carbonate sequence from the Alagoas Stage - Barra Velha Formation is among of the best oil reservoir in the world, whose production varies between 30-65 thousand bbl/day. The analysis realized for this work contemplate cores, sidewall cores and thin sections associated with electrical, sonic, density, nuclear magnetic resonance logs, and borehole image were integrated with seismic and impedance image cubes from fields in Santos Basin. The rock analysis revealed as original depositional facies shrubstones, rudstones, grainstones, beside breccias, silicites, mudstones and packstones. Within build-ups observed in seismic lines, cores revealed carbonate intervals with intense dissolution, breccias, silicified levels, soils, collapse zones, rock fragments, allochthonous blocks, highly fractured and faulted blocks, and fracture filling. Those attributes represent epigenic karst systems, that occurred at depositional moments when the level of the lake was lowered. The recognition of karst zones was defined in logs that permitted lateral correlation with other wells, standing as highly porous and permeable intervals. In other areas however, build-ups are composed of intensely silicified, fractured, brecciated intervals with high dissolution, preserving only residual parts of original depositional rocks such as shrubstones and rudstones. Through thin sections analysis minerals such chalcedony, microcrystalline and macrocrystalline silica, barite, dawsonite, saddle dolomite, blocky calcite was described. This mineral suite was associated with the occurrence of hot fluids from hydrothermal vents enriched in CO₂, CH₄, Si and other ions, responsible for an important dissolution and subsequent precipitation of exotic minerals. Ascending hydrothermal fluid flow represents hypogene karstification responsible for high-permeability zones in build-ups fault-controlled. The recognition and seismic mapping of karstified zones has been applied in the static and dynamic reservoir modeling, improving the recognition of oil and gas dynamics, and helping during the location of producer and injector wells.

SESSION TITLE: Theme 1: Reservoir Studies III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Gas Geochemistry as Complementary Technology to Understand the Petroleum System in Complex Petroliferous Basins: Examples from Offshore and Onshore Brazil and Colombia.

AUTHORS (FIRST NAME, LAST NAME): Marcio Rocha Mello¹, Pedro Parra²

INSTITUTIONS (ALL):

1. Brazilpetrostudies
2. GEMS

ABSTRACT BODY:

Abstract Summary: In the last 20 years, oil companies started to proclaim gas geochemistry technology in petroleum exploration as miraculous indicators of the presence of large hydrocarbon accumulations in deeper reservoir horizons in unexplored sedimentary basins. The gas data suggested that because the gases are the lightest hydrocarbons (e.g., lowest atomic size) their leaking properties are the highest (e.g., permeability in sediments, micro fractures, faults, unconformities, etc.) and, therefore, it can be detected above giant oil/ gas fields that have almost perfect seal properties.

It also cannot be denied that gas data have been used all around the world in conventional reservoir characterization to infer reservoir compartmentalization, separation between two geological sequences, seal integrity, migration distance, volumetric leakage, residual volumetrics in a structural trap, etc. However, although gas geochemistry is not expensive, it is very complex to sample, analyze and interpret it. False positives and negatives, sampling reliability and, most importantly, preservation of sampling until laboratory measurement are critical factors.

We have performed a lot of sampling and measurements in Cretaceous and Paleozoic offshore and onshore basins in Brazil, Mexico, and Colombia. The data part of a major multidisciplinary gas project was critical to pinpoint areas with deep oil and gas potential in a predominantly shallow basins and determine gas cracking, gas mixing allowing to identify gas vs oil prone character and quantify the contribution and thermal evolution of different source rock systems present in the basins. These technologies are the only ones capable to solve the puzzle “why to go deeper aiming giant hydrocarbon accumulations”.

SESSION TITLE: Theme 5: Case Studies in Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Major and Trace Element Concentrations in Organic Rich Shale Deposits, A review of the Paleo-Redox conditions during the accumulation of the Woodford Shale, Oklahoma.

AUTHORS (FIRST NAME, LAST NAME): Carlos Molinares-Blanco¹

INSTITUTIONS (ALL):

1. SierraCol Energy

ABSTRACT BODY:

Abstract Summary: The final concentration of organic matter in the sediment depends on multiple factors, but the degradation of organic matter during deposition and early diagenesis is a critical factor to preserve the organic matter that will be then transformed in hydrocarbons. The oxidizing of the organic matter does not end with the O₂ depletion. Marine sediments become anoxic at variable depths when the rate of burial of particulate organic matter exceeds the rates of degradation by other secondary oxidant agents.

These anaerobic oxidizing agents are in order of decreasing energy: 1) nitrate reduction, 2) manganese reduction from valence IV to II, 3) iron reduction from valence III to II, and 4) sulfate reduction. In fact, anoxic conditions are certainly fully established only when all these oxidant agents have been depleted and the concentrations of H₂S produced by sulfate-reducing bacteria is high enough that it can ultimately auto-inhibit their activity. Anoxic conditions can be euxinic (sulfidic), which means a state in which hydrogen sulfide (H₂S)_{aq} is free in water.

Major and Trace elements concentrations are reviewed to establish original paleo-redox and oxygenation conditions during the accumulation of the organic-rich, Woodford Shale deposits. They were subdivided into two different categories according with their behavior under oxic, anoxic and euxinic conditions. The first group includes the elements whose valency does not change with redox conditions and/or form highly insoluble sulphide phases under euxinic conditions (e.g. Ni and Cu). The second group embrace the elements which valency vary with the redox potential, which are reduced to reactive or insoluble species of lower valency under anoxic(euxinic) conditions (e.g. Mo and U).

The Late Devonian oceans were characterized by Nitrogen (N) inventory depletion, because of denitrification during permanent greenhouse-anoxic conditions. These conditions normally persist on geological time scales, only if anoxic conditions are companied by Fe and Mo as bio-limiting nutrients. The significant Iron concentrations increments coinciding with the end of euxinic conditions and changes of marine productivity supports the idea that changes in Fe (and possible Mo) contents during the Late Devonian Frasnian/Famennian transition, affected the oceanic bottom-water redox conditions, the marine productivity and increased the organic matter contents available to be preserved.

SESSION TITLE: Theme 1: New and Emerging Plays I

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Insights into Geological Framework of Northeastern South America: Implications to Petroleum System and Opportunity Assessments

AUTHORS (FIRST NAME, LAST NAME): Marel Sanchez¹

INSTITUTIONS (ALL):

1. Actus Veritas Geoscience

ABSTRACT BODY:

Abstract Summary: The Eastern Venezuela basin (EVB) is a record of a typical Wilson Cycle that started with the Jurassic rifting, followed by a Cretaceous to Paleogene passive margin developments, and culminated with a Neogene foreland. The basin is genetically connected with the Guyana Basin located to the southeast along the Atlantic margin. Onshore, the EVB is bound by the Guayana Shield to the south and the Serrania Oriental to the north - a product of the oblique convergence of the Southeastern edge of the Caribbean plate. A world-class Cretaceous source rock, Querecual Formation, is a foundation for a prolific petroleum system in the EVB. This formation marks the main anoxia event that extends to Trinidad and Guyana (Naparima Hill, and Canje). This genetic relationship provides a geological baseline for analyzing the critical risk factors in play assessments in the region.

Companies carried out exploration activities in the Eastern Venezuelan basin for more than 100 years estimating remaining recoverable reserves of around 20 billion barrels of hydrocarbons, plus 267 billion barrels of extra heavies at the Orinoco Oil Belt. Multiple plays were identified in the EVB. The latest major play was discovered in the 1980s, the thrust fold related Furrial trend added more than 5 billion BOE of recoverable light oil. It was before modern technologies, and play-based exploration methodologies were developed. Towards the east, the passive margin expands from Cretaceous to Recent and extends beyond the Orinoco delta towards the Guyana basin to the southeast. Twenty years of regional geologic studies led to the cluster of discoveries in Guyana and Suriname, starting with the Liza discovery in 2015. It opened a deep-water play extending along the passive margin towards the Orinoco delta area.

The tectonic and stratigraphic evolution of Northeastern South America has a complex geologic record from Paleozoic to the Present with documented Paleozoic, Jurassic, Cretaceous, and Neogene petroleum systems. In that sense, Northeastern South America should be analyzed as a conjugate to the MSGBC (Mauritania, Senegal, Gambia, Guinea Bissau, and Guinea Conakry) basins. This paper integrates and analyses the recent publications, knowledge of the explorationists of the margin accumulated over the last three decades. We review petroleum systems of the EVB and the Guyana basins and analyze the extent and critical risks of the documented, and possible exploration plays along the margin.

SESSION TITLE: Theme 1: Reservoir Studies II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Tracing Stratigraphic Surfaces in the Cretaceous “La Luna Formation”

AUTHORS (FIRST NAME, LAST NAME): Manuel Paez-Reyes¹, Oscar Romero-Ballen², Gabriel Mendoza-Rodriguez³, Alexandra Delgado⁴, Maria Teresa Cantisano⁵, Camilo Dávila⁶, Felipe Pastor⁷, John Ortiz⁸

INSTITUTIONS (ALL):

1. Servicio Geológico Colombiano/Universidad EAFIT
2. Servicio Geológico Colombiano
3. Servicio Geológico Colombiano
4. Servicio Geológico Colombiano
5. Servicio Geológico Colombiano
6. Servicio Geológico Colombiano
7. Servicio Geológico Colombiano
8. Servicio Geológico Colombiano

ABSTRACT BODY:

Abstract Summary: Organic-rich limestones of the Cretaceous “La Luna Formation” in the Middle Magdalena Basin (MMV) of Colombia is a liquid-rich unconventional petroleum play with estimated resources of 100000 million barrels in place. Rocks in this formation, however, change from facies in short distances, adding risk to the exploration of this play. In this work, we tackle the problem by defining stratigraphic surfaces that track changes in accommodation space and sediment supply at the basin scale. A minimum in the thickness of the parasequences and a low detrital influx suggests sediment starvation and a maximum in the accommodation space in the lowermost part of the Salada Member. This evidence allows the definition of a maximum flooding surface (MFS) and a condensate section (CS) for this part of the sequence. A regressive surface in the upper part of the Salada Member is demonstrated by the increase of detrital material and higher thickness of the parasequences. The thicker parasequences and the accumulation of muddy sandstones in the Pujamana Member are consistent with the progradation of proximal facies into the basin constituting a sequence boundary (SB). A decrease in the thickness of the stratigraphic cycles and a gradual decline of detrital input marks a rise in sea level defining a new transgressive surface (TS) below the Pujamana-Galembó contact. A minimum thickness in the stratigraphic cycles, the deposition of mudstones of foraminifera, and the higher values of organic matter recorded in the lower part of the Galembó Member coincide with an MFS and a CS. A slight increase in detrital fluxes in the middle part of the Galembó Member records a drop-in sea level; however, rocks are carbonate-dominated suggesting that proximal facies did not reach the basin and therefore an SB was not fully developed. The middle and upper part of the Galembó Member displays thin cycles and two flooding surfaces of second-order characterized by low detrital input and high contents of organic carbon. During the Campanian, cyclical sequences of calciturbidites were deposited under a fluctuating but relatively high sea level. Finally, a forced regression and a regional SB-xenoconformity are indicated by the transition of the Galembó Member to the siliceous mudstones of the Umir Formation. This surface that can be traced in the MMV and other basins of Colombia and Venezuela is consistent with a reorganization of the basin driven by tectonism at the Campanian-Maastrichtian transition.

SESSION TITLE: Theme 1: Stratigraphy and Processes

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Bottom-current Sediments: A New Prospective Opportunity In Colombian Caribbean Offshore.

AUTHORS (FIRST NAME, LAST NAME): Oscar Marín¹, Paulo Correa²

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Recently, bottom-current sediments are becoming prominent good-quality reservoirs along with world-class petroleum provinces like the Gulf of Mexico, North Sea, or Brazil Offshore, among others. Sandy contourites are found in mixed environments where bottom-currents disrupt turbulent deposits (Turbidites) generating a usually extended distribution of well-sorted sediments with high porosities.

New regional evaluations along the southern Caribbean basin, offshore Colombia, have permitted to recognize bottom-current depositional systems, such as contourite drifts and seismic facies associated to reworked sediments. Additionally, spectral decomposition analysis shows how these deposits are distributed around channel-levee complexes developed mostly in lower-slope depositional environments.

Further exploration and characterization of this type of deposits along the Colombian Caribbean deep and ultra-deep waters would open a new play-concept associated to already recognized and hypothetical petroleum system, opening new exploratory opportunities for this frontier exploration basin.

SESSION TITLE: Theme 1: New and Emerging Plays I

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: The prolific Guyana-Guinea-Bahamas petroleum province: Reconstructing a Superbasin

AUTHORS (FIRST NAME, LAST NAME): Jon Teasdale¹, Tim Debacker²

INSTITUTIONS (ALL):

1. Geognostics
2. Geognostics

ABSTRACT BODY:

Abstract Summary: Over the past decade the Guyana-Suriname Basin has attained 'Superbasin' status with at least 8 bboe proven in prolific basin floor turbidite fans. The petroleum play elements that contribute to these discoveries include widespread Late Jurassic-Early Cretaceous anoxic source rocks, excellent Late Cretaceous clastic reservoir, late burial/charge and both structural and stratigraphic traps. These play elements formed in a complex plate tectonic setting as South America, Africa and North America separated. The interplay between tectonics and paleogeography is key to understanding play context and predicting play extensions into unexplored areas in this now-widely-dispersed basin.

High resolution plate tectonic modelling using GEM™, the Geognostics Earth Model gives significant new insights into the evolution of this complex Superbasin through a series of basin phases:

- (i) Late Triassic-Earliest Jurassic Central Atlantic syn-rift and salt deposition synchronous with voluminous CAMP magmatism;
- (ii) Mid Jurassic -Early Cretaceous evolution of the narrow proto-Caribbean-Central Atlantic seaway with continued paleogeographic restriction from the evolving Bahamas oceanic plateau. World class source rock deposition on oceanic crust during this basin phase was a consequence of tectonic restriction and global anoxia;
- (iii) A major kinematic shift in the Early Cretaceous Equatorial Atlantic separation, initially transpressional then transtensional;
- (iv) Early Andean/Laramide tectonism driving continental scale uplift, erosion of Paleoproterozoic sheet sandstones and drainage systems culminating in distal deep water turbidite fan deposition;
- (v) Neogene proto-Amazonian drainage, again driven by Andean tectonics, providing late sediment loading that pushed Cretaceous source rocks into the oil window.

Our new tectonic model for these basin phases provides a powerful predictive framework for understanding potentially prospective play domains beyond currently explored areas in this prolific 'new' basin.

SESSION TITLE: Theme 1: Reservoir Studies II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Conceptualization Of Dual Boosting Esps Completion In Field Ayatsil, Marine Region of Mexico

AUTHORS (FIRST NAME, LAST NAME): Sarita Sandoval Perez¹, Mario Treviño², Emaglin Hernandez³, Lorena Lopez⁴

INSTITUTIONS (ALL):

1. Baker Hughes
2. Baker Hughes
3. Baker Hughes
4. Baker Hughes

ABSTRACT BODY:

Abstract Summary: From the reservoir point of view, the total amount of fluid that can be produced basically depends on the Productivity Index(PI) and to define the expected production scenarios over time it is important to consider the annual decline rate of Reservoir pressure, RGP forecast and %water to be produced, these dynamic conditions must be considered to define the field's production strategy. From an artificial lift point of view, the total amount of fluid that can be produced from a well can be limited to 75% of the maximum flow (AOF), due to factors such as critical rates, well depth, casing restrictions and the energy required to move the fluid from the bottom to the surface. The objective of this proposal is produced 6000 BFPD/per well of heavy oil field (10API) with low %water, 21% H₂S and BHT 130 C are offshore applications, this formation is naturally fractured carbonate with a PI range is between 10.5 to 89 BFPD/PSI. The main problem for this field is the high decline in reservoir pressure (9 Kg/cm²/year) and high %H₂S, which implies changes in the static level of fluid with low pressures at the pump inlet, high % of gas at pump and reduction of submergence. For this reason, the operator is planning to migrate from dual encapsulated systems (backup ESP) to encapsulated booster systems that will allow deepening the equipment and distribute the loads between both systems, currently the ESP is located between 2700 to 2900 mD with power 800 Hp. Deepening the equipment would imply reaching the limit of the standard capabilities of most systems of artificial lift. This document shares the analysis and design criteria developed for the conceptualization of ESP booster system. The Sensitivities will considered to change in PWS and produced fluids, as well as the comparison with the current configuration (backup ESP) considering efficiency, power requirements, operational flexibility and reliability, these analyzes will be carried out with Prosper and Autograph and will allow define the evaluation methodology to be implemented to select settlement depths of each ESP system, optimize power consumption by distributing the loads based on the total required TDH, effects of temperature and pressure, improvements configuration, logical of operation. The implementation of ESP booster systems will allow expanding the application window of the ESP system and the design methodology will serve as a guide for the implementation of this configuration in other fields.

SESSION TITLE: Theme 2: Andean Structural Styles III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Geometrical and kinematic analysis of the Mesozoic extension in the Western Foothills of the Eastern Cordillera and Middle Magdalena Valley, Colombia

AUTHORS (FIRST NAME, LAST NAME): Martin Reyes¹, Jonas Kley², Andrés Mora³, Juan Sebastian Carvajal-Torres⁴

INSTITUTIONS (ALL):

1. Georg-August-Universität Göttingen
2. Georg-August-Universität Göttingen
3. Ecopetrol Brasil
4. Grupo de Investigación en Ciencias de la Tierra y Energía

ABSTRACT BODY:

Abstract Summary: Geological 3D modeling has gained significant importance over the last decades as it has evolved into a tool that permits increasingly-realistic representations of complex geological conditions. 3D models are particularly valuable for reducing uncertainties and exploration risks in the search for subsurface mineral resources. Our study area is located in the northern Andes of Colombia, whose geologic history reflects the interaction between the South American, Nazca, and Caribbean plates. Mesozoic extensional structures became inverted during the Cenozoic as a result of the Andean orogeny. The data used in the development of our project comprises subsurface information, including a grid of 2D seismic lines and borehole and surface data, such as maps and stratigraphic columns. Detailed mapping and interpretation of the units permits kinematic restoration of inversion structures and the definition of extensional geometries during the Mesozoic. Our analysis confirms the presence of regional master normal faults and associated extensional basins in the area, particularly the La Salina, Boyacá, and Suarez faults. During Mesozoic extension, these faults accommodated oblique extension which was mainly NE-SW orientated. The basin geometries varied as back-arc extension progressively intensified from Triassic to Jurassic times. During the Early Cretaceous, a marked widening of the basins has been noted. Based on the geometrical analysis of the architecture of the extensional sub-basins, and some age control from new isotopic dating of volcanic rocks, the basin experienced different opening pulses that reflected stress field variations.

SESSION TITLE: Theme 2: Andean Structural Styles II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Vertical-axis Block Rotations in an Oblique Convergent Margin. 3D Seismic Examples from Bahia Basin, Offshore Colombian Caribbean

AUTHORS (FIRST NAME, LAST NAME): Pedro A. Galindo¹

INSTITUTIONS (ALL):

1. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Vertical-axis block rotation is a typical kinematic indicator of strike-slip zones world-wide and at different scales. However, most examples of vertical-axis block rotation have been documented in onshore regions using geodetic, paleomagnetic, and seismological methods. In this study, seismic data from the offshore Bahia Basin, Colombian Caribbean, illustrates two magnificent examples of vertical-axis block rotation within a strike-slip zone at the rear of an accretionary prism in response to oblique subduction. Oblique convergent margins are characterized by the occurrence of strike-slip deformation which controls basin formation and evolution. These strike-slip faults are commonly parallel to the trench and located at the rear of the accretionary prism resulted from subduction. Given the complex nature of a strike-slip deformation zone, time slices and seismic profile sections are included to fully characterize the tridimensional configuration of the deformation. Furthermore, computed seismic attributes such as coherency and spectral decomposition are also used to interpret the 3D configuration of fault planes. Following basic principles of seismic interpretation, a first example shows the identification of structural features and characteristic elements of strike-slip zones like negative flower structures and en-échelon normal faults. These observations allow to propose a kinematic model for the opening of a relay zone in response to right-lateral, vertical-axis block rotation, which also may explain the occurrence of compressional deformation and mud diapirs at the boundaries of the block. In a second example, closely spaced, low-displacement, planar normal faults are mapped within the Miocene strata. In map view, the fault traces curve toward their tips, describing a sigmoidal geometry that terminates at discrete NE-SW trending fault zones. The structures observed may correspond to either tension fractures or antithetic shear fractures with normal displacement. These scenarios allow to propose a clockwise block rotation of between 20° and 40° within the dextral shear zone. This study shows two impressive examples of vertical-axis block rotations observed offshore in the western end of the South Caribbean margin and correspond to important examples of the use of 3D seismic data to identify rotations where paleomagnetic studies are not available.

SESSION TITLE: Theme 2: Salt and Shale Tectonics

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Structural and Stratigraphic Seismic Interpretation Associated With Diapirism, Northeast Mexico

AUTHORS (FIRST NAME, LAST NAME): Iza Canales-García¹

INSTITUTIONS (ALL):

1. Universidad Nacional Autónoma de México

ABSTRACT BODY:

Abstract Summary: The northeast region of Mexico, located on the Coastal Plain of the Gulf of Mexico within the state of Tamaulipas, has a complex history of sedimentary deposits, stratigraphic successions, and structural deformation events, which make it a study area of great scientific and economic interest.

In this work, 3D seismic information corresponding to 600 km² will be analyzed, performing the stratigraphic and structural interpretation of an area located 125 km inland and 30 km from the city of Reynosa.

The stratigraphic and structural model begins with the Basement, which is made up of metamorphic and igneous rocks of the Permian-Triassic age affected by extension faults associated with the opening of the Gulf of Mexico during the Middle Jurassic (Salvador, 1987; Winker and Bluffer, 1988). The first sedimentary layers deposited on the Basement are made up of rocks of continental origin, which accumulated in the trenches formed by the rift, which make up the Huizachal Group, of Upper Triassic-Lower Jurassic age. During the Callovian Middle Jurassic and up to the Oxfordian Upper Jurassic, a period of cortical subsidence is considered, which allowed the invasion of oceanic water, generating shallow seas conducive to the deposit of evaporitic rocks and carbonates from the Minas Viejas and Olvido Formations; these accumulations of salt subsequently formed isolated diapir.

The objective of this work is to carry out a geological-geophysical model of the structures described above, with special emphasis on the location and modeling of a diapir, the extraction of seismic attributes will be carried out to determine whether it is a diapir of salt or of clay and the influence it has exerted on the deformation of the strata overlying it will be analyzed.

SESSION TITLE: Theme 2: Salt and Shale Tectonics

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Role of shale tectonics in the variation of the structural style in the Sinú Offshore basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Jhon Meyer Muñoz-Barrera¹, Andrés Pardo Trujillo²

INSTITUTIONS (ALL):

1. University of Bergen
2. Universidad de Caldas

ABSTRACT BODY:

Abstract Summary: The results of the deep-wells (e.g., Kronos-1 and Calasú-1) in the Sinú offshore basin have tested the hydrocarbon prospectivity successfully. Although 2D and 3D seismic reflection data cover the area, the geological knowledge is limited due to the data confidentiality. Few studies have deciphered the structural style integrating 2D seismic reflection with few ancient wells data. However, these works do not consider the interaction between stress regime and rock's mechanical properties. We use pre-stack depth migrated and pre-stack time migrated 2D seismic reflection data and the results of 15 wells, including the Calasú-1 well, to decipher the influence of the shale tectonic in the structural style and its variation along strike within the Sinú offshore basin.

The Sinú offshore shows faults that create folds principally with an NW vergence and long back limbs. Folds are disharmonic with the presence of mud-diapirs, mud-volcanoes and welds. The detachment zone is located above the oceanic crust with local changes in the detachment level. Areas with a thick overburden show low to absent structural relief. In contrast, areas with thin overburden display a high structural relief and a high percentage of mud-related structures. Based on the change in structural style along strike, we divided the basin into four structural provinces: Fuerte (shear-fault-bend folds and detachment folds), Sinú (detachment folds and Mushwad), Magdalena (structureless) and Bahía (negative-flowers). In addition, we divided the provinces along the dip direction into inner (continental shelf) and outer (continental slope and rise) deformation zones based on their structures and growth strata. We interpret that shale tectonics modified the structures generated during the deformation. The weight of imbricate structures and sediments brought from the continent triggered lateral migration of the shale bodies generating mud-diapirs and -volcanoes. The mud-related and imbricate structures controlled the sediment routing and depositional system in the basins. This work shows the type of structural traps in the Sinú offshore basin and their modification due to the shale tectonic.

SESSION TITLE: Theme 2: Andean Structural Styles II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Quaternary kinematics and deformation rates along the Llanos Foothills thrust system. Impacts for the segmentation of faulting and folding, and the distribution of hydrocarbon accumulations.

AUTHORS (FIRST NAME, LAST NAME): Gabriel Veloza¹, Michael Taylor², Andrés Mora³ **INSTITUTIONS (ALL):**

1. Hocol S.A.
2. University of Kansas
3. Ecopetrol Brasil

ABSTRACT BODY:

Abstract Summary: The eastern thrust front of the Eastern Cordillera bounds the Llanos basin and is experiencing active uplift along the seismically active Cusiana, Yopal, Paz de Ariporo and Tame thrust faults, which are part of what is known as the Llanos Foothills thrust system (LFTS). The LFTS is comprised of east directed thrust faults that are listric in geometry with shallowly west-dipping décollements and steeper near surface geometries. Locally, actively growing, north-south plunging folds are cored by blind thrust faults, while regionally short wavelength folds that are continuous along strike are also seen, bounded by emergent listric faults that are being incised by antecedent east-flowing streams. Using a combination of field-based observations on the geometry of faulted and folded fluvial terraces, seismic interpretation and geochronology from terrestrial cosmogenic nuclides, we show that the fluvial terraces have been uplifted, and locally incised >200 meters at incision rates exceeding 4 to 5 mm/yr. Along strike shortening gradients within the thrust front reflect not only the style and velocity of thrust front advance at different time scales in active orogens, but also the proximity of the development of such strain markers to the emergent faults. This precludes the widely accepted hypothesis that older terraces are always located at higher elevations, relative to the antecedent river. Moreover, the northwardly increasing rates of shortening agree with the shortening gradients in the same direction, previously obtained from balanced cross sections. Thus, our findings shed light on the evolution and development of uplifted strain markers and help us to understand the rates at which deformation and folding and faulting processes operate. In turn, this helps us to understand the presence and distribution of oilfields along the Andean thrust front.

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: An example of DFN modeling in the Bolivia Sub-Andean Fold and Thrust Belt for near-field exploration

AUTHORS (FIRST NAME, LAST NAME): Connor Moore¹, Daniel Peña², Pedro Vieira³, Camilo Restrepo⁴, Samael Fontenla⁵, Sebastián Córscico⁶, Tomas Zapata⁷

INSTITUTIONS (ALL):

1. Repsol
2. Repsol
3. Repsol
4. Repsol
5. Repsol
6. Repsol
7. Repsol

ABSTRACT BODY:

Abstract Summary: The Boicobo-X1ST discovery well was drilled in 2020 in the Southern Sub-Andean fold and thrust belt in Bolivia, northwest of the Margarita and Huacaya gas/condensate fields. The main reservoir is the Devonian Huamampampa naturally fractured sandstone, which relies heavily upon secondary fracturing as the primary control for fluid flow and reservoir performance. The purpose of building a Discrete Fracture Network (DFN) in Boicobo is to understand the fracture distribution and hierarchy within the reservoir by utilizing outcrop data and various kinematic and geomechanical models. The DFN model can be used as a predictive tool to optimize field development in Boicobo and applied to future exploration opportunities.

Due to the poor borehole quality in the upper section of the reservoir, UBI images were unable to be obtained. For this reason, the sonic scanner was used to identify fracture characteristics, specifically using the stoneley wave as a proxy in the zone without image logs. The results showed a high correlation with the lower reservoir sections containing image logs.

There are two main fracture families in Boicobo. The E-W oriented fractures are interpreted to be formed during the pre-deformation stage and later reactivated during the translational stage, and N-S oriented fractures potentially forming during both pre-deformation and folding stages. The eight geomechanical zones in the well contain their own fracture sets with unique fracture orientation and intensity. Fracture aperture data was taken from nearby well data in the Margarita/Huacaya fields, and the local DFN was calibrated to the DST data to validate the fracture permeabilities. The field scale model is composed of two fault blocks that separates Boicobo South and Boicobo North; the two structures being separated by an out-of-sequence fault after the main structure was formed. The tectonic history implies that a fracture hierarchy at different scales is evident, with the dominant fractures being developed during the translational and folding events of the structure. Therefore, fractures associated with translational stress in the strike-slip regime were modeled using nearby outcrop data in Abra Del Condor, and fractures associated to strain during the folding events were modeled using various kinematic and geomechanical models. The fault damage zone, when comparing to outcrop data, can be up to 200m in width, and was modeled in accordance with the fault throw along the structure.

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Fracture Prediction in Thrustbelt Reservoirs; Lessons from Cusiana and Florena-Moro-Pauto Fields, Eastern Cordillera of Colombia

AUTHORS (FIRST NAME, LAST NAME): Michal Nemcok¹, Andrés Mora², Andreas Henk³

INSTITUTIONS (ALL):

1. EGI Laboratory at SAV
2. Ecopetrol
3. University of Darmstadt

ABSTRACT BODY:

Abstract Summary: Based on the knowledge coming from outcrop and reservoir data from thrust sheets of thin-skinned thrustbelt, reservoir rocks can be divided into matrix-dominated ones and ones that underwent fracturing-related permeability enhancement. Using 4-step forward models of restored balanced cross sections and subsequent finite-element modeling, we focus on the fracture geometry, kinematics and sequence of development prediction in Cusiana and Florena-Moro-Pauto fields in the Eastern Cordillera. Steps represent 23, 15, 11 and 0 Ma and 23, 11, 5 and 0 Ma for Cusiana and Florena-Moro-Pauto fields, respectively. Modeled reservoirs include Guadalupe, Barco and Mirador formations.

Both fields are represented by two profiles running through their central and most cylindrical portions. Their numerical modeling yields distribution of plastic strain, mean stress, differential stress and principal stress vectors. Sensitivity analysis tests the role of the fault friction in the stress perturbation and strain distribution inside studied thrust sheets. Interpretation of calculated data results in cross sections with mapped fracture types and their geometries. Prediction indicates that stress and strain patterns vary among thrust sheets (1) developed by different folding mechanisms, (2) characterized by different mechanical stratigraphy, (3) bounded by faults with different geometry and friction. This allows to conclude that sweets spots with fracturing-enhanced permeability cannot be found intuitively. Instead, a rigorous balancing process followed by thermo-mechanically coupled numerical simulation is needed.

SESSION TITLE: Theme 2: Andean Structural Styles II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Styles of basement involved deformation in the Castilla and Chichimene oil fields and adjacent trend: Key elements to understand the recent discoveries in the area.

AUTHORS (FIRST NAME, LAST NAME): Johan Leonardo Ortiz Quiros¹, Andrés Mora¹, Jaime Martínez¹, Jaime Gelvez¹, Andrés Valencia¹, Oscar Sánchez¹, Yudy Estevez¹, Camilo Restrepo², Sebastián Córscico²

INSTITUTIONS (ALL):

1. Ecopetrol
2. Repsol

ABSTRACT BODY:

Abstract Summary: Basement involved deformation is frequently associated with different modes of inversion tectonics. In the area of the Chichimene and Castilla oil fields and surroundings, recent 3D seismic acquisition permits an in depth understanding of the structural styles and trapping mechanisms. Here we document a variety of styles of basement involved deformation with and without relationship with inversion tectonics. In Chichimene partial and total inversion of Early Cretaceous normal faults is documented with classical harpoon shaped structures and inverted normal faults. However, southwards and along the same trend, Cenozoic inversion is dominantly related with footwall shortcuts while the faults bounding the half-graben structures are passively transported by the shortcuts. The adjacent trend, associated with Castilla, seems to not be associated with inversion. In Castilla, basement involved trishear fault propagation folds have been observed with contractional deformation at the basement level while the crest of the Cenozoic anticlines is affected by normal faults. The presence of an E-W sigma 1 impinging on NE-SW oriented inherited normal faults and the presence of extensional horse tails, documented with the aid of the 3D seismic data in Castilla allowed us to interpret that basement involved deformation in this region is related with dextral transpression. However, the data available, allows to document that the giant heavy oil traps in the area are not related with the inversion anticlines but stratigraphic traps charged during an earlier (Oligocene) migration and later folded and redeformed during the Miocene to Recent contractional deformation. In contrast, lighter oil accumulations in deeper Lower Cretaceous reservoirs are related with typical structural traps. Finally, to have a complete picture of the structural styles and trapping mechanisms the important role of hydrodynamics should be considered. Titled oil water contacts in Castilla, and proximity and connection with freshwater recharge zones in the Sierra de la Macarena to the south suggests that some of the traps are not only related with early stratigraphic trapping, forelandward pinchouts and styles of inversion. Hydrodynamics also play an important role controlling the existing accumulations and the exploration of new ones along the same trend. Recent discoveries like Lorito and Nueva Esperanza have proved the successful application of these concepts.

SESSION TITLE: Theme 2: Andean Structural Styles III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Structural Styles along the Andes: An Overview

AUTHORS (FIRST NAME, LAST NAME): Gonzalo Zamora¹, Andrés Mora²

INSTITUTIONS (ALL):

1. Specialists, Repsol, Madrid, Spain.
2. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The Andes is considered a global type-example of ocean-continent convergence with a long-lived evolution of the convergent margin and continuous subduction of the oceanic lithosphere of the Pacific Ocean, beneath the continental lithosphere of South America during the Cenozoic and Mesozoic. Variations in the direction and rate of convergence, together with changes in the slab dip have shaped the present Andean configuration. However, this subduction was preceded by a complex Paleozoic and Proterozoic tectonic history, with the amalgamation of different terranes and the creation of basins that constructed the Pre-Andean framework. This intricate tectonic history has favored the development of a large number of sedimentary basins. Some of them are highly mature in terms of hydrocarbon production, with source rocks and reservoirs from Paleozoic, Mesozoic and Cenozoic sedimentary sequences, while others are still underexplored. These basins have a wide coverage of seismic data (2D and 3D), allowing to image a large variety of structural styles. Although the geological history spans a timeframe starting in the Proterozoic, it is the Mesozoic and Cenozoic history which shaped the present-day configuration. The structural styles are related, to some extent, with the variability in the stratigraphy, which sets up the conditions for large differences in mechanical stratigraphy. For example, the presence of one or more effective detachments, synorogenic deposits and erosion, and thick and thin sedimentary sequences, are all factors related with the basin stratigraphy. All of these, together with the basement configuration or the changes in the stress regime through time, have controlled the structural styles within these basins.

This regional configuration of the Andes has yielded a large variety of structural styles. Fault-related folds either from thin-skinned or thick-skinned deformation are common structures along the length of the Andes. Triangle zones and wedge structures are present and well identified along many of the Andean foreland basins. Presence of several detachment levels have produced structural disconnection from upper and lower sections. Salt detached structures have favored the eastward advance of some sector of the Andes and the development of large transport thrusts. Growth strata are common in many regions also allowing a good dating of the structures. All these make the Andes a natural laboratory for structural geologists.

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Testing the role of different tectonic models to predict pore pressure and temperatures based on basin modelling procedures.

AUTHORS (FIRST NAME, LAST NAME): Andrés Mora¹, Ernesto Cristallini², Francisco Sanchez³, Juan Hernandez⁴, Joaquín Nigro⁵, Daniel Balciunas⁶, Vinicius Rigueiro⁷, Oriol Pla⁸, Gustavo Camelo⁹

INSTITUTIONS (ALL):

1. Ecopetrol Brazil
2. La.Te.Andes
3. La.Te.Andes
4. La.Te.Andes
5. La.Te.Andes
6. La.Te.Andes
7. Eneva
8. Ecopetrol Brasil, Barcelona, Spain.
9. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Direct pore pressure data is normally obtained from well tests while temperatures can also be directly measured in boreholes. On the other hand, seismic interval velocities can be used to detect overpressures along seismic profiles. From the evolutionary point of view burial and uplift can control the dominant pressure and temperature regimes in a basin. Therefore, if there is a good knowledge of the different rock properties and facies distribution, a well-known evolutionary framework, and lateral variations in heat flow, then basin modelling software should be able to predict the pressure and temperature regimes. However, to have the most precise tectonic evolution, an important input prior to petroleum systems modelling (for example in salt tectonic settings and contractional belts) are the structural restorations. An early calibration regarding pressure and temperature regimes, heat flows or rates of burial and erosion is a critical task that ideally should be done during the restoration workflow so that the petroleum systems models can be even more precise. With the currently available workflows this is rarely possible. In this work we use a balancing software package where we can also calibrate the cross-section itself regarding pressures and temperatures during the restoration workflow. We test different evolutionary scenarios in two tectonic settings (passive margins and contractional belts) to see the influence of contrasting overburden and erosional patterns in the final observed pore pressure regimes and temperatures. The results are compared with the outcome obtained from conventional basin modelling software, seismic velocities and actual pressure and temperature data from boreholes. We suggest that one of the advantages of this workflow would be to show how the modelling results can reinforce the evidence that favors the most likely tectonic evolution of a basin.

SESSION TITLE: Theme 2: Andean Structural Styles III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Updated age, amounts of extension and structural styles of rifting in the Colombian Eastern Cordillera.

AUTHORS (FIRST NAME, LAST NAME): Andrés Mora², Martin Reyes¹, Iván Camilo Higuera³, Gianreto Manatschal⁴, Victor Caballero⁵, Victor Valencia⁶

INSTITUTIONS (ALL):

1. Georg-August-Universität Göttingen
2. Ecopetrol Brazil
3. Ecopetrol
4. Institut Terre et Environnement de Strasbourg, University of Strasbourg
5. Ecopetrol-ICP
6. Empty

ABSTRACT BODY:

Abstract Summary: Cretaceous rift events in the Southern Atlantic typically have a duration of about 20 to 30 Ma before the drift phase starts. In this study, we analyze the syn-rift units of the Middle Magdalena Valley, to understand the duration of rifting. We also compare those records with the eastern side of the Eastern Cordillera. Here we report new U/Pb ages for the Triassic-Jurassic syn-rift units in the Middle Magdalena Valley. The youngest provenance ages are Late Jurassic, while the oldest crystallization ages from tuffs are Late Triassic. Based on our assessments, we document, for the first time in the Northern Andes, a locality with evidence of continuous Mesozoic rift events for about 50 Ma. The implications of these new ages are intriguing. For example, with such a long timeframe for the deposition, the sedimentation rates are higher than those in the overlying Lower Cretaceous Formations. Regarding the petroleum systems, and based on the previous observations, sedimentation rates allowed us to conclude that the syn-rift phase in the Middle Magdalena Valley was mainly coeval with the Triassic-Jurassic units, while the Lower Cretaceous units would therefore be associated with a thermal subsidence phase. This implies lower Eo-Cretaceous heat flows in comparison with previous times. An earlier, and longer (Triassic-Jurassic), rift phase in the Middle Magdalena Valley implies a positive scenario for the Early Cretaceous source rocks and for the yet-to-be explored petroleum play of the Middle Magdalena Valley. Regarding the geodynamic conditions, during the Triassic-Jurassic deposition, coeval calcalkaline magmatism suggests that these units were deposited near an active back-arc setting, which is at odds with previous hypothesis. In addition, this timing of deposition unambiguously shows an eastwards migration of the rift activity during the Cretaceous (i.e., the eastern flank of the Eastern Cordillera). Moreover, prominent footwall uplift and rapid marine transgression along the eastern side of the Eastern Cordillera suggests that the Cretaceous rifting in this sector of the Andes was related with larger amounts of extension, albeit in a shorter time period in comparison with the Middle Magdalena Valley.

SESSION TITLE: Theme 7: Critical Minerals for Energy Diversification

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Technical Evaluation of Lithium Brine Deposits – A Structured Approach

AUTHORS (FIRST NAME, LAST NAME): Michael Rosko¹

INSTITUTIONS (ALL):

1. Montgomery & Associates Consultores Limitada

ABSTRACT BODY:

Abstract Summary: Lithium brine mineral resources are fluid deposits of variable density and mobility, and need to be evaluated differently than traditional hard rock resources. These mineral-enriched brines are hosted in porous- and fractured-rock aquifers, typically within closed hydrologic basins where lithium has been concentrated via evaporation over long periods of time. The conceptualization and exploration of brine mineral resources requires not only an understanding of the spatial and temporal variability of brine densities and concentrations, but also the hydraulic parameters of the aquifer. Similar to reservoir evaluation in the petroleum industry, key parameters such as brine volume and grade, aquifer geometry, hydrogeologic unit definition, effective porosity, specific yield, flow rate, recoverability, etc. are used in order to meet the definition of reasonable prospects of economic extraction and define the mineral resource. To compare in situ amounts versus the potential for recovery of lithium from a brine deposit, one must understand the mobility and concentration of the brine prior to and during extraction pumping. With a good understanding of the aquifer stratigraphy, the fluid nature of the deposit allows for increased efficiency during the exploration phase, with fewer exploration wells being required than for typical hard rock deposits. Practical methods have been developed to characterize and evaluate lithium brine resources and reserves. Although the same elements need to be evaluated for other types of mineral resources (types and methods of exploration and sampling, adequacy of the conceptual model, type and quality of the resource and reserve numerical models, and method and adequacy of the resource or reserve estimation), how these elements are evaluated often varies from traditional evaluation of hard rock deposits. For example, a traditional resource categorization of an ore deposit is a function of the spacing between exploration boreholes, with decreasing distance between boreholes resulting in increasing confidence in the resource category. Although more boreholes or wells will also provide increased confidence in the understanding of a lithium brine resource, an understanding of the aquifer framework and its hydraulic parameters is more important than the spacing given that lithium brine chemistry tends to be less variable in an aquifer except in zones where dilution with fresh water may occur.

SESSION TITLE: Theme 7: Critical Minerals for Energy Diversification

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Geology of Economic Natural Lithium Deposits

AUTHORS (FIRST NAME, LAST NAME): Camilo Raul de los Hoyos¹

INSTITUTIONS (ALL):

1. SRK Consulting (Argentina) S.A.

ABSTRACT BODY:

Abstract Summary: The natural occurrence of lithium in potentially economic contents is currently constrained to the following deposit types:

“Hard-rock” deposits

- Li – Cs – Ta (LCT) Pegmatites: Bulk 0.58 to 1.18 wt% lithium
- Jadarite: Bulk average 0.84 wt% lithium

“Soft-rock” deposits

- Hecorite (lithium-rich clay): Bulk 0.17 to 0.24 wt% lithium
- Lithium-rich tuff: Bulk average 0.30 wt% lithium
- Dissolved lithium deposits (brines)
- Continental brine in salars: 0.01 to 0.18 wt% lithium
- Geothermal brine: 0.01 to 0.03 wt% lithium
- Oilfield brine: 0.01 to 0.05 wt% lithium

The largest economic lithium resources and reserves in the world are currently hosted in three deposit types: LCT-pegmatites (“hard-rock”), Li-rich clays (“soft-rock”) and continental brines (dissolved lithium). In general terms, lithium brine deposits tend to have the lowest grades and tonnages are highly variable, with giant high-grade deposits such as Zhabuye (China, 0.100 wt% lithium) and Atacama (Chile, 0.184 wt% lithium) and the smallest and lowest-grade Clayton Valley deposit. Lithium-rich clay type deposits have medium grade and tonnage, with the largest and richest deposits represented by Thacker Pass (USA, 0.236 wt% lithium) and Sonora (Mexico, 0.229 wt% lithium). LCT-pegmatites are the highest in lithium grades, best represented by giant deposits such as Greenbushes (Australia, 1.091 wt% lithium) and Pilgangoora (Australia, 0.580 wt% lithium). In relatively recent years, other currently economic volcanogenic deposits such as Falchani, composed of felsic lithium-rich tuffs (Peru, 0.296 wt% lithium), and Jadar, where lithium is hosted in a sodium-lithium boron silicate hydroxide named Jadarite (Serbia, 0.836 wt% lithium).

LCT pegmatites have been extensively exploited given the high lithium contents in their minerals and they account for less than 40% of the known global resources. Lithium-rich continental brines account for nearly 60% of the global lithium resources. The discovery and characterization of huge lithium-clay deposits such as Thacker Pass and Sonora, as well as important improvements for lithium processing has located lithium-rich deposits as novel important lithium resources. The current predicted demand up to the year 2100 is 20 Mt lithium; world resources are currently estimated at more than 62 Mt lithium. Thus, abundant resources exist, and no long-term shortage is predicted.

SESSION TITLE: Theme 5: Case Studies in Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Migration Routes: A new target for Unconventional Exploration. Insights from the Montney Play of Western Canada.

AUTHORS (FIRST NAME, LAST NAME): Tristan Euzen¹, Neil Watson², Albert Cui³, Jordan Wilson⁴, David Cronkwright⁵

INSTITUTIONS (ALL):

1. IFP Technologies (Canada) Inc.

2. Enlighten Geoscience Ltd

3. Agat Laboratories

4. Agat laboratories

5. Enlighten Geoscience Ltd

ABSTRACT BODY:

Abstract Summary: After over 15 years of appraisal and development of unconventional plays in the Americas, it is now clear that beyond oil and gas retained in source rocks, there is a vast realm of unconventional resources along hydrocarbon migration routes, from reservoirs interbedded with source-rock intervals, on a continuum to tight sandstone fringing large conventional accumulations.

The Montney play of Western Canada is one of the largest, most active, and best-documented unconventional plays in the world. The analysis of a huge public domain dataset from over 7,000 horizontal wells demonstrates that this resource play is mostly produced from carrier-bed reservoirs. In-situ hydrocarbon distribution resulted from migrated oil subsequently cracked into condensate, wet gas and dry gas along a regional thermal maturity trend and further modified by up-dip secondary gas migration. Geothermal gradient variations across the Montney deep basin controlled different sub-play types and secondary gas migration fairways were also influenced by pressure compartments developed through structural features and the stratigraphic framework. Finally, understanding production fractionation mechanisms is paramount to estimate gas and liquids recovery potential and design development plans accordingly.

This presentation aims at illustrating key characteristics and fundamental controls on a carrier-bed play, and introduces a new approach integrating geochemistry, hydrodynamics, and PVT data to map fluids recovery potential. This workflow, although initially developed for the Montney, is applicable to other resource plays. Ultimately, applying ideas and concepts developed in extensively drilled and well-developed basins such as in the Montney play, can help refining exploration strategies and broaden perspectives, in basins where unconventional resources are yet to be developed.

SESSION TITLE: Theme 5: Case Studies in Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Effect of Estimated Geomechanical Properties using Seismic Inversion for Well Planning: Comparison of Simultaneous and Facies-Based Inversions in an Unconventional Reservoir

AUTHORS (FIRST NAME, LAST NAME): Joaquin Aristimuno¹, Jorge Fernandez-Concheso², Yoryenys Del Moro³

INSTITUTIONS (ALL):

1. Ikon Science
2. Ikon Science
3. Ikon Science

ABSTRACT BODY:

Abstract Summary: We present in this work a comparison of geomechanical properties of an unconventional reservoir estimated from two seismic inversion techniques: Simultaneous and Facies-based inversions.

The elastic properties calculated out of the seismic inversion techniques were used to estimate Maximum and Minimum Horizontal Stresses (SHmax and Shmin), Young Modulus (E) and Poisson Ratio (PR). Three different datasets were compared: two Simultaneous Inversions datasets, whose only difference was the removal of one well out of the low-frequency model building; and one Facies-based inversion. A complete geomechanical model was defined on a well scale, and the same parameters for Dynamic to Static E calibration, vertical stress, hydrostatic and formation pressures were applied on the different 3D datasets to define the geomechanical model from seismic inversion.

By comparing the simultaneous seismic inversion results is possible to identify the effect of the low-frequency model on the estimated elastic parameters and consequent geomechanical model. The magnitudes of geomechanical properties such as Maximum Shear Stress [$(SH_{max} - Sh_{min}) / 2$], which is related to casing shear risk, are different between the two simultaneous inversion datasets. These differences highlight the bias effect, and therefore increase in uncertainty, characteristic on the simultaneous inversion towards the low-frequency model used.

Facies-based inversion uses rock-physics trends per facies to constraint the absolute values of the elastic properties that matches the seismic data when convolved with a wavelet. The rock-physics trends are defined using available data (wells or theoretical relationships) and do not depend on the location or number of wells, assuming all facies are represented with the rock physics models defined. Collapse Pressure was estimated in one well using well log data, and three Collapse Pressure volumes generated from geomechanical properties obtained from the three different seismic inversion datasets. Traces were extracted from the volumes at the well location and compared.

Finally, Collapse Pressure volumes were used to compute volumes of Mudweight that represents the pressure needed to maintain wellbore stability, for both vertical and horizontal well cases. We conclude that facies-based inversion can provide a more robust estimation (bias free) of geomechanical properties that drilling engineers can use for drilling planning.

SESSION TITLE: Theme 5: Rock and Fluid Characterization of Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Corrections And Extensions to the GRI Technique: Dual Imbibition, NMR, and SEM Image Analysis.

AUTHORS (FIRST NAME, LAST NAME): Clara Palencia¹, Lori Hathon², Michael Myers³ **INSTITUTIONS (ALL):**

1. University of Houston

2. University of Houston

3. University of Houston

ABSTRACT BODY:

Abstract Summary: The GRI technique for characterizing samples of unconventional reservoir formations is performed on crushed material, and typically used to measure the total porosity of unconventional reservoirs and to estimate their permeability. The addition of water and oil imbibition, NMR, and SEM imaging and image analysis allows an extension of that technique for the quantification of in situ pore fluid salinity, mineral hosted and organic porosity, and corrections to total for fractures generated during the sample preparation process. Comparisons between total porosity (GRI Boyle's law) and imbibed water volumes, suggest that the crushed samples imbibe considerably more water than the measured total porosity. Sample characterization (including ICP on supernatant fluids after conductivity equilibration is observed, post-imbibition NMR, and image analysis) indicate that multiple corrections to imbibed volumes must be applied. These corrections include: the effect of dissolution pores created by anhydrite (salt) dissolution and corrections for fractures induced during sample preparation. Porosity created during sample preparation (grain fractures internal to the individual particles) was observed in post-imbibition NMR results, and in SEM images. When these two corrections are applied, a comparison of pre-test Boyle's Law measurements and imbibed water volumes results in relatively good agreement between the two measurements, although the imbibed water volume is less than the as received total porosity from Boyle's Law. The difference between the Boyle's Law and imbibed water porosity is interpreted to correspond to the organic matter hosted porosity. This result illustrates that water does not enter the organic matter hosted pores, and suggests that at thermal maturities between 1.4-2.5% Ro, the organic remains oil wet. Oil imbibition performed on a separate aliquot of material, provided a measure of organic matter hosted porosity. When we add the corrected water imbibition and oil imbibition porosities together, there is good agreement between pre-test Boyle's Law porosity and the imbibed volumes. The new approached is a promising technique for estimating organic porosities in shale gas and shale oil reservoirs. Additionally, it may provide a basis for a possible GRI (Gas Research Institute) total porosity measurement correction, particularly in high carbonate content unconventional reservoirs.

SESSION TITLE: Theme 5: Rock and Fluid Characterization of Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Integrated reservoir characterization of an unconventional reservoir in the Catatumbo Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Felipe A. Lozano¹, Diego Delucchi², Alvaro Lasso³, Nelbett Marfisi⁴, Nelly Rubio⁵, Maria Florencia Segovia⁶, Tatiana Milena Juliao Lemus⁷, Ivan Acosta⁸

INSTITUTIONS (ALL):

1. Ecopetrol, Bogota, Colombia.
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol
8. Ecopetrol

ABSTRACT BODY:

Abstract Summary: In complex structural areas like the Catatumbo Basin in Colombia, the characterization of natural fractures for shale-oil and shale-gas unconventional reservoirs is essential for the estimation and prediction of the reservoir performance. In addition, the integration of multidisciplinary data is critical for the construction of geocellular and Discrete Fracture Network (DFN) models that are required for geomechanical hydraulic fracture simulation and dynamic simulation. For this study, we integrated the interpretation of a recently reprocessed anisotropic prestack time migrated 3D seismic data (192 km²) and the analysis of three vertical wells with petrophysical and geomechanical data. Two of these wells have core data with advanced laboratory analysis and image logs used for petrophysical, geomechanical, and natural fracture characterization.

Modern seismic attributes computed in conjunction with seismic impedance inversion and unsupervised seismic multiattribute classification analysis allowed us to identify subtle fracture corridors that were not previously identified with the standard discontinuity seismic attributes (coherence-type and curvature).

Matrix (porosity and TOC) and geomechanical properties (Young's Modulus) were distributed based on correlations with seismic impedance inversion at the interval of interest.

The construction of the DFN model included the well core and image log fracture analysis. The fracture sets distribution was constrained by the mechanical stratigraphy and following regional fracture conceptual models build for the study area (fold-related and fault-related fractures). The DFN was distributed into the geocellular model integrating seismic acoustic impedance and the computed seismic volumes obtained from the multiattribute classification. Reservoir properties and DFN models obtained in this project were delivered for dynamic and hydraulic fracture simulations to predict well performance, define field development plans, and resource estimations.

SESSION TITLE: Theme 5: Case Studies in Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: High resolution 3D static modeling applied to unconventional resources. A case study from the Argentinian Patagonia

AUTHORS (FIRST NAME, LAST NAME): Jaime Vargas¹, Dolores Vallejo¹, Ezequiel Lombardo¹, Esteban Rives¹, Ryan Wilson¹, Morgan Sullivan¹

INSTITUTIONS (ALL):

1. Chevron

ABSTRACT BODY:

Abstract Summary: Summary

Geological modeling has been a key tool for the successful development and forecasting of conventional hydrocarbon resources for the last 25 years. The techniques and workflows established for the modeling of these resources have been a key focus of knowledge creation in several areas. Modern applications in modeling techniques can range from representing complex structural regimes or to even characterize the rock quality at the centimeter-scale.

However, for unconventional resources, the tools used during initial stages of exploration and asset development were at a state of infancy and were in many cases overly simplistic and did not adequately represent variance in geologic controls observed in seismic, well-logs, and core. The models strongly favored 'layer cake' stratigraphy of coarse units (100's of feet) with no evident stratal terminations, geometry, architecture, facies concepts, or realistic fracture models. This was largely the result of a "factory mode" development program, where well locations need to be defined in almost real time.

During the last 5 years, Chevron has been actively pursuing new unconventional workflows using cutting edge technology in stratigraphy, modeling, and reservoir simulation. The objective of these new techniques is to better characterize 'the rock' to facilitate ranking and prioritization of landing-zone targets, as well as optimization of well placement for completion design to maximize EUR.

This paper aims to provide a brief description of each of the project stages needed for a successful completion.

Background

The workflow is simple: high resolution sequence stratigraphy at 3rd to 5th order level will limit sequences and parasequences that will effectively determine the extrapolation of mineral properties away from well control. The extra-detail added to the model will reduce the amount of statistical error inherent from traditional geostatistical methodologies. This technique will emphasize a semi-deterministic over the traditional simulations and will target the "best estimated" scenario for well landing. Following the construction of the stratigraphic framework, a fault model is built. The objective of the fault model (besides the correct representation of the structure) is to associate the occurrence of faults with the frequency of natural fractures. In practical terms, the methodology uses the faults as a fracture's driver. The amount and location of natural fractures could control the size and direction of the induced hydraulic fractures, which determine the final well production. Lastly, geological (mineral, porosity, etc.) and rock (Young Moduli, Poisson Ratio, etc.) properties are correlated with seismic attributes to help the propagation and reduce uncertainty.

The static models are then subjected to a rigorous validations using reservoir simulation. Uncertainty in the model response is measured and used for the decision-making process.

The incorporation of high-resolution sequence stratigraphy, a robust structural framework, and reservoir properties from seismic have helped Chevron to reduce uncertainty and maximize production in the Neuquen Basin. The integration of these technologies has been a major accomplishment of this multidisciplinary team, and has been used as a standard to leverage for other unconventional assets in Chevrone's portfolio.

SESSION TITLE: Theme 5: Rock and Fluid Characterization of Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Organic porosity study from Late Cretaceous source rocks in The Middle Magdalena Valley Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Maria Florencia Segovia¹, Tatiana Milena Juliao Lemus², Maria Juliana Robayo³, Nelbett Marfisi⁴

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Located in the Middle Magdalena Basin in Colombia, La Luna Fm. is a thick succession of organic rich rocks of Middle to Late Cretaceous, with clay content lower to 30%. It is the main source rock of the Tertiary reservoirs that are producing in the basin since 1921.

La Luna become increasingly important for the economy of the country, due to the hydrocarbon resources associated to these unconventional rocks. Storage assessment is critical in the valuation of acreage and definition of the economic opportunity that a given project may yield (Newsham, Comisky and Chemali, 2019). Storage defines the opportunity (Newsham et al, 2019) and the capacity mainly depends on porosity and hydrocarbon saturation (Sondergeld, 2010; Newsham et al, 2019).

The shale oil/ gas reservoirs are characterized by a complex pore system, including organic porosity, interparticle (interparticle or intergranular), intraparticle (Loucks, et al 2012) and natural fractures (Curties, 2002). The porosity varies in depth and is affected by compaction, maturity, organic matter content, diagenesis (Loucks, 2012). The organic porosity increases with depth (maturity) and organic matter content, while inorganic porosity (interparticle and intraparticle) uses to decrease. The textural study shows a porosity development in rocks artificially evolved by hydropyrolysis processes under increasing temperature from the beginning of the oil window to the gas generation window. A gradual increase in pores (Hg porosimetry) was observed, particularly in the amount of macropores and mesopores (sizes: 5.5-12000 nm) with increasing thermal maturity of organic matter. The nitrogen adsorption also shows a significant increase in the total volume of adsorbed gas representing an increase in micro-mesopores and small macropores, and in the specific surface area BET (Brunauer, Emmett y Teller). The CO₂ adsorption isotherms display a substantial increase in the volume of ultra-micropores. All this is due to the cracking of the primary organic matter to produce oil and, later to the cracking of solid bitumen in gas. In this work we would like to share the results of several analyzes carried out in the various laboratories, such as Instituto Colombiano del Petróleo (Ecopetrol), Ingrain (Halliburton) and the Instituto de Ciencia y Tecnología del Carbono de Oviedo, España (INCAR), to improve the knowledge of the pore system analysis, calibrate the porosity and accurate the in-place volume estimates.

SESSION TITLE: Theme 5: Rock and Fluid Characterization of Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Characterization of unconventional reservoirs using rock physics and drill cuttings.

AUTHORS (FIRST NAME, LAST NAME): Ramil Ahmadov¹, Fabien Allo²

INSTITUTIONS (ALL):

1. GeoSoftware
2. CGG

ABSTRACT BODY:

Abstract Summary: The application of rock physics modeling for reservoir characterization is well known and can help to delineate fluid and facies changes. With the advent of unconventional resource exploration & production, and the adoption of long laterals to maximize reservoir contact and recovery, use of elastic rock properties for reservoir characterization becomes increasingly important. Derivation of an accurate, robust, and reproducible predictive reservoir characterization models has proved challenging in unconventional plays. Lacking the model with robust predictive power, drilling and completion decisions are often made on non-geologic criteria tangentially related to the rock properties within their production targets. Zones of interest originally assumed to be homogeneous and isotropic are proving to be quite complex leading to renewed interest in the utilization of workflows to create geological and engineering models ahead of the drill bit. Technological advances in both equipment and computer software have enabled the implementation of new approaches in generation of mineralogical datasets at well sites. These datasets are currently utilized by hydraulic fracturing engineers to assist in designing optimized fracture stage intervals in horizontal wellbores, in contrast to the assumption of uniform intervals between frac'ing stages. Mineralogical data is generated by downhole wireline logging tools, and on drill cuttings, whole cores, and rotary sidewall core plugs utilizing a variety of analytical instrumentation techniques. In this paper, we present a workflow to incorporate microtextural data derived from drill cuttings into Rock Physics Modeling. Several wells from one of the unconventional fields have been interpreted for petrophysical properties. Corresponding drill cuttings have been analyzed and interpreted to derive microtextural data. RPM has been performed and a set of synthetic elastic logs has been computed and calibrated to well logs available in vertical well. Weakness planes have been incorporated into computation of the weakness and finally, breakdown pressure has been derived and compared to the actual pressure obtained in-situ. Results are in good agreement, thus providing valuable insights and merging field observations with RPM-based analysis.

SESSION TITLE: Theme 5: Case Studies in Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Vaca Muerta High-resolution Stratigraphic Framework for Improved Landing Zone Prediction

AUTHORS (FIRST NAME, LAST NAME): Hernán Reijenstein², Karina Anis¹, Daniel Sotelo², Ryan Wilson², Walter Brinkworth¹, Jaime Vargas²

INSTITUTIONS (ALL):

1. YPF S.A.

2. Chevron

ABSTRACT BODY:

Abstract Summary: The Vaca Muerta self-sourced unconventional play is characterized by a set of prograding clinoforms (shelf-attached), whose bottomsets constitute the organic-rich mudstones currently being developed with horizontal wells, whereas the overlying un-developed prospective clinoform forests contain interfingering organic-rich mudstones and organic-lean limestones. While bottomsets are highly continuous spatially and lack drastic changes in reservoir properties and thickness, the foresets in contrast, display a clear stratigraphic control on their spatial distribution. Striking N42E, foreset facies are highly continuous along this direction, but drastically change along depositional dip, both in terms of reservoir properties and thickness. The main goal of this study was to build a high-resolution 3D static earth model capable of capturing stratigraphic heterogeneity at the landing-zone scale to help: 1) reduce depth uncertainty in well trajectory planning & execution, 2) better constrain reservoir properties during static model population, and 3) better predict reservoir presence, quality, and spatial distribution away from well control. For that, we developed a sequence stratigraphic scheme based on 3D seismic interpretation, and rigorous well-log stacking patterns correlation across ~450 vertical wells. Additionally, we included geosteering pointsets from ~235 horizontal wells, which were key to build consistent surfaces and improve spatial distribution of landing zones. To construct the model grid, we utilized a hybrid VBM-Pillar gridding technique combining seismic horizons and well tops. Based on detailed well-log stacking pattern correlations that thin out below seismic resolution, we have proven that seismic reflector terminations, i.e. lapouts, do not necessarily translate to stratal terminations, as evidenced by bedsets continuity, both up and downdip along the clinoform. Resultant landing-zone scale stratigraphic framework (5-30m thick layers / 5th-order sequences) is unique in the basin due to its high resolution and spatial control (680+ wells, 40+ layers, 18000+ well tops). It has provided tremendous value and application in day-to-day operations, trajectory planning, real-time execution, and identification of prospective benches in the foresets. Horizontal-well trajectories executed after model construction were compared against the model frame as a quality-control blind test, showing remarkable consistency with errors below 2m.

SESSION TITLE: Theme 5: Rock and Fluid Characterization of Unconventional Resources

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Why core matters in the integrated characterization of unconventional shale reservoirs? a case study from the Middle Magdalena Valley Basin, Colombia

AUTHORS (FIRST NAME, LAST NAME): Nelly Rubio², Felipe A. Lozano¹, Adriana Prada³, Juliana Riaño⁴

INSTITUTIONS (ALL):

1. Ecopetrol, Bogota, Colombia.
2. Ecopetrol
3. Ecopetrol
4. Empty

ABSTRACT BODY:

Abstract Summary: Appropriate characterization of shale reservoirs requires advanced well core analysis to reduce uncertainties regarding the rock heterogeneity that cannot be addressed from well log analysis. In this study, we analyzed approximately 726 feet of core from an integrated perspective, including advance analysis of CT scan videos, SEM images, XRD/XRF, image logs and spectral gamma-ray. The methods used included an exhaustive quality control of the raw and interpreted data, the analysis (mineralogy, petrography, lithology, and petrophysics) of the core including the characterization of the geological features that can affect the efficiency of the hydraulic fractures: natural fractures (density, apertures, fillings), laminations (thickness, frequency), concretions (size, frequency), and tuffs. Finally, a multidisciplinary integration was performed to understand the reservoir potential and the impact of the different geological features in the operations.

The results showed three heterogeneous units (U1, U2 and, U3) with distinctive characteristics that without integration of the independent core and log analysis could lead to weak interpretations and misleading conclusions. The visual core description defined all three units as carbonate rocks (wackestone/packstone), but further multidisciplinary analysis showed a higher content of quartz and clay compared to the carbonate percentage. U1 core description showed a composition of carbonate 60%, but after the integrated analysis the results showed a composition of Qz 72%, Clay 14% and carbonate only 14%. The same happened to U2 with an initial interpreted carbonate composition of 77%, but after integrated analysis, it showed Qz 70%, Clay 6% and Carbonate 24%. U3, showed 55% of carbonate and after integrated analysis, Qz 45%, Clay 12% and Carbonate 43%. The interpretation of image logs along with CT scan videos allowed us to better characterize the natural fractures (higher density, apertures, and filling material), and have a better insight into the characterization of the laminations (frequency), concretions, and tuffs.

This multidisciplinary integrated core characterization provides the basis for a more robust reservoir characterization (3D geomechanical static model for simulations). In conclusion, the integration of the different methods allowed us to better characterize the different geological features and add value on the drilling (landing zone), hydraulic fracture design and impact the wells productivity

SESSION TITLE: Theme 2: Andean Structural Styles III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Andean Structural Styles: Challenges in Seismic Imaging

AUTHORS (FIRST NAME, LAST NAME): Rob Vestrum¹, Greg Cameron²

INSTITUTIONS (ALL):

1. Thrust Belt Imaging
2. Thrust Belt Imaging

ABSTRACT BODY:

Abstract Summary: This presentation develops the themes presented in Chapter 2 of the AAPG publication, Andean Structural Styles: A Seismic Atlas. Seismic data in areas like the Andes have unique challenges that break traditional seismic-imaging methods designed for offshore exploration. Reducing exploration risk in these basins requires a workflow tailored to the geologic setting. The under-constrained nature of the seismic data requires tight integration with the structural geologist.

Seismic imaging is a vital tool for mapping the complex geologic structures of the Andes. The method of imaging the Earth's subsurface with seismic waves is powerful, and it has certain limitations—especially when deployed in complex-structure land areas like the mountain ranges and high plains of the Andes. Understanding the technologies involved and how they are applied to this specific geologic setting will improve our understanding of the risks and uncertainties involved in the interpretation of structures on seismic images.

Seismic data in thrust-belt environments are typically low data density and have low signal-to-noise ratios, all while attempting to image complex geologic structures. The data are acquired over rough topography with laterally varying velocities from the surface down. If the near surface is the lens through which we image the subsurface, our lens is bumpy and distorted. These are the challenges of seismic processing in fold thrust belts, and decades of technology development has gone into facing those challenges, from weathering corrections for the near-surface, to advance migration algorithms that can image below major thrust faults.

SESSION TITLE: Theme 2: Andean Structural Styles II

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Structural evolution and charge of the San Francisco oil field, Upper Magdalena Valley. A kinematic history unraveled with a unique seismic record of unconformities related with different tectonic events.

AUTHORS (FIRST NAME, LAST NAME): Alexis Rosero¹, Milton Carrero², Claudia Ceballos³, Andrés Mora⁴

INSTITUTIONS (ALL):

1. Hocol S.A.
2. Hocol S.A.
3. Ecopetrol
4. Ecopetrol

ABSTRACT BODY:

Abstract Summary: 3D seismic data in the areas within and adjacent to the San Francisco Anticline allowed us to document unique examples of syn-rift and syn-inversion unconformities. First, the Jurassic-Cretaceous unconformity is related with a Mesozoic rift history, while a Miocene-Oligocene unconformity post-dates the main and first inversion event. The Mesozoic unconformity allows interpretation of the proto-San Francisco Anticline as related with a Mesozoic Jurassic half-graben structure, which underwent contractional deformation starting during the Oligocene. Early inversion associated with the San Francisco Anticline is not related with normal fault reactivation but with a new rupture to the east, within the former footwall of the Mesozoic half-graben, being therefore a footwall shortcut. This earlier inversion is transferred to the east as thin skin deformation with flat detachments within the Meso-Cenozoic sedimentary units and is coeval with thick skin deformation further east of San Francisco, associated with Oligocene uplift and exhumation of the Natagaima basement high. Out of sequence late Oligocene to early Miocene deformation is finally related with direct reactivation of the San Francisco half-graben boundary fault. After these events deposition resumes above the Oligocene-Miocene unconformity. This unconformity post-dates the erosion that peneplanized the previous topographic relief. Most of the faults bounding the structures cut the unconformity which means that they are further reactivated from the Pliocene to present day. Interestingly, the San Francisco oil field is not filled to spill. That and the presence of potential early kitchens west of the modern anticline allowed us to hypothesize that the structure was filled during the earliest contractional reactivation phases, prior to the onset of deposition of the Honda group above the unconformity. At that time the anticline had a structural relief that is less than the relief that it has today and the potential spill point by that time would mean a smaller oil column if compared with the column that the field would have if it were filled to spill today.

SESSION TITLE: Theme 2: Geomechanics, Faults and Fracture Characterization

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Automated quantification of fault shape and optimisation of kinematic parameters in modelling fold and thrust belt deformation

AUTHORS (FIRST NAME, LAST NAME): Manoel Valcárcel¹, Cathal Reilly²

INSTITUTIONS (ALL):

1. Petroleum Experts

2. Petroleum Experts

ABSTRACT BODY:

Abstract Summary: Identification of appropriate parameters to use in kinematic modelling of fold and thrust belts is traditionally a manual, iterative and time-consuming process. Commonly, this is done through a trial and error forward modelling procedure, with results being assessed visually by the user. Here, an automated method of kinematic parameter search is presented with examples from around the world, including Colombia.

This method builds on existing methodologies and has a range of benefits when compared to traditional, manual modelling methods: (i) it speeds up the modelling process (ii) it is flexible and adaptable to different scenarios and kinematic algorithms, (iii) it ensures documentation and reproducibility of the modelling procedure and (iv) it minimizes subjectivity.

Recent research has developed automated searches for kinematic modelling parameters (e.g. Trishear inverse modelling) that are implemented using scripting. However, these methodologies are not yet available in a commercial, graphically interfaced, structural modelling software package. The method presented here has the distinct benefit of leveraging well established, widely utilised structural geological modelling software in combination with a graphical solution formulation platform to provide an automated parameter search workflow without the need of using computer programming languages. This method is illustrated using fault-propagation folds from around the world, including Colombia, where input data is of poor quality and interpretation is incomplete. Using this workflow we can efficiently constrain the fault shape and deformation parameters to aid understanding of the structure.

Starting from an incomplete interpretation the workflow automatically quantifies fault shape and slip magnitude, then used as inputs for a numerical search engine to identify trishear parameters (fault tip position, propagation slip ratio/ trishear angle and trishear zones). This process is automatically iterated using a particle swarm optimiser to find the best set of parameters. Using this automated numerical approach we remove subjectivity associated with traditional kinematic modelling of fold and thrust belt deformation. The method presented offers increased efficiency in its automated quantification of kinematic parameters which will dramatically reduce the time required to model, and understand, the kinematics of fold and thrust belt structures and is adaptable to virtually any other kinematic problem.

SESSION TITLE: Theme 2: Salt and Shale Tectonics

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Three-dimensional interaction between detachment folds, thrust faults, and salt diapirs: examples from the Sureste Basin, offshore Mexico

AUTHORS (FIRST NAME, LAST NAME): Mark Rowan², Josep Antón Muñoz¹, Eduard Roca³, Oriol Ferrer⁴, Pablo Santolaria⁵, Pablo Granado⁶, Marco Snidero⁷

INSTITUTIONS (ALL):

1. University of Barcelona (Spain) Geomodels Research Institute
2. Rowan Consulting Inc.
3. University of Barcelona (Spain) Geomodels Research Institute
4. University of Barcelona (Spain) Geomodels Research Institute
5. Empty
6. Empty
7. Empty

ABSTRACT BODY:

Abstract Summary: Contractional deformation in salt-bearing rifted- and convergent-margin settings often involves diapirism. Diapirs may predate the onset of shortening, in which case they exert a pronounced influence on how contractional strain is accommodated, or they may be triggered by the shortening. Analog models have been used to help understand the interaction and evolution of detachment folds, thrust faults, and diapirs, but few surface or subsurface datasets provide adequate three-dimensional images to test and refine the experimental results. Here we use 3D depth-migrated seismic data from the Sureste Basin in the southern Gulf of Mexico to map two structures, one dominated by salt-cored anticlines and one characterized by thrust faults. Associated diapirs along each structure include both pre- and syncontractional stocks and walls. We show that although experimental models nicely reproduce some of the seismic geometries, there are also apparent mismatches. Whereas models often generate decapitated diapirs and thrust-fault salients centered on the diapirs, such features are absent in the study area; instead, the diapirs form thrust reentrants that are a function of the intersection of vertical diapirs and dipping thrust faults. Moreover, in contrast to model faults that dip 20-45°, faults in the study area are steeper, ranging from 50-75°. We bring in observations from other salt basins, from both orogenic and rifted-margin settings, to discuss these discrepancies, possible explanations, and suggestions for improving the applicability of models to nature.

SESSION TITLE: Theme 2: Andean Structural Styles III

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Petroleum potential and structural styles of the Central Colombian Eastern Foothills. A successful case study of exploration in complex contractional settings.

AUTHORS (FIRST NAME, LAST NAME): Mario Patino¹, Jaime Martinez², Paola Castano Giraldo³, Andrés Mora⁴, Eliseo Teson⁵, Luis Enrique Soto⁶

INSTITUTIONS (ALL):

1. Ecopetrol
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ABSTRACT BODY:

Abstract Summary: Exploring in foothills includes the common presence of poor seismic images which are usually related with complex deformation and rugged topography. Therefore, seismic interpretation in these settings should be supported by structural techniques, which allows to perform predictive balanced geometric and evolutionary models. The several discoveries in the Eastern Foothills, including the most recent RW discovery, have proven that these models have been successful and should be routine task. In the Central Eastern Foothills the southern segment of the cylindrical Nunchia Syncline has been successfully explored while the northern segment is still underexplored. However, its cylindrical lateral continuity along the southern and northern segments allows to infer the presence of similar structural styles and number of stacks in analogue thrust sheets. Thus, to extend the interpretation to the less explored zone with a concept that has proven successful to the south, we use the area of the producing examples, as a template for the interpretation. The cylindrical Nunchia Syncline displays the Neogene units uplifted more than 4 km above the undeformed regional level to the east. Here we propose an interpretation workflow that, using well log data, seismic, and surface geology allowed us to interpret that the uplifted core of the Nunchia Syncline is related with at least 3 stacked thrust sheets which include the productive reservoir levels. We use the available seismic surveys and well data to suggest that the best documented thrust sheets have a structural style of faulted detachments folds. The main thrust sheets initially grew as adjacent detachment folds during the Late Oligocene. Later, the individual thrust sheets were stacked in an eastwardly-propagating sequence on top of each other during the Late Cenozoic until a late (Pleistocene to Recent) movement breached and uplifted the internal (western) Monteralo and El Morro thrust sheets in an out-of-sequence way. Given the structural concept, similar mechanical stratigraphy and the persistence of the key structural patterns to the north, we expect thrust sheets with similar aspect ratio, similar geometry and similar detachment levels, compared with those producing examples to the south. The extrapolation of that concept and a success rate of almost 60% for the structurally most complex triangle zone allow us to suggest the presence of yet to be found resources of several billions of barrels.

SESSION TITLE: Theme 4: AVO, DHI and Seismic Data Inversion for Exploration and Development

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: DHI assessment in carbonate Pre-Salt reservoirs

AUTHORS (FIRST NAME, LAST NAME): Antonio Velasquez¹, Ricardo Zavala², Juan Miguel Rodriguez³, Lizbeth Calizaya⁴, Erika Leao⁵

INSTITUTIONS (ALL):

1. Ecopetrol
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3. Ecopetrol
4. Ecopetrol Brazil
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ABSTRACT BODY:

Abstract Summary: Abstract

Seismic amplitudes have been widely used to predict both facies and pore-fluids in any type of reservoirs. However, AVO techniques face significant challenges when used to reveal rock properties and fluid saturation in heterogeneous carbonates, such as the PreSalt reservoirs. The influence of the pore structure and mineral content, that in carbonates dominate the wave propagation more than a simplistic compaction trend, together with the image quality and the amplitudes preservation below the salt, are reasons for such limitations.

In investigating the feasibility to apply AVO/AVA inversion techniques, seeking potential carbonate rocks sensitive in responding to porosity and pore-fluids, we analyzed elastic rock properties in representative Pre-Salt wells. Different rock physics models were applied, and fluid substitution synthetic modeling were carried out to understand the nature of the seismic response and their significance in predicting different pore-fluids, including brine, oil, gas, and CO₂. The latter, the most common contaminant fluid in Pre-Salt fields of the Santos Basin.

The elastic properties related to the best reservoir intervals (Phie > 10%) within the so-called SAG Sequence (K48 – K46), dominated by microbial carbonates, exhibit acceptable correlation with aspect ratio values ranging from 0,1 to 0,25. These intervals also record impedance values below 14,000 km/s g/cc and Poisson's ratios (PR) < 0,3. Below the anhydrite cap rock the AVO response modeled is class IV for in-situ saturations of oil with CO₂ dissolved. Interestingly, while impedance has well-behaved correlation with effective porosity, the PR is sensitive to fluid saturation. Therefore, for good reservoirs brine and hydrocarbon saturations are theoretically distinguishable. This result provides confidence when interpreting potential DHI's such as cross cutting reflections (e.g., flat events) observable in many fields, discoveries, and prospects of the PreSalt. Conversely, AVO cannot provide reliable distinguishable signatures between oil and CO₂.

Inspired by these feasibility insights, several analogs were characterized into a data base of prior probabilities called Basin DHI Model. A Bayesian approach was then applied to estimate the DHI PoS uplifts/downgrades. Moderate uplifts were obtained for amplitude-supported prospects, suggesting a remarkable applicability of DHI assessment in de-risking Pre-Salt portfolios.

SESSION TITLE: Theme 4: AVO, DHI and Seismic Data Inversion for Exploration and Development

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Optimizing Seismic Inversion Results Through Fully Seismic Driven Background Models Generation

AUTHORS (FIRST NAME, LAST NAME): Bruno De Ribet², Gerardo González¹, Horacio Vera³

INSTITUTIONS (ALL):

1. Emerson
2. Emerson
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ABSTRACT BODY:

Abstract Summary: The deliverables, obtained after a quantitative seismic interpretation project, are today de facto systematically requested for any G&G interpretation workflow.

Optimization of inversion algorithms, paired with an increasing high performance computing capability, favor the rapid availability of such deliverables for prospect delineation, stratigraphic interpretation, or investigating the applicability of ML-based applications, such as lithofacies or rock type prediction.

Those interpretation workflows allow a greater contribution from geophysical studies for creating a geo-cellular model. Also, inversion results are still directly used by geoscientists when propagating elastic properties of the reservoir and analyze their distribution. Therefore, whatever technology a geoscientist may select in a QSI project for running a seismic inversion, it implies a particular care when validating and sharing the results.

Quantitative interpretation experts are facing a series of challenges when they run a model-based seismic inversion. Because seismic is bandwidth limited, low frequency trend is usually obtained from well data, another option is to propagate such trend with the geologic model and use it as the initial guess in a deterministic seismic inversion workflow. Project deadlines, technology and even asset choices may have an impact on the quality of the geologic model, which would result in a simplified structural and stratigraphic representation of the reservoir.

The progresses of imaging algorithms allow the development of new strategies to increase the usage of the seismic into the construction of a more geologically consistent background model. The level of details, from seismic data, clearly invalidates a simple application of a geostatistical approach when representing the micro-layering within a reservoir, especially if we want to consider the presence of discontinuities such as faults or intrusive bodies.

To rely on an integrated and valid subsurface image of the reservoir which maintain the consistency with seismic, high resolution models are required. This presentation compares a conventional workflow for creating the background model with two breakthrough approaches:

- 1) an advanced reservoir modeling approach, paired with a volumetric reservoir-scale interpretation workflow
- 2) a structural seismic guided velocity interpolation algorithm, maintaining structural trends observed in the seismic data.

SESSION TITLE: Theme 4: AVO, DHI and Seismic Data Inversion for Exploration and Development

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: The Value of Preconditioning in an Unconventional Montney AVO Inversion Workflow

AUTHORS (FIRST NAME, LAST NAME): Andrew Mills¹, Evan Mutual², Raul Cova³, Bill Goodway⁴, Wendell Pardasie⁵

INSTITUTIONS (ALL):

1. Qeye
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ABSTRACT BODY:

Abstract Summary: Seismic data preconditioning is a vital step in optimizing the inputs to pre-stack AVO inversion workflows and generating results more consistent with other measured data. Preconditioning can include denoising, amplitude and alignment corrections, and spectral operations on migrated gathers as well as on angle stacks. As AVO inversion for elastic properties depends on variations of seismic amplitude with offset, these steps are critical to achieve improved accuracy. In this case study, we demonstrate the effects and value of properly preconditioning seismic data prior to inversion, using an unconventional Montney dataset. A focus is placed on noise removal and proper event alignment, in both gather and angle stack domains. Pre-stack, experiments on ordering of RMO correction and radon demultiple operations are tested, with an iterative approach eventually being selected to minimize erroneous corrections. After angle-stacking, seismic warping, or alignment, is applied to correct for any remaining residual moveout by iteratively aligning all anglestacks to a reference stack. At each preconditioning step, thorough QC is performed to justify these processes and their parameters. AVO inversion is conducted on seismic both with and without this rigorous preconditioning applied. The inverted elastic properties from each workflow are compared to each other and to well logs. A relative inversion is used for this step, as the omission of a detailed background model ensures the results and any conclusions from them are driven mainly by the seismic data. Subsequently, a rock-physics inversion for porosity is performed on each dataset using calibrated rock-physics templates. By following this approach and inverting both preconditioned and raw datasets, we can directly assess inversion performance, and thus the uplift of the seismic preconditioning workflow. Small changes in acoustic impedance as a result of the preconditioning workflow can be correlated to non-negligible changes in inverted acoustic impedance, and as a result, on porosity. Additionally, after preconditioning there was found to be an increase in the correlation between inverted subsurface parameters and production.

SESSION TITLE: Theme 4: AVO, DHI and Seismic Data Inversion for Exploration and Development

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Application and Use of Seismically Derived Sequence Stratigraphic Framework in High Resolution Rock Properties and Fluids Inversion

AUTHORS (FIRST NAME, LAST NAME): Azer Mustaqeem¹, Valentina Baranova², Trino Salinas³

INSTITUTIONS (ALL):

1. Petro-Explorers Inc.
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ABSTRACT BODY:

Abstract Summary: In the presence of unconformities and mixed lithologies such as coal, calcareous layers, and thin beds it is quite difficult to clearly distinguish lithologies through reflection amplitudes only. Presence of multiples, tuning amplitudes and waveform interference can add to this uncertainty. Many subtle traps of commercial significance are below the conventional seismic resolution. To achieve reasonable results in rock properties and fluids distribution, an enhanced multi-stage inversion workflow is applied.

The seismic inversion workflow, controlled with well data, starts with conditioning of pre-stack gathers and stacked data. The conditioning process is calibrated by rock physics and reflectivity models produced through ray tracing. Interpretation of the post-stack seismic is carried out using seismic sequence stratigraphy workflow. The resultant volume is a dense set of horizons defining the sequence boundaries and flooding surfaces.

Deterministic pre-stack inversion requires background model, extracted wavelets and angle gathers. Using the well data and sequence stratigraphic framework a background model is built. Wavelet is extracted at various angles of incidence and over multiple temporal windows. Deterministic inversion thus provides the results of P-impedance (Z_p), S-impedance (Z_s) and density (ρ) within the regular seismic bandwidth. In the next step bandwidth enhanced seismic gathers are used as input along with bandlimited results to achieve enhanced Z_p , Z_s and ρ volumes.

Neural Network inversion has shown promising results when the input volumes are closely related to the rock properties. Z_p and Z_s volumes are further combined to create incompressibility (λ - ρ) and rigidity (μ - ρ) volumes. Through neural network inversion process, incompressibility and rigidity volumes are then converted to lithology (V-shale), porosity (ϕ) and water saturation (SW) cubes.

The presentation will cover the application of workflow through on-shore datasets from various sedimentary basins.

SESSION TITLE: Theme 2: Salt and Shale Tectonics

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Role of salt detachment in the fold belt of the axial zone of the Eastern Cordillera, Northern Andes

AUTHORS (FIRST NAME, LAST NAME): Juan Camilo Ruiz Amaya¹, Antonio Teixell²

INSTITUTIONS (ALL):

1. Universitat Autònoma de Barcelona
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ABSTRACT BODY:

Abstract Summary: The external part of the northern Andes of Colombia is characterized by the Eastern Cordillera (EC). This mountain belt is a double verging thrust system formed during the Cenozoic by the inversion of a Mesozoic back-arc rift. The tectonic configuration of the EC has been described in several studies that reflect the diverse conceptions. The foothills of the EC are dominated by foreland-directed thrusts, extensively documented in abundant literature because of its hydrocarbon productivity. In contrast, the axial zone (Sabana de Bogotá) consists of a fold belt without a dominant vergence nor major thrust translations, which has been much less documented. In this work we have constructed a series of structural sections with sequential restorations based on 2D seismic lines and a revised mapping obtained from own field work and a compilation of other authors structural surface data.

The structural style defined for the Sabana de Bogotá fold belt suggests detachment over a weak décollement level. We have been incorporated salt tectonics concepts (e.g. Hudec and Jackson, 2001) to develop a detailed geological model of this axial part of the EC. Even though the salt presence in this region has been reported by numerous authors (including numerous salt springs and occasional diapir occurrences at the surface), to date there was no detailed structural model that addressed the origin of the main structures and their possible relationship with salt as detachment level or potential diapiric phenomena. We address the structure of the Sabana in the light of this new perspective and a new chronology of the compressional deformation which allows to re-evaluate the petroleum system in this zone of the EC, as well as to provide an analog for other areas in Colombia where salt has played an important role in the tectonic-sedimentary evolution and has been overlooked

SESSION TITLE: Theme 4: AVO, DHI and Seismic Data Inversion for Exploration and Development

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Leveraging seismic inversions and novel geologic modeling workflows to enable rapid development of Guyana's resource

AUTHORS (FIRST NAME, LAST NAME): Jana Simo¹, Michael McGlashan²

INSTITUTIONS (ALL):

1. ExxonMobil

2. ExxonMobil

ABSTRACT BODY:

Abstract Summary: Defining subsurface scenarios that represent the entire plausible uncertainty space is challenging, yet is critical to development planning. We demonstrate that integrating seismic inversion tools and reduced order modeling approaches can be leveraged for rapid reservoir characterization, and show how these approaches enabled accelerated decision making in a large development project in Guyana. The integration frames a data-driven uncertainty space while still allowing the flexibility to incorporate geologic concepts, and measures impact and credibility with a cross-disciplinary full loop from inversion, concept and reservoir modeling through simulation and forward-seismic modeling. Early model builds, focused on flow impact, accelerated concept development through integrated simulation, experimental mentality, and positive team dynamics. By embracing the uncertainty and focusing on the alignment of geologic concepts with geophysical data, the process can efficiently lead to multiple models with different stratigraphic architecture and early fluid flow scenarios. We show how these methods and technologies were applied to guide concept select from the outset of a development project in Guyana.

SESSION TITLE: Theme 2: Salt and Shale Tectonics

SESSION DAY & DATE: Friday, April 22, 2022

SESSION TYPE: Oral

TITLE: Analysis of salt-sediment interplay and its implications for structural hydrocarbon trap geometries in Southern Gulf of Mexico

AUTHORS (FIRST NAME, LAST NAME): Ulises de Jesus Rodriguez¹, Jose Carlos Ruiz¹, Luis Enrique Salomon¹, Rolando Heberto Peterson¹

INSTITUTIONS (ALL):

1. Petroleos Mexicanos (PEMEX)

ABSTRACT BODY:

Abstract Summary: Minibasins are depressions that subside into relatively thick salt surrounded by upwelling salt. Interplay between salt and sediment plays a crucial role in the evolution of minibasins and their associated bounding salt structures, which exhibit a wide range of geometries (salt rollers, anticline/pillows, diapirs, allochthonous sheets) and may contribute to form structural traps for hydrocarbons. Additionally, evolution of minibasins is directly related to the maturity of source rock, distribution of reservoir facies, as well as presence of hydrocarbon migration pathways. The Southern Gulf of Mexico is an active area of exploration where salt tectonics has a strong influence on the different elements of Petroleum Systems, and a better understanding of such influence is critical to maximize exploration in new prospective areas.

This study is aimed to investigate the influence of minibasins development on distribution of reservoir units and evolution of structural trap geometries. To achieve this, a combination of 3D seismic interpretation, seismic attributes and structural analyses was applied and calibrated with borehole data to determine analogues and rank the best geometries with conditions for hydrocarbon accumulation and preservation.

Active salt diapirism and lateral emplacement of salt bodies are the main controlling factor for both sediment distribution and structural trap geometries within the basin; also, the degree of confinement of every minibasin is directly related to the presence of reservoir rocks. Salt-sediment interface acts mainly as a pathway for hydrocarbons migration whereas prospectivity of traps related to salt bodies depends not only on distribution relative to vertical salt bodies, type of closure, and lithology of seal rocks, but also on the synchronicity of trap formation and later conditions for preservation.

ON-DEMAND ONLY

SESSION TITLE: Theme 1: Petroleum Systems

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

EXTENDED ABSTRACT: Integrated Characterization and Modeling to Develop and Explore Marrat Formation in Abduliyah and Dharif Fields, West Kuwait

Faical Ben Amor¹; Fatema Hussain Alfaiakawi²; Abdelmoniem El Araby¹³; 1. Schlumberger, 2. Kuwait Oil Company, 3. Cairo University

Introduction

The Lower Jurassic Middle Marrat Formation, of West Kuwait Abduliyah (AB) and Dharif (DF) fields, hosts an underexplored prolific carbonate reservoir with limited aquifer support and fast pressure depletion, being currently close to bubble point pressure conditions. The depositional environments of this reservoir express vertical and aerial variations along the study area. The reservoir is commonly known to have been deposited in a dominantly homoclinal carbonate ramp, with an overall upward progradational depositional motif. While the dominantly retrogradational lower units show a prevalence of middle and outer ramp facies, the dominantly progradational upper units express a development of inner ramp and shoal facies intervening with lagoonal and tidal flat lime-mudstone. Of lower to middle Jurassic age, the Middle Marrat reservoir rock consists mainly of grainstone, packstone and wackestone lithology; with a porosity range of 10-20% and a permeability range of 0.1-1000 mD. With no clear fluid contact inferred from the few existing crestal wells, there is a large uncertainty in the net reservoir rock extension, the spatial distribution of the oil-bearing zones, and the estimated in-place hydrocarbons. An integrated subsurface description was therefore essential to address these key uncertainties in order to meet the long-term production and reserves requirements.

Located to the southwest of Burgan field, the AB and DF structures are interpreted to be related to a regional West Kuwait Arch Lineament. Striking north-northeast, these structures represent sub-parallel asymmetrical anticlines and are associated with a seismic defined reverse fault, bounding the DF from the west. They are characterized by elongated narrow anticlines, plunging mainly in the north-northeast and south-southwest directions (**Figure 1, a**). With a structural growth initiated during the Turonian (ca. 92 Ma), the current-day structure is known to be the result of dominant drape and slip-folding formed above a salt inversion ridge at depth.

During the Jurassic, the region of the State of Kuwait was located in a shallow water of the Arabian Plate intrashelf basin along the southwest margin of the Neo-Tethys Ocean. From south-west of AB to north-east of DF fields, the Middle Marrat depo-environments are expected to be ranging from shallow inner ramp to outer ramp realm (**Figure 1, c**).

Framing the Middle Marrat Stratigraphy & Depositional Model

Different modeling scopes have initially been expected for the two fields; and have been designed and budgeted to be executed synchronously by two different teams. However, to decipher the Middle Marrat stratigraphy and depositional frameworks, there was a need to consider the regional context through combining the two fields under the same subsurface study; and to have them consistently linked to mature analog fields from West and North Kuwait. Integrating the AB and DF fields in the same study was indeed a key decision, as it enabled us to have a wider geologic picture of >40km of dip-oriented section of ~1000ft of Middle Marrat thickness.

Detailed sedimentological study of core depofacies in eight cored wells, being integrated with calibrated petrophysical model has enabled to build a sequence stratigraphic model made of

identified parasequences, flooding surfaces, depositional environments, and system tracts (**Figure 1, b**). The reliance on sequence stratigraphy approach aims to unravel the fine-scale stratigraphic architecture of (more or less) predictable facies & sedimentary systems. The main objective was to narrow down the uncertainties we have in reservoir geometry and spatial continuity of genetically related reservoir components. Unlocking new appraisal opportunities was also a key objective. High-resolution sequence stratigraphic approach is a powerful methodology to unravel the fine scale stratigraphic architecture of sedimentary systems through correlation of cycles of increasing and decreasing accommodation potential across the different depositional environments. The surfaces are the timelines, and the resulting stratigraphy model expresses the predictable variability of the facies in between them, reflecting thereby the geometrical relationships of the various sediment packages. Flooding surfaces are marked by increase in bathymetry being reflected by lithofacies characteristics. Parasequences are genetically linked beds and bed sets confined on the top and bottom by flooding surfaces or their equivalent correlative surfaces.

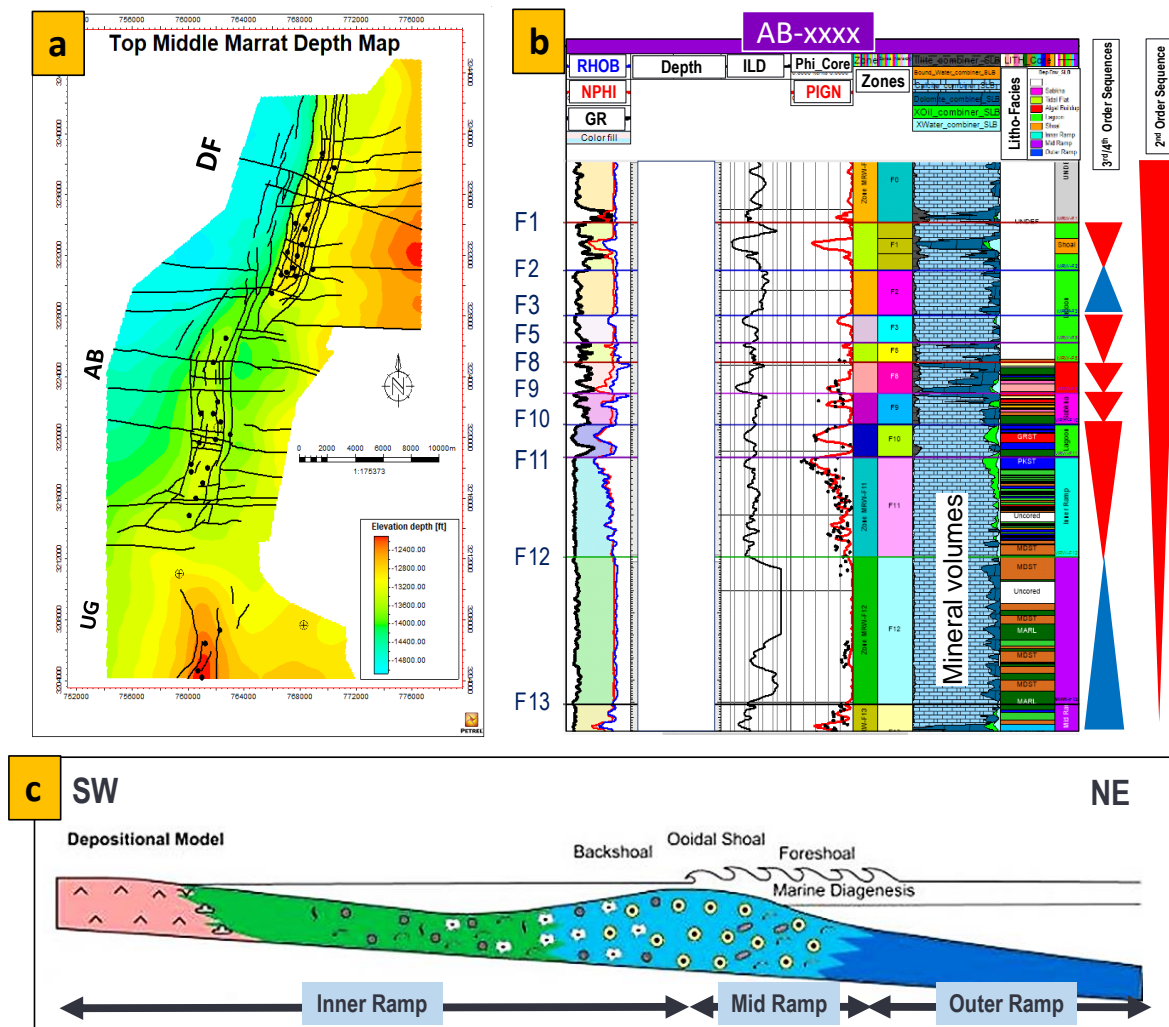


Figure 1: **a:** Structure map showing the fields and wells' locations; **b:** Log composite of raw & processed logs, RCA, litho & depo-facies, and stacking patterns in Middle Marrat cored section of AB-xxxx; **c:** Conceptual depo-environments expected along a SW-NE oriented dip-profile. Due to absence of biostratigraphic data and limited cored intervals in the study area, calcareous nannofossil zonation (Kader et al, 2015) and previous regional studies were used as key references

in the reconnaissance and correlations of major and minor isochronous surfaces throughout AB and DF Fields based on core and E-Log signatures.

A unified and completed high-resolution stratigraphic schema, consistent with neighboring mature analog fields from West and North Kuwait, has for the first time been utilized to link AB to DF field; thereby getting rid of all associated inconsistencies between their legacy soloed stratigraphic frameworks and getting a depositional picture of more than 40 km length of northeast-southwest trending dip-oriented cross section. A unified and harmonized set of open-hole and processed logs, multi-mineral volumes, core plug data (RCA) & descriptions in term of litho and depofacies have been used (**Figure 1, b**). The normalized GR logs displayed on a logarithmic scale was particularly a key visualization tool to reveal the log cyclicity, particularly within high-energy deposits of the prograding Middle Marrat units. The GR and Neutron logs are known to lack character due to absence of clay minerals in high-energy beds. Indeed, the use of GR log in logarithmic scale has optimized the well-to-well chronostratigraphic correlations of high-resolution (HR) parasequences across AB and DF fields (**Figure 2**), yet consistently linked to neighboring Umm-Gudair (UG) and Minagish (MN) mature fields from West Kuwait, and North Kuwait fields.

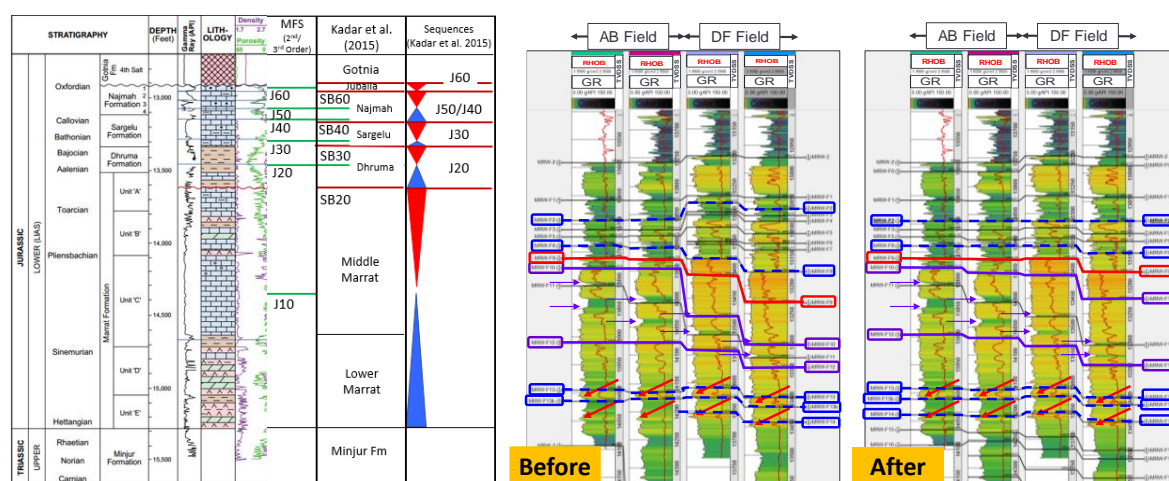


Figure 2: Left: Lithostratigraphic and chronostratigraphic subdivisions of the Marrat Formation (Kadar et al., 2015); **Right:** Stratigraphic well correlations of the Middle Marrat at the transition from AB to DF field: before and after reconciliation.

Figure 3 (Left) displays the reconnaissance of Middle Marrat major chronostratigraphic surfaces, Maximum Flooding Surfaces (MFS) and Sequence Boundaries (SB), along AB-xxxx cored well based on a type-section from the published Minagish-27 analog well (Kadar et al. 2015). The Middle Marrat Formation is interpreted as one 2nd order sequence having a retrogradational tendency in its lower part and a progradational pattern in its upper part. Deposited within passive margin settings during Toarcian, the lower Jurassic Marrat Formation is regionally known to have been deposited during a relatively quiescent tectonic activity. The XS1 line (in blue) - overlying the isopach maps - represents the transect line outlining the position of the 5 wells that are displayed in the middle of **Figure 3 (Right)** and considered as a type-section extracted from the developed stratigraphy framework. Interpretation of 3rd/4th and 2nd orders stacking patterns are also displayed.

The prolific upper half of the Middle Marrat cycle is inferred to be composed of a series of coarsening upward 3rd/4th order parasequences, dominantly sea-level controlled. Dominated by

coarsening up lithofacies, the parasequences show gradual shallowing up depositional environments, implying that the parasequences are exhibiting a prograding geometry. In line with this observation, the interval thicknesses defined by the Middle Marrat major MFS and SB surfaces have been contoured to produce isopach maps respectively for the two Middle Marrat halves of the 2nd order sequence. The isopach maps exhibit a broadly northwest-southeast thickening trend. The lower half sequence, inferred to have been deposited during an episode of relative sea level rise, is seen characterized by a carbonate factory depocenter situated more towards the southern parts of our area of interest (AOI). In the other hand, the upper half sequence isopach expresses a shift of the carbonate factory towards the northeastern areas. This suggests that the sea-level lowering, characterizing the upper half sequence, resulted in basinward shift in facies distribution rather than in a dramatic halt of carbonate sedimentation. A schematic block diagram is attached at the bottom of the two isopach maps to illustrate the change in depositional pattern from eustasy level and expected dominant depo-facies (Figure 3, Right).

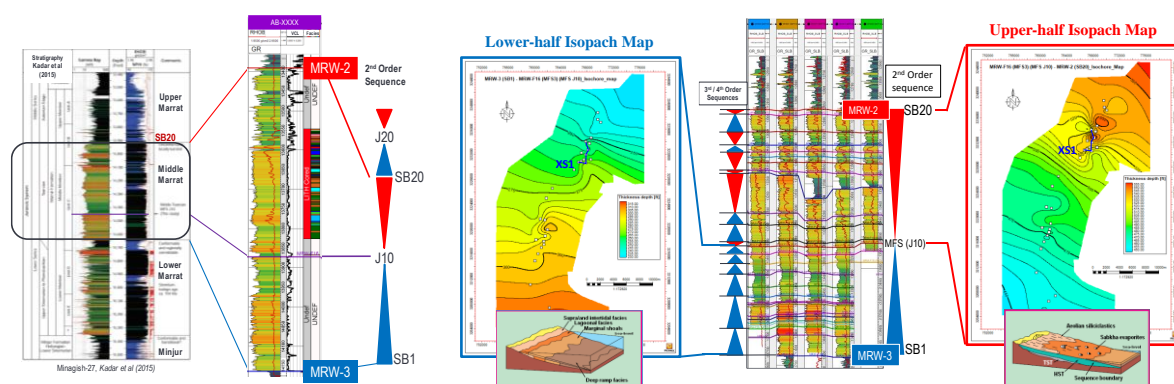


Figure 3: Left: Reconnaissance of Middle Marrat major MFS and SB chronostratigraphic surfaces in one key well (AB-xxxx), based on a type-section from published Minagish-27 analog well; **Right:** Middle Marrat depositional pattern based on isopachs' trends of the two halves of a 2nd order sequence. The XS1 line (in blue) represents the transect line outlining the position of the 5 wells, displayed in the middle, with interpreted 3rd/4th order parasequences and associated stacking pattern. The lower half sequence, deposited during an episode of relative sea level rise, suggests a carbonate factory situated more towards the AOI southern areas. The upper half sequence, deposited during an episode of relative sea-level fall, highlights a carbonate factory shift towards the AOI northern areas. The schematic block diagram are provided to illustrate the change in depositional pattern from eustasy level and dominant depo-facies standpoints.

A regional SW-NE dip-oriented cross section of more than 40km length (Figure 4, Inset b) enabled to link AB structure to UG and Jahtan (JH) structures in the south; and to DF structure in the north (Figure 4, main). The lower Middle Marrat half sequence (i.e., F27 to F16 parasequences), made of lagoonal lime-mudstone facies of poor reservoir quality, is inferred to represent the “catch-up carbonates” of mid to outer ramp depo-environments. The upper Middle Marrat half sequence (i.e., F1 to F15 parasequences) is found to be the most prolific reservoir interval made of oolitic bioclastic shoals. It is inferred to represent the “keep-up carbonates” of inner ramp environments. Highlighted with the dashed yellow line in Figure 4, a drastic localized thickening of the F9 parasequence witnessed towards the DF southern area, together with an erosively-based form, argue for incision origin. These erosive features, recorded at DF field typically within the F9

parasequence and to a less extent within the F5 parasequence (highlighted with the dashed green line), are interpreted to have been formed as incision, as a result of regional base-level (e.g., relative sea-level) drops, being associated with erosion on the platform margins. They are inferred to be more as by-pass channels. An episode of relative sea-level fall is supported with the dominance of core described sabkha facies within F9 and F5 parasequences, being recorded more towards the south of AB field. This observation corroborates with the results of multi-mineral based petrophysical analysis, with an increasing amount of anhydrite volume been recorded towards the most southerly part of study area at the F9 and F5 parasequences (**Figure 4, Inset a**).

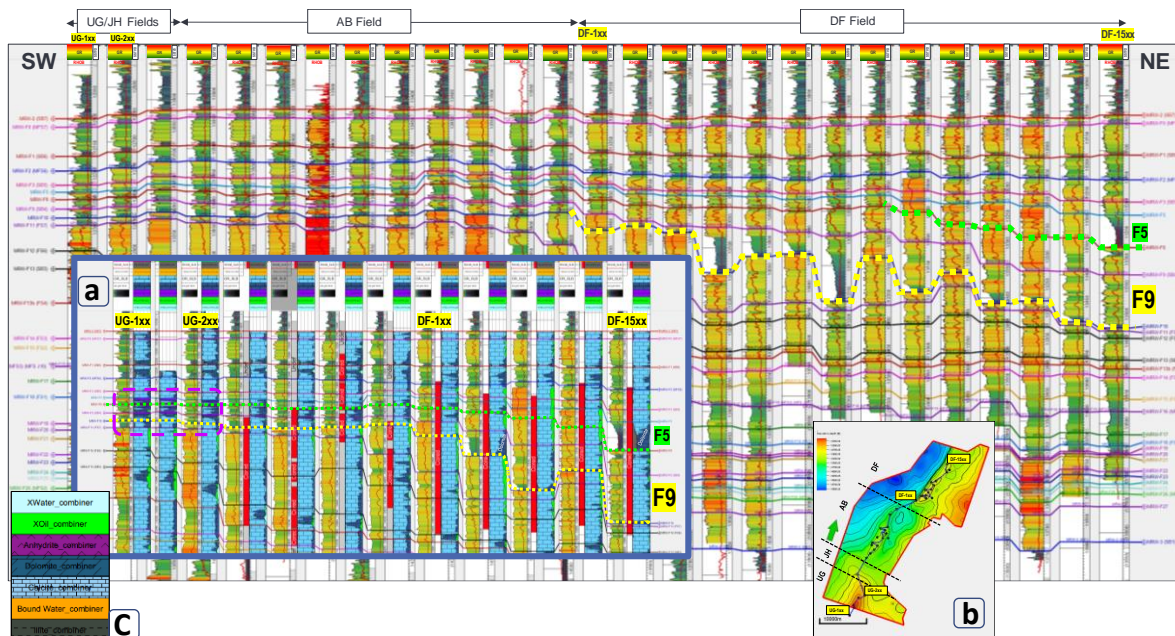


Figure 4: General dip-oriented cross section showing the resolved stratigraphic framework over Middle Marat, showing incision features identified at the most northerly wells (flagged with green and yellow dashed lines). **Inset a:** simplified section, with fewer wells only, showing increasing anhydrite volume at the most southerly wells (see dashed purple rectangle) recorded over F5 and F9 parasequences, associated with increased dolomite volume as well. **Inset b:** well's locations map, highlighting the transversal limits between DF, AB, JH and UG structures. **Inset C:** mineral volumes template used in the simplified section of the Inset a. UG-1xx, UG-2xx, DF-xx and DF-15xx, highlighted in yellow, are for wells referencing at the location map and the two well sections.

Beds of depositional evaporites are found immediately above subtidal deposits and within supratidal deposits. When anhydrite occurs within a subtidal sequence, it most likely represents a change in sea level and marks the top of a high-frequency cycle. The occurrence of evaporites within supratidal deposits can suggest a change in sea level or a growing restriction related to sedimentary processes, such as the construction of a barrier bar (**Lucia, 2007**).

The updip evaporitic deposition at the exposed areas in the south (i.e., UG and southern AB areas); being synchronously associated - downdip - with erosional (incision) features towards deeper areas in the north (i.e., central and northern DF areas), suggest that F9 and F5 parasequences have been deposited under a very restricted environment and a maximum shifting of the shoreline seaward witnessed during this period of Middle Marat. This is illustrated in **Figure 5 (left)** via a

diagrammatic view (Lucia, 2007) of a prograding evaporitic tidal flat during a fall in the sea level, with peritidal facies composed of tidal-flat capped cycles typically found in the most landward position of a carbonate shelf. The deposition of salt/anhydrite in a supratidal environment is occurring synchronously while the intertidal environment (ramp upper slope) was being eroded by the downslope currents. The dolomite, being associated with anhydrite, expresses a peritidal to sabkha facies association. It reflects the most proximal depositional set up of a 'Prograding Highstand System Tract', an HST (see the dashed purple rectangle in **Figure 4, Inset a**).

The sediments deposited when relative sea level is lowest are said to be deposited in the lowstand systems tract (LST). This can suggest that F9 and F5 parasequences have been deposited as part of a Lowstand System Tract. The best reservoir quality recorded at these parasequences is inferred to be associated with a concentration of grain-dominated packstones and grainstones generally produced within high-energy conditions of a ramp crest (**Figure 5, right**).

Vertically, the basinward shift (through time) of incision features from a more proximal position (during F9 parasequence deposition) towards a more distal position (during the F5 parasequence deposition) can infer a basinward migrating "Margin" shoal complex producing outer-shelf clinoform deposits, as highlighted in the well sections of **Figure 4**; and schematically illustrated in the right-hand diagram of **Figure 5** (Lucia, 2007).

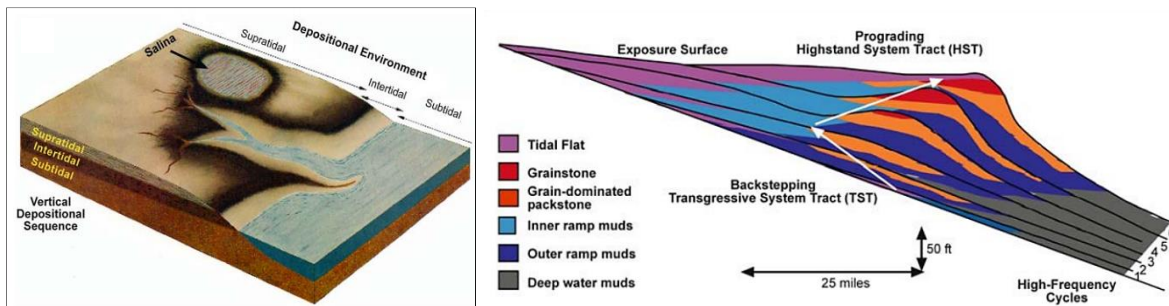


Figure 5: Left: Diagrammatic view of a prograding evaporitic tidal flat showing peritidal facies composed of tidal-flat capped cycles and normally found in the most landward position of a carbonate shelf. **Right:** Diagram showing the distribution of depositional textures and high-frequency cycles of Transgressive System Tract (TST) and Highstand System Tract (HST), with grainstones concentrated in the basinward migrating ramp crest (Lucia, 2007).

The iso-thickness lines of the isopach maps of most of the HR parasequences suggest a paleo-shoreline, shelf-slope and shoal barrier axis striking NW-SE, broadly matching with a commonly known West Kuwait homoclinal carbonate ramp, trending NW-SE and gently sloping towards the NE (**Figure 6**). The detailed analysis of the isopach maps made for the different HR parasequences suggests, however, that the carbonate ramp geometry has evolved through time during the deposition of Middle Marrat. It is inferred that a graded homoclinal carbonate ramp geometry has prevailed during the dominantly retrograding lower half-cycle of the 2nd order sequence; that evolved into an out-of-grade (i.e., distally steepened and stepped) ramp configuration at the dominantly prograding upper half-cycle of Middle Marrat. **Figure 6 (Left)** displays the F18 parasequence isopach map as an example from the dominantly retrograding lower half of the 2nd order sequence. Separated from the lower half sequence by the regional F16 (J10) MFS surface,

the dominantly prograding upper half sequence is represented by the F14 isopach map (**Figure 6, Right**). The transition from the lower half to the upper half of the 2nd order sequence - via the J10 MFS surface - is highlighted by a shift in the carbonate depocenter (i.e., thickest section) from South to North, reflecting the passage from a dominantly transgressive package (i.e., below the J10 MFS) into a dominantly regressive package (i.e., above the J10 MFS).

Characterized overall by dominantly isopachous thinly bedded micritic units, the Middle Marrat lower half parasequences express a uniformly spaced pattern of iso-thickness lines. This is expressed via the F18 isopach map displayed in **Figure 6 (Left)**. Such pattern suggests a homoclinal (or graded) carbonate ramp configuration, gently sloping into deep waters towards the NE of DF field. In contrast, the F14 expresses a flat-topped platform at AB southern and central areas, suggesting a shallow marine platform (or epeiric sea) depositional environment. Further to the north, at the transition between AB and DF fields, the F14 parasequence displays closely spaced iso-thickness lines suggesting a gradually increasing slope (i.e., stepped ramp), before a graded ramp configuration is regained downdip towards the DF central area and beyond.

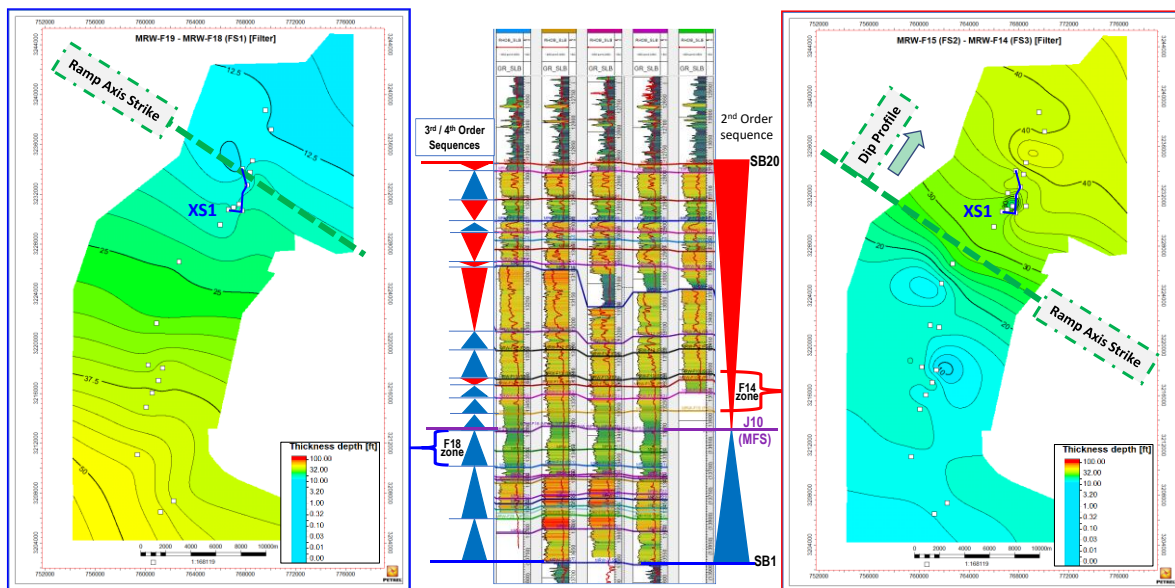


Figure 6: Middle Marrat ramp geometry evolution from ‘graded’ configuration during the deposition of the lower-half HR parasequences into an ‘out-of-grade’ configuration during the deposition of the upper-half HR parasequences. **Left:** F18 isopach map representing the dominantly retrograding lower-half; **Right:** F14 isopach map representing the dominantly prograding upper-half. The small white squares represent the wells’ locations; **Middle:** 2nd order sequence major surfaces, interpreted 3rd/4th order parasequences, and associated stacking patterns. The XS1 line (in blue) represents the transect line outlining the position of the typical 5-wells’ extract.

Two more examples of isopach maps are displayed in **Figure 7** to illustrate the spatial & temporal carbonate ramp evolution throughout the deposition of the different parasequences. **Figure 7 (Left)** displays the F10 isopach map highlighting a typical example of a rimmed carbonate ramp. While a flat epeiric ramp is inferred to dominate the AB southern and central areas, closely spaced contours are seen sharply marking the AB-DF transition area, characterized by a thick belt that

exceeds 100ft in thickness and striking NW-SE, and inferred to outline the position of a well-established shoal barrier. The isopach map expresses a sharp steepening at both edges of this inferred shoal barrier belt, although a sharper slope increase is observed more pronounced at the seaward edge. A high concentration of the orange shoal facies, as illustrated via the **Inset 'a'** of **Figure 7 (Left)**, confirms that the inferred shoal barrier position coincides with the thickest part of the F10 isopach.

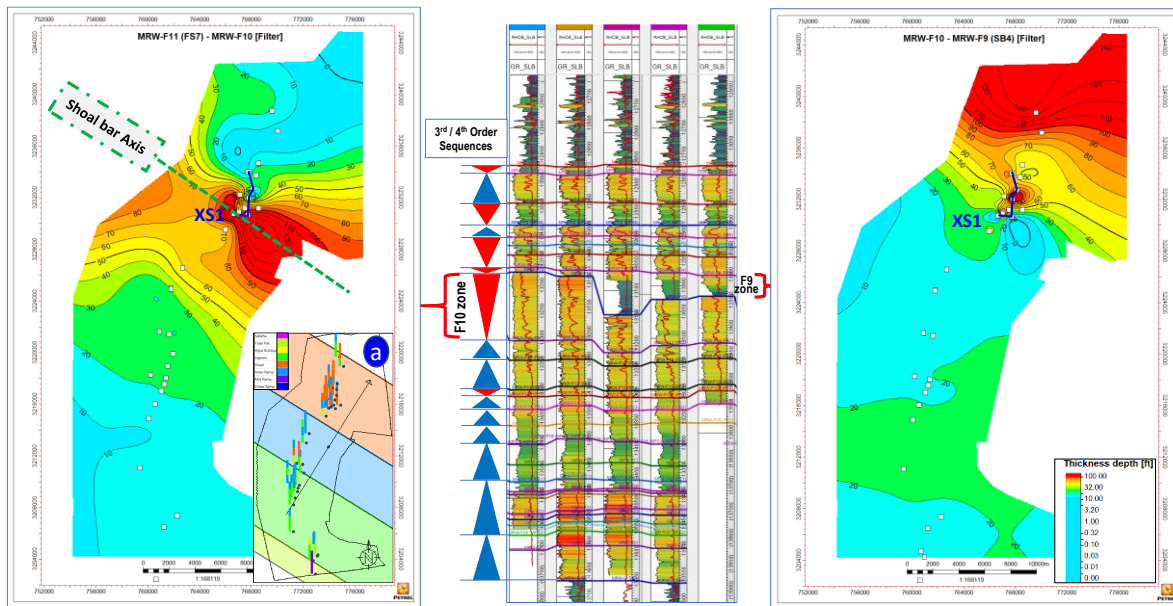


Figure 7: Middle Marrat ramp geometry evolution from rimmed configuration during the deposition of F10 parasequences into out-of-grade (stepped) configuration during the deposition of erosive F9 parasequence. **Left:** F10 isopach map highlighting a rimmed carbonate ramp, resulting from the development of a thick shoal belt, striking NW-SE and situated at the AB-DF transition area; **Inset-a:** aerial distribution of F10 depofacies at wells, and inferred progradational model geometry. **Right:** F9 isopach map highlighting a flat ramp throughout most of the central and southern parts evolving into distally steepened ramp that initiates at south of DF; **Middle:** interpreted 3rd/4th order parasequences and associated stacking patterns. The XS1 line (in blue) represents the transect line outlining the position of the typical 5-wells' extract.

The build-up of an over steepened slope is suggested to have been gradually developed during the deposition of the Middle Marrat upper half cycle of the 2nd order sequence; and inferred to be the response of ramp-margin aggradation and progradation that characterized most of the Middle Marrat upper half parasequences. Structural control in the form of episodic push up pulses might have also accentuated the relief of the ramp crest. The F10 is inferred to be the shallowest parasequence during which a rimmed ramp has reached its best configuration; and witnessed the build-up of a well-developed shoal barrier. Due to sea-level fall, the F10 was then heavily eroded as witnessed by the F9 incision features.

In a distally steepened ramp, gravity flow deposits may be common beyond the main slope. **Neog et al. (2010)** reports possible gravity flows in the North Kuwait embayment southeast of Sabryiah and Bahrah fields. Vertically, the basinward shift (through time) of the incision features from a more proximal position (during F9 deposition) towards a more distal position (during the F5

deposition) can infer a basinward migrating “Margin” shoal complex producing outer ramp clinoform deposits, as illustrated in **Figure 4**.

Figure 7 (Right) displays the isopach map of F9, a dominantly regressive parasequence. Characterized by a flat ramp across most of the southern and central areas, the F9 isopach map suggests a distally steepened ramp with a marked increase in slope at the seaward edge. An ‘out-of-grade’ (or stepped) carbonate ramp is inferred to have prevailed during the deposition of F9 parasequence. Locally, closely spaced iso-thickness lines are found to be perpendicular to the regional NW-SE striking shoal belt, suggesting that incised channels have likely occurred exactly where the ramp starts its steep sloping seaward, as a result of sharp sea level fall. The incised F9 and F5 parasequences are inferred to have been deposited when relative sea level reached lowest levels, which suggests their deposition to be part of an LST system tract.

Figure 8 summarizes the spatial & temporal carbonate ramp evolution throughout the deposition of the different Middle Marrat parasequences. It is proposed a hybrid stratigraphy model reflecting a transition from a homoclinal ramp to a rimmed platform setting. With high sediment production, the response to sea level change during transgression and early highstand initially creates a “keep-up” situation where deposition is predominantly aggradational and subtidal, then “fill-up” and “spill-out” as deposition becomes increasingly progradational and peritidal. At time steps 4, 5 and 6, the shelf and ramp terms can be used interchangeably, as we aren’t sure whether the ramp has evolved into carbonate shelf or not, although this is possible in carbonate platforms.

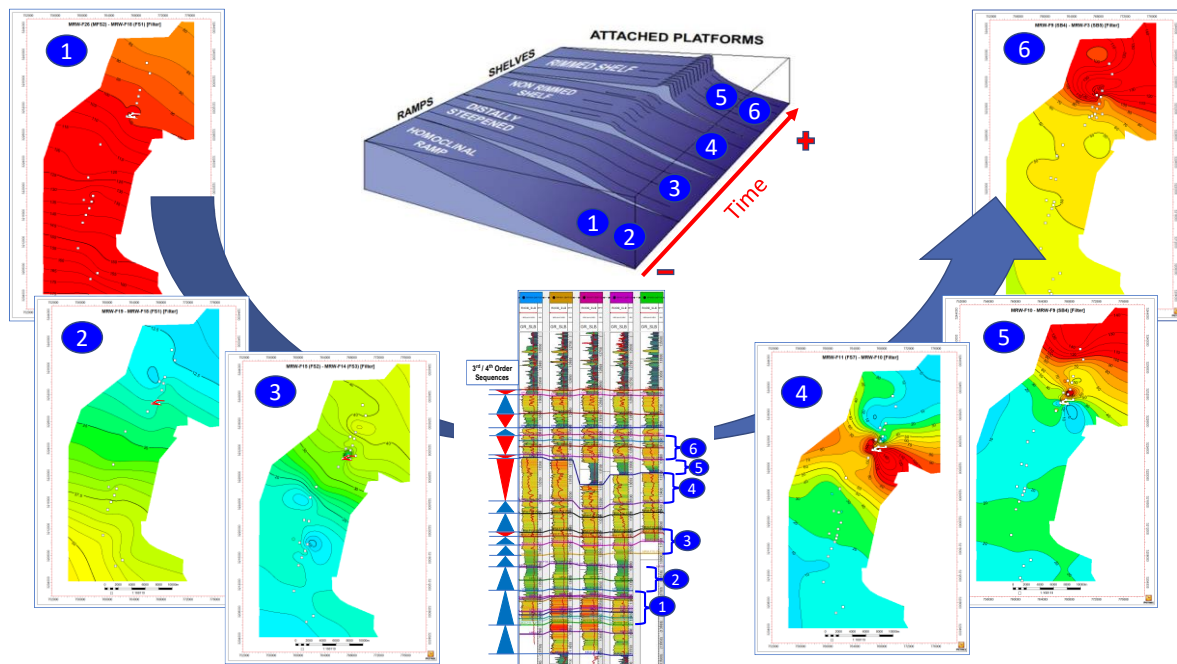


Figure 8: Spatial & temporal carbonate ramp evolution at different time steps of the Middle Marrat deposition.

The observed erosive-based log motif, together with the analysis of thickness contours, suggest the presence of mud-prone low-sinuosity incision features recorded particularly within F9 and F5 prograding parasequences. These incision features are inferred to be cutting downslope through an over steepened ramp crest as a result of sharp fall of the relative sea-level falling below a low

stand base level. An over steepened slope, probably in response to faulting and shelf-margin aggradation, is likely prone to gravitational collapse, sediment bypass to the basin, and perhaps the effect of periodic erosion due to sea level changes (**Schlager, 1986**).

To characterize the width and aerial distribution of the identified geobodies, an attempt for geobody extraction was made using a relative impedance volume from seismic inversion, but the seismic resolution was not good enough to map them confidently. Nonetheless, encouraging results have yet been obtained via the generation of a maximum magnitude seismic attribute. Calculated over a 40ms window, bounded at 20 ms below the MRW-2 surface (i.e., top Middle Marrat) and 20 ms above the MRW-3 (i.e., bottom Middle Marrat), this attribute was able to depict a set of narrow and less sinuous (elongate) bodies that corroborate with the log-based identified features. The bodies are seen characterized with high impedance values, represented in green, yellow, and red colors; with red color representing the highest impedance values (**Figure 9**).

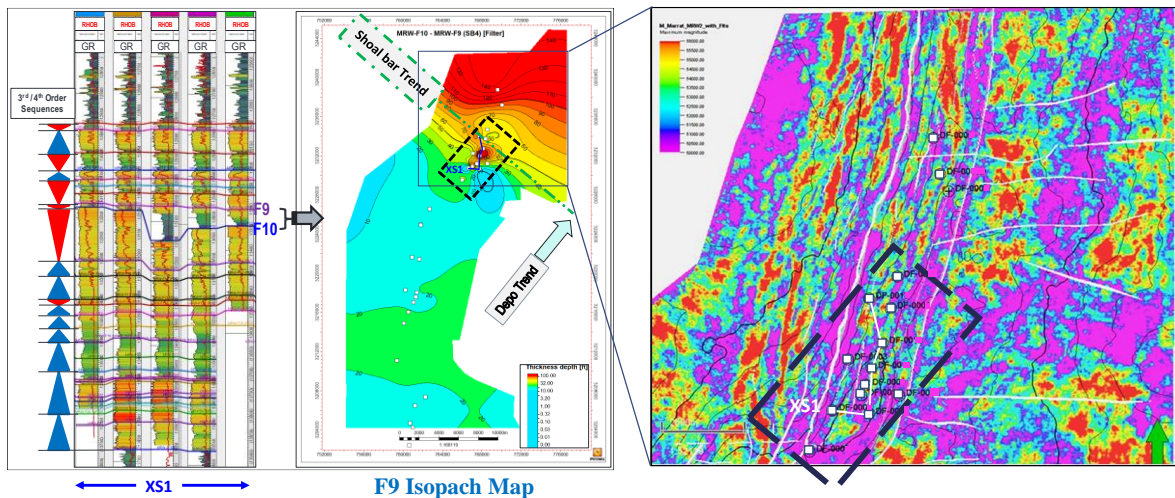


Figure 9: Evidence of channelized incision features observed on well logs, thickness map and impedance seismic attribute. **Left:** erosive-based log motif seen on GR and density (RHOB) logs within the F9 parasequence at the typical 5-wells' extract. **Middle:** isopach map of the F9 parasequence highlighting the distally steepened ramp around DF southern area (outlined in black with a dashed rectangle) and further downdip. Inside this rectangle, the XS1 transect line (in blue) is cutting exactly through the suspected channelized DF area. The XS1 highlights a sharp localized thickening of F9, which is found to be perpendicular to the regional NW-SE oriented shoal bar axis, occurring exactly where the ramp starts its steep sloping seaward. **Right:** maximum magnitude seismic impedance attribute focusing on DF area only, highlighting the north-south low-sinuosity features. The DF well controlled area of the middle isopach map is highlighted, for reference, with the same dashed black rectangle. The XS1 transect line is displayed in white colour. The wells' positions are displayed at both maps as small white squares.

A tentative interpretation of the high confidence geobody edges was made directly on the attribute map (**Figure 10**). With the focus made primarily on the well-controlled area of the crest of the DF structure, a hand-drawn outlining (in dashed black lines) was made to outline the edges of some high-confidence elongated (channelized) bodies, especially those corroborating with the

observations made based on the erosive-based log motif (**Figure 11**). The same outlining was extended to the rest of DF structure, resulting in few elongated features being nicely recorded at the DF western flank. It is inferred that the channelized features, estimated at 300-500m width, have initiated at the southern DF areas; and continued their path northward cutting downslope through an over steepened ramp. It is inferred that the lowering of sea level has restricted the current to narrower straits, causing a faster flow and possibly enhanced sea-floor erosion (**Richardson et al., 1969**). Observed to be spanning throughout the entire DF field, these channelized features are likely extending towards deeper waters further to the north.

The channelized features are seen to be guided by two major faults, flagged as Fault1 and Fault2 in **Figure 10**. Deposited during the Jurassic rifting phase, an extensional configuration in horsts and grabens might have assisted the deposition of Middle Marrat. Episodic push-up movements (pulses) of the Hormuz evaporites likely reactivated some of the Neoproterozoic deeply rooted normal faults, bounding the main AB-DF structure and parallel to the north-south Burgan Arch.

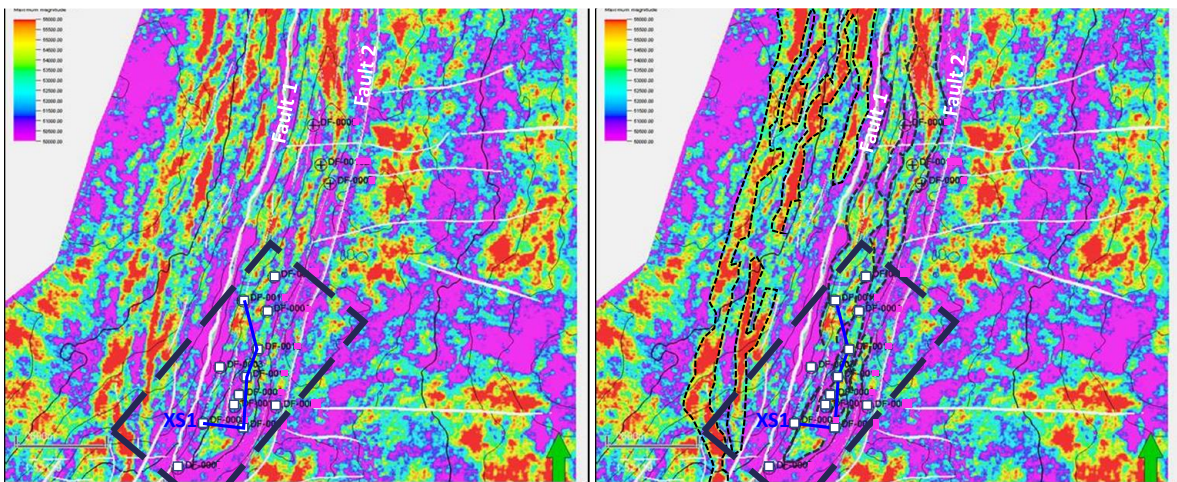


Figure 10: Incision geobody mapping using maximum magnitude attribute derived from relative P-Impedance volume. Channelized bodies are characterized with high impedance values in green, yellow, and red colours, with red colour representing the highest impedance values. **Left:** Raw impedance map calculated over 40 ms window centered around mid-Middle Marrat. **Right:** Impedance map with tentative interpretation of high confidence geobody edges, drawn in dashed black lines, focused on the crestal drilled area and the western flank of DF structure. The XS1 intersect line is displayed in blue colour at both maps for reference.

The basal draping of mudstone-prone facies, seen at the base of the erosive F9 and F5 (**Figure 11**), as depicted by the ELAN computed mudstone volume, is inferred as the deposition of fine-grained tails of largely bypassing downslope currents that has settled out of suspension through the water column. Such currents seem to be the primary source of the double carbonates (i.e., limestone and dolomite) characterizing these basal fine-grained facies. The channelized F9 and F5 bodies are found to be concentration zones of muddy dolomite, as evidenced by the computed dolomite volume (**Figure 11, right**), as an output of the multi-mineral petrophysical analysis.

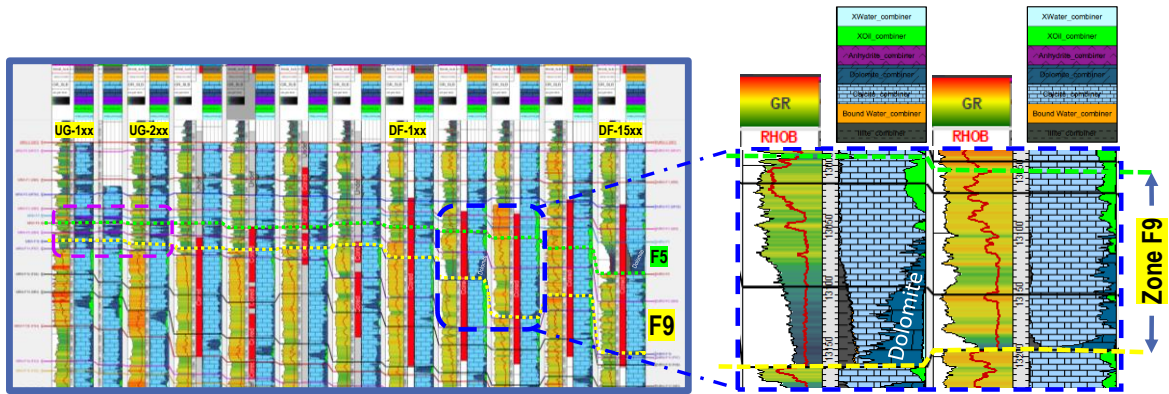


Figure 11: Left: The simplified dip-oriented cross section used in the inset 'a' of Figure 4. Right: zoomed view highlighting the concentration of muddy dolomite draping the incision body of zone F9, taken here as an example. Note the erosive-based GR and RHOB logs motif and the high clay (illite) volume at the F9 base, favouring a mud-prone incision feature scenario.

The nature of this dolomitization suggests a marine-meteoric mixing model of great duration circulation of Mg-rich sabkha originated saline waters mixed with marine water, and confined to the incision body, enough to intensely transform the fine-grained material draping the incision bodies into dolomicrite (**Tucker and Wrigt, 1990**); thereby enhancing relatively their associated porosity. The hypersaline brine, likely originating from evaporitic sabkha deposits in the AOI southern parts (i.e., UG north and AB south), are inferred to have been carried downslope by largely bypassing currents.

Figure 12 (left) presents an example of isopach analysis made on the F14 parasequence. The observed NW-SE regional trend has enabled to depict the azimuth of the carbonate ramp axis. The localized thickening around the DF well-controlled area, as highlighted by the black arrow, occurring perpendicular to the inferred ramp axis, can be interpreted as the direction of a possible channelized body cutting through the ramp. These extracted geometric information, specific to each HR parasequence, have subsequently been used to decide on the direction of the progradational trend and the direction of the facies boundary lines, separating the different gross depositional environments (GDEs) for a given parasequence.

Figure 12 (middle) displays an example of the distribution of the core-based depositional facies, displayed on map view in the form of a stripped column next to each well location. It is a graphical representation of the upscaled depofacies cells in each well for the parasequence in concern. The statistical analysis of this data has allowed to distinguish between clusters of wells with dominant depo-facies each, enabling thereby to accurately position the boundary lines between the different GDEs present in the parasequence in concern. The inferred progradational model geometry, established per parasequence, will constrain subsequently the 3D modeling of the corresponding GDEs using as technique the 'Truncated Gaussian (TG) with trends' (**Figure 12, right**). Snaps from the 'TG with trend' - based GDEs 3D model for each of the fourteen Middle Marrat cored parasequences (i.e., F0 to F13) are summarized in **Figure 13**.

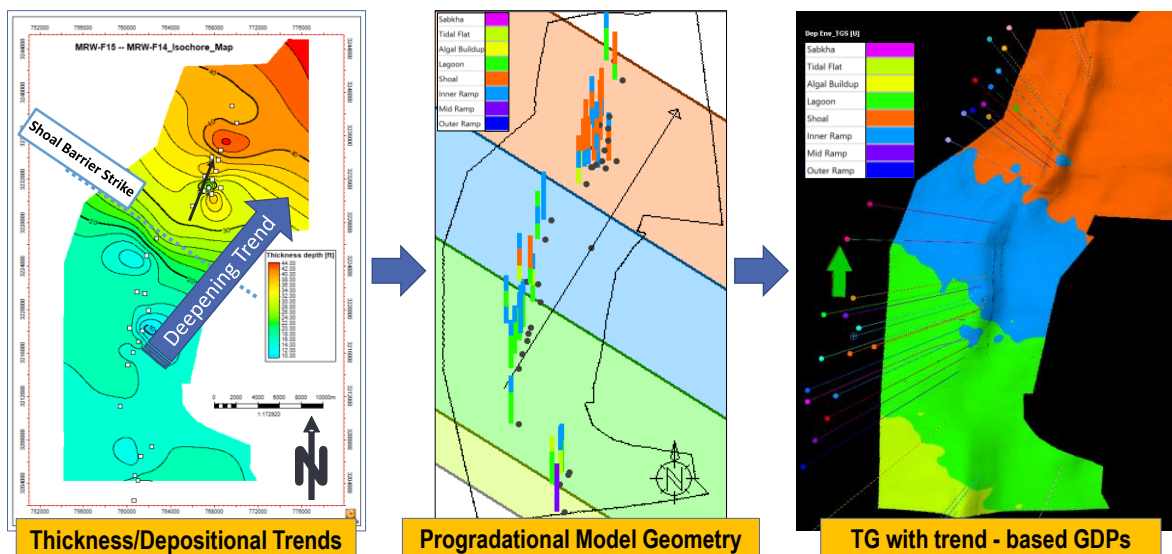


Figure 12: Thickness map of F14 parasequence, taken here as an example, enabling to depict the azimuth of the carbonate ramp axis and the inferred direction of a channelized body in the DF well-controlled area, highlighted with a black arrow (*left*). The inferred NW-SW shoal bar orientation was, in turn, used to draw the boundary lines between the GDEs for a given parasequence (*middle*). The black dots represent the wells' locations. The stripped column next to each well location is a graphical representation of the upscaled depofacies cells at each well. The inferred progradational model geometry, established per parasequence, will constrain subsequently the 3D modeling of corresponding depo-environments (*right*).

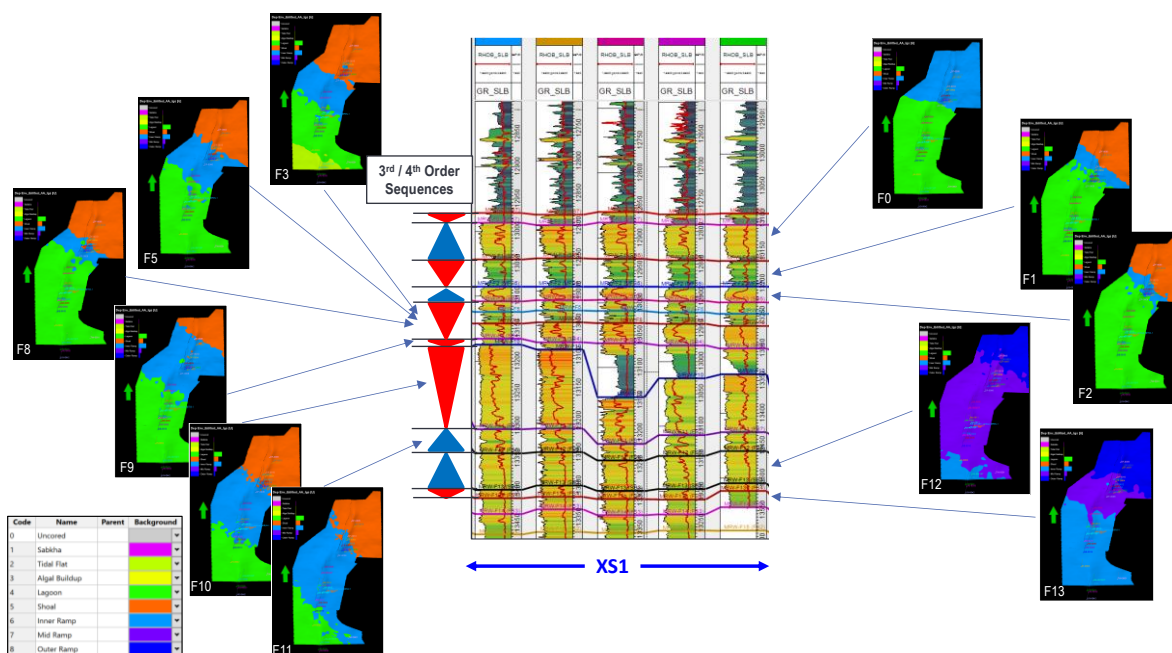


Figure 13: Snaps from 'TG with trend' - based GDEs 3D model for each of the fourteen Middle Marrat cored parasequences (i.e., F0 to F13). The typical 5-wells' extract (*Middle*), outlined by the same XS1 transect line used in the previous figures, is used here for referencing the positions of the fourteen cored parasequences.

Petrophysical properties will be distributed according to the established GDEs and rock-fabric facies patterns. The 2-D distribution of petrophysical properties is controlled by the lateral facies' progression. The Middle Marrat upper half cycle is inferred to represent a classic shoaling-upward succession of mud-dominated to ooid grainstone textures. They typically show well-developed tidal-flat-capped cycles landward, evolving laterally to lagoonal mud-dominated subtidal cycles, grain-dominated packstone and grainstone capped cycles and reefs at the ramp crest, and mud-dominated cycles in the outer shelf and basinal positions (Lucia, 2007). **Figure 14** displays the same SW-NE dip-oriented general cross-section of **Figure 4**, however using effective porosity (PIGN) as log template. The stratigraphy framework has been overlain with hand-drawn clinoform polylines to illustrate the inferred basinward migration of progradation wedges that characterize most of the Middle Marrat upper half-cycle parasequences. The 2nd order 'Prograding Highstand System Tract' is interpreted from J10 (MFS) to SB7, a.k.a. SB20. The polylines numbered 2, 3, 4, 5, 6, 7, 8 and 9 illustrate the inferred basinward migration of dominantly prograding wedges (clinoforms), associated with a migrating "Margin" shoal complex. The migration has been marked with a clear porosity development recorded at the north of AB field, and DF northeastern parts.

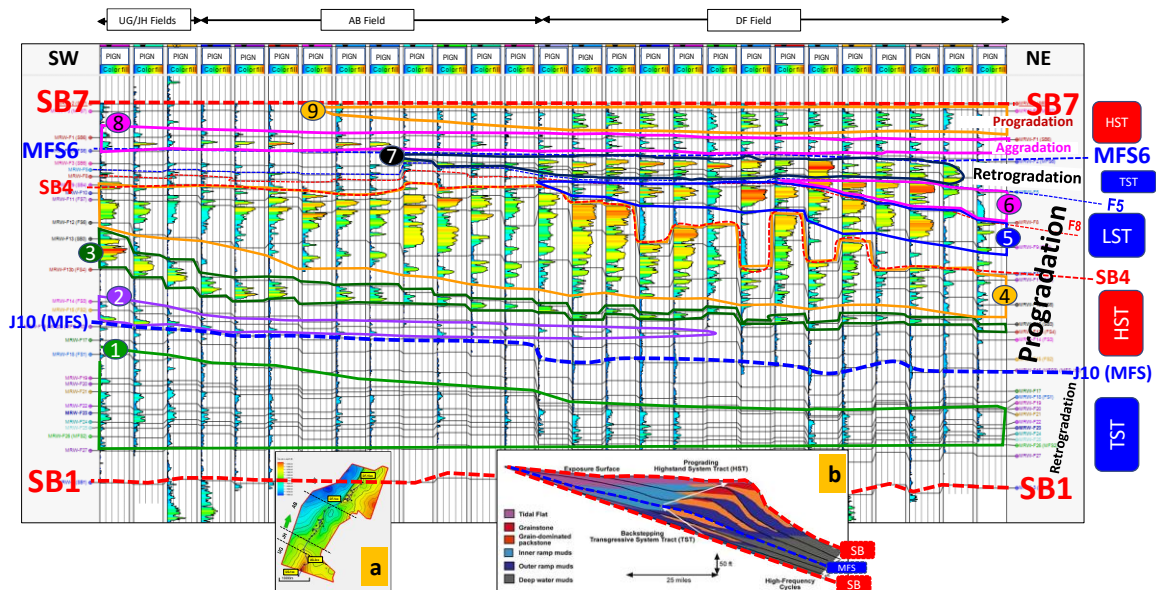


Figure 14: Sequence stratigraphy framework, flattened on Middle Marrat top SB7, and outlining the position of the main time surfaces (dotted lines) and system tracts; using the PIGN as log template with hot colours representing the best porosity intervals (porosity scale: 0 - 30%). The prograding, aggrading and retrograding wedges are displayed as solid polylines: the 2nd order 'Prograding Highstand System Tract' is interpreted from J10 (MFS) to SB7 as the clinoforms numbered 2, 3, 4, 5, 6, 7, 8 and 9, to illustrate the inferred basinward migration of dominantly prograding wedges, associated with a migrating "Margin" shoal complex. The 2nd order 'Backstepping Transgressive System Tract' is interpreted from SB1 to J10 (MFS), being mainly covered by the clinoform numbered 1. **Inset a:** well's locations map. **Inset b:** diagram showing the distribution of depositional textures and high-frequency cycles of a High-Frequency Sequence, HFS (Lucia, 2007). The grainstones are seen concentrated in the ramp crests of the high-frequency cycles of a 'Prograding Highstand System Tract (HST).

Insights on Unlocked Appraisal Opportunities

The porosity development towards the northeast of DF field is inferred to be associated with a basinward migration of progradational parasequences that characterize most of the Middle Marrat upper half cycle (**Figure 15**), delineating most of the reservoir shoal facies. The dashed ellipses (displayed in black color) are inferred to delineate the highest reservoir rock quality expected along the prograding wedges, as grainstones concentrated at the ramp crest and separated by layers of carbonate muds of lowest reservoir quality.

Upside opportunities are therefore expected basinward towards deeper waters, which reside in the greater ability of flows to bypass material downslope, via the identified incised channels, cutting perpendicular to the prograding carbonate margins. Particularly in rimmed platform settings, it is known that the transported sediments by downslope currents are sourced from the platform top itself; and would commonly nucleate submarine canyons that contain coarser grains or more reefal sediments. For it to be a hydrocarbon exploration target, however, more analyses are required in relation to finding and characterizing grain size, reliable closure and containment of potential gravity flow sediments transported downslope. Few “step-out” exploration wells are yet to be drilled to confirm the associated potential.

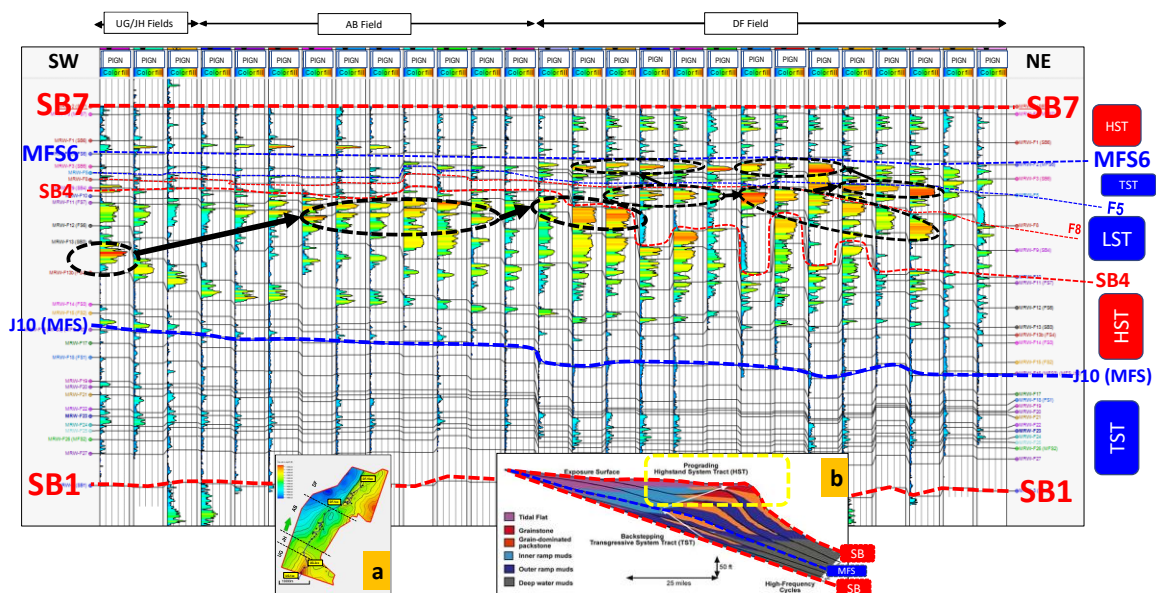


Figure 15: Sequence stratigraphy framework, flattened on Middle Marrat top SB7, using PIGN as log template. The dashed ellipses (in black) are displayed to delineate the grainstones expected at the ramp crest along the prograding wedges. **Inset a:** well's locations map. **Inset b:** diagram showing the distribution of depositional textures and high-frequency cycles of a Prograding Highstand System Tract (HST), being highlighted with a dashed rectangle (in yellow). The highest quality grainstones are concentrated in the ramp crest (*Lucia, 2007*).

Poro-Elastic Analysis and Rock Types 3D Modeling

Given a long diagenetic history on an early Jurassic carbonate reservoir with a considerable diagenetic overprint proven from core data analysis and reservoir rock typing, the lack of

comprehensive diagenetic studies performed over the Middle Marrat reservoir in the area of interest made it very challenging to build a representative static model of the reservoir petrophysical properties. Well-calibrated seismic inversion data remain one very good alternative to capture the key seismic-scale diagenetic features, otherwise very difficult to achieve when relying solely on conceptual GDEs and Reservoir Depositional Elements' (RDE) maps. Geophysical and petrophysical data were combined through deterministic seismic inversion and an Absolute Acoustic Impedance (AAI) volume was generated for the Marrat carbonate reservoir. Petro-elastic analysis using P-Impedance output; log-based porosity; and petrophysical rock types (RRTs) revealed that the distinction between the five classified RRTs based on the AAI seismic volume is not possible due to a similar impedance signature expressed by the RRTs of the same porosity class (**Figure 16, Step-1**). Supported by pressure and oil mobility data, a hierarchical modeling workflow enabled to firstly resolve the clustering of P-Impedance data into three seismic facies (i.e., rock containers), a.k.a. porosity classes (**Figure 16, Step-2**). The analysis of relationships observed at the wells between the seismic-based P-impedance and the log-based porosity, color-coded with RRT, has enabled the clustering of the 5-class RRT schema into three (03) RRT clusters; and the transformation of the P-impedance volume - via properly estimated cutoffs- into three porosity sub-volumes representing the poor, moderate, and good quality rock containers. Then, the three porosity sub-volumes have been transformed into probability of occurrence' volumes that match with the frequency distribution of the samples relevant to each RRT container (**Figure 16, Step-3**). This approach optimized the use of P-impedance seismic volume via extracting the embedded spatial trends of dominant seismic responses (seismic facies, or RRT containers) that reflect only the significant changes in facies compositions being associated with sharp impedance contrast.

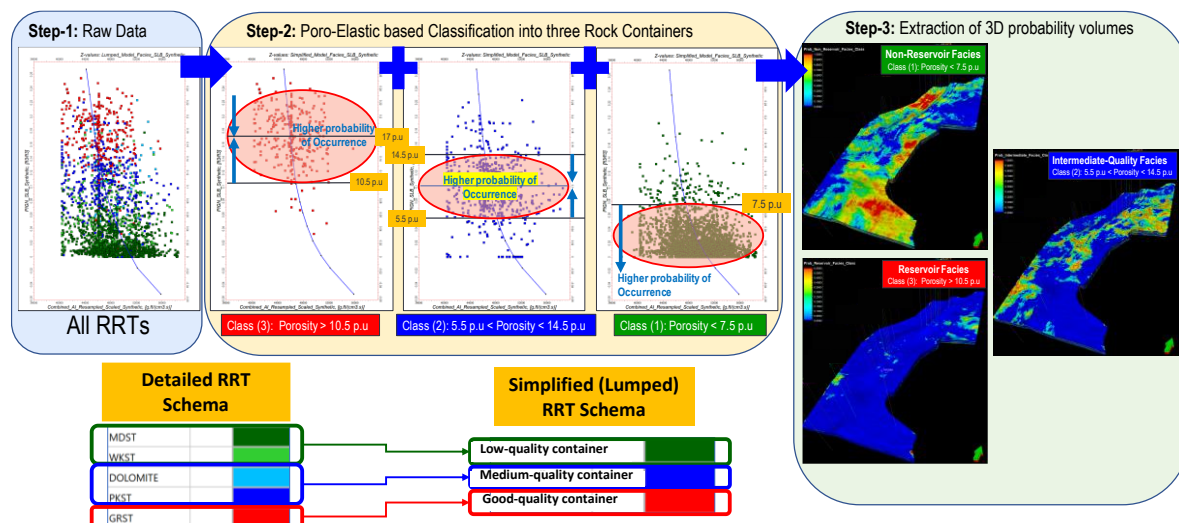


Figure 16: Cross-plot of effective porosity (PIGN), in Y axis, vs. P-Impedance (AAI), in X axis, being colour coded by RRT (**Step-1**) used for clustering of RRTs into three main rock containers (low-quality, medium-quality and good-quality facies), or porosity classes (**Step-2**); in turn used to transform deterministic inversion cube into sub-volumes of their probability of occurrence (**Step-3**).

In a hierarchical order, the simplified RRT model will subsequently condition - as a container - the probabilistic distribution of the five high-resolution RRTs. Indeed, this modeling strategy

represents an effective way to bridge the gap between the seismic domain and the core/log domain. To overcome the limitation of the vertical resolution, in particular, a common approach to integrate the seismic data into building a high-resolution probability trend model for the 5-class RRT schema, is to use the output of the 3-class simplified model in the form of 2D trend (i.e., probability) maps averaged over reasonably thick intervals. This will serve to constrain the lateral (and not the vertical) distribution of the simulated high-resolution facies model. The vertical heterogeneity, however, will be guided by the vertical proportion curves (VPCs). Through a properly designed lumping of the high-resolution stratigraphy zones (parasequences), the twenty-eight (28) zones' stratigraphy model has been lumped into only seven (07) groups of zones, thereby making the individual thickness of one remapped zone (i.e., group of high-resolution parasequences) being closer to the vertical seismic resolution. For more information on this remapping (or down-scaling) process, you can refer to **Ben Amor et al. (2019)**.

The fit-for-purpose methodology, used for the 3D modeling of RRTs was to create – per parasequence - a link between the kriged RRT propensity (fraction) map and the corresponding average seismic porosity map. As such, we will create a facies fraction map guided at the well locations by the first information, and in between by the second. These maps will then be directly integrated as input in the final RRT simulation, in order to give consistent information between the RRT and porosity models. The seismically driven well-calibrated porosity volume was a key input to reservoir property mapping. For more information on this process, you can refer to **Ben Amor et al. (2019)**.

Conclusions

A solid sedimentary model was proposed providing a relative time framework for the sedimentary succession across a large modeling area. Building the first ever unified stratigraphy framework across the different West Kuwait fields enabled an enhanced understanding of the inter-relationship of the reservoir components, depositional settings, and their lateral correlations. The Middle Marrat stratigraphy model in AB-DF and West Kuwait area has always been assumed a simple homoclinal carbonate ramp. This study came to propose a rather hybrid model reflecting a transition from a graded ramp-like platform, during early deposition stages, into an out-of-grade configuration at later stages. Dominantly controlled by relative sea-level lowering, carbonate sedimentation rates and possibly episodic structural pulses via faulting, it is inferred that the Middle Marrat carbonate ramp has evolved successively from homoclinal into stepped, then rimmed all the way to a steep-sided platform configuration.

With high sediment production, the response to sea level change during lower Middle Marrat transgression and early highstand initially has created a “keep-up” situation where deposition was predominantly aggradational and subtidal, then a “fill-up” and “spill-out” situation as deposition becomes increasingly progradational and peritidal. With the continued decrease of the relative sea level that typified the Middle Marrat upper half-cycle, the parasequences expressed a clinoform geometry and an overall progradational pattern prevailed. Reflected by a lateral migration of the sigmoidal clinoforms advancing basinward, the progradational pattern was associated with a shift of the reservoir shoal facies towards the northeastern parts of DF field.

Cutting downslope through an over steepened ramp, striking regionally NW-SE, incision features are inferred to have initiated where the ramp starts its steep sloping seaward. Identified for the first time ever in West Kuwait, these mud-prone erosional truncations have been characterized based on their erosive-based log motif and their signature on the iso-thickness lines. Although challenging to be identified at seismic scale, they were seen intimately associated with distinctive amplitude anomalies. Geobody extraction using seismic inversion derived attributes helped to depict a set of narrow and less sinuous (elongate) channelized geobodies.

The high-resolution based parasequences, their spatial continuity, and the identified incision features play a key role in predicting the porosity developments at the prolific shoal facies. New exploration traps beyond the well-defined structures in DF field are therefore expected basinward towards deeper waters. This resides in the likely downdip extension of the prolific progradational wedges (i.e., F9, F8 and F5); or towards the untapped porosity development further downdip at the shallowest progradational parasequences F4, F2 and F1.

Upside opportunities can also reside in the greater ability of flows to bypass material downslope, via the identified incised channels. Particularly in rimmed platform settings, it is known that the transported sediments are sourced from the platform top itself and would commonly nucleate submarine canyons that contain coarser grains or more reefal sediments.

The introduction of rock types enabled a good characterization of the reservoir at both field and plug scale, notably with regards to incorporating the diagenetic overprint. With a limited understanding of the depositional and/or diagenetic origin of the dolomitization, the ability to predict their occurrence and effects on reservoir quality becomes quite limited. Seismic inversion driven porosity was an excellent proxy to map the reservoir quality in 3D space, being the combined product of depositional and diagenetic processes, and correlating much better with petrophysical reservoir rock types (RRTs) than with depofacies.

Constrained by depo-facies conceptual modeling and P-impedance inversion data, a hierarchical modeling approach enabled to build a revamped static model covering AB and DF fields. It incorporated a simple but effective change in the layering methodology according to a reconciled sequence stratigraphy framework. Specifically, baffles and matrix thief zones were implemented, making a key improvement in connecting the different hydraulic units in the correct way; and enabling the dynamic model to reproduce the actual depletion patterns.

To test the model's predictability and helping the KOC team with planning infill well's locations, few recently drilled wells revealed that more than 75% of the static model properties (i.e., layer continuity, porosity, saturation) are matching with actual log results, confirming robustness of the static as well as the dynamic representation of the reservoir performance.

Acknowledgements

Authors wish to thank KOC's West Kuwait Management and Ministry of Oil, Kuwait to grant permission to publish this paper.

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SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Thermal transformation of organic-inorganic sulfur and hydrogen sulfide formation in high sulfur-containing lacustrine shale during semi-open pyrolysis

AUTHORS (FIRST NAME, LAST NAME): Weijiao Ma¹

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: The in-situ conversion process (ICP) is believed to be the effective technique to realize successful exploitation of low- to medium thermal matured lacustrine shales oil (0.5–1.0% Ro) in China, and the shale of the seventh member of the Triassic Yanchang Formation in the Ordos Basin (abbreviated as Chang 7 shale) is the most potential and representative shale for ICP. However, the Chang 7 shale is rich in sulfur, in some organic-rich laminae, pyrite (FeS₂) even accounts for more than 50% of the mineral content). During semi-open pyrolysis experiments, a large amount of hydrogen sulfide (H₂S) was generated accompanied with hydrocarbons. H₂S is toxic and corrosive, special facilities are needed and additional treatment to remove it can be expensive. Therefore, detailed characterization on the thermal transformation of organic-inorganic sulfur and H₂S formation is a key issue for the effective and environmentally friendly development of ICP.

The field emission scanning electron microscope (SEM), X-ray photoelectron spectroscopy (XPS), X-ray diffraction (XRD), and elemental analysis were combined to examine the partitioning of sulfur between the organic and inorganic phases with increasing thermal stress and to further reveal the evolution of H₂S. Kerogen decomposition and the corresponding products exerted strong influences on the transformation of organic-inorganic sulfur and, thus, on H₂S formation. Before the peak hydrocarbon generation stage (1.24 %Ro), H₂S showed an abnormally sharp increase and little or no secondary FeS₂ was formed. The sulfur generated by FeS₂ decomposition partly formed H₂S and partly incorporated into the organic matrix of kerogen. Hydrogen radicals generated by kerogen decomposition and secondary oil cracking are proposed as the controlling factor in the initial FeS₂ decomposition. The results are expected to help predict the H₂S release during the true ICP of the Chang 7 shale.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Revealing Biogenic Gas Province in Central Sumatra Basin

AUTHORS (FIRST NAME, LAST NAME): Afrizon Setiawan1,
Faisal Rachman2

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: Biogenic gas currently remains under-developed in proven oil pool Central Sumatra Basin. A review based on regional gravity data and sampled well data along the basin has been conducted to evaluate basin-scale prospective resources.

A basin-scale analysis on the biogenic gas preferable area has been conducted using gravity data to investigate paleo-high distribution within the Central Sumatra Basin. A thorough analysis of Binio (Lower Petani) Formation as a proven biogenic gas reservoir and most likely source rock has been evaluated on the selected well which represents the distribution and heterogeneity of the Basin. Gas Formation evaluation, temperature gradient, paleoenvironment, and sedimentation rate were used to evaluate the potency of biogenic gas generation.

The model calculates the maximum yield of biogenic methane gas as a function of source sediment volume.

Integration to the distribution of paleo-high and sedimentation concepts provides a model of the biogenic gas province as a clearer guide into the untapped prospective area for biogenic gas accumulation within the Basin. The model suggests the total maximum yield of biogenic gas exceeds 400 TCF and considering migration factors, such as migration loss through time and diffusion/leakage, the potential trapped biogenic gas resources in Central Sumatra Basin is approximately reached up to 12 TCF. This biogenic gas has a potential accumulation in the structural trap, stratigraphic trap, and the combination of both structural and stratigraphic. Currently, only one-tenth of resources has been proven and producing a sweet dry biogenic gas in Central Sumatra Basin. The production activity of biogenic gas has shown an economic sound and effective production cost. The exploration concept and biogenic gas province model in the Central Sumatra Basin may reveal significant resources of untapped biogenic gas and could potentially fulfill increasing gas demand in the near future.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Geological and Geochemical Characteristics of a Gas and Condensate accumulation in the Boicobo Structure (Northwest of Margarita–Huacaya Field) in the Southern Sub-Andean Zone of Bolivia

AUTHORS (FIRST NAME, LAST NAME): Daniel Peña¹, Connor Moore¹, Antonio Martin Monge², Maicol Moron¹, Camilo Restrepo¹, Sebastián Córscico¹, Tomas Zapata³

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: The Boicobo structure lies northwest of the Margarita(MGR)/Huacaya(HCY) gas-condensate field, in the southern sub-Andean zone of Bolivia. The structure, interpreted as a three-way dip, fault-dependent closure, is the northwestern continuation of the MGR/HCY duplex system. A major thrust fault separates Boicobo from the backlimb of the Huacaya structure. The BCS-X1ST exploration well, drilled in 2020, targeted this structure and encountered a gas condensate accumulation in the naturally-fractured sandstones of the well-known Devonian Huamampampa Fm.

The major thrust fault that separates the Boicobo and Margarita/Huacaya structures has been interpreted in 3D seismic data. While the drill-stem test conducted at BCS-X1ST did not show clear indications of nearby faults during the main build-up phase, the measured fluid properties are notably distinct when compared to adjacent accumulations. Furthermore, there is ~100 m difference between the gas–water contacts of the Huacaya field and the Boicobo discovery. This has spurred a multi-disciplinary effort, based on post-drill analyses, to better understand the geological and geochemical characteristics of the gas condensate accumulation in the Huamampampa reservoir found at the BCS-X1ST location, principally aimed at pinpointing its relationships with neighboring structures and petroleum accumulations. This contribution will summarize some of the outcomes of this multi-disciplinary study, including:

1. Structural interpretation and modelling, geological mapping and integration with published and newly-acquired thermochronological data, which indicate that the thrust fault separating Boicobo and Huacaya was developed in the last 3 Ma.
2. A fault juxtaposition analysis performed for the fault plane which is interpreted to separate the Boicobo and Huacaya structures. shows a favorable fault seal juxtaposition of the Huamampampa sandstones (hanging wall) against the Los Monos seal (footwall), with only three relatively small areas with juxtaposition of reservoir intervals.
3. A geochemical assessment of reservoir compartmentalization using oil and gas separator samples from the Huacaya-2ST and BCS-X1ST wells. Oils were investigated using bulk fraction characterization, whole oil high-resolution gas chromatography and gas chromatography–mass spectrometry. Gases were analyzed by gas chromatography and gas chromatography–isotope ratio mass spectrometry. Data were processed and integrated to characterize their similarities.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Controls on Deposition and Reservoir Character of the Miocene Cicuco Field, NW Colombia: A Low-latitude Shallow-water Transitional Carbonate System

AUTHORS (FIRST NAME, LAST NAME): Angela Torres-Zamora¹, Diana Ortega-Ariza², Evan K. Franseen³, Gabriel Veloza⁴, Hugo Caycedo⁵, Josué Alejandro Mora Bohórquez⁶

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ABSTRACT BODY:

Abstract Summary: Modern low-latitude shallow-water carbonate systems are typically dominated by reef-building photosynthetic organisms (photozoans) when photic zone conditions are ideal. However, under adverse conditions (e.g., increased nutrients, cooler water), photozoans can be greatly reduced, and heterozoans (e.g., mollusks, echinoids, bryozoans) can dominate (termed transitional carbonate systems; TCS). Distinguishing between the two systems is important because facies types, stratal architecture, dominant mineralogy, diagenetic potential, and resultant reservoir character can be different. Despite their importance as reservoirs, TCS are not well understood or recognized. During the Miocene, adverse conditions created by well-documented upwelling in the Caribbean resulted in widespread development of shallow-water TCS. This project focuses on the early Miocene Cicuco Field, NW Colombia to better understand controls on deposition and reservoir character of a possible TCS. Our initial results from core, well log, and seismic data indicate shallow-water carbonates, and associated siliciclastics developed on basement paleo-highs. Core study indicates grainy carbonate (packstones and grainstones) and mixed carbonate-siliciclastic (fossiliferous siltstones and sandstones) facies are dominant. Carbonate facies include heterozoan and photozoan components. Dominant heterozoans include gastropods and bivalves. Photozoans are limited to corals (mostly *Porites*), large benthic foraminifera, and red algae, all known to tolerate elevated nutrients, turbidity, and cooler water conditions. The facies characteristics are similar to those found in nearby areas in Colombia (e.g., El Difícil Field) and TCS systems documented around the Caribbean, which formed under adverse photic zone conditions related to upwelling. Initial core data also indicate a general vertical facies trend. Mixed carbonate-siliciclastic facies are dominant in basal portions (nearest underlying basement) and pass upwards to grainy heterozoan and photozoan carbonates, including abundant in-place and reworked coral-rich facies in upper portions. Similar vertical facies patterns have been documented in time-equivalent rocks elsewhere in the Caribbean, and interpreted to reflect changing upwelling conditions tied to relative sea-level fluctuations. Our ongoing studies are continuing to evaluate the significance of regional and local controls on deposition and reservoir character.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Porosity Characterization of Travertines as Analogs of the Campos Basin in Brazilian Pre-Salt

AUTHORS (FIRST NAME, LAST NAME): Amanda Midory Rios¹, Karl Jan Clinckspoor Laboratory for Oil Reservoirs², Alessandro Batezelli³, Rosangela Barros Zaroni Lopes Moreno⁴

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4. Laboratory for Oil Reservoirs - University of Campinas (UNICAMP)

ABSTRACT BODY:

Abstract Summary: Oil recovery in carbonate reservoirs is complex because of their high petrophysical and geological heterogeneities, chemical reactivity and physicochemical interactions into the porous media during the fluids flow. Understanding microbialitic reservoirs from Campos Basin in the Brazilian Pre-salt is limited, so petrophysical analogs are commonly used.

This work focuses on the pore characterization of pre-salt microbialitic carbonates analogs using travertines from the Tivoli area, that have abundant laterally continuous shrub-like fabrics, primarily in horizontal layers with progradation and aggradation stacking patterns, such as microbialites. Petrographic analyses allowed the identification of shrub morphotypes such as narrow dendritic and poorly developed pustular structures. Besides that, there is an abundant presence of peloidal micritic aggregates in spar calcite.

Moldic porosity formed by the decomposition of reeds was observed. The mold of these structures serves as a substrate for the crystallization of shrubs. A large part of the moldic pores is filled with equant and dogtooth spar. Shrubs usually reflect specific microenvironments controlled by rates of water flow, evaporation, and microbial activity. Narrow dendriform morphologies occur in moderate/low energy flows, showing faster runoff conditions. Slow flow is more conducive for pustular types, being strongly influenced by evaporation.

From computed tomography of vertical and horizontal plugs from two travertine blocks, it was observed the lateral continuity of the samples porosity, generated by the dissolution of structures that extend horizontally. In contrast, in vertical direction, the samples characterize themselves by higher matrix density, which leads to low vertical porosity. Pores with volumes from 0,002 to 355,159 mm³, with radii ranging from 0,078 to 4393,17 mm and shape factors from 0,398 to 17,9 were also featured.

The analysis developed in this work showed that Tivoli travertine has a pore fabric formed by the dissolution of structures and empty spaces created by the microbial activity and carbonate precipitation, with extensive horizontal inter-pore connectivity, such as fractures with dissolution. That shows that travertine is a challenging rock given its high reactivity, creating many holes, which can lead to difficulties in preparing samples for specific studies, but, at the same time, configuring itself as an excellent analog to microbialites from the Brazilian pre-salt.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

EXTENDED ABSTRACT: Unlocking Basement Reservoir Play Concept of Musi High and The Giant Prospect of South Palembang Sub Basin in South Sumatra Basin, Indonesia

Syefriyandi¹, Alan Inabuy¹, M Alfatih Syaifurrahman¹, Noha Muhamad¹, Ary Wahyu Wibowo², Wisnu Prihantono³, Yudha Risnandar Sinulingga³;

1. KSO Indrillco Hulu Energy 2. PT Pertamina Hulu Rokan 3. SKK Migas

Abstract

The South Sumatra Basin is one of the most hydrocarbon prolific basins in Indonesia. While hydrocarbon from the Pre-Tertiary basement has been produced in Jambi, North and Central Palembang sub-basin, the viability of the same play in the South Palembang sub-basin remains a mystery. The pre-tertiary framework of South Sumatra itself consists of four terrains: the Malacca, Mergui, Woyla, and Mutus terranes. Fractured basement reservoirs in Southern Sumatra are typically combinations of intrusive and metamorphic terrains. Musi High was a paleo-high basement since the Tertiary period and remained high until Middle Miocene when carbonate reefs started to develop. Carbonate of the Baturaja Formation was well spread in this platform, hence, it lies on the top of the pre-Tertiary basement.

The hydrocarbon discovery from R-2 well-deepening result proves that the Pre-tertiary basement has a working petroleum system. Three different types of hydrocarbon play concepts that can be applied here, are the Weathered Basement, Fractured Basement and, Onlapping Basement Washed. Understanding of Basement play in Musi High will be the beginning of discovering the potential of the sleeping giant.

Introduction

Pre-tertiary basement reservoirs are becoming regionally one of the most important exploration targets, with the successful developments in Jambi sub-basin (Jabung block), North Palembang sub-basin (Sakakemang block) and Central Palembang sub-basin (Sumpal, Suban and Dayung block). Meanwhile the basement in South Palembang sub-basin has not yet been considered as exploration potential. The Musi high (Musi Platform) is located in South Palembang sub-basin, and it is interpreted as a large paleo-basement highs since Early Tertiary. The most productive play in Musi high is Early – Middle Miocene Baturaja limestones that spread throughout this high area. The lack of exploration activity – and therefore data – on the pre-tertiary basement of Musi High has made this interval an unattractive reservoir target as opposed to the carbonate reservoir of Baturaja Formation.

R-2 well has been drilled in 2008 targeting the carbonate reservoir of Baturaja formation. The drilling itself reach the top of basement at 1183 meters and suffer a partial loss and Gas (chromatograph) reading of 1413 units, before reaching the total depth at 1200 meter. Based on this data, the deepening program was carried out in 2021. This study is expected to provide an overview of the

sleeping giant hydrocarbon potential in the pre-tertiary basement with the discovery of R-2 well deepening.

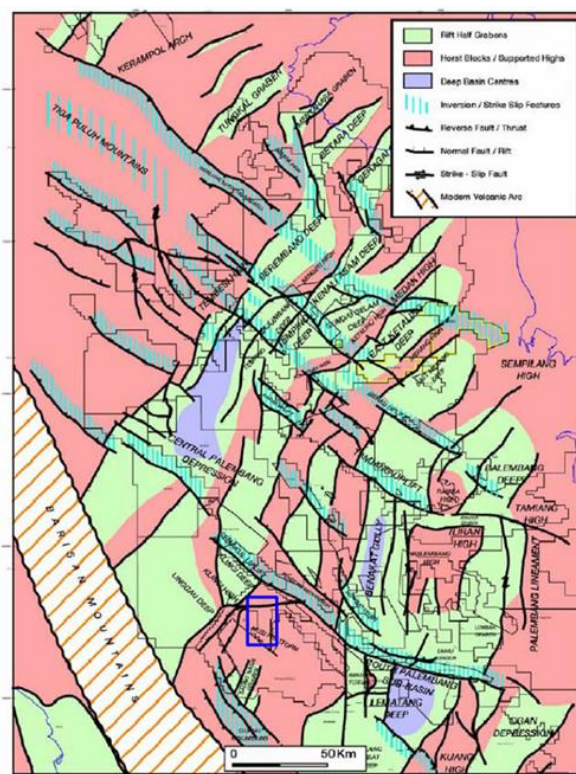


Figure.1 Key structural elements of the South Sumatra basin, showing Eocene-Oligocene age (Ginger,2005)

Geological Setting

The collision of Indian-Australian plate with the Eurasian plate and the subsequent subduction of the former under the latter formed the present-day tectonic framework of Sumatra containing a series of Cenozoic back-arc and fore-arc basins with complicated basement architecture and varied lithology. Pre-Tertiary basement structures in the Sumatra Island are made of various NW-SE trending tectonic belts (Figure 1) sometimes called micro-plates or terrains (i.e. Pulunggono and Cameron, 1984; Barber et al. 2005, Figure 2). The Pre-Tertiary basement consists of metamorphic, igneous, volcanic, and mélangé rocks where their boundaries are marked by sutures, thrusts or strike-slip faults. The convergence began in early Cretaceous when the Woyla Terrain collided with the southern edge of the Sumatra Island (Cameron and Pulunggono, 1984).

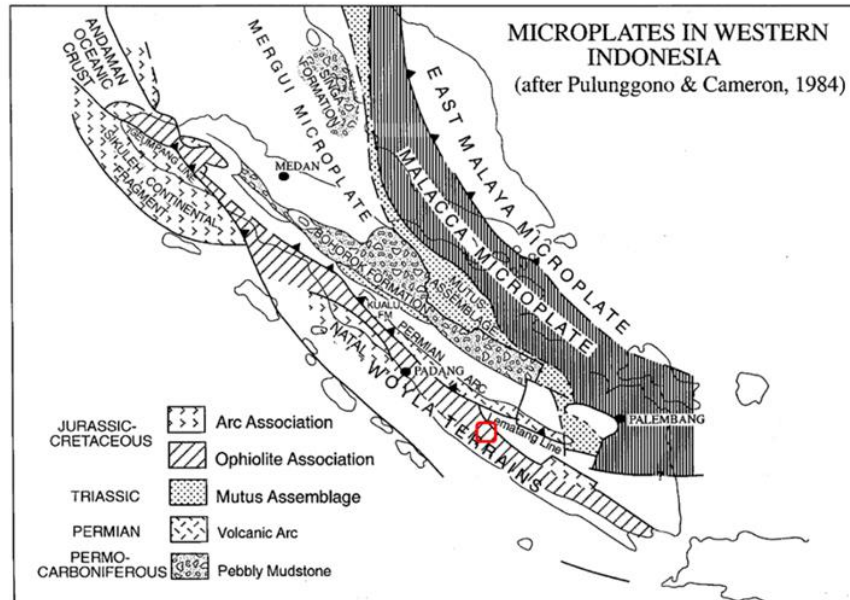


Figure.2 Microplate in western Indonesia from Pulunggono (1985), after Pulunggono and Cameron (1984)

Methodology

Integrated exploration concept involving the analysis of well data, (mud logs and wireline logs) and seismic data was carried out in order to identify the Weathered Basement, Fractured Basement and, Onlapping Basement Washed in our study area. The geological concept applied in interpretation of seismic and well data allows the assessment of possible presence of basement reservoir prospect. In addition to that, the result of R-2 well deepening where the Pre-tertiary oil was discovered, declared that the petroleum system of the basement reservoir is proven.

Basement Interpretation and Architecture

The basement rocks lithological types in South Sumatra basin was known to be complicated due to a series of tectonic activities as mentioned above. Several lithology could be identified from well data, i.e. quartzite-meta quartzite that is interpreted to spread in the northern part of the study area; Marble – metalimestone in the central area; whereas Felsic Intrusive (Granite-granodiorite) was found in the southern area (based on R-2 well data). The characteristics of Quartzite – Metaquartzite was found at well U-1 and D-1 according to mud logs, whereas Marble – Metalimestone was found at well M-1 with low grade metamorphosed limestone. This sample is characterized by a tectonic fabric and textures suggestive of a low-grade metamorphic event. In terms of mineral, the sample is composed of non-ferroan calcite with subordinate amounts of quartz and an opaque phase mineral. It is not possible to identify the origin nature of the limestone due to the development of the tectonic fabric. The characteristic of Felsic Intrusive Granite – Granodiorite was found at R-2 well, the basement composed of Igneous Rock Fragment (Basement Rock) and can be describe as Greenish grey, dark grey, reddish brown, hard, sub platy to platy, locally blocky, quartz. A composite of 2D seismic section that crosses key wells in the study area was generated to help determine the deployment of the pre-tertiary basement (Figure 3).

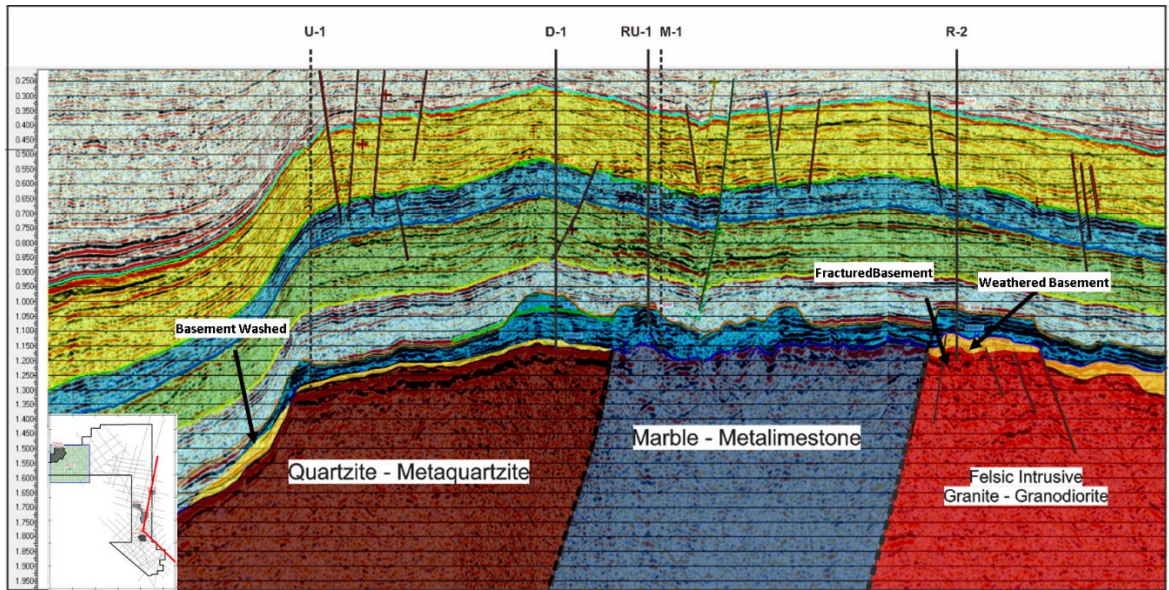


Figure. 3 Composite seismic section (North to South) through key wells in the study area. Basement lithology was derived from mud-log data.

Figure 4 shows the log data from well R-2 that penetrate through the basement interval. The well data shows 2 different characters between the upper interval (weathered basement) and the lower interval that are interpreted as fractured basement zone. Although the sonic and density range are very similar between the 2 zones, they exhibit different characters, with the upper interval having more intercalation between 'hard' and 'less hard' rocks as compared to the lower interval. The low Gamma ray reading in 1250 m-MD is interpreted as layer that distinguish between the 2 types of basement. Note also, that the resistivity reading tends to be slightly higher (more resistive) in the fractured zone as compared to the weathered one, while the porosity is slightly tighter in the fractured basement zone. Conventional seismic section and some of its derivative attributes was used to help identify the different characters of the basement interval. It could be observed from the seismic data that the weathered basement zone exhibits more continuous seismic energy / events, while the fractured basement zone shows more chaotic internal seismic character.

Figure 5 (top panel) shows a 2D seismic section in Northwest – South east direction of the study area, with well R2 projected some distance away from the seismic line. Our well R2 is drilled through both the weathered and the fractured zone, with the total depth of 1315 m-MD. The magenta line marks the top of basement, with yellow shaded zone indicating weathered basement, and blue shaded zone indicated fractured zone. As it can be observed, the weathered basement interval is characterized by its strong and continuous events, while the fractured zone is more chaotic and exhibit weaker amplitude response. Some seismic attributes were derived to help identify the different characters of the basement interval. Figure 5 – lower panel shows the Seismic Normalized Energy, which combines the seismic envelope and instantaneous phase attributes, here again we

observe that the weathered basement zone exhibit more continuous seismic energy / events, as compared to the fractured basement zone.

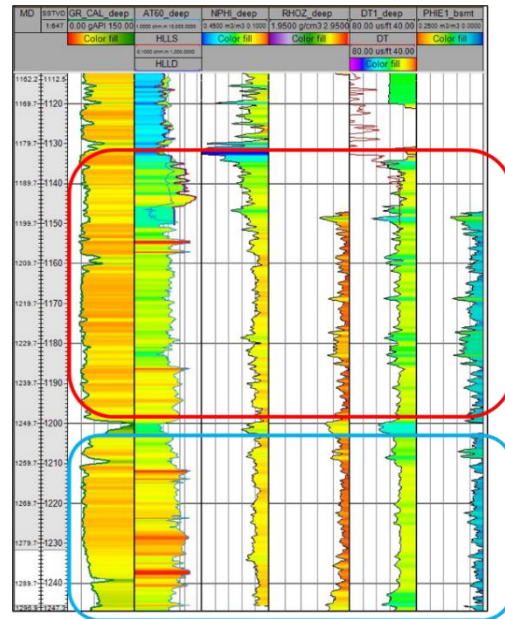


Figure 4. Well log data of R2 well, From left to right: Depth (MD and SSTVD), Gamma Ray, Resistivity, Neutron, Density, Sonic, and porosity. The scales are slightly exaggerated to highlight the detailed character of the log.

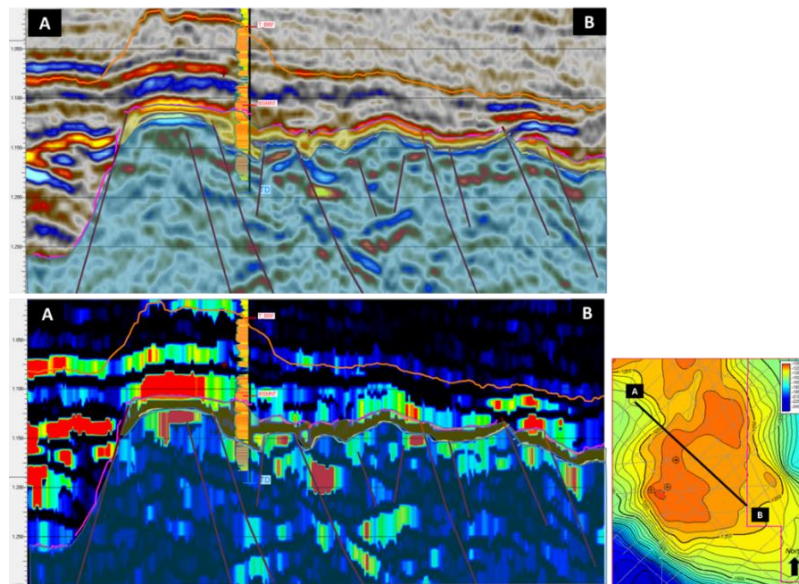


Figure 5. Top panel - Seismic section that pass through well R2 (projected by some distance), lower panel-left – The seismic attribute (Normalized Seismic Energy), and lower –right the basemap index with Weathered basement depth structure. Noted that the low gamma ray response that separate the 2 basement zone falls at the top of the interval where the internal seismic events starts to become more chaotic (as opposed to the continuous event overlying it).

Conclusions

Pre-tertiary basement in Musi High is still consider at the frontier stage of exploration. In this study the intrusive Granite-Granodiorite basement in the southern part of the study area were divided into 2 zone, weathered basement and fractured basement based on well data and seismic interpretation. The integrated analysis of well and seismic data allow us to identify the potential of basement reservoir, and with the discovery of the Pre-Tertiary oil from recent well deepening program, the basement reservoir of South Palembang sub basin (Musi High) is proven and expected to be further explored and developed.

Acknowledgement

The authors wish to thanks the management of KSO Indrillco Hulu Energy, PT Pertamina Hulu Rokan and SKK Migas for their permission to publish this paper.

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SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Sedimentary Characteristics of Flood Overlake in Faulted Lacustrine Basin——A Case Study of Paleogene in Dongying Sag, Bohai Bay Basin, Eastern China

AUTHORS (FIRST NAME, LAST NAME): Jinshuai Liu¹, Chengyan Lin², Xianguo Zhang³, Zongwei Zhang⁴, Zhengchun Shen⁵

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ABSTRACT BODY:

Abstract Summary: Flood overlake sedimentary system was formed in the shallow lake with flat paleotopography in the early stage of lacustrine basin development under the condition of arid and semi-arid climate. And near-source paroxysmal flood deposits, which is different from the common lacustrine fluvial delta system, is often developed in this environment.

The target layer of this study is the lower part of the fourth member of Paleogene Shahejie Formation in Dongying Sag, Bohai Bay Basin, Eastern China. Core, well logging, 3D seismic and geochemical data analysis are utilized to study the flood overlake sedimentary characteristics of shallow lakes under alternating wet and dry climates. The results show that: 1) The target layer develops the iconic red layer, which is the result of the alternation of humid short-term flood period and dry long-term flood intermittent period under the condition of dry climate; 2) Two different depositional environments and climatic conditions are identified in the target layer, which can be divided into two parts. The lower part of the target layer was formed in the flood intermittent period, indicating arid climate, resulting in decline of lake level and reduction of the lacustrine basin scale, which manifests a high-frequency turbulent lacustrine basin in the relatively low water level period, developing flood overlake deposits, mainly including flood overlake sand flat, sand-mud mixed flat and mud flat. The upper part of the target layer was deposited in flood period, with humid climate, rising lake level and expanding lake basin. It was a high-frequency turbulent lacustrine basin during the relatively highwater level. Shallow delta and shore-shallow lake were deposited successively in the upper part of the target layer, the main sedimentary types of which are underwater distributary channels, interdistributary bays and beach bars. Based on the understanding, the deposition model of flood overlake deposition has been established, including two deposition models of flood period and flood intermittent period. Under the guidance of the models, the distribution of sedimentary facies in the study area was characterized by using drilling and 3D seismic data, which provides geological support for oil and gas exploration in the study area.

SESSION TITLE: Theme 1: Petroleum Systems

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Agent-Based Modeling for Secondary Hydrocarbon Migration – A Wessex Basin Case Study

AUTHORS (FIRST NAME, LAST NAME): Arne Kreiensiek¹, Quentin Corlay², Bastian Steffens³, Thomas Wagner⁴, Vasily Demyanov⁵

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ABSTRACT BODY:

Abstract Summary: This work aims to validate a novel approach for secondary hydrocarbon (HC) migration by applying agent-based modelling (ABM) to a data rich petroleum system. The method allows modelling HC flow from source rock to reservoir dynamically. Agglomerations of HC molecules are modelled by independent but interacting agents (particles) whose movement is subject to simple rules that reflect fluid behaviour within a geological environment. These rules are based on the main drivers of migration: buoyancy, porous media permeability and present structural and stratigraphic features. Due to the fast computation this method is suitable for uncertainty quantification studies and allows to quickly screen through various geological scenarios. For instance, it can help identify and verify uncertain scenarios of kitchen location and migration pathways. This study will validate the method applied to the Wessex basin case study with its well-studied petroleum system. Firstly, regional open-source data is gathered and interpreted. Secondly, broad 2D seismic interpretations are utilised to construct a 3D structural model covering the entire petroleum system. Facies distributions are modelled with universal kriging and consider interpreted core data, wireline logs, and outcrop analogues. Uncertainties of each interpretation and modelling workflow step (e.g., fault transmissibility, fault offset, range of permeability) are identified and integrated into a Monte Carlo simulation to generate multiple scenarios. Secondary migration is then simulated through ABM for each scenario. Tectonostratigraphic events within the area of interest, resulting in a diverse spectrum of possible migration scenarios, are accounted for through adjustment of generated and expelled HC volumes as well as through stochastic geological model restorations. Lastly, accumulations of agents from the simulated approach are compared to proven oil reserves in place to elucidate potential play scenarios and validate the method. Through several postprocessing steps the migration pathways are analysed and assessed on their geological realism. Results indicate that this method is suitable to quickly mitigate the risks of potential prospects by validating and/or discarding various migration scenarios. Applying this original approach and complementing it with 3D geological models can be utilised at underexplored frontier basins to enhance the quality of quantitative judgment on future development decisions.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Net Sand Distribution of the Pliocene Forest Formation Topsets, Southern Basin, Trinidad.

AUTHORS (FIRST NAME, LAST NAME): Christie Carr¹

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: This study investigates the net sand distribution of the Pliocene Forest Formation topsets of the Orinoco Delta within a section of the Southern Basin, Trinidad. The primary objectives were to understand the Forest Formation sand distribution and determine its deltaic regime by focusing on three units of interest: Upper A-B, Lower A-B and the C-D Unit, all picked from well data. To achieve this a series of steps were done as well as basic principles such as delta morphology and regime (wave-tide-fluvial) along with regressive and transgressive cycles were considered and played a major role in building this project. Before correlating wells, a 1D analysis was created to understand periods of regression and transgression. Units were picked and sand maps created, followed by deltaic regime interpretations. Facies distribution maps were also made for the same units using the distribution of well log facies which were represented by pie charts. This allowed for distinct trends to be observed regarding the distribution of specific well log characters throughout the area. Based on their associated depositional environments, an appropriate deltaic regime was then assigned, as well as estuary networks were now able to be interpreted. Next, GDE models were made for the units of interest. To justify if there were estuaries present, a sequence stratification interpretation was done for a few wells where down cut areas were compared to the networks created from the facies maps. Finally, the value of this study is such that it can be useful for future projects in terms of understanding reservoir geometry and quality since the facies analysis method gave a more detailed and defined resolution as to locating the area with the best sand. This is essential when placing a well since I learnt that despite the net sand map showing obvious sand thicknesses, it does not consider regime and the presence of estuaries which can affect flow because of there being stacked sequence boundaries. Recommendations to improve this study includes the incorporation of production data and seismic, as well as the creation of a database for the facies to test if the same results can be replicated for another delta. This study has the potential for further development as it can assist in accurately modeling GDEs and reservoir geometry for well placement.

SESSION TITLE: Theme 1: Stratigraphy

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Characterization from Wheeler diagrams of the petroleum system in the north offshore of Argentina

AUTHORS (FIRST NAME, LAST NAME): Facundo Pagan¹, Sebastian Arismendi², Juan Pablo Lovecchio³, Ofelia Silio⁴, Tomas D'Biassi⁵, Maria Eugenia Pascariello⁶, Nestor Darwin Bolatti⁷

INSTITUTIONS (ALL):

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7. YPF S.A.

ABSTRACT BODY:

Abstract Summary: The Colorado basin has an area of approximately 120.000 km², most of them corresponding to the continental shelf and slope, where it reaches water depths greater than 3900 m. Maximum sedimentary thicknesses are greater than 12.000 m in the eastern depocenter.

The stratigraphic column begins with a pre-rift section of mainly Paleozoic rocks, followed by syn-rift fluvial and lacustrine deposits of Jurassic age and, ultimately, by cretaceous fluvio-deltaic to marine sag deposits and later by Cretaceous and Cenozoic deep marine passive margin deposits. There are several levels that could act as possible source rocks, reservoirs and seals and even certain clues of the existence of a working petroleum system, confirmed by the well Cruz del Sur in the 1980s.

A highlight of the Colorado basin is the so-called External High. This feature is a huge structure located at the external part of the Colorado basin, separating it from the North Argentina basin. This basement high shows normal faulting in its flanks, associated with the reactivation of the faults involved in the formation of the different cretaceous basin depocenters. Moreover, in its formation it is highly probable the contribution of differential compaction. Based on the analysis of the elements extracted from seismic interpretation, like stacking patterns, geometries, geomorphology, thicknesses and the utilization of concepts of base level and geological time lines (Wheeler, 1958, 1964) it is possible to identify areas with high hydrocarbon generation potential, reservoir zones and seals, and to evaluate its lateral continuity and spatial distribution. This regional characterization of the petroleum system elements could strengthen prospect exploration and trigger new questions for the study area.

To complement the conventional workflows, semi-automatic interpretation flows were used on the totality of the seismic data that allowed associating geological ages relative to all horizons and building a lithostratigraphic framework to deepen the understanding of stratigraphic evolution. In this way it would be possible to synthesize the knowledge in a practical way for its application in exploratory prospecting.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Paleosalinity of Shahejie Formation, Qikou Sag, Bohai Bay Basin, China

AUTHORS (FIRST NAME, LAST NAME): Xiangbai Liu¹, Guangdi Liu², Zezhang Song³

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ABSTRACT BODY:

Abstract Summary: Whether transgression in the Bohai Bay Basin exist has been a matter of debate. The significance of this study is that it emphasises the application of paleosalinity indicators to interpret the paleoenvironmental changes correctly and to judge whether offshore lake basins are affected by seawater. In order to study the paleosalinity of the ancient water body and reconstruct the depositional environment when Shahejie formation deposited, the composition of clay minerals and elemental geochemical analysis were carried out. In this study, B/Ga and Sr/Ba ratios are sensitive to paleosalinity, indicating the ancient water body had mixed with fresh and salt-water. Paleosalinity calculated with Couch's method by boron content is 4.29‰-13.16‰ and with an average value of 7.79‰. These results indicated that the ancient water body of Qikou sag in Shahejie formation has typical brackish water characteristics or rather belongs to mesohaline water. In terms of the trend of the Sr/Ba and B/Ga ratios, as well as Sp, from Es3 to Es1s formation, the paleosalinity of the water body first increased and then decreased. The paleoclimatic analysis shows that the Qikou sag had warm and humid paleoclimate, and this climate was conducive to increasing the weathering intensity and the input of surface runoff. The changes of paleosalinity have no inevitable relationship with climate, and the brackish water environment during the Shahejie formation deposited is possibly related to transgression event, which allows salt water to invade and lead to the mixed water.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

EXTENDED ABSTRACT: Clastic Reservoir Characterization with logging-while-drilling (LWD) Dual-Physics Imager in Oil-base Mud

Shiduo Yang, Schlumberger, Clamart, France; Chandramani Shrivastava, Schlumberger, Houston, USA

Introduction

Complex structures or salt tectonics often lower the confidence in seismic interpretation for wells positioning in expected reservoir intervals, and high-resolution borehole images can provide much needed confident geological data in such cases. Development wells drilled with high-angle and horizontal trajectories may get limited or no access for post-drilling logging operations due to well stability or other operational constraints; thereby emphasizing the need of logging while drilling (LWD) technology to provide high-resolution image logs fit for detailed interpretation. Drilling with oil-base mud make it even more difficult due to historical unavailability of LWD geological imagers for non-conductive mud system. Recently deployed industry's first and only dual-physical imager provided an opportunity for delineation and facies identification in an offshore drilling environment with poor quality seismic.

A case study from undisclosed Tertiary clastic system is being used to demonstrate the reservoir characterization from this dual imager. The bedding boundary dips were picked confidently from resistivity images; and micro-scale faults and fractures were identified and classified benefitting from the dual-physical measurements. The structural dip was computed from bedding boundary and cross bedding dips with an innovation approach. Near-well structure with NE-SW strike was constructed from zonal structure dips suggesting the structural controls.

Paleocurrent analysis from crossbedding picked on images suggested North-West depositional source direction; and dip vector plot for each sand group in three-dimension provided the fundamental information for sand body prediction. Fluvial channel and delta sedimentary environment were classified based on textural features and sedimentary structures from high resolution images; and 3D sand bodies were inferred. Near well clastic reservoir characterization is successfully achieved from single well LWD dual images.

LWD Dual Imager Measurement principles

This case study demonstrates the capability of LWD dual imager to provide detailed geological interpretation, both structural and stratigraphic. In fact, the multiple images that are acquired ensure no feature worth interpretation escapes the geologists' eyes. The study area represents Tertiary sedimentation of a clastic system in a broad shallow marine depositional setting, transitioning from terrestrial sedimentation.

Recently introduced dual-image logging-while drilling (LWD) tool (Maeso, 2018) is configured with two electromagnetic (EM) sensors and four ultrasonic (US) sensors to acquire multiple images (Shrivastava, 2019) for subsurface characterization while drilling.

The two EM sensors are positioned on the drilling collar 180° apart, while the four focusing ultrasonic sensors are positioned mutually orthogonal in one plane and 1.7 ft behind the electromagnetic sensors. The tool measures an electrical impedance that is sensitive to the formation electrical resistivity. The use of a guarding scheme prevents the contribution of stray currents in the computed impedance, leading to a more robust measurement with minimized environmental effects. The focusing scheme has been adapted to remain operational across the entire radio-frequency range of the tool and a dedicated sensor has been developed to apply the guarded measurement.

The ultrasonic measurement based on the pulse-echo principle uses four focused transducers designed to work in borehole sizes up to 10.5-in with a beam diameter of about 4 mm (0.16-in) in the target standoff range (Maeso et al., 2018). Data are sampled every 2° azimuthally (180 sectors) and 5mm (0.2-in) vertically for each sensor. The round-trip travel time and amplitude are computed for first echoes using an efficient filtering method.

Dip picking and classification

The dual-physical imager provides resistivity and ultrasonic image (Maeso et al., 2018). Dipping features can be picked from dual images and validated on the different image responses (Fig. 1). Bedding boundary indicated by the green sinusoid has larger resistivity contrast compared the contrast on the ultrasonic image. Also, the fine-scale bedding boundaries are well-defined on the ultrasonic compared with the resistivity image. The crossbedding dips (red color) are more identifiable on the resistivity image in the lower clay component depth interval. In relative higher clay depth interval, the crossbedding dips are more visible on the ultrasonic image (Fig. 1).

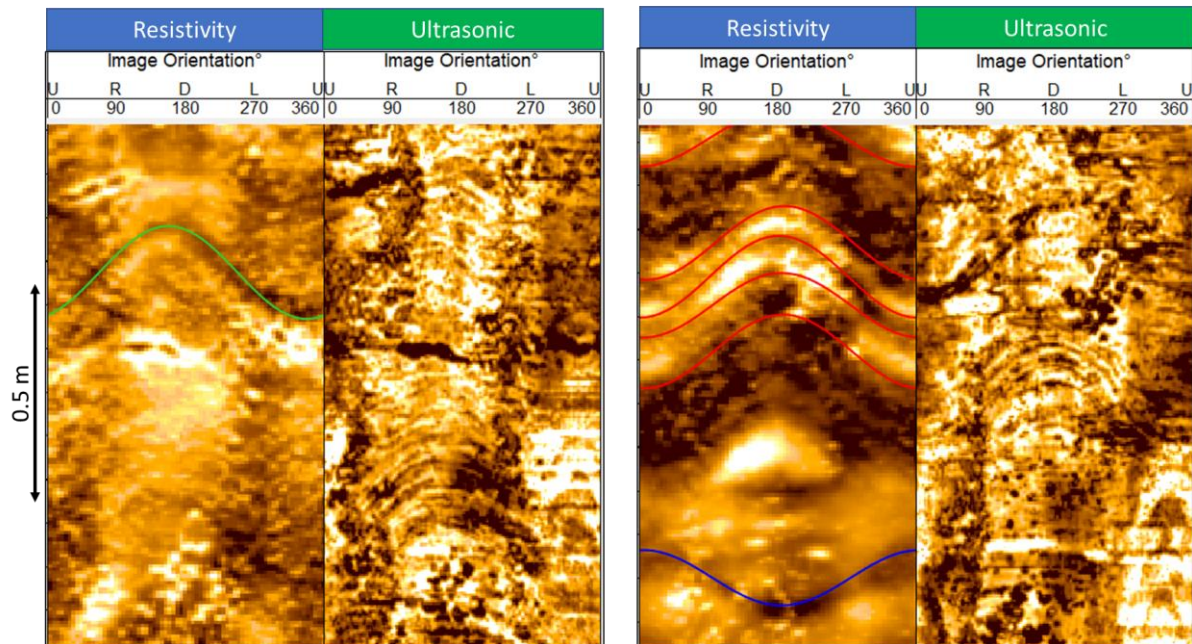


Fig. 1 Dip picking and classification from dual images.

Fracture dip indicated by the blue color is easily identified on the resistivity image (Fig. 1), but the dip classification is very challenging in the oil-based mud environment. By combining resistivity image with the ultrasonic image in this interval, the fracture is classified as closed.

More fracture features were identified on the resistivity image as shown by the blue arrows in Fig. 2; however, there was no clear response on the ultrasonic image. Sub-seismic fault was identified on resistivity image, shown with topmost arrow in Fig. 2, high amplitude response was observed on the ultrasonic image suggesting potentially sealed classification.

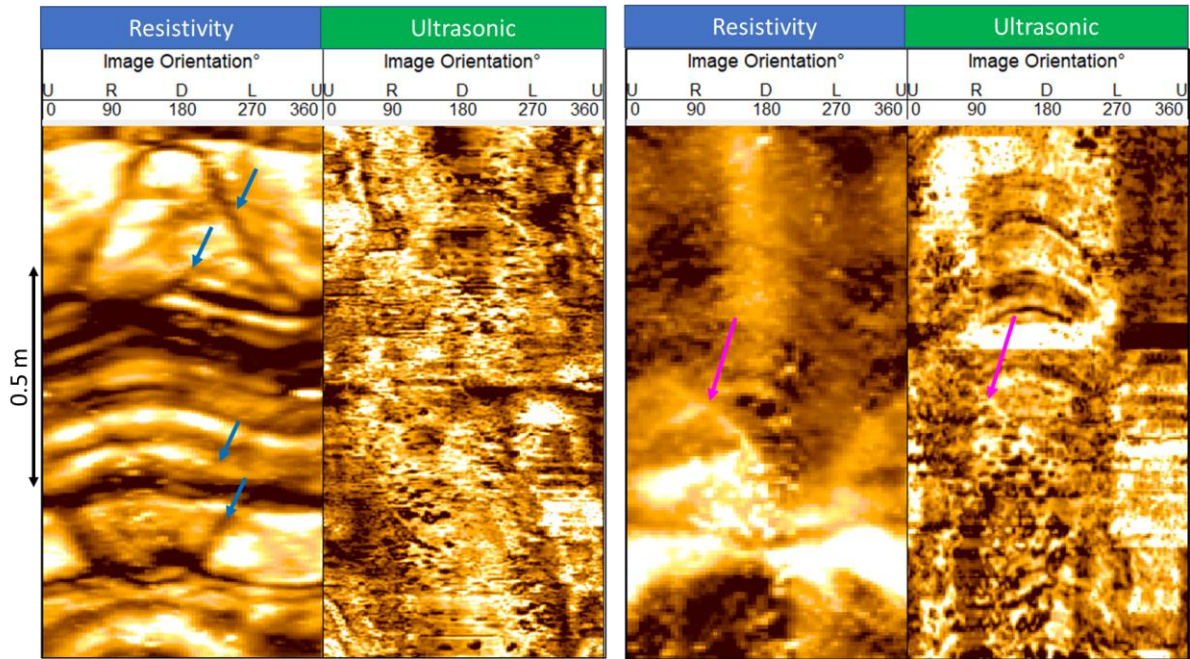


Fig. 2 Fault and fractures feature identification and classification based on dual images.

Structure dip computation and three- dimensional structural modeling

In general, the bedding boundary dips picked in shale formation represent the structural dip. However, there is only a short section in the logged interval with shale lithology at top in this case study and dominant lithology is sandstone interbedded thin the silty sandstone layers (Fig 3). The dips picked from image are mainly dominated by crossbedding and the structure dip could not be computed directly in this case. An innovative method (Yang et al., 2013) was applied to compute the structural dip from crossbedding dips. These crossbedding dips were sharing a similar slope plane during the deposition time. The bedding boundary and crossbedding were merged to compute the local constant dip (LCD) and the local constant axis (LCA). The pole of the bedding boundary and the cross-center point of the great circle of crossbedding should match in theory. The structural dip can be computed based on the center point of LCD and LCA on stereonet (Fig. 3). In the lower stereonet in the Fig. 3, only the LCA dips computed from crossbedding were available, the structural dip was computed from the cross position of the great circle of the LCA.

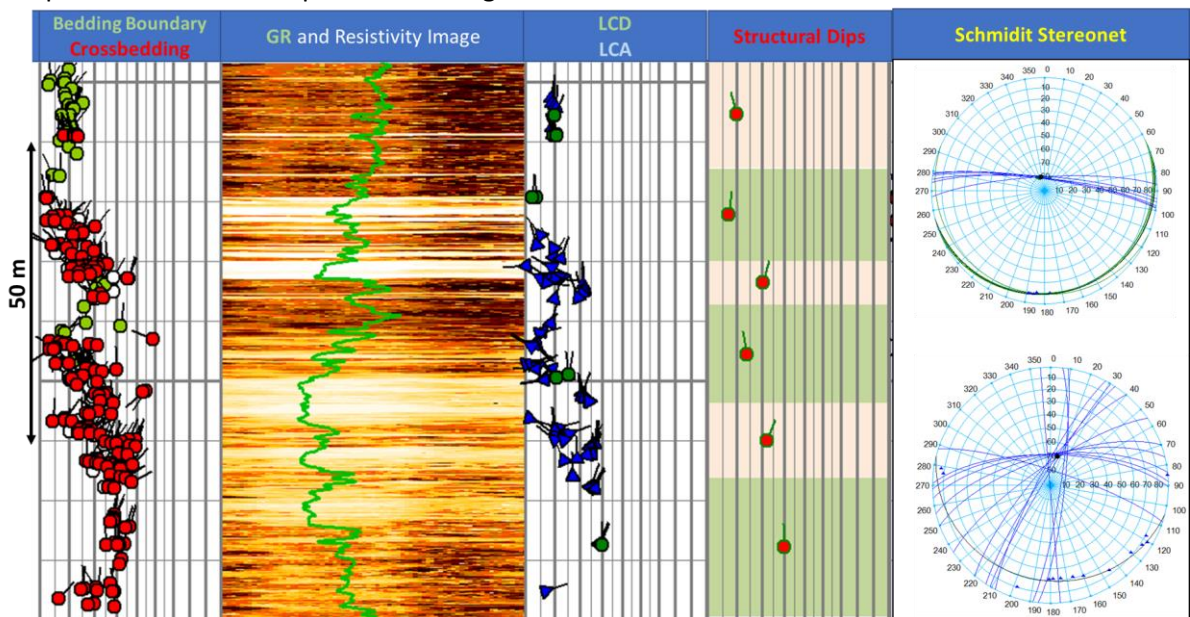


Fig. 3 Structural dips computation from the bedding boundary and crossbedding dips.

The structure dips computed from the bedding boundary and crossbedding were projected into three dimensions by following the structure axis and parallel fold model principle; The isopach maps were estimated from the identified five geological markers. Three minor faults were identified from the image data. The formation displacement features are clearly shown on the images (Fig 2). Due to the small displacement of minor faults, the structure modelling was not influenced significantly; thus, these three faults were not included in the structural modelling. The geological surfaces were built from projected dips as shown in Fig.4a (Yang et al, 2014); the structural model was generated from the surfaces with a well-known reservoir static modelling application software (Fig. 4b).

Based on the near-well modelling result, the structure in the study area was relatively simple. Dominant dip azimuth is northerly; the structural dip angle varied at certain locations and a small-scale anticline was observed locally. The bottommost two surfaces were relatively flat compared to the top surfaces. The pinch-out of bottom formation could be an anomaly caused by the dip projection parameter setting and should be compared with seismic data.

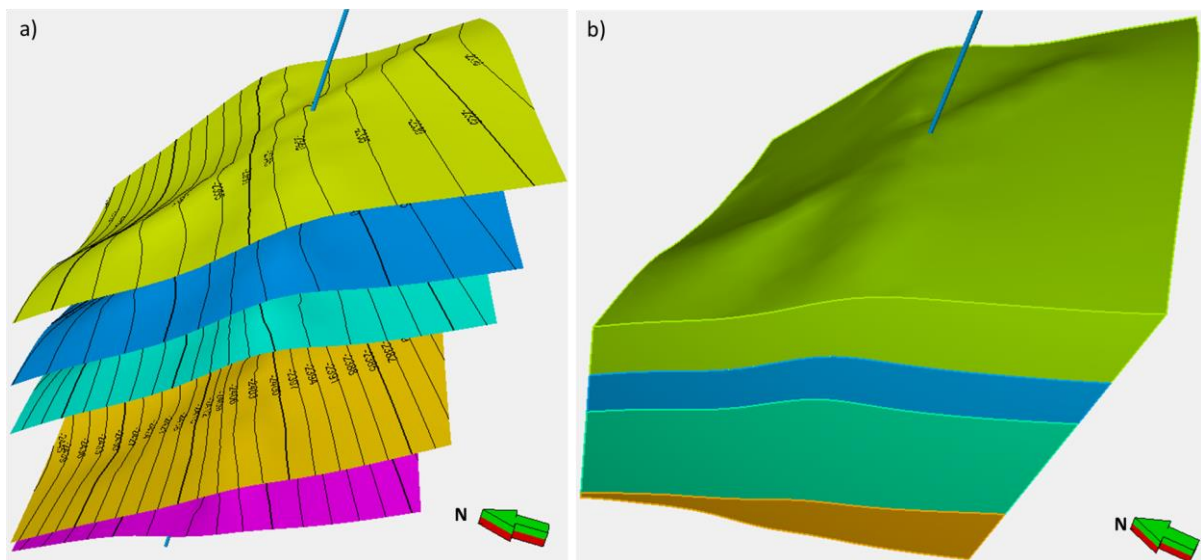


Fig. 4 Three-dimensional structural modelling evaluation results. a) Formation surfaces built from structural dips computed from bedding boundary and crossbedding dips; b) Near-well three-dimensional structural framework.

Sedimentary geometry analysis

Since the structural dip varied from approximately 10° to more than 30°, the crossbedding needed to be processed with structural dip removal. As shown in Fig. 5, the dip azimuths changed dramatically between the original crossbedding and where the structural dip was removed. The crossbedding picked in the sandstone intervals indicated by low gamma ray (GR) and high resistivity on image were influenced by the structural dip showing similar dip azimuth. The structure dip removed (SDR) crossbedding illustrated the paleocurrent direction at the deposition time.

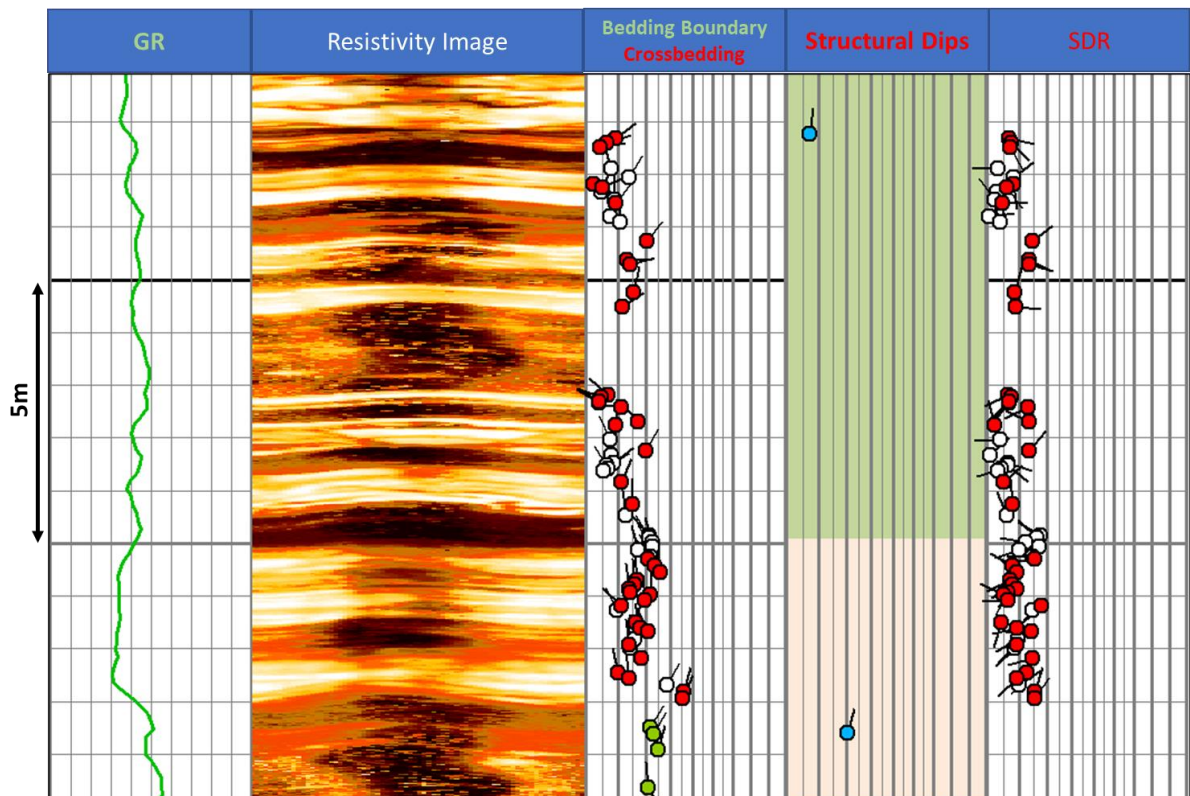


Fig. 5 Cross-bedding comparison between original and structural dip removed dips.

Four basic crossbedding dip patterns were introduced in the sedimentary geometry analysis (Fig 6). Both boundary and internal geometry were integrated for the detailed sedimentary geometry patterns classification. 14 detailed sedimentary geometry patterns were developed and identified from the SDR crossbedding in this case study (Fig. 6). The crossbed (Xbed) Planar is more representative of the standard angular dip pattern; the Xbed Tangential is the same as the classic tangential; but the Xbed trough is more indicative of the concave pattern. The incline ripple was not developed for the study area.

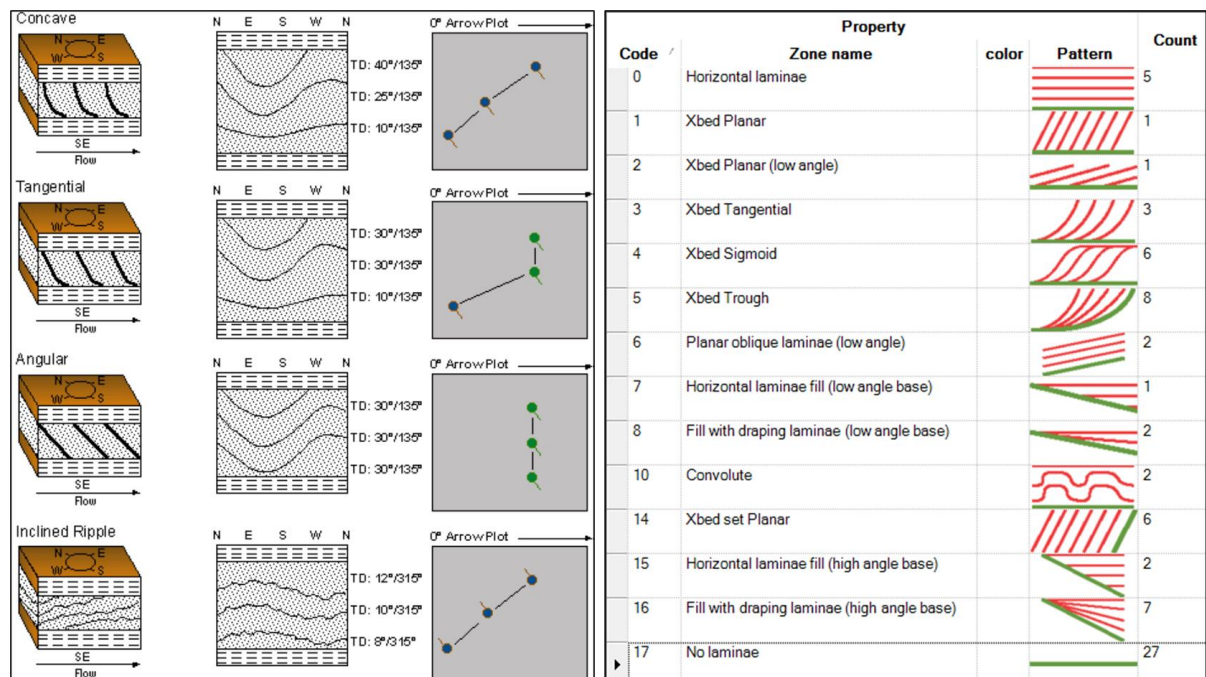


Fig. 6 Dip patterns classification. On the left: common basic dip patterns (Modified from Gilreath, 1985); On the right: pre-defined and classified dip patterns in this case study with statistics in the logging interval.

Based on the statistics, five dip patterns were dominant in the logging intervals: Horizontal laminae, Xbed sigmoid, Xbed trough, Xbed set planar, and filling with draping laminae (high angle base). The Xbed trough and filling with draping laminae dip patterns are very common in the fluvial system, while the Xbed sigmoid and Xbed set planar are more distributed in the delta mouth bar deposition. None of the laminae indicated massive deposition or clear crossbedding developed in the related intervals

The sedimentary geometries were computed automatically from structural dip removed crossbedding dips; in some interval, the geometry was adjusted manually because of lack of dips or inaccurate dips. The sedimentary geometries classification was matching well between image feature and dip patterns (Fig. 7).

Sedimentary structure and microfacies interpretation

The sedimentary structure interpretation can be obtained automatically with the predefined interpretation rules from sedimentary structure geometry, shale content and layer thickness (Yang et al., 2014). 15 sedimentary structures were identified from a total of 39 predefined categories. The statistics suggested that the major sedimentary structures were related to channel filling and mouth bar depositions, with or without steep bank, cross bed or trough cross bed, large sand wave or large sand wave set. The cross bed was classified into two types: one was related to fluvial system; and another was more related to delta mouth bar deposition.

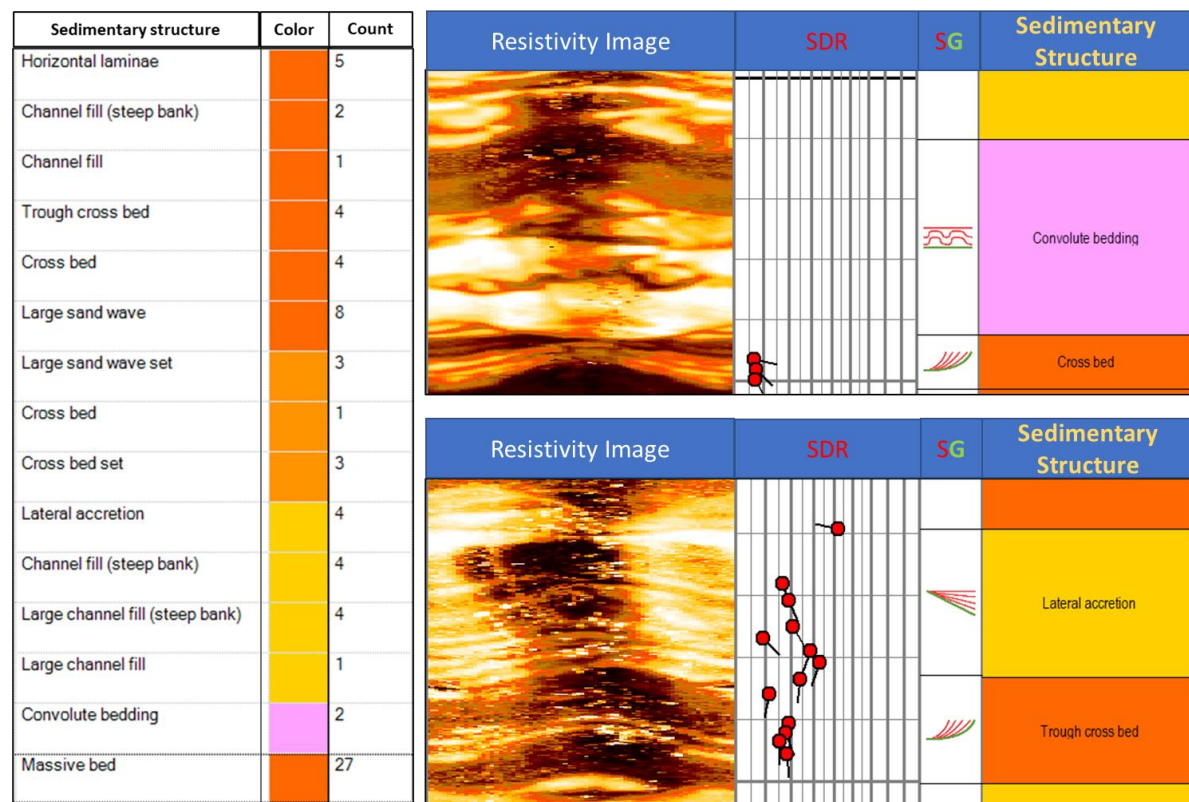


Fig. 7 Sedimentary structure analysis and statistics. The left is identified sedimentary structure and statistics result; the right are sedimentary structure examples with image feature, structural dip removed cross bedding dips and sedimentary geometry.

Based on the sedimentary structure interpretation results, the microfacies were identified by combing the rhythm and texture features of the image. The GR log also provided the rhythm trend on a different scale. In the logging interval, major facies associations developed are: the dominated fluvial system at the top of logging interval; and the mouth bars of delta and interbedded distributary channels towards the bottom of the interval (Fig. 8).

In the top fluvial system logging interval, there are four microfacies associations as shown in Fig. 8. The bottom microfacies association was a channel thalweg deposition. The sedimentary structures were large scale planar cross bed sets, trough cross bed and channel filling. The GR log was showing a box shape with slight up-finining trend. It was the thickest channel sandstone deposition in the top of fluvial system. The bottom secondary association was showing a classic fluvial system deposition pattern with the channel filling at base, a point bar at middle and a levee at top. The cross bed and channel fill were dominated sedimentary structures. The lateral accretion dip pattern was not clear in the point bar interval.

The third microfacies association comprised of a channel fill, a distributary channel and a point bar. The channel fill and distributary channel were corresponding to the different dip patterns. The resistivity image feature was darker with higher GR in the distributary channel comparing with the normal channel fill. The point bar had a lateral accretion dip pattern with a relatively low-dip angle compared with the channel filling.

The fourth microfacies association included an abandoned channel with clay plug and channel fill. The major difference between these two microfacies was the convolute bedding observed on the image (Fig. 8).

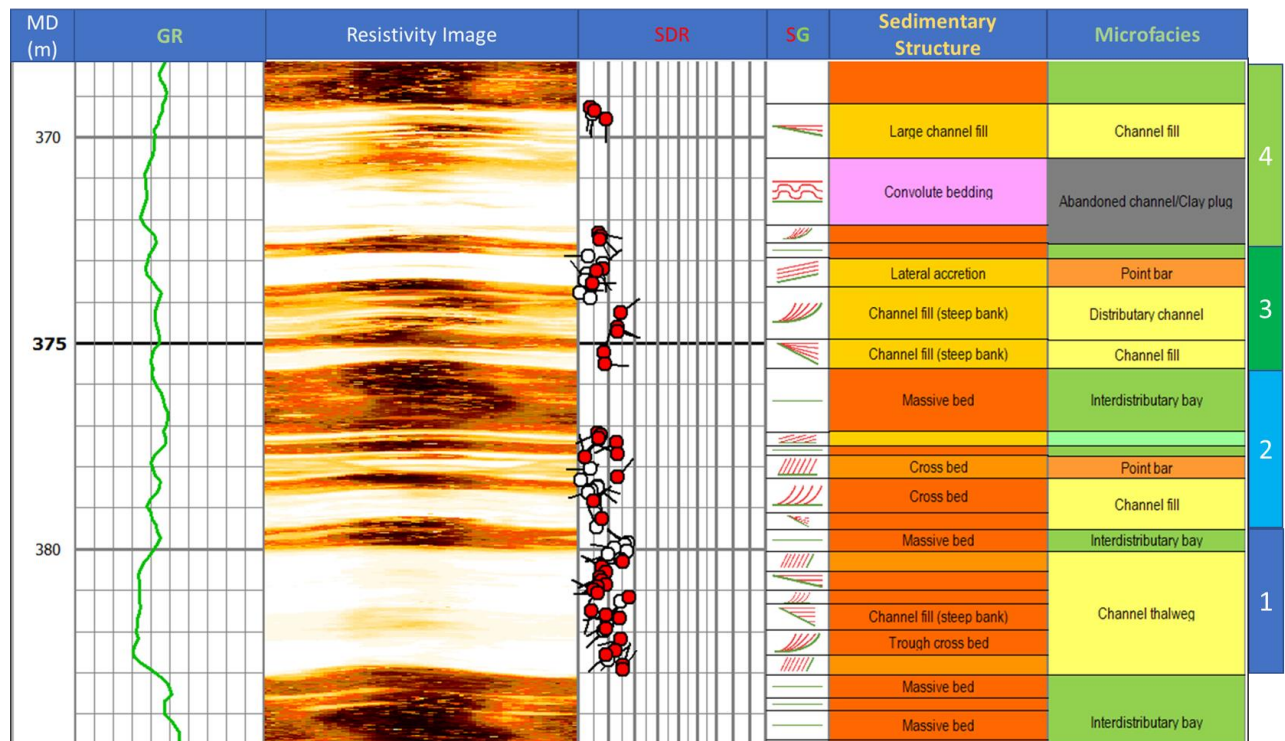


Fig. 8 Micro-facies analysis result in fluvial system logging interval.

The microfacies associations in bottom logging interval were dominated by distributary mouth bars and distributary channels (Fig. 9). The distributary channels developed at top of the distributary mouth bar. The thickness of the distributaries was approximately 10m, slightly thicker compared

with the distributary channel, which is about 2 to 3m. The large sand wave sedimentary structure associated with the Xbed sigmoid and Xbed planar set were to a greater extent developed in the distributary mouth bar; the Xbed trough and filling with draping laminae were more easily observed in the distributary channel deposition.

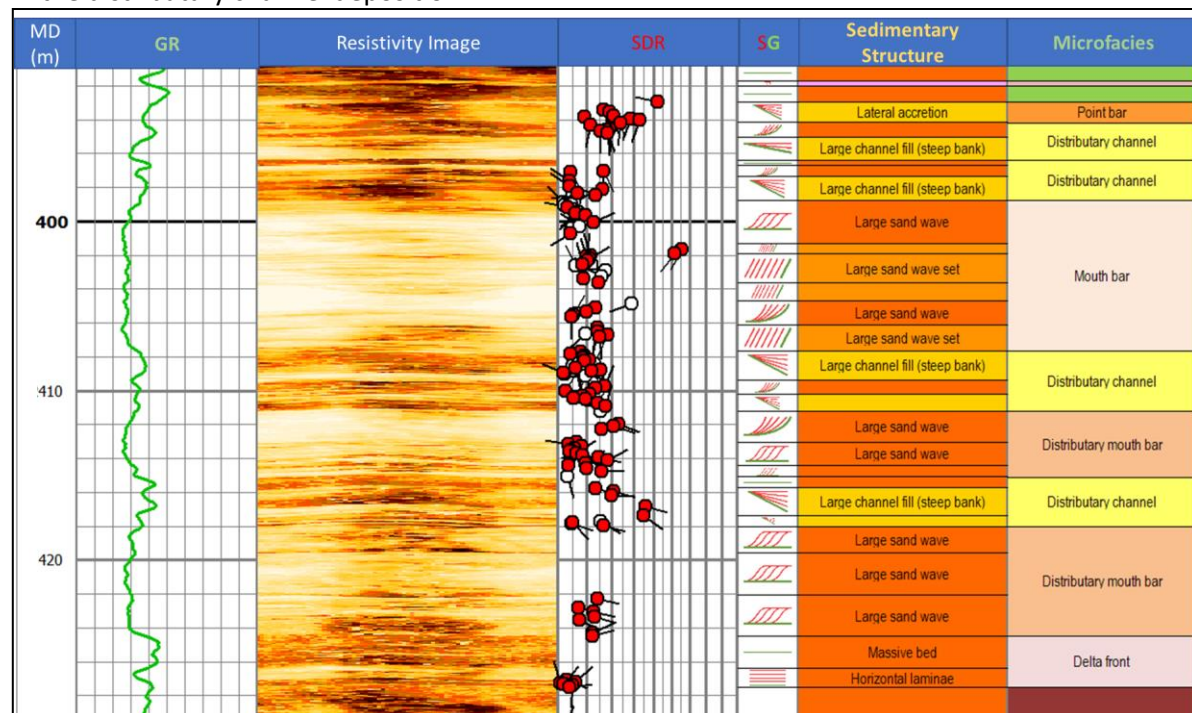


Fig. 9 Micro-facies analysis result in delta depositional environment interval.

The microfacies were gradually changed from the distributary channel and point bar to the interdistributary bay gradually. A thin over bank deposition was observed intermittent with thick interdistributary bay facies. In general, the development of distributary channels was relative thinner than the channel fill in top sessions.

Paleocurrent direction analysis and sand body orientation prediction

Paleocurrent direction can be predicted based on the structural dip removed crossbedding, but the sand body extension trend has different rules in the related microfacies. In the delta environment, the cross bedding at bottom channel filling of the distributary channel was indicating the “cut and fill” and influenced by the scour surface. The dip trend may not be consistent between the paleocurrent and the major sand body extension direction. The cross bedding at bottom channel filling of the distributary channel was more indicative of the paleocurrent direction (Fig. 10).

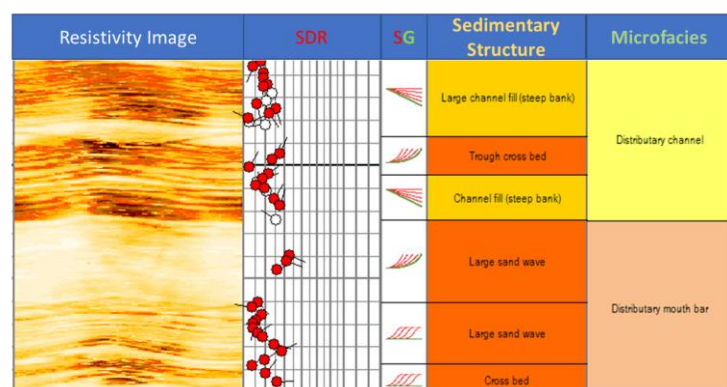
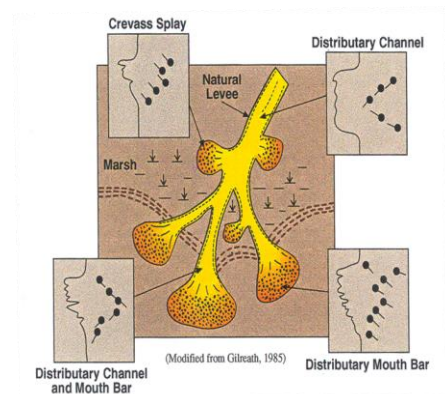


Fig. 10 On left is commonly preserved deltaic features and their associated dip patterns (Modified from Gilreath et al., 1985); On right is micro-facies analysis results in the fluvial system logging interval.

As shown in Fig. 10, the dip patterns were consistent between this case study and commonly preserved in delta environment. In the distributary mouth bar, the dip angle increased, and then reduced again from the bottom to the top; the sand body extension direction was perpendicular to the dip azimuth. In the distributary channel, the dip angle was decreased and then increased from the bottom to the top; the dip azimuth at the top interval was indicating the paleocurrent and sand body extension direction. There are two groups in the distributary channel with opposite dip azimuth. The paleocurrent direction in the bottom section was influenced by the closed micro-fault, and the structural dip removed crossbedding was not precise, but the dip angle trend was consistent. In the top fluvial system, the paleocurrent and sand body extension have similar features with the distributary channel.

Based on the dip patterns analysis in different depositional environments, the sand body extension direction can be predicted along with microfacies analysis (Fig. 11). In bottom three zones, the microfacies patterns were similar to each other: the bottom distributary mouth bar was overlaid by the distributary channel. The sand body orientation was perpendicular to the dip azimuth of distributary mouth bar and parallel to the dip azimuth of the distributary channel as shown with red double arrows in Fig. In the top intervals, the sand body orientations were along with vector plots shown as colour lines in Fig 11. The colour lines were varied into different orientations.

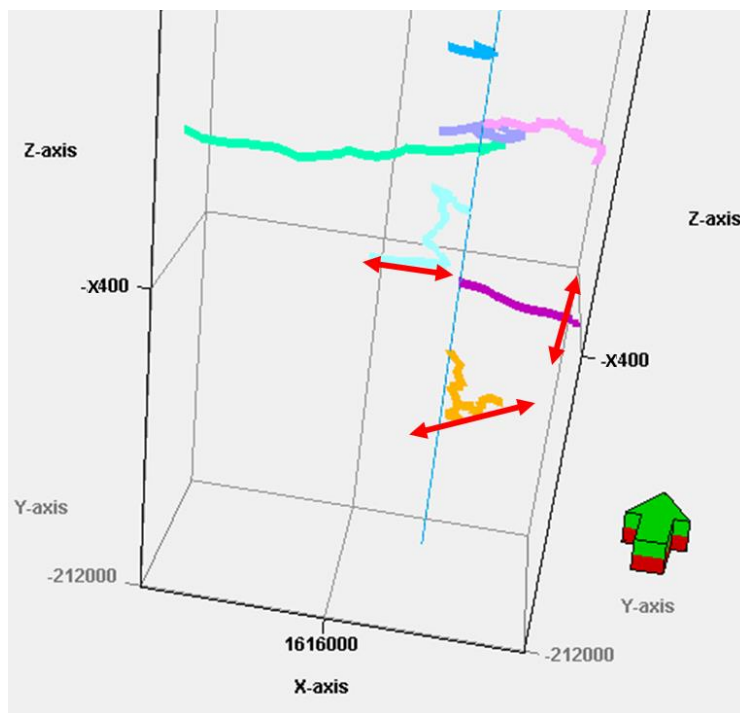


Fig. 11 Paleocurrent analysis and sand body prediction in 3D.

By integrating of the paleocurrent directions in both sessions, the major paleocurrent direction in this study area was determined to be north to south.

Conclusions

New advances in LWD technologies have ensured the acquisition of high-resolution borehole images while drilling that provide high quality data like wireline logging. This has opened avenues for

availability of geological data in all well-profiles per need, and geological modeling can be updated and fine-tuned. In this case study, structural dips were computed by merging bedding boundary and cross bedding dips picked and validated on dual images in non-conductive mud system. The three-dimension surfaces and structural model were built up from computed structural dips after identifying the geology markers. This new structural model provided more accurate information against poor quality seismic data. The sedimentary geometry and structures were classified from structural dip removed from cross bedding; the micro-facies were identified by integrating the dip patterns, image texture features and the GR efficiently. The paleocurrent direction and sand body orientation were interpreted. LWD images stand at the forefront of detailed geological interpretation like never before today.

Acknowledgements

The authors thank their peer at various operating companies and Schlumberger for discussions leading to this work. They also acknowledge the unattributed data release to show image log examples.

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SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Application of Digital Rock Physics to Analysis of the Effects of Diagenesis on Petrophysical Properties

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ABSTRACT BODY:

Abstract Summary: It has been proven that digital rock physics (DRP) is a robust tool to predict rock properties, investigate flow mechanisms in rocks, and figure out the impact factors of petrophysical properties. Nevertheless, the comprehensive analysis of the effects of diagenesis on rock properties using DRP has not been reported. During the formation of sedimentary rocks, they may experience various diagenesis events, e.g., cementation and dissolution, which lead to chemical and physical reactions. Such reactions have a significant effect on rock properties. In this talk, we present a comprehensive investigation of the effects of diagenesis events and diagenesis pathways on rock properties. Firstly, we will propose a robust method to construct the original rock model which integrates the discrete element modeling method, quartet structure generation set algorithm. Then, the original model similarly undergoes four diagenesis events (two cementations and two dissolutions) along with two different diagenesis pathways for generating new models. Finally, some properties of pore space, transport, and elastic of all the models are analyzed and compared to investigate the effects of diagenesis events and pathways, including porosity, fractal dimension, two- and multiple-point correlation functions, pore and throat size distributions, coordination number distribution, tortuosity, absolute permeability, velocity field distributions of single-phase flow simulation, formation factor, and elastic moduli. The comparisons indicate that the sample that experiences the cementation and then dissolution exhibits larger porosity, fractal dimension, aperture, coordination number, and permeability, and smaller tortuosity, formation factor, and elastic moduli than the one which undergoes the dissolution and then cementation. Thus, understanding the sequence and magnitude of the diagenesis process can help us to better predict the flow and mechanical properties of rocks without conducting extensive experiments and computations.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Understanding the Hydrocarbon Generation Potentials of Cretaceous Source Rocks on the Eastern Benin (Dahomey) Basin, Southwestern Nigeria: A Two-Dimensional Basin Modeling Approach

AUTHORS (FIRST NAME, LAST NAME): Olugbenga Ehinola², Oladotun Afolabi Oluwajana¹, Abraham Opatola³, Olajide Adamolekun⁴, Otobong Ndukwe⁵, Gabriel Olawuyi⁶, Collins Ofiwe⁷, Taiwo Bolaji¹⁰, Bamidele Adebambo⁸, Lawal Olutayo University of Ibadan⁹

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4. Institute of Applied Geosciences - Karlsruhe Institute of Technology
5. Federal University Oye-Ekiti, Nigeria
6. Leon H. Charney School of Marine Sciences - University of Haifa - Israel
7. National Agency for Science and Engineering Infrastructure - Centre of Excellence in Nanotechnology and Advanced Materials - Nigeria
8. Obafemi Awolowo University - Nigeria
9. University of Ibadan, Nigeria
10. Federal University Oye-Ekiti - Nigeria

ABSTRACT BODY:

Abstract Summary: The Cretaceous sediments of eastern Dahomey (Benin) Basin are host to one of the largest bitumen deposits in the world. Understanding the hydrocarbon generative potentials of Cretaceous source rocks is key to future exploration success in the basin. This study integrates data from LECO TOC/ Rock Eval-2 pyrolysis of Cretaceous shale samples from four (4) shallow exploration boreholes (< 60 m), and two-dimensional (2-D) basin models constructed based on data from five (5) exploration wells (< 3,000 m) that penetrated sedimentary successions and Basement Complex rocks, were used to determine the maturity, timing, and distribution of hydrocarbon generation in eastern Dahomey (Benin) Basin. The reliability of the 2-D models was tested by comparing the generated models with hydrocarbon shows in each of the exploration wells and also with surface hydrocarbon occurrence on an exposed outcrop section. The analyzed shale samples from shallow intervals (< 60 m) have TOC content in the range of 0.24 and 2.50 wt. %, and can be considered as poor to excellent source rocks. The cross plots of HI vs. OI and S2 vs. TOC indicate that the analyzed shale samples at shallow depths contain type III and type IV kerogen with the potential to generate gas and/or condensate. However, the Rock-Eval pyrolysis Tmax and PI show that the shale samples are immature at the present shallow depths. The results of 2-D basin modeling indicate that Maastrichtian source rocks underwent two phases of hydrocarbon generation with the first early generation phase occurring during Eocene and a second, intense generation during Miocene. Liquid hydrocarbon generated and expelled from the deeply buried Maastrichtian shale must have migrated upwards along the sediment-basement interface and unconformity-bound surfaces. The simulated 2-D models presented conditions favourable for oil and gas accumulations in the basal conglomeratic sandstone. The occurrence of heavy oil in outcrop sections and boreholes, light oil in all the wells reflects the viability of the Cretaceous play in the eastern part of the Dahomey (Benin) Basin. Exploration success in the eastern Dahomey (Benin) Basin hinges on the identification of deeply buried Cretaceous source rocks that has sufficient burial depths.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Counterclockwise Migration of River Flow Direction Triggered by Localized Rotation of Fault Block- A Case Study from the Kendong Uplift in Bohai Bay Basin, China

AUTHORS (FIRST NAME, LAST NAME): Yu Wang¹, Youlu Jiang², Simin Gong³

INSTITUTIONS (ALL):

1. China University of Petroleum (East China)
2. China University of Petroleum (East China)
3. China University of Petroleum (East China)

ABSTRACT BODY:

Abstract Summary: Objectives

For post-rift basins, fluvial sandstones are often the main reservoirs in fault blocks, nevertheless, identifying the distribution of rivers in fault blocks remains a challenge. Taking the Kendong Uplift in the Bohai Bay Basin as an example, based on the restoration of the river channel distribution from the Pliocene to the Holocene, combined with the analysis of paleo-topography and fault block tectonic evolution law, we clarified the reason for the counterclockwise migration of the river flow direction.

Procedures

Firstly, based on seismic attributes and coherence cube, we identified the distribution laws of faults and river channels in different time slices. When the fault throw is relatively large, a complete channel will be divided into different parts and appear in different time slices, otherwise, the channel can be fully displayed in a single time slice. We manually combine the divided parts of the channel in different time slices to restore the original appearance of the channel during the deposition period. Based on the position of the river channel in the hanging wall and footwall, we can identify the relative upstream and downstream of the river, and clarify the river flow direction. We restored the river flow direction in about 900 individual time slices from the Pliocene to the Holocene. Then, paleo-topography from Pliocene to Holocene was restored and fault block tectonic evolution law was established. Finally, the relationship between river flow direction, paleo-topography, and fault block rotation was clarified, which provides an excellent reference case for the study of the source-sink system.

Results

- (1) The river flow direction has an obvious counterclockwise migration trend from the Pliocene to the Holocene in the Kendong Uplift.
- (2) The river flow direction is relatively consistent with the paleo-topography of the area, indicating that the topography is one controlling factor of river flow direction.
- (3) The change in paleo-topography is attributed to the localized rotation of fault block during late Pliocene to early Pleistocene. Therefore, we believe that the localized rotation of fault block is the main reason for the counterclockwise migration of river flow direction, as the localized rotation of fault block has changed the initial topography of the subsequent filling formations.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Organic Geochemistry and Depositional Environment of the Source Rocks in the Qikou Sag, Bohai Bay Basin, China

AUTHORS (FIRST NAME, LAST NAME): Xiangbai Liu¹, Guangdi Liu², Zezhang Song³

INSTITUTIONS (ALL):

1. China University of Petroleum (Beijing)
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ABSTRACT BODY:

Abstract Summary: The Bohai Bay Basin is a crucial petroliferous basin in eastern China. It accounts for 20% of China's petroleum resources and 40% of China's proven reserves. Its annual crude oil production exceeds 70 million tons. Qikou sag is one of the most petroliferous areas and has been discovered significant proven oil reserves and undiscovered resources, which is a highly-explored area of petroleum exploration in Bohai Bay Basin, China. The most essential oil-producing formations of this sag is the Shahejie formation (Es) and Dongying formation (Ed). The organic matter abundance of source rocks is evaluated by TOC commonly, and the fundamental to hydrocarbon generation in source rocks is the OM. The values of TOC indicates that source rocks in the Es formation are better than that in the Ed formation. Besides, rock pyrolysis parameters are used in evaluating the quality of source rocks. According to the organic matter type classification diagram of HI-Tmax, the organic matter type of source rocks in Es formation are type II1 and type II2 kerogen. While in Ed formation, kerogen composition ranges from type I to type III. The GC and GC-MS analyses were carried out on extracts from source rocks. Low Pr/Ph ratios indicate that source rocks in Qikou sag deposited in a suboxic and weak reducing environments. C29 dominates over C27 and C28 steranes in Es and Ed formations. Tmax values of source rocks reflect early mature-mature character. The low to high 22S/(22R + 22S) homohopane, 20S/(20R + 20S), and $\beta\beta/(\alpha\alpha + \beta\beta)$ sterane ratios and moretane/hopane ratios, indicate early mature-mature character for the samples. Gammacerane is used as an indicator of a salinity-stratified water column. Low Pr/Ph ratios often coexist with high gammacerane index values in the source rock extracts deposited under anoxic saline environments. This is the situation in our study, as suggested by the gammacerane index in Es formation higher than that in Ed formation, while Pr/Ph ratios in Es formation lower than that in Ed formation. In addition, in terms of the trend of the gammacerane index, the paleosalinity of the water body first increased and then decreased. The abundant organic richness, humic kerogen, and medium thermal maturity demonstrate that these rocks are effective oil and gas source rocks. The source rocks in the Es and Ed formations collectively constitute a petroleum generation system and represent the main exploration target for oil and gas discovery for the Qikou Sag.

SESSION TITLE: Theme 1: Geochemistry

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Origin and Evolution of Overpressure in Jurassic in the Hinterland of the Junggar Basin, NW China

AUTHORS (FIRST NAME, LAST NAME): Zaihua Han¹, Hua Liu², Hongrui Zhang³

INSTITUTIONS (ALL):

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ABSTRACT BODY:

Abstract Summary: Overpressure is widely developed in petroliferous basins, which is closely related to the generation, migration, accumulation and preservation of hydrocarbon. The Junggar Basin is rich in oil and gas resources. The overpressure could be found generally in the oil and gas bearing strata of Jurassic in the Hinterland of the Junggar Basin.

Four empirical methods including logging curves combination method, Bowers method, velocity-density crossplotting method, porosity comparison method were applied to identify the origin of overpressure and a comprehensive analysis based on geological conditions of different genetic mechanism was carried out. Then, fluid inclusion microthermometric, PVTx and basin modeling techniques were applied to study the overpressure evolution process of Jurassic strata. The results of empirical methods and comprehensive geological analysis are consistent. The overpressure intensity in the source rocks is closely related to the maturity and hydrocarbon generation intensity of the source rocks and the origin of overpressure is hydrocarbon generation.

Overpressure in non-source rock strata are mainly caused by pressure transfer. The pressurization process of Jurassic reservoirs is consistent with the reservoirs forming time. There are three different overpressure evolution models: (1) Pressurization-decompression model: Hydrocarbon was supplied by Permian source rocks and hydrocarbon accumulation caused pressurization(145~77Ma). Then, tectonic adjustment and continuous pressure relief occurred in the reservoirs(77Ma~present). (2) Pressurization-decompression- Pressurization model: Hydrocarbon was supplied by Permian source rocks, and the first stage of hydrocarbon accumulation caused pressurization(135~80Ma). Then, small tectonic uplift and pressure relief occurred in the reservoirs(80~40Ma). After that, Jurassic source rocks generated and discharged hydrocarbon and the second stage of hydrocarbon accumulation caused pressurization in the reservoirs(40Ma~present). (3) Pressurization-strong Pressurization model: Hydrocarbon was supplied by Permian and Jurassic source rocks successively and there is no tectonic uplift and obvious pressure relief in the reservoirs. The pressurization caused by the second stage of hydrocarbon accumulation(135~80Ma) is significantly stronger than that caused by the first stage(35Ma~present). In this study, a series of mature methods were established to study the origins and evolution of overpressure in basins.

SESSION TITLE: Theme 1: Petroleum Systems

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Risk Analysis of Petroleum System Elements- Case Study: Cuenca Argentina Norte 2D Petroleum System Modelling, Offshore Argentina.

AUTHORS (FIRST NAME, LAST NAME): Maria Eugenia Pascariello¹, Ignacio Brisson¹, Ofelia Silio², Juan Pablo Lovecchio¹, Sebastian Arismendi³

INSTITUTIONS (ALL):

1. YPF S.A.
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ABSTRACT BODY:

Abstract Summary: Petroleum systems modeling is a discipline that has become a critical tool for hydrocarbon exploration and is used by oil companies to predict on a regional scale the potential generation and accumulation of hydrocarbons in an area of interest. The choice of making a model in one dimension (1D), in two (2D) or in three (3D) is conditioned by the availability of existing data and the objectives of the project.

Both the slope and basin floor of the Argentine Atlantic margin are highly underexplored. The study area includes the northern sector of the Argentine slope, in the so-called Cuenca Argentina Norte, located about 300 km offshore from the town of Mar del Plata. The results of recent seismic campaigns, in addition to the data obtained from wells on the African conjugate margin, have encouraged the exploration of the region.

With the purpose to evaluate the critical processes that led to the generation and expulsion of hydrocarbons in this area a two-dimensional petroleum system model was built. The absence of well data generates great uncertainty regarding the physical and geochemical properties of the different elements of the system. In order to estimate the associated risk, and after considering the more suitable analogues, a sensitivity analysis on the basics elements of the petroleum system was performed.

A regional W-E 2D seismic section, where the main sedimentary and morphostructural features were interpreted, was used for the construction of the physical model. The assumptions that were used to constrain the model properties and boundary conditions are also presented. The properties and processes related to the generation and expulsion of hydrocarbons within this context were analyzed, and the critical factors and processes of the system were defined. The sensitivity analysis presented in this work highlight those key factors to focus the analysis in order to limit the degree of uncertainty and consequent impact on the results.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The Influence of Silica on Pre-Salt Carbonate Reservoirs from the Mero Field (Santos Basin, Brazil): a Petrographic and Well-log Approach

AUTHORS (FIRST NAME, LAST NAME): Carolina Ribeiro¹, Julia Favoreto¹, Gustavo Pires¹, Fernando Neves¹, Gilberto Raitz¹, Michele Arena¹, Héllisson Santos¹, Pedro Coelho¹, Leonardo Borghi¹

INSTITUTIONS (ALL):

1. Federal University of Rio de Janeiro

ABSTRACT BODY:

Abstract Summary: The success of the Pre-salt carbonate reservoirs of Brazil is attributed to the high-quality reservoirs composed of coquina lithofacies of the Itapema Formation (ITA), Rift Sequence, and the 'Post-rift Sequence' of the Barra Velha Formation (BVE) formed from in-situ carbonate lithofacies (e.g., spherulestones and shrubstones) and reworked lithofacies (calclutites, calcarenites and calcirudites). In the Mero Field, both formations display moderate-to-high porosity-permeability character. In addition to the lithofacies complexity and the high-degree of porosity-permeability heterogeneity, the effect of diagenesis (especially silicification) on the reservoir properties is not yet fully understood. The objective of this study is to characterize the occurrence and distribution of silicified zones in a well from the Mero Field using whole core, core plugs, sidewall core plugs and over 120 petrographic thin-sections and integrating these results with the petrophysical analysis of well-logs and seismic data. Petrophysical analysis using wireline logs (including BHI, NMR and ECS) together with XRF data, focused on characterizing porosity distribution in relation to the silicification. The silicified zones observed in the studied well are mainly concentrated in the bioclastic calcarenite and calcirudite lithofacies (coquinas) of the upper ITA and the calclutites and calcarenites which occur in basal part of the lower BVE. Well-logs responding to a silica zone in the bioclastic ITA, show a high-porosity 10m thick interval, where the silica partially or completely fills original moldic porosity, but not the interparticle (mainly remaining) porosity. In the BVE, quartz, chalcedony and chert occur in centimetric tabular bands associated with spherulestones and spherulitic calcarenites also in a 10m thick interval. Unlike in the ITA the silicified zone of the lower BVE displays low porosity; the lateral continuity of the silica bands may strongly affect vertical permeability and form baffles/barriers. In addition, dolomite fills residual pores in calcarenites after silicification. The presence of these silicified zones has a clear effect on the reservoir elastic properties. Low silica content yields a significant reduction in the bulk density and P-wave sonic velocity in logs that is being investigated in the 3D seismic volume, assisted by a neural network acoustic impedance inversion.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Late Mesozoic eolian dunes and reconstruction of paleo-wind belts in Central Asia

AUTHORS (FIRST NAME, LAST NAME): Xutong Guan¹, Chaodong Wu² I

INSTITUTIONS (ALL):

1. Peking University
2. Peking University

ABSTRACT BODY:

Abstract Summary: Eolian deposits not only recorded paleoclimate, paleoecology, and paleoenvironments but also are a basis for the reconstruction of the paleocontinent and paleogeography. Aridification happened in Central and East Asia in the Late Mesozoic and led to drastic environmental change, including widespread eolian deposits. However, the eolian deposits in the Junggar Basin in the late Mesozoic were contentious. We firstly report on the eolian deposits in the late Middle Jurassic in the Jurassic Basin which are the oldest reported inland eolian deposits in Asia. We systematically investigated the eolian deposits in the late Middle Jurassic and Early Cretaceous and driving mechanisms in the Southern Junggar Basin in northwestern China, Central Asia. Firstly, A 3D model using an unmanned aerial vehicle was built to characterize the eolian architecture. The plane view of the 3D model allows identifying interdune migration surfaces, superimposition surfaces, and reactivation surfaces easily. Secondly, we reconstructed the sedimentary evolution in the Late Mesozoic. The paludal environment changed to a fluvial environment with local eolian dunes from the late Middle Jurassic to Late Jurassic and erg environments with widespread eolian dunes in the earliest Cretaceous, which evolved into a lacustrine environment. The eolian dunes are characterized by well-sorted, round-grained, sandstones with little suspension load, thick, large-scale, and high-dip trough cross-bedding, inversely-graded lamination, dominant saltation grains, and typical eolian grain surface textures, including crescent-shaped, and dish-shaped impact scars. Thirdly, 53 heavy mineral data and 76 effective grains of detrital zircon ages were attained to analyze the provenance of the eolian deposits. Stable heavy minerals increased dramatically, such as ilmenites, zircons, garnet, and tourmalines. Syn depositional volcanic materials provided a large amount of sediments because Jurassic detrital zircons constitute 35.5% of the zircons. The detrital zircon age distribution was compared with the crystallization age in the potential provenances and collected detrital zircons, we assumed that the aeolian deposits were mainly fed by the North Tianshan Orogenic Belt and proposed a source-to-sink evolution model in the Mesozoic in the southern Junggar Basin. Lastly, the data of 70 dip-azimuths from large eolian cross-bedding foresets of in 3 sections demonstrates that eolian dunes in the Toutunhe Formation is the product of the easterly belt in the late Middle Jurassic, whereas the eolian dunes in the Kalazha Formation are a response to the westerly belt in the Early Cretaceous. We classify the paleowind belts in Central and East China combined with the paleocurrent data from other basins. The study demonstrates that the change of prevailing surface-paleowinds was the sedimentary response to the atmospheric circulation transition, caused by the true wander polar and the migration of the subtropical high belt. The true polar wander displaced the Junggar Basin from high latitude to middle latitude and the subtropical high belt was compressed from 40°N to 30°N.

Keywords: erg environment, paleo-wind belt, Central Asia; unmanned aerial vehicle; source-to-sink system

SESSION TITLE: Theme 1: Stratigraphy

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Tectonic Impact on the Topset Architecture Across a Segment of the Paleo-Orinoco Shelf, Trinidad

AUTHORS (FIRST NAME, LAST NAME): Ariana Osman¹, Ron Steel², Ryan Ramsook³

INSTITUTIONS (ALL):

1. The University of the West Indies
2. The University of Texas at Austin
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ABSTRACT BODY:

Abstract Summary: The first entrant of Orinoco sands into the Columbus Basin, Trinidad, was deposited by the 3rd order Pliocene Forest/ Moruga/ Mayaro clastic wedge. This clastic wedge is strongly segmented by both syn-depositional growth faults, and syn- and post- transpressional events associated with the eastward migration of the Caribbean plate, making it challenging to correlate strata across the basins.

130 wells and outcrop exposures across the Southern and Columbus basins were integrated to reconstruct a sub-regional dip correlation, defining 11, 4th order, clinoform topsets (F10 - F110) across the shelf margin and some of their earliest clinoforms (F10 - F20). The oldest sub-wedge (Forest-Gros Morne sands, (F10 – F40) shows the development of at least four topset clinoforms and records some of the fastest progradation rates for the Trinidad Orinoco wedges (up to 25 m/ ky), extending the shelf margin ~40 km eastwards in the early Pliocene. This sub-wedge is dominated on the outer-shelf by coarsening upward successions of well-developed mouth bar sands and hyperpycnal flows, indicating the overall fluvial dominance of the delta. This characteristic may have been controlled by the southward growing thrust on the margin, which created an embayment and hindered reworking by waves. The focused sedimentation of the fluvial deltas on the outer-shelf initiated growth faults resulting in impressive over-thickening of these topsets across the margin, from 600 to 1500 ft on the inner- to mid-shelf, and > 7,500 ft towards the shelf edge. The subsequent topsets (F50-F110) show a mixed fluvial-wave influence and the development of double clinoforms on the mid-shelf. However, as the delta lobes prograded across active growth faults on the shelf margin, the increased accommodation not only resulted in a reduction of their forward growth but also led to a longer period of wave reworking on the delta.

SESSION TITLE: Theme 1: Petroleum Systems

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The Pannonian Back-Arc Basin Complex: an Overview

AUTHORS (FIRST NAME, LAST NAME): Gabor Tari¹

INSTITUTIONS (ALL):

1. Omv Upstream

ABSTRACT BODY:

Abstract Summary: The Pannonian Basin has been described as the type example of a Mediterranean back-arc basin where extension did not advance to the opening of an oceanic basin. In some of the sub-basins of this large basin complex the style of Neogene extensional deformation almost reached the stage of hyper-extension but it stopped short of exhuming lower crustal or mantle units at the basin floor. Continental extension terminated due to the space constraints provided by the docking of the surrounding Carpathian thrust-fold belt onto various divergent and transform margin segments of the European plate.

Similarly to some other back-arc basins of the Alpine orogenic belt, the extension was triggered by an episode of continental escape. A part of the Alpine orogen was extruded towards the east during the Early Miocene and occupied the Jurassic oceanic Magura embayment of the European margin. Due to the removal from the Alpine collision zone the overthickened lithosphere collapsed during the Middle Miocene. The various modes of syn-rift extension, such as the metamorphic core complex, wide rift and narrow rift deformational styles are well constrained by exceptional large subsurface data sets acquired by the petroleum industry in the region for more than a century.

The Late Miocene to Pliocene post-rift thermal subsidence saw the sedimentation of an unusually thick basin fill locally exceeding 8 km thickness compared to the typically much thinner syn-rift sequence not more than 2 km thick. This particular character of the Pannonian Basin can be understood in the source-to-sink evolution of the broader provenance area of the Carpathian-Pannonian system during the Neogene.

Basin-scale inversion commenced during the Pliocene by eastward propagation of shortening across the Pannonian Basin due to the ongoing northward movement of the Adriatic promontory to SW. Locally, positive inversion occurred by the selective reactivation of pre-existing Alpine contractional elements. Since the neotectonic deformation of the Pannonian basin system is still in its infancy, it provides a very well-constrained template for other back-arc basins where this process may be much more advanced. The vast amount of reflection seismic and drill hole data sets in the Pannonian Basin, acquired during hydrocarbon exploration efforts for more than a century, qualify it as one of the best studied back-arc basins in the world.

SESSION TITLE: Theme 1: Stratigraphy

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Estimation of recoverable oil related to the concentration of the porous medium in naturally fractured carbonate reservoirs in a case study

AUTHORS (FIRST NAME, LAST NAME): Francisco López-Rabatté¹, Jaime Ríos-López², Joel Hernández³, Gabriel Hernández⁴, Zaira Vera⁵

INSTITUTIONS (ALL):

1. Pemex
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ABSTRACT BODY:

Abstract Summary: Abstract

The research was carried out to estimate the free oil, obtaining an approximation of the recoverable oil and the determination of the additional recovery factor.

This methodology can estimate the residual oil saturation, through the partitioning of the porous medium classified into three types (interparticle, vugs and fractures), it's made from the elastic parameters, obtaining velocity-porosity models which in turn they are related to sedimentary facies features. The estimation of free oil is very useful in the valuation of reserves, making the geological and petrophysical considerations typical of a static characterization of the reservoir and the dynamic considerations of the reservoir influenced by the extraction conditions of the hydrocarbons.

The recovery of hydrocarbons from a triple porosity carbonate reservoir, such as the present case study in the Cantarell field, it is generally estimated using factors that depend on the degree of knowledge of the reservoir; previously approximations are obtained by correlation with analogous fields, as the reservoir is exploited, this recovery factor is required with the support of the extraction-operation conditions and the collection of information that is acquired through the development wells and injection wells. according to the case.

In reservoirs of this nature, volume data, reserves and recovery factors are updated, as information is added, knowledge increases, technologies are incorporated and, eventually, commercial circumstances influence.

The determination of the additional recovery factor was 4.6%, it is a significant aspect, in this case study the petrophysical aspect is addressed considering investigations applied by other authors Salazar, (1993), Fernando Samaniego, (2015) and specific studies of wells in naturally fractured reservoirs of the Campeche Sound (México), where estimates an increase-profit range of recoverable oil.

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: From reference case modelling to multi-realisation modelling: Fast Model Update (FMU)

AUTHORS (FIRST NAME, LAST NAME): Gabriel Matos¹, Daniel Vasconcelos², Ian Troth³, Karime Glitz⁴, Eliany Teran⁵, Kaluan Juk⁶

INSTITUTIONS (ALL):

1. Equinor Brazil
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5. Equinor
6. Equinor

ABSTRACT BODY:

Abstract Summary: Huge volumes of subsurface data are generated from the discovery through to production phases of oil/gas fields. These data can include seismic acquisition, well log measurements and well test data. At production start-up, several wells may be brought online in rapid succession. This stream of incoming data imposes a challenge to reservoir modelling, i.e. how to incorporate the new information in an agile and efficient way so it can be used to underpin future decisions? In field developments with large CAPEX and a complex subsurface, integrating new data in a timely and efficient manner can impact upcoming well location, well design, completion solutions and scheduling decisions.

Fast Model Update (FMU™) is an internally-developed reservoir modeling automation process and it is applied in projects across Equinor's global portfolio, enabling a fast incorporation of static and dynamic data, from reservoir modeling to simulation, and uncertainty management, leading to new insights into the reservoir development strategy. FMU facilitates multi-realisation modelling through the ability to integrate depth conversion, geological and dynamic parameters in the same workflow manager, spanning the full range of uncertainty. The result is tailored models on demand that allow robust field development decisions to be made in a more iterative and agile way.

The main steps of the FMU workflow are summarized below:

Provide interpretation of the main reservoir horizons and structural uncertainties.

Provide interpretation of the different possible geological environments and distribution of properties based on the well data.

Generation of an ensemble of geological models.

Identification of the most important dynamic parameters as well as non-subsurface factors (schedule, operational variables) and associated uncertainties.

Combination of geological models and dynamic parameters in different scenarios by Monte Carlo simulation. Selection of models that match the available historical dynamic data (well tests and production data)

Generation of production profiles to support future decisions

SESSION TITLE: Theme 1: Reservoir Studies

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

EXTENDED ABSTRACT: Reservoir Characterization and Production Controlling Factor Analysis by Advanced Logging While Drilling Data for Challenging High Temperature Offshore Condensate Gas Fields

Yunjiang Cui¹, Xinwu Liao¹, Peichun Wang¹, Yue Wang¹, Fangfang Wu², Shenzhuan Li², Xin Zhou², Liang Cai²; 1. CNOOC Tianjin Branch, 2. Schlumberger China

Summary

BZ condensate gas field is a big discovery in offshore Bohai Bay Basin, and more than one hundred billion cubic meters of condensate gas has been discovered mainly in its Archaeozoic metamorphic reservoirs. However, reservoir characterization is a great challenge due to its harsh operation environment and strong formation heterogeneity. To better reveal the reservoir quality and the production controlling factors, advanced logging while drilling (LWD) technologies integrated with comprehensive answer products are deployed to tackle the problems.

Introduction

BZ block is located at Bozhong depression in Bohai Bay Basin. The lithology mainly includes granite gneiss and some intrusive rocks such as diorite porphyrite and diabase. Because of multi-period tectonic movements and long-term weathering process, a large number of faults, fractures and vugs are developed in its Archaeozoic metamorphic rocks (Xu Changgui et al., 2020), which, in return brings extra complexity to formation evaluation.

The first challenge is the strong reservoir space heterogeneity introduced by fractures and vugs. Natural fractures developed with different types, different length and different aperture act as pathways to fluid communication, whereas drilling induced fractures which are formed in drilling process make no contribution; Vugs of different size and shapes are also developed in the reservoir (Fig.1), which serves as main storage space for hydrocarbon accumulation. In general, their heterogeneous distribution brought a lot of difficulties to reservoir characterization.

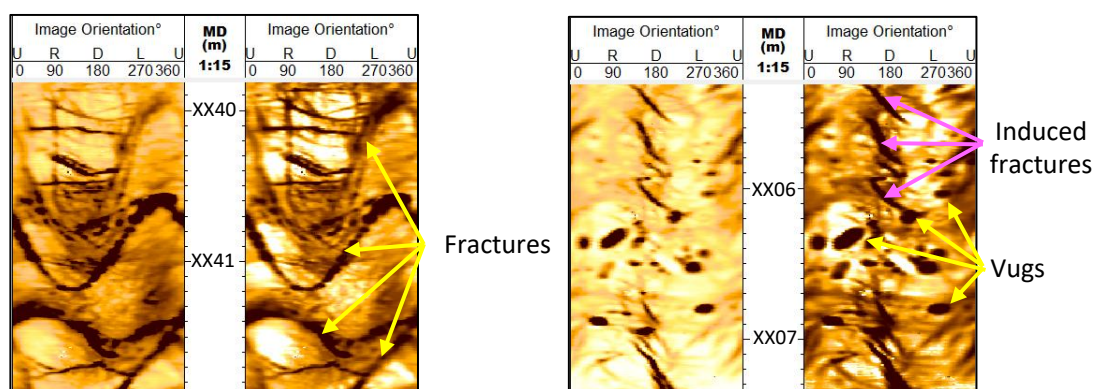


Figure 1-Characteristics of fractures and vugs appeared on the electrical images of BZ metamorphic rocks

The second challenge is to understand the association between reservoir characteristics and production rate in buried hill. It is observed that adjacent wells in the same block may have quite different gas production, while conventional logs only will be inadequate to solve the puzzle.

Advanced logging suites like high-resolution image and full waveform acoustic services are required.

The third challenge is the tough operation environment. With a buried depth of the metamorphic reservoir deeper than 4400m, the reservoir static temperature could reach 200 degC (Fig.2). With the increase of well deviation and extension in development phase, the operation environment is beyond the limit of the advanced wireline logging tools.

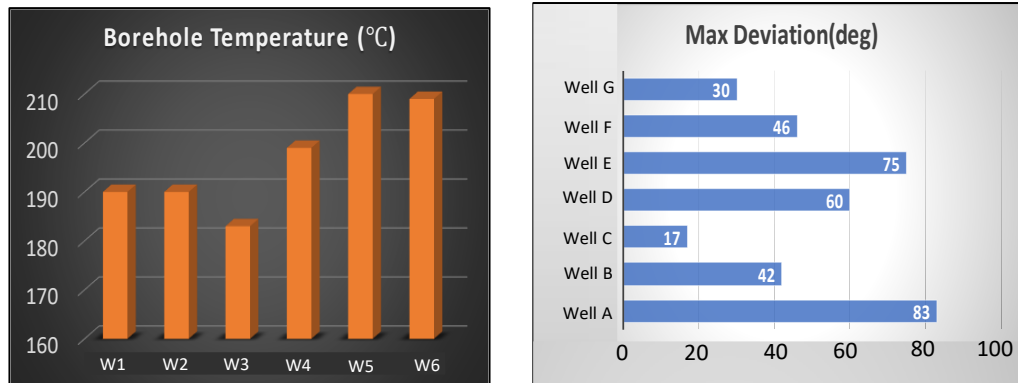


Figure 2-Borehole temperature and max deviation of some wells in BZ block

To overcome the difficulties, LWD solution including high-definition electrical image and sonic services were selected. Eventually, high-quality logging data was acquired successfully due to its advantages of high temperature resilience while circulating and strong tool robustness in long deviated wells.

Based on the high-quality data, fractures and secondary pores were analyzed and evaluated for each single well, and an integrated study was carried out to find out the main production controlling factors by combining logging data and well production data.

Fracture Characterization

Fractures are quite important for metamorphic rock reservoirs, for one thing, fractures can dramatically improve reservoir permeability, for another, fractures provide the migration pathway for fluids, which contribute a lot on dissolution process and hydrocarbon accumulation. Based on the LWD electrical images, conductive fractures, resistive fractures and drilling induced fractures were differentiated (Magdi Bazara et al., 2013). Conductive fractures appear as dark sinusoid on the borehole electrical images (Fig.3), which are open or filled by conductive minerals; resistive fractures appear as bright sinusoid on the borehole electrical images, which are filled by resistive minerals like calcite; drilling induced fractures appear as discontinuous cracks arranged in feathery symmetry at 180 degrees.

After fracture identification and classification, fracture occurrence and the maximum in-situ horizontal stress direction were obtained. This is very important for the drilling of horizontal wells or highly deviated wells because we have to try to cross more natural fractures while keep the borehole more stable. In addition, conductive fractures were evaluated by quantitative parameters including fracture density(P10C), fracture length(P21), fracture aperture (MEAN APERTURE) and fracture porosity(P33) based on LWD electrical image data (The Nguyen Dac et al., 2016).

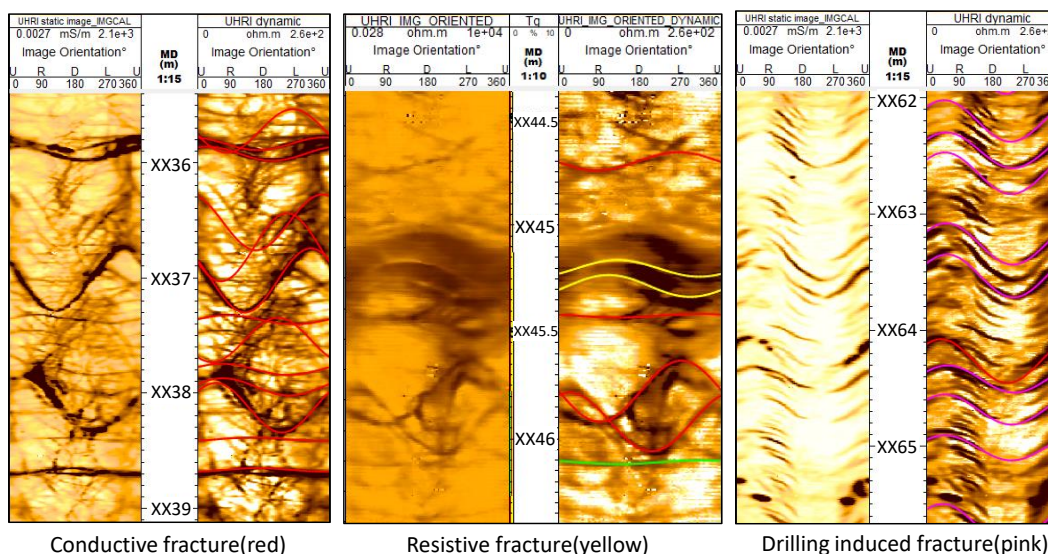


Figure 3-Fracture classification and characteristics on LWD borehole electrical images

Fig.4 shows the fracture results from one well, the strike of the conductive fractures is mostly around east-west direction, and the angle of the conductive fractures mainly ranges between 30 to 90 degrees. And the induced fractures indicate that the maximum horizontal in-situ stress direction is NEE-SWW direction. Based on the quantitative parameters, the interval of XX47-XX48.7m has bigger fracture aperture and higher fracture porosity, and the reservoir of this interval should be better.

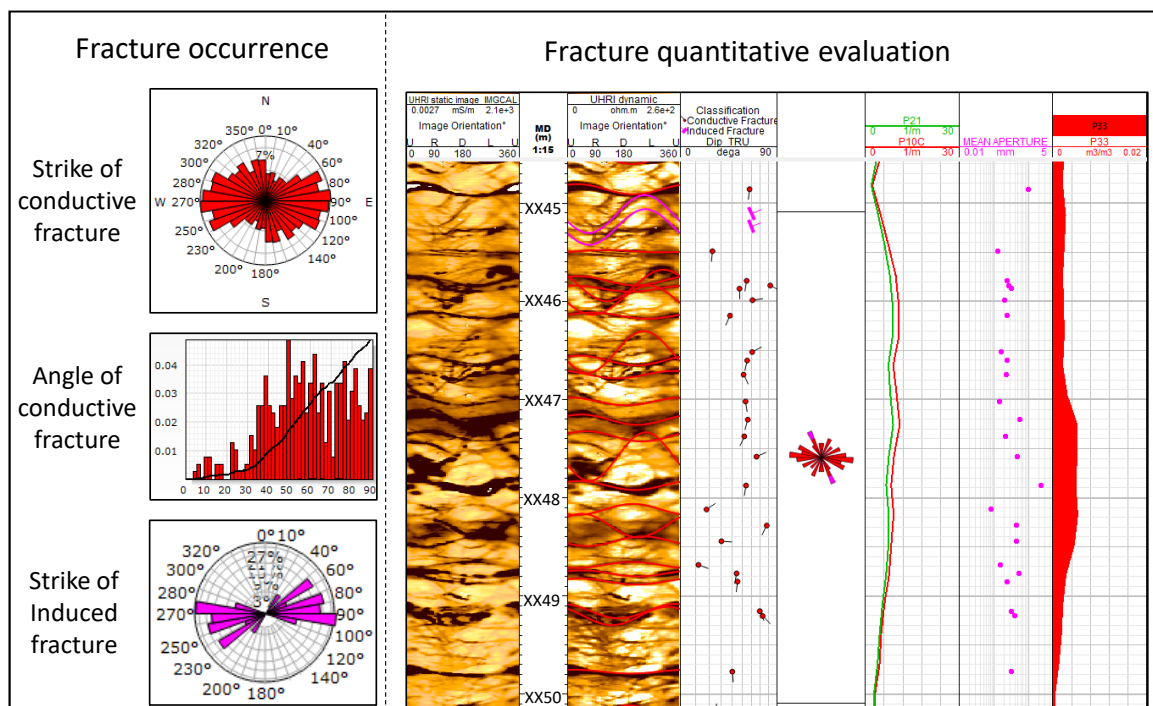


Figure 4-Fracture occurrence and quantitative parameters

Secondary Pore Characterization

Both fractures and vugs are developed in BZ metamorphic rocks, which are the main storage space for gas accumulation. Open fractures and open vugs appear as conductive heterogeneities on the borehole electrical image data, and Porotex technique can characterize the features of the conductive heterogeneities (Yamada, T., 2013). The processing includes 4 steps, namely matrix extraction, heterogeneity delineation, interactively cutoff selection and false heterogeneities removal (Fig.5). This method can extract both conductive fractures and conductive vugs regardless of fracture length, fracture angle, vug size and vug shape. And human-computer interactive method was used for cutoff selection instead of just using an empirical formula. Another advantage of this technique is that false heterogeneities such as drilling induced fractures and breakouts can be removed, which make the result more objective. After processing, geometrical properties of the heterogeneities such as conductive inclusion surface proportion (HTR_Prop) and conductive inclusion size (HTR_Size) can be derived. High HTR_Prop and high HTR_Size corresponds to porous and high permeable zones.

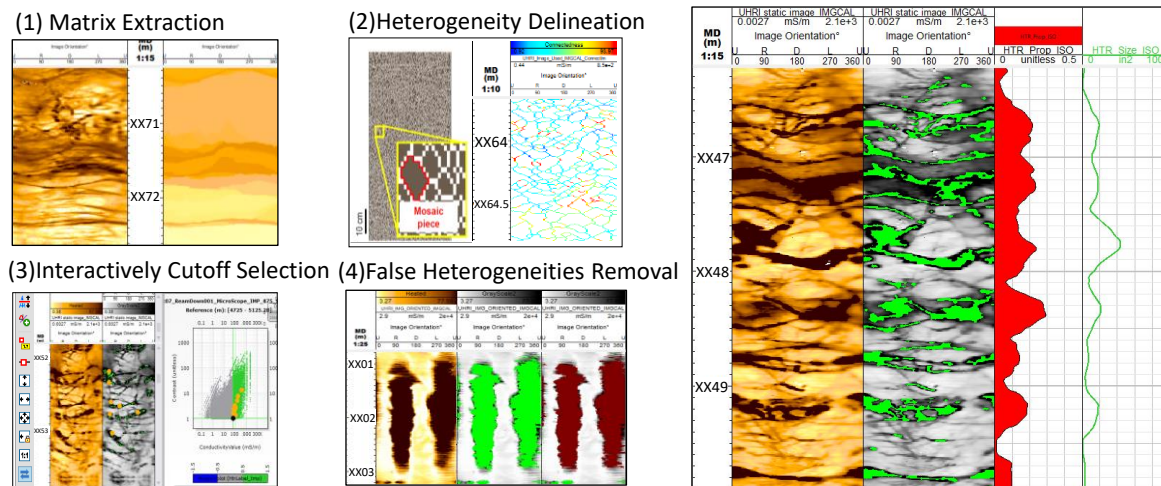
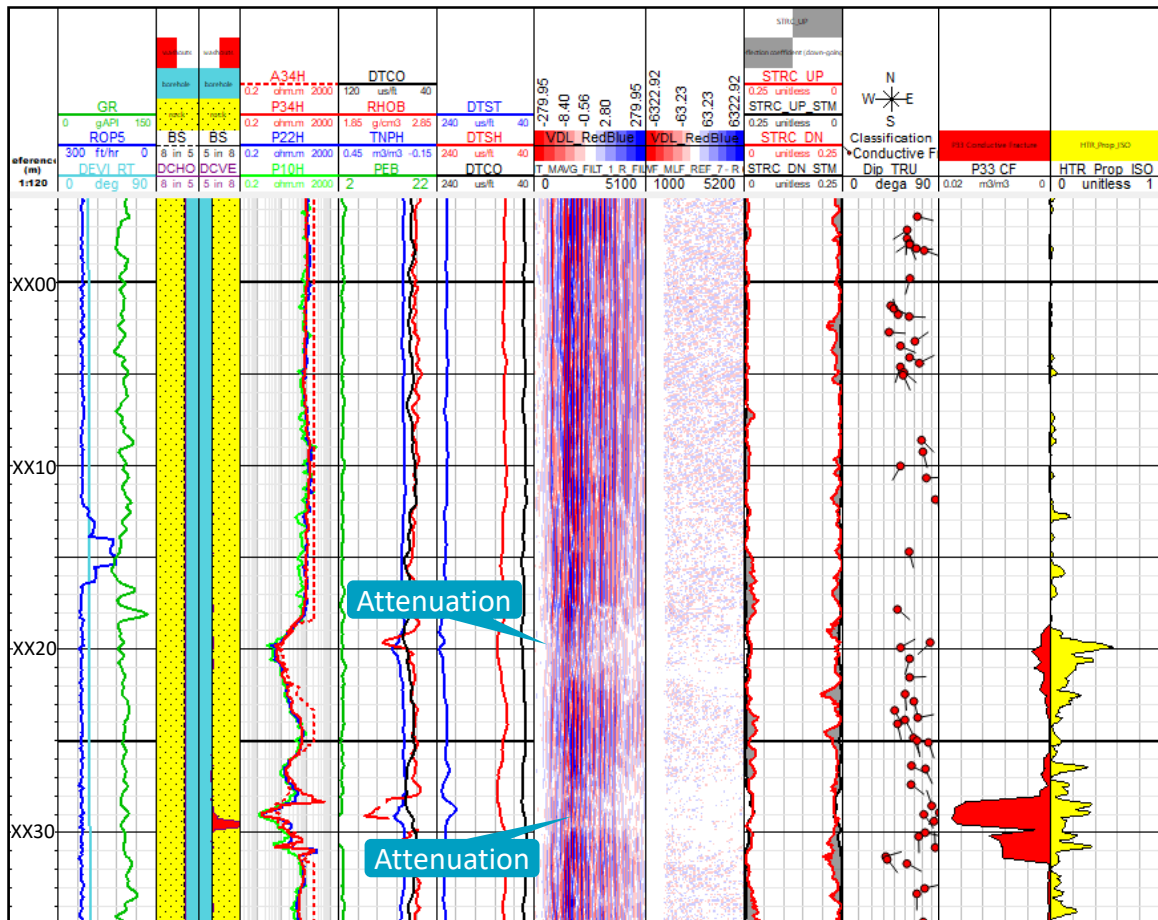


Figure 5-Secondary pore evaluation techniques and results

Open Fracture and Open Vug Validation

Conductive fractures and vugs were identified from LWD electrical image data, but they may be open or may be filled by conductive minerals. To further evaluate their effectiveness, sonic data was used. Stoneley wave is very sensitive to effective fractures or permeable zones, when met with vugs, opened fractures and groups of fractures, the reflection coefficient of stoneley wave is relatively higher, and obvious attenuation can also be detected as a response of fluid mobility. (Takeshi Endo et al., 1997 & 1998). For example, in interval XX19-XX35m, there are a lot of conductive fractures identified from the electrical images (Fig.6), the fracture porosity and HTR_prop is higher; according to stoneley wave response, the reflection coefficient is high in the interval of XX19-XX35m, and stoneley wave attenuation is obvious in the intervals of XX19-XX23m and XX26-XX32m. These responses indicate that there are more open fractures and open vugs in this interval.



Production Controlling Factor Analysis

Based on the result of single wells, an integrated study was carried out for multi-wells through combining relevant information including lithology, structure position, fractures, vugs, reservoir types and effective reservoir thickness.

It was found that well production is not controlled by structure position. In Fig.7, Well D, Well E and Well G have high natural gas production, and Well G has the highest gas producibility, while it was located at the lowest position among the 7 wells.

High production wells have 3 characteristics: 1. High production wells have small angle difference between the strike of conductive fractures and the maximum horizontal in-situ stress direction, usually less than 30 deg; 2. High production wells have more fracture-pore reservoir type and have better vertical connectivity. Fracture-pore reservoirs not only have high fracture porosity, but also have high HTR_Prop, which indicate that both fractures and vugs are developed. All the high production wells of well D, well E and well G have more fracture-pore reservoirs and better vertical connectivity; 3. High production wells have good reservoir quality with reservoir quality index (RQI) more than 20. RQI is an integrated parameter created especially for this block by using quantitative parameters and production data. This parameter combines fracture parameters, vug parameters, sonic parameters, and effective reservoir thickness. ROI matches well with the well

production (Fig.7), high production wells have higher RQI value, and low production wells have lower RQI value.

In conclusion, well production is controlled by open fractures, open vugs, reservoir types, effective reservoir thickness and maximum horizontal in-situ stress direction.

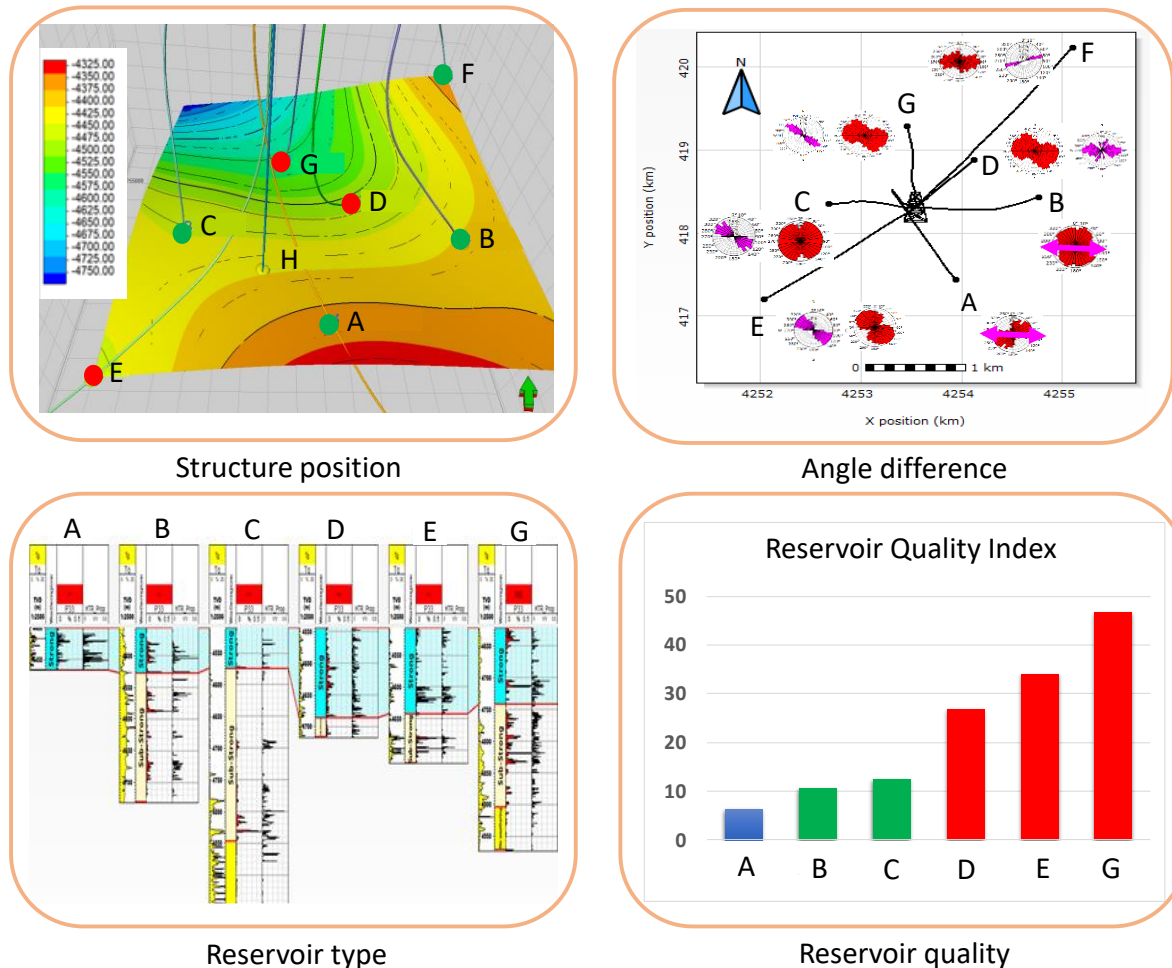


Figure 7-Production controlling factor analysis

Conclusions

High-resolution LWD electrical image data and high-quality LWD sonic data provide the basis of reservoir characterization under extremely high-temperature condition.

Combining fracture quantitative parameters and PoroTex parameters, one can conclude a more objective evaluation of secondary pores as well as reservoir types.

Well production in BZ block has less relationship with structure position. Wells located in lower position may have very high production, while wells located in higher position may have very low production.

Well production is mainly controlled by open fractures, open vugs, reservoir types, effective reservoir thickness and maximum horizontal in-situ stress direction.

High production wells normally have 3 characteristics: a. small angle difference between the strike of natural fractures and the maximum horizontal in-situ stress direction, usually less than 30 deg; b. more fracture-pore reservoir types and better connectivity; c. high reservoir quality index (RQI), usually more than 20.

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SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Regional Pore Pressure Forward Modelling: study case in a compressive area, Eastern Foothills, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Aura Roa¹, Linda Montilla², Reinel Corzo Rueda³, Diego Vargas⁴, Eliseo Teson⁵, Sergio Ibanez⁶, Juan Pablo Arias⁷, Jaime Castellanos⁸, Julio Cesar Garzon⁹

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Tip Colombia
5. Ecopetrol
6. Ecopetrol
7. Ecopetrol
8. Ecopetrol
9. Ecopetrol

ABSTRACT BODY:

Abstract Summary: The estimation and understanding of pore pressure is an important and critical process that should be carried out from the early stages once the opportunity is identified and well planning begins.

We are proposing a new methodology focused on predicting this parameter in exploratory areas with high structural complexity and limited geological information. This modeling consists of 1D and 2D/3D pore pressure and stresses estimation from well data, basin modeling and seismic information. This work is focused on understanding the pore pressure and state of stresses evolution and distribution over time, identifying the mechanisms generating overpressure; the impact of pore pressure on the physical properties of fluids and supporting well planning and execution processes, identifying and minimizing both risks and operational problems during drilling allowing the operation assurance.

By the integration of these methodologies, it is possible to identify and to evaluate different pressure-generating mechanisms (stress mechanical, dynamical transfers, thermal stresses etc) and to get a more complete understanding in a local scale around the well and in a regional framework. The geopressure models represent an input data in the modeling of petroleum systems with a focus on the prediction of the physical properties of fluids, reducing uncertainty as well as in the development of the geomechanical and wellbore stability models that support the well mechanical design and the mud window, among others.

Currently, the methodology has been applied in four prospects in the Llanos foothills and we can share a significant knowledge of the studied areas, based on pore pressure distribution scenarios for the prospects analyzed, as well as detailed information on offset wells, logs, stresses, geomechanical properties, supporting the reduction of prospect maturity times, accelerating the first oil and the competitiveness of the project.

The added value of this methodology is materialized in a substantial improvement within the exploratory process; reducing uncertainty, risks and costs in the execution of exploratory wells, with the expectation of increasing operational viability, allowing a better planning of surface facilities and being extrapolated to any basin of interest to the business group.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Structural model and kinematic analysis of the La Cira Basement-high, Middle Magdalena Valley, Colombia.

AUTHORS (FIRST NAME, LAST NAME): Martin Reyes¹, Jonas Kley², Andrés Mora⁷, Daniel Bello-Palacios³, Andrés Vargas⁴, Juan Sebastian Carvajal-Torres⁵, Jose Osorno⁶

INSTITUTIONS (ALL):

1. Georg-August-Universität Göttingen
2. Georg-August-Universität Göttingen
3. Ecopetrol
4. SierraCol Energy
5. Grupo de Investigación en Ciencias de la Tierra y Energía
6. Agencia Nacional de Hidrocarburos
7. Ecopetrol Brasil

ABSTRACT BODY:

Abstract Summary: Structural modeling and kinematic analysis has allowed us to characterize and reconstruct basin evolution. Several industries employ this powerful tool to reduce uncertainty, nevertheless, these models present some limitations depending on the quality of the data available and the geological complexity. This work presents the structural model of the La Cira Basement-high through seismic interpretation and validates its evolution through structural kinematic restorations. The La Cira Basement-high is located in the central part of the Middle Magdalena Valley of Colombia. This structure represents a major basement anticline truncated by an early Eocene unconformity. An east-verging, buried, reverse fault limits this structure to the west, while an east-dipping normal fault bounds it to the east. In addition, the inverted Infantas fault cuts its crest.

In accordance with the subsurface data, we interpreted the present-day structure of the La Cira Basement-high. This interpretation was tested through forward modeling and kinematic restoration to validate our interpretation of the structure's development and compare it with previous interpretations from other works.

Our model proposes that the La Cira Basement-high is linked to a deep-seated, blind-basement, east-verging thrust. The inversion of the Mesozoic structures is evidenced in the thickness variations and the normal fault offsets at deeper structural levels. In the end, we identified the late Paleocene – early Eocene thrusting and folding event that terminated when the sedimentation rates were larger than the structural relief.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The Boomerang Hills (Bolivia): Example of Thin- to Thick-skinned Tectonics Transition and Inherited Structure Effects

AUTHORS (FIRST NAME, LAST NAME): Hodei Uzcheda¹, Mayte Bulnes², Josep Poblet³, Gonzalo Zamora⁴

INSTITUTIONS (ALL):

1. Terractiva Consulting
2. Universidad de Oviedo (Departamento de Geología)
3. Universidad de Oviedo (Departamento de Geología)
4. Specialists, Repsol, Madrid, Spain.

ABSTRACT BODY:

Abstract Summary: The Boomerang Hills is an important prospective area located in front of the Bolivian Andes, close to the Bolivian Orocline. This region has been explored for more than fifty years what have resulted on the acquisition of multiple 2D and 3D seismic surveys, as well as the drilling of hundreds of wells. With the aid of 2 2D and 2 3D seismic surveys and 31 wells we were able to create cross sections, maps, a 3D geological model, a velocity model and decompaction curves. Two different structural and stratigraphic regions may be separated within the area: the southern Boomerang Hills representing the buried frontal part of the Andes and the northern Boomerang Hills that correspond to the Beni-Chaco Plain. The main features of the southern unit are: dominant thin-skinned contractional structures of Late Cenozoic age, with N-directed thrust emanating from a basal detachment level situated close to the Silurian base; and an angular unconformity at the base of the Mesozoic that erodes Silurian to Carboniferous rocks, progressively younger towards the S-SW. The northern domain key characteristics are: frequent thick-skinned extensional faults of pre-Andean age (Paleozoic, Mesozoic and Early Cenozoic); and a Mesozoic sequence lying mostly directly on top of the pre-Silurian basement. The boundary between these two zones is approximately defined by the tipline of the basal detachment level. One remarkable structural feature of the Boomerang Hills is that its structures tend to show E-W strikes, in contrast with the general orientation of the Andean Cordillera, mostly NW-SE to WNW-ESE. The two main reasons for that would be: the pre-Silurian inherited basement configuration and the distribution of the cover rocks (Silurian to Cenozoic). The sequential restoration of a cross section and the 3D backstripping of the geological model should help to decipher the evolution of the area since Paleozoic times.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Completion and Wellbore Geomechanics in High Stress Settings – A Case Study from the Vaca Muerta Shale

AUTHORS (FIRST NAME, LAST NAME): Jonathan McKenna¹, Ruth Ehlich²

INSTITUTIONS (ALL):

1. MicroSeismic, Inc.
2. Pan-American Energy

ABSTRACT BODY:

Abstract Summary: Proximity to active tectonic boundaries can be one of the most important factors controlling treatment and wellbore designs. In this case study, the initial estimate of SHmax was not nearly as large as that required to explain the observed flaws in design and the associated costs.

Wells and completions were designed to typical Texas standards where normal stress regime is the norm. However, textbook “hydraulic” fractures were not observed and the majority of the stimulation reactivated large-scale faults. Geomechanical analysis of observed focal mechanisms reveals a very different stress regime that explains the constant screen outs and casing deformations. Focal mechanisms observed during the stimulation were evaluated to determine a theoretical stress state that best-fit the majority of the focal mechanisms. The main dip-slip focal mechanism has two nodal planes that are equally possible. Each nodal plane was evaluated based on temporal and spatial hypocenter propagation characteristics as well as the failure potential using both the sonic- and microseismic-derived stress models. In addition, the wellbore stability was evaluated to understand which nodal plane and stress model predicted the casing deformation with highest precision.

Concerning focal mechanism nodal planes, the shallow-dipping planes became the obvious choice based on the 3D alignment of event locations. In addition, the shallow-dipping planes were most susceptible to failure using the microseismic-derived stress model. Under these conditions, faults required $\ll 300$ psi of net pressure, which was observed during the stimulation. The sonic-derived stress model would not have predicted the casing collapse observed along one of the wells. In conclusion, the microseismic stress model shows that drilling oblique to SHmax can result in an increase in wellbore stability.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Syn-Rift Tectonics and Kinematics of Santos and Campos Basins, Offshore Brazil: Primary Control on the Pre-Salt Structural Architecture

AUTHORS (FIRST NAME, LAST NAME): Luciano Magnavita¹, Nolan Dehler²

INSTITUTIONS (ALL):

1. Independent
2. Petrobras

ABSTRACT BODY:

Abstract Summary: The offshore Santos and Campos basins located in the southeastern margin of Brazil have been focusing extensive hydrocarbon exploration after large discoveries made in the sedimentary package known as pre-salt. In our conception, the structural architecture of those basins that control facies distribution during and after rifting is consequence of the change in the extension direction along the Eastern Brazilian margin in the Early Cretaceous: initial E-W extension in the Hauterivian/Barremian was followed by distal NW-SE opening in the Aptian as the tectonic activity migrated offshore. During initial rifting when world class source rocks and coquina reservoirs were deposited in the basins, the trend of the Brazilian margin was strongly controlled by basement heterogeneity, which also determined the NE-SW direction of rift propagation. In this way, because the initial E-W extension was oblique to the direction of rift propagation, oblique rifting dominated Santos basin, with a transition to suborthogonal in the southern Campos basin. Consequently, a complex structural framework resulted with the alternance of prominent highs and lows controlled by transfer zones, which kinematics depended on the orientation with respect to the regional extension. Those transfer zones compartmentalized the basins along the strike during the initial rifting; however, some regional structures formerly interpreted as developed during the syn-rift probably evolved during post-rift times in the Late Cretaceous. The tectonism along the margin tended to rejuvenate eastward during the Aptian as the opening direction changed from E-W to NW-SE. Therefore, previous existing structures were reactivated and developed in the internal, initial rift, but the external rift became the locus of the main tectonic activity as the margin evolved until final break up took place. Our interpretation has important consequences on the distribution of reservoirs and source rock facies of the so-called pre-salt in the proximal/internal and distal/external rifts.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The Structure and Deformation of Accretionary Foldbelts in offshore Colombia: New Insights from Regional Reprocessed Data in the Caribbean

AUTHORS (FIRST NAME, LAST NAME): Antara Goswami¹, Kyle Reuber², Charles Campbell³ **INSTITUTIONS (ALL):**

1. ION Geophysical
2. ION Geophysical
3. ION Geophysical

ABSTRACT BODY:

Abstract Summary: Regional-scale reprocessing of seismic data offshore Colombia in the Caribbean has revealed new insights into the structure and deformation of the entire northern accretionary margin. A framework of 60,000 line km of 2D seismic surveys was processed and analyzed as a single contiguous dataset during this study, supported by well log and gravity data.

The Magdalena Fan lies between the compressional domain of the Sinu accretionary foldbelt to the southwest and the South Caribbean Deformed Belt (SCDB) as well the extensional and transtensional environments of Bahia and Guajira basins to the northeast. Using the newly re-imaged data, we can clearly contrast the thick, relatively undeformed sediments of the Magdalena delta with the adjacent accretionary sections. The lack of deformation could be due to the high volume of young sediment input from the Magdalena River since Late Miocene, influenced by a slab tear in the Caribbean Plate. The stratigraphic section of the 8 km-thick Magdalena Fan has created regionally extensive MTCs across the Colombian basin, several of which were mapped during this study.

We demonstrate that there is a high variability in the complexity of deformation from west to east across the sediment accretion zone. Structural styles within the accretionary foldbelts have developed in different magnitudes and appear to correlate with the angle of obliquity of the downgoing Caribbean Plate. A single basal detachment has been observed in the eastern Sinu prism; a second, mid-section detachment develops in the western Sinu area. The SCDB in the Guajira region contains two detachments over the majority of the belt and a third in the eastern reaches.

This dataset has allowed for a regional-scale correlation between these areas for the very first time and allowed us to examine the transition between the structural domains along the northern margin. In this study we present our updated understanding of the evolution of accretionary belts and development of marginal basins and foldbelts in offshore Colombia.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Negative Inversion in Folded Belts: an Underappreciated Structural Process?

AUTHORS (FIRST NAME, LAST NAME): Gabor Tari¹

INSTITUTIONS (ALL):

1. Omv Upstream

ABSTRACT BODY:

Abstract Summary: Extensional reactivation of former thrust planes in thrust fold belts, designated as "negative inversion", received much less attention by both the petroleum industry and the academia than the opposite process. This obvious imbalance in the understanding level of positive versus negative inversion is clearly reflected by the preference in the petroleum industry to focus on what has been simplified to just "inversion" instead of positive inversion.

This choice is obviously driven by the fact that many hydrocarbon fields are associated with positive inversion. Negative inversion, occurring by the extensional reactivation of pre-existing compressional structures, has been first observed in the exposed interior segments of thrust fold belts. In general, it is more difficult to make a convincing case for negative rather than positive structural inversion, especially when only subsurface data sets are available. As negative inversion has an extension event or period as the last deformational phase, the resulting basin fill typically covers up all the surface evidence for the pre-existing contractional fabric. Therefore negative inversion manifests itself dominantly in subsurface data sets.

Based on the structural review of many case studies of positive and negative inversion they display contrasting kinematic patterns. One of the obvious structural differences is the development of shortcut structures during the advanced stage of inversion. In the case of positive inversion a shortcut thrust develops within the footwall of the major inverted fault to better accommodate the ongoing shortening. In contrast, a shortcut normal fault develops within the hangingwall of the partially inverted master fault during negative inversion. While the shortcut thrust associated with positive inversion typically does not produce traps, the shortcut extensional listric fault during negative inversion is trap-forming, both within its footwall and hangingwall. In the broader Alpine-Carpathian-Pannonian region, there are many examples of hydrocarbon fields where some of the trap elements are due to negative structural inversion. Therefore it is suggested here that even though negative inversion may not be as important for petroleum exploration as its positive counterpart, yet, it may produce more traps in the internal parts of thrust fold belt than currently perceived.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Seismic Interpretation and Trap Definition Challenges in the Southern Subandean Fold and Thrust Belt of Bolivia

AUTHORS (FIRST NAME, LAST NAME): Oskar Vidal-Royo¹, David E. Menzoza Ticona², Gary Beccar Montaña³

INSTITUTIONS (ALL):

1. Terractiva Consulting
2. Petrobras Bolivia S.A.
3. Petrobras Bolivia S.A.

ABSTRACT BODY:

Abstract Summary: In this chapter we present the challenges associated to the interpretation of a seismic section across the San Alberto, South Aguaragüe and Madrejonas Ranges of the Southern Subandean fold-and-thrust belt in Bolivia. Field data, geological mapping, seismic, wells, forward modelling and restoration are integrated into one valid geological model, allowing us to understand trap configuration and evolution through time. The scarce well data, the poor seismic quality in the anticline cores and the decoupling of structural styles above and below the Mid-Devonian décollement require the use of structural modelling techniques to decrease the uncertainty of seismic interpretation and trap definition at depth. The interpretation is compatible with a foreland-directed sequence of folds and thrusts. The sequence from Los Monos Fm. to the Neogene synorogenic infill develops as a fold train verging to either the east (Aguaragüe) or to the west (San Alberto). The Kirusillas to Huamampampa sequence where most structural traps are defined, instead, is interpreted as a series of east-verging fault-related anticlines developed on double-ramp thrust sheets.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The role of inherited rift structures in controlling the architecture and evolution of contractional belts

AUTHORS (FIRST NAME, LAST NAME): Gianreto Manatschal¹, Andrés Mora²

INSTITUTIONS (ALL):

1. Université de Strasbourg, CNRS, ITES
2. Ecopetrol

ABSTRACT BODY:

Abstract Summary: A long-standing challenge in the interpretation of contractional belts is to evaluate the initial condition at onset of convergence. Integrating this initial condition and its role is a prerequisite to understand and model the structural and thermal evolution of contractional belts. This requires defining the initial condition, which corresponds to that of a rift system, and for which inheritance includes a transient thermal state and a persisting inheritance, which encompasses long-lasting structural and compositional inheritance.

The aim of the presentation is to illustrate the role of rift inheritance based on the work done in the Biscay-Pyrenean system. There is a general agreement that this system documents the reactivation of an increasingly mature rift system along-strike, ranging from a mature rifted margin in the west to an immature and segmented hyperextended rift in the east. In the past, different models have been proposed to explain the preceding rifting and its influence on the subsequent reactivation. The new interpretation highlights the sequential reactivation of rift-inherited decoupling horizons and identify the specific role of exhumed mantle, hyperextended and necking domains during compressional reactivation. It also highlights the contrasting fate of rift segment centres vs. segment boundaries during convergence, explaining the non-cylindricity of internal parts of collisional orogens. The observations made in the Biscay-Pyrenean system suggest that the role of inheritance is more important during initial collision. In contrast, during later stages, the orogenic evolution is mostly controlled by the classical Coulomb Wedge theory, which may account for the simpler and more continuous architecture of external parts of collisional orogens. This may also explain why models can reproduce better the final and more external orogenic structures observed in the fold and thrust belts compared to those of initial collisional stages. The new concepts established in the Biscay-Pyrenean system are now ready to be tested at other orogenic systems that result from the reactivation of former rift systems, such as the Colombian cordilleras and the Caribbean system. The new learnings ask us to rethink existing interpretations and allow to test for potential future plays in contractional belts that are not only limited to the exploration of hydrocarbons, but also include native hydrogen or hydrothermal systems.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Low-angle Extensional Faults on Passive Margins - Comparative Examples from Australian Passive Margins and the South China Sea

AUTHORS (FIRST NAME, LAST NAME): Ken McClay¹, Hongdan Deng²

INSTITUTIONS (ALL):

1. Australian School of Petroleum and Energy Resources, The University of Adelaide, South Australia

2. School of Earth Sciences Zhejiang University Hangzhou China

ABSTRACT BODY:

Abstract Summary: Passive continental margins are a key terrane worldwide for the exploration and production of hydrocarbons. New models for the formation of passive margins have been proposed invoking variable large extensional displacements on low-angle fault systems and depth dependent stretching of continental crust until eventual breakup and crustal separation. New high quality 3D seismic data combined with new 2D data and legacy regional seismic sections across the Australian Northwest Shelf passive margin as well as along the southern Australian margin have been used to determine the role of low-angle fault systems in these terranes. New interpretations of these areas are presented and compared with recent results obtained from the South China Sea. Our studies have shown that extremely low angle faults commonly occur on these margins and in places these may evolve to extreme deformation and the formation of metamorphic core complexes. Extreme crustal thinning in these settings also may lead to significant magma emplacement in the footwalls of these low-angle faults systems. The models developed from this research and their implications for hydrocarbon systems are compared to other passive margins such as the Norwegian North Atlantic margin as well as metamorphic core complex terranes in the western USA, Greece and Turkey.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The Gulf of Suez - Northern Red Sea Rift System - Templates for Rift Systems and for the Initiation of Passive Margins

AUTHORS (FIRST NAME, LAST NAME): Ken McClay¹, Samir Khalil², Bill Bosworth³

INSTITUTIONS (ALL):

1. Australian School of Petroleum and Energy Resources, The University of Adelaide, South Australia
2. The Department of Geology, Suez Canal University
3. Apache Egypt

ABSTRACT BODY:

Abstract Summary: The Oligo-Miocene Present Day Gulf of Suez and Red Sea Rift system is the best exposed example of a Present day marine rift on the verge of becoming a passive margin. The NNW-SSE striking rift faults were spatially controlled by Neoproterozoic basement fabrics and these result in an overall rhomboidal rift fault system. In the Gulf of Suez the three distinct sub-basins are half-grabens formed by arrays of planar extensional faults that change polarities across the complex accommodation zones between the sub-basins. Detailed mapping and structural analyses shows that rift initiation occurred at or near sea level with the Latest Oligocene (Chattian) first rift sediments deposited in isolated hanging wall synclinal basins formed by short (~ 3 - 10 km strike-extent) planar extensional faults. With continued extension longer, larger displacement (1 - 7 kms) overlapping and linked rift fault systems evolved largely by breaching of relay ramps. Hangingwall sub-basins coalesced and were infilled with up to 6 km of Lower Miocene syn-rift marine strata. Extensional fault-propagation folding generated synclinal hanging wall basins. The large displacement sub-basin border faults underwent significant footwall uplift that in places probably exceeded 4kms.

The patterns of faulting, fault evolution and syn-kinematic sedimentation together with the characteristics of the petroleum systems in the Gulf of Suez and northern Red Sea may be used as templates for rift systems elsewhere as well as for understanding the early stages of passive margin evolution.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Strong Strike-Slip Deformation as Seen in New 3D Data in the Pre-Salt of the Santos Basin – Petroleum Potential

AUTHORS (FIRST NAME, LAST NAME): Pedro Victor Zalan¹, Eric Newman², Mike Saunders³ **INSTITUTIONS (ALL):**

1. ZAG Consulting in Petroleum Exploration
2. TGS
3. TGS Houston

ABSTRACT BODY:

Abstract Summary: Recently shot 3D surveys over the southward extension of the External High beyond the EEZ in the Santos Basin unveiled the existence of a structural style yet unknown in the prolific Pre-Salt section. Very large positive and negative flower structures of great relief and amplitude can be observed. Vertical faults that cut through the upper brittle crust are seen offsetting the salt wall as if it were an elastic/brittle body. An unprecedented view of the intensively broken, faulted, uplifted and twisted outer continental crust can be observed. Amidst this complex style, very large structural closures, such as the Puri Prospect (> 1000 km² of 4-way closure) occur completely sealed by salt, despite the intense deformation. Some of such structures consist of inverted Pre-Salt grabens due to transpression. Typical Pre-Salt reservoir seismic facies can be seen at the crests of the structures. Planar, parallel reflectors indicative of the carbonate ramp model of microbialite deposition and travertine cones/buildups related to hydrodynamically active syn-rift faults can be visualized right beneath the base of salt. Another important feature revealed by the 3D surveys is the presence of thick, deep-seated grabens filled by sedimentary strata adjacent to or underneath such highs. Their existence is important as they may contain the so-needed source rocks of the External Kitchen. All Pre-Salt section was deposited in a syn-rift setting, being its typical extensional structural style strongly overprinted by an overlapping to later strike-slip deformation. The age of the strike-slip tectonism is deduced to be late syn-rift to syn-salt deposition. For the first time, a glimpse into the highly complex deformation history of the last lapses of continental separation can be attained.

The External High is the most important feature of both Santos and Campos basins because, being a >600 km continuous feature, it plays the role of the main focusing high for both surrounding Internal and External Kitchens. It acts just like the backbone and the surrounding depressions of the ribs. The External High controls the location of most of the Pre-Salt and Post-Salt producing fields. These very large structural highs mapped at the base of the salt upon this newly identified extension of the External High show great potential for future discoveries of large accumulations.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Fracture Probability Factor for Quantifying Rock Deformation

AUTHORS (FIRST NAME, LAST NAME): Zakiyah Alkhadrawi¹, Abdullah Theyab¹

INSTITUTIONS (ALL):

1. Saudi Aramco

ABSTRACT BODY:

Abstract Summary: Several graphical and numerical methods characterize rocks deformation. These include elastic moduli cross-plots, Mohr circle, failure envelopes, and brittleness index. The natural fracturing probability curve is a common way to describe rock deformation based on elastic behavior. Poisson's ratio and Young's modulus are dynamic elastic variables that also quantify rock deformation based on density, shear, and compressional sonic wireline logs. These moduli are measured in the lab by subjecting rock-sample plugs to variable stress and measuring corresponding strain and deformation. Poisson's ratio and Young's modulus at the failure point of a rock plug define the point at which the rock stops deforming elastically. The measured failure point values from multiple plugs and from a given formation, are plotted on a Poisson ratio-Young modulus cross-plot. The best-fit trend line for those points represents the transition from ductile to brittle behavior. This trend line is known as the natural fracturing probability curve for a given lithological unit. Quantifying how far the plug readings are from this curve characterizes the sealing integrity of the corresponding plug. Data points from wells plotted below this curve are interpreted to be ductile. Meanwhile, data points above this curve are interpreted to be brittle and prone to breach.

This two-dimensional analysis can be viewed in one-dimension to simplify the interpretation of the rock behavior, especially when looking at wireline logs. An equation was developed to use the Young modulus and Poisson's ratio in to calculate the distance from the natural fracturing probability curve. The distance from the natural fracturing probability curve is called the Fracture Probability Factor (FPF). If the FPF values of a lithological zone are positive, the zone is characterized as a ductile healing region. However, if the values are negative, it is described as a brittle, failing region.

This methodology can be practical in defining vertical compartments in a given well from wireline data. The FPF log against pressure data provides a basis to determine whether FPF positive zones can explain pressure differences between reservoirs. The significance of the FPF is to provide a variable to correlate with brittleness index measurements. These can be compared to elastic measurements and mineral content. Moreover, FPF can be used for seal effectiveness analysis or characterizing fracking intervals.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The San Martín anticline: a classic example of a fault-bend fold in the Camisea fold and thrust belt, Central Andes, Perú.

AUTHORS (FIRST NAME, LAST NAME): Alfredo Disalvo¹, Emilio Rocha², Juan Pedro Doine Cabre³, Juan Francisco Chung Ching⁴

INSTITUTIONS (ALL):

1. Consultant
2. Pluspetrol
3. Pluspetrol
4. Pluspetrol

ABSTRACT BODY:

Abstract Summary: The Camisea fold and thrust belt is a classic thin-skinned fold and thrust belt with five structural trends, made up of sequentially-imbricated thrusts sheets. These thrusts generate several anticlines, many of which hold hydrocarbon accumulations totaling more than 25TCF and 1.3 BBC in the entire area.

High-quality 3D depth-migrated seismic allows a detailed interpretation of the San Martín Anticline, which will be the focus of this work since it is a typical structure in the Camisea area. The San Martín anticline is an excellent example of a duplex formed by imbricated fault-bend folds, with the basal detachment in the Devonian shales and the upper detachment in the lower section of the Cenozoic strata. It can be clearly interpreted, with a thrust fault plane, cut-off angle and dips of the back and frontal limbs that resemble Suppe's first mode fault-bend folds. This structure is folded by a second thrust sheet and therefore a break-forward imbricate thrusting style is proposed. Additionally, high angle reverse faults with minor displacement and southern vergence are interpreted in the eastern portion of the San Martín structure.

A kinematic evolution of the structure, starting from its undeformed state and reaching the final interpreted cross-section is presented in order to balance and validate the structural cross-section interpretation.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The Kuqa Fold-and-Thrust Belt: Geometry of a Deformed Multilayered System Involving Coal and Salt Décollements. Results from Analogue Modelling

AUTHORS (FIRST NAME, LAST NAME): Oriol Pla¹, Esther Izquierdo-Llavall², Eduard Roca³, Oriol Ferrer⁴, Òscar Gratacós⁵, Josep Antón Muñoz⁶

INSTITUTIONS (ALL):

1. Ecopetrol Brasil, Barcelona, Spain.
2. IGME-CSIC
3. University of Barcelona (Spain) Geomodels Research Institute
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ABSTRACT BODY:

Abstract Summary: The 3D geometry of fold-and-thrust belts is strongly controlled by both syn-tectonic sedimentation and décollement rheology. Its influence has been extensively tested through analogue models. However, the influence of syn-tectonic sedimentation in fold-and-thrust systems with two décollements has rarely been tested although it is a common scenario in the outer parts of fold-and-thrust belts such the Apennines, the Appalachians, the Pyrenees, the Zagros or the Sub-Andean and Kuqa fold-and-thrust belts.

The Kuqa fold-and-thrust belt, in the southern foreland of the central Tian Shan Range (NW China), is a oil-bearing fold-and-thrust system that was contractionally deformed during Late Mesozoic and Cenozoic times as recorded by well-preserved syntectonic continental sequences. Its structural evolution was strongly controlled by synorogenic salt (Eocene-Oligocene in age) and presalt décollements (Upper Triassic-Lower Jurassic coals and lacustrine mudstones) with varying spatial distribution.

In this context, the present study aims to understand how the rate of syn-contractional sedimentation influences the deformational style in the foreland of fold-and-thrust belts involving multiple décollements. To achieve this purpose we designed an analogue experimental program with a set-up inspired in the Kuqa fold-and-thrust belt. It is based on compressional wedges involving two interlayered weak décollements. The upper décollement is made of pure silicone polymer (simulating salt), it is syn-compressional and its length varies along-strike. The lower décollement is constant thickness and consists of a mixture of sand and silicone polymer (simulating coals and lacustrine mudstones) that changes its mechanical properties laterally. Using this set-up, three syn-tectonic sedimentary rates were tested and results were compared to a baseline model without syn-tectonic sedimentation.

Experiments yield results that are consistent with the deformation pattern observed in nature. It provides valuable insights on how the rate of syn-kinematic sedimentation and décollement rheology influences the deformation style in the foreland areas of a fold-and-thrust belt involving multiple rheological different décollements. It also contributes to a better understanding of the previous poorly characterized structure of the Mesozoic units underlying the salt in the Kuqa fold-and-thrust belt, where the main oil reservoirs are found.

SESSION TITLE: Theme 7: Critical Minerals for Energy Diversification

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Lithium Isotopes and Geochemical Analysis in the Exploration of Salar Brine Aquifers

AUTHORS (FIRST NAME, LAST NAME): Walter Rojas², Ricardo Alonso¹ **INSTITUTIONS**

(ALL):

1. UNIVERSIDAD NACIONAL DE SALTA (FACULTAD DE CIENCIAS NATURALES)
2. ERAMINE SUDAMERICA SA

ABSTRACT BODY:

Abstract Summary: In the Puna region, located in the NW portion of Argentina all the salar basins have been evolved along the time since the early Quaternary. The brine in each basin has a specific geochemical signature, which is the consequence of the interaction of several factors (temperature, pH) or natural process (weathering). The brine hosted in the deep or shallow aquifers, has some constant ratios among the main ions, which in some cases are key due to their impact on the LCE production cost (Mg, SO₄, Cl, As, Fe, etc). In addition, the Li⁷ isotope contents should be considered as other main feature due to the linking with the evaporation evolution rates and the brine residence time. A combination of the geochemical analysis and Li⁷ contents would allow to understand the evaporation history and what could be the main lithium source. Conceptually, the brine residence time is very important and a key element that needs to be defined because there is a very straight correlation with the lithium grades.

SESSION TITLE: Theme 7: Critical Minerals for Energy Diversification

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Acquisition of Critical Minerals in the United States to Fuel the Energy Transition, Analysis of the Bear Lodge Carbonatite and Associated Alkaline Silicate Rocks, Crook County, Wyoming, United States

AUTHORS (FIRST NAME, LAST NAME): Mike Bingle-Davis¹

INSTITUTIONS (ALL):

1. Kirkwood Oil and Gas, WY, United States.

ABSTRACT BODY:

Abstract Summary: Rare Earth Elements are currently being produced at the Mountain Pass Mine, Mountain Pass, California (USA) from a carbonatite deposit. This deposit supplied an estimated 15.8% of the world's rare-earth production in 2020 and is the only rare earth mining and processing facility in the United States. The United States hopes to construct a domestic critical mineral industry, which can prove to be a daunting task when considering the environmental, economic, and political hurdles. The paradox of wanting a carbon-free world while simultaneously preventing the industries that are required to make that future plausible.

The Bear Lodge carbonatite is one of the largest rare earth deposits in the United States, with a project-wide measured and indicated resources of 10 million short tons at a grade of 3.05% total rare earth oxide. The complex displays variable weathering which in turn results in light and heavy rare-earth elemental enrichment based on weathering profiles. The deposit is zoned with weathered materials located to a depth of approximately 590 feet (180 meters) where it grades into unaltered carbonates.

The Bear Lodge Mountains are considered to be a part of the Black Hills Uplift which was the result of a Tertiary-aged alkaline igneous complex towards the end of the Laramide Orogeny. The carbonate itself is expressed as a series of northwestern trending dikes intruded into the three diatreme structures. It is thought that through isotopic analysis that the carbonatitic magma responsible for the deposit was derived from the subcontinental lithospheric mantle. These deposits were further altered through chemical interactions with both hydrothermal interactions as well as meteoric waters. The carbonatite was enriched further through partial melt of a small depleted mid-ocean ridge basalt as well as an enriched mantle-1 signature suggested to be derived from subduction of the Farallon crust.

Closer examinations of the complex address the questions including, can it be done economically, are there environmental safeguards in place, what are the alternatives and how can the materials be extracted responsibly. The Mountain Pass Mine remains the most viable source for the United States because of its grade, size, and simple metallurgy.

The amount of research completed on the Bear Lodge complex is significant and because of this amount of work completed it provides insights into other global localities.

SESSION TITLE: Theme 7: Critical Minerals for Energy Diversification

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Unconventional lithium play in the Neuquina Basin-Argentina: Potential resources of lithium from oil field brines.

AUTHORS (FIRST NAME, LAST NAME): Raul Gutierrez¹, Gustavo Dardo Vergani², Gonzalo Mauro de la Hoz³

INSTITUTIONS (ALL):

1. Tecpetrol
2. Empty
3. Empty

ABSTRACT BODY:

Abstract Summary: The need to take urgent actions against climate change, accelerated the vision that renewable electricity generation sources can, in the short or medium term, replace hydrocarbons. For this reason, there is currently a worldwide demand for lithium since it is highly required in the manufacture of batteries for electric vehicles, smartphones and on a large scale for energy storage. Nowadays, the metal production capacity is geographically limited, which is why, it will not only have to increase, but also diversify into different sources of lithium to guarantee global supply.

The world lithium supply comes from two main resources: pegmatites (26%), and brine deposits (58 %), but currently 70% of the world production comes from pegmatites and 30% from brines. In Argentina, the main lithium production is restricted to the Puna region from brine deposits found in salt flats. The most common extractive method is solar evaporation in pools. Although processing costs are low and efficient, it is strongly dependent on arid climate conditions.

It is estimated that around 3% of the world's lithium resources are contained in oilfield brines, as can be seen in different places of the United States (North Dakota, Wyoming, Oklahoma, Arkansas, and East Texas). The Smackover Formation in the Gulf Coast of the United States hosts 1 million metric tons of lithium resources. This allows lithium to be quickly recovered applying technologies such as adsorbents, membrane-based processes and electrolysis-based systems.

The following work aims to give visibility to possible unconventional sources of lithium in volcanic reservoirs in the Neuquina Basin, from oil field brines. Additionally, other prospective zones are mentioned in other types of reservoirs such as evaporitic and siliciclastic.

At present, there are no public data about the presence of lithium in chemical analysis from oil field brines in Neuquén basin, since does not belong to the commonly determined ions. We propose a series of studies and places where the characterization of oil field brines could be carried out in order to confirm the relative value of lithium as a recoverable mineral. This could allow the incorporation of a new source of lithium in Argentina, which extraction would not require the drilling of new wells and companies could benefit by reducing their costs from the income generated with the recovery of lithium and helping in the transition towards a circular economy.

SESSION TITLE: Theme 7: Critical Minerals for Energy Diversification

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Radiometric mapping for coltan prospection in shallow alluvial deposits using in situ gamma ray spectrometry with NaI detector

AUTHORS (FIRST NAME, LAST NAME): Emilio Darriba¹, Haydn Barros²

INSTITUTIONS (ALL):

1. Nuclear Physics Laboratory, Simón Bolívar University, Venezuela - Geosciences and Environment Laboratory Cergy, CY Cergy Paris University, France

2. Nuclear Physics Laboratory, Simón Bolívar University, Venezuela - LabNuclear Technical Services LLC. TX, US

ABSTRACT BODY:

Abstract Summary: Coltan is a strategic mineral as it is one of the most important ores for the extraction of tantalum and niobium, two resources with very special physicochemical properties and of enormous interest for technological development from the 20th century (Hughes et al. 2011). The concentrations of uranium and thorium in Venezuelan coltan samples, previously measured by the Simón Bolívar University Nuclear Physics Laboratory (LFN-USB) and the previous description of several alluvial deposits in the Parguaza Region (southern Venezuela) showed the potential feasibility of localizing shallow coltan deposits using gamma-ray spectrometry by mapping the radiation associated with U and Th in these minerals. In this work we investigate this probability by using a high-density scintillation detector (NaI 4"x4" Bicron 4H4/3). Coltan samples were used on a test field conditioned to emulate a shallow alluvial deposit, as those observed in some areas of the Parguaza region, obtaining that for detailed prospecting a 2.5x2.5 m² spaced survey grid using a BGO detector is effective in detecting significant quantities of coltan (kilograms), even at a depth of 40 cm (depth at which artisanal extractions have been described in recent years). The need to prioritize the quantification of thorium and especially uranium was also evidenced, using their more energetic emission lines. This first approach for the prospection of coltan showed promising results with data processing allowing a clear identification of coltan location. The high energy gamma emissions of U (1765 keV) and Th (2615 keV) have a high penetrating power so they can easily pass through several centimeters (near to a meter in the tested cases). This is why the proposed method is rather adequate in a context with many scattered spots of some kilograms of coltan each, buried up to 1 m underground. Since most of the low energy emission of the gamma spectrum (also the more frequent from zones without coltan) will be attenuated (filtered) by the ground, the quantification of the total-count has been confirmed to be a good classifying method for larger formations or different geological areas. While on the other hand, a detailed high special resolution survey focused on the detection and quantification of U and Th, is a way to track down coltan sources, resulting in the location of what artisanal miners describe as "sweet spots".

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Recognition of Deep-Water Deposits Using Machine Learning / Deep Learning Routines. (Colombia-offshore).

AUTHORS (FIRST NAME, LAST NAME): Marcelo Garcia¹, Antonio Velasquez², Luis Gerardo Figueroa³

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol Brasil
3. Ecopetrol

ABSTRACT BODY:

Abstract Summary: This article explores how AI can assist the geoscientist to do a faster and accurate seismic interpretation work, reducing time and costs. We have tried machine learning and deep learning approaches for addressing deep-water deposits, in the case of Complex Channels (CC). The Aggregate Channel Features (ACF) algorithm detected small segments of the CC but could not enclose the whole stratigraphy element. The latest experimental results using Regions with convolution neural networks (R-CNN) algorithm confirmed high efficiency to enclose the whole CC in a single box even more, the U-net went deeper, recognizing every detail that compounds the CC, facilitating the interpretation enhancing recognition of lateral and vertical distribution of the stratigraphic element. This result allowed to include CNN's in our current AI system, available for replicability to each interpreter into Ecopetrol.

Keywords: Deep-water Deposits, Machine Learning, Deep Learning, Regions with convolution neural networks, Aggregate Channel Features.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Using AI Tools to Fill Gaps in an Incomplete Well Log Database

AUTHORS (FIRST NAME, LAST NAME): Hodei Uzcheda¹

INSTITUTIONS (ALL):

1. Terractiva Consulting

ABSTRACT BODY:

Abstract Summary: One common issue found when working with well log data is the irregular abundance/availability of the different parameters that may be registered. This is especially true when working with datasets collected in different campaigns that may span through many years, even decades. Artificial Intelligence may be useful to fill gaps in the original database, resulting in a more complete, standardised one. The process can be performed iteratively, successively populating the database with missing parameters, starting with those for which there are more available training data and whose results are more reliable. In this work, we present an example in which we filled an incomplete dataset consisting of wells provided by the UK National Data Repository (NDR) of the Oil & Gas Authority (OGA). The performance of some of the most commonly used artificial intelligence methods (random forest, multi-layer perceptron, gradient boosting etc.) was tested varying their hyperparameters until reaching an adequate result. A segmented analysis of the predictions was carried out to determine whether the regression reliability varies depending on properties such as lithology, stratigraphic unit, location, etc. If the predicted values are accurate enough, filling the gaps also helps to improve the training and application of classifiers as more observations may be included.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Assisted 3d Model Construction And Facies Propagation In Golfo San Jorge Basin Reservoirs For Modelling Eor

AUTHORS (FIRST NAME, LAST NAME): Jose Damian Llanes¹, Alejo Viñales², Juan Juri³, Mario Grinberg⁴

INSTITUTIONS (ALL):

1. YPF S.A.
2. YPF S.A.
3. YPF S.A.
4. Empty

ABSTRACT BODY:

Abstract Summary: Three-dimensional modelling is at the critical path to map the by-passed oil in multilayer fluvial systems in the San Jorge Basin. Integrated reservoir modelling teams dedicate an important amount of time to create these three-dimensional models to decrease risk pursuing chemical injection for enhanced oil recovery. Traditional static reservoir modelling requires an important effort from the geologist to construct the interwell correlation. The objective of this work is to show the implementation of two unsupervised algorithms to automate/assist integrated reservoir modelling. We create multiple possible three-dimensional models of real multilayer static reservoirs and accelerate simulation. The first part of the work obtains the stratigraphic representation of the entire reservoir structure. We use the available lithology well logs as spontaneous potential and gamma ray to identify automatically the permeable and shale rocks with unbiased interpretation by their deflection responses in each well for the entire target reservoirs. Then we construct a graph in which each of the deflections is represented by a node. The edges that join each pair of nodes have an assigned weight depending on the difference in depth and the distance in plan of the nodes. Then we use an adapted version of the Girvan-Newman algorithm to make a community detection by eliminating nongeological connections/features, to find the community with greater modularity. These communities represent the existing correlations between the deflections of the different wells.

In the second part of this work, we obtain the facies distribution in the reservoir, using 3D Markov chains. We implemented Jaccard distance to measure the mismatch of geological features and objects between the true synthetic case and reconstructed model. Through modeling of two incomplete synthetic cross section cases using Markov chain propagation of a transition matrix the reconstruction reveal that we recover 90% of the original case even when we Input only 5% of the true data initially in the model. Then we tested a very fine real 3D model created by an experienced geologist. The analysis of the reconstructed model features reveals that the Jaccard distance is a reliable indicator of the geological features. Using the computational algorithms implemented, it is possible to obtain a stratigraphic model and the facies model in less than four hours that speed up definitely reservoir modelling.

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Comparative determination of In-situ oil content in shale oil plays

AUTHORS (FIRST NAME, LAST NAME): Jinbu Li¹, Min Wang², Liang Xu³, Shuangfang Lu⁴

INSTITUTIONS (ALL):

1. China University of Petroleum (East China)
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ABSTRACT BODY:

Abstract Summary: The determination of accurate in-situ oil (hydrocarbon) content is critical for shale oil plays to determine total resource and their recovery in-place. Recently, although the correction of light hydrocarbons to S1 has been studied via the sealed or pressure-preserved cores, in the process of S1 detection using Rock-Eval and TD-GC methods, some hydrocarbons are still lost due to the crushing of samples. However, this has not received enough attention. Here, we present a methodology applied to pristine cores to determine the in-situ oil content per gram of rock (mg/g) by combining geophysical and geochemical techniques, which include four parallel methods: Dean-stark, NMR T1-T2 mapping, TD-GC-SE, and Rock-Eval-SE. The former two methods are conducted on the small block shales with 3-5 cm size pieces, while the latter two methods are TD-GC and Rock-Eval experiments (powders, 60 mesh) combined with solvent extraction (SE) to determine total oil content. In addition, a series of experiments such as NMR, TD-GC-SE, and Rock-Eval-SE are performed on the pristine shales with different storage time to investigate fluid changes. Examples of 109 lacustrine pristine (pressure-preserved) shale examples reveal that both the total oil and water contents measured by the Dean-stark and NMR methods show good agreement. A novel approach and workflow, namely NMR T1-T2 mapping is proposed, and its advantages in determining the total oil content and oil saturation of the pristine shales are discussed. The total oil content detected by the four experiments follows the order of Dean-stark (av. 14.74 mg/g) \approx NMR (15.54) > TD-GC-SE (10.24) > Rock-Eval-SE (8.12). Sample crushing and crucible waiting process of Rock-Eval 6 results in a loss of one-third to one-half of the total oil in pristine shales. To the best of our knowledge, this is the first time to notice that the total oil content of the pristine shales is underestimated by the Rock-Eval and TD-GC method, and the previously proposed correction coefficient of S1 seems to be 50 percent underestimated. During the storage (open system) of pristine shales, both water and free oil/light hydrocarbons (C14-) evaporate quickly, while adsorbed oil remains unchanged. Thermal maturity and TOC are the main control factors affecting S1 evaporation. The understanding of in-place fluids such as hydrocarbon content, components, and their occurrence in pore space can provide basic data to obtain accurate phase characteristics (GOR).

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Leveraging “Res-Frack Analog” Insights From the Eagle Ford to Optimize Development of Jafurah Basin Shales in Saudi Arabia

AUTHORS (FIRST NAME, LAST NAME): Jason Eleson¹, Michael Whitney²

INSTITUTIONS (ALL):

1. Enverus

2. Enverus

ABSTRACT BODY:

Abstract Summary: Significant investments have been made to evaluate shale gas & condensate potential within the Jafurah Basin of Saudi Arabia. The main drilling target is the Middle Jurassic Tuwaiq Mountain formation, calcitic and TOC-enriched mudstones deposited in depositional lows of the carbonate-prone Arabian plate. The Jafurah Basin was later deeply buried during the closing of the Tethyan Sea, and horizontal drilling targets are now mostly within the gas and condensate window. Published research indicates that multiple drilling and completions strategies have been attempted here, but optimal development design has not yet been achieved. To aid in Jafurah shale development optimization, the Late Cretaceous Eagle Ford formation of Texas was chosen as a “res-frack analog” because of comparable lithology, depth of burial, pressure and an abundance of drilling and completions data. Hundreds of drilling, completion and geologic variables were run through a gradient boosting machine learning model, which enabled identification of a smaller subset of variables most impacted productivity and economics. Play-wide results indicate spacing decisions had the largest impact on oil productivity, whereas gas production was more impacted by geologic variation. Focusing on post-2016 completion variables from study area wells, our results show that of the six operators in the region, ConocoPhillips and Devon have hydrocarbon recoveries and half-cycle NPVs closest to optimal. Our modeling indicates that the bottom two-thirds of operators have potentially left 21-32% of optimal recoveries and \$908MM of NPV across 475 wells. Because Jafurah horizontal wells have targeted gas- and condensate-prone carbonate mudstones, a subset of high carbonate, gas/condensate Eagle Ford wells were further analyzed. The Lower Eagle Ford was isolated for this study, and spacing calculations were performed utilizing an average radial distance for all zones. Results indicate that hybrid fracturing jobs outperformed slickwater fluid design on NPV per well and per section metrics. Optimal proppant-to-fluid ratios and well spacing was exemplified by ConocoPhillips relative to other operators. These insights from the Eagle Ford can be leveraged to rapidly optimize drilling and completion strategies in the Jafurah Basin. Furthermore, this study illustrates how North American unconventional reservoirs will be key “res-frack analogs” that can help unlock potential from other international shale plays.

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Modeling and Characterization of Multimineral and Multiscale Digital Rocks of Shale Samples

AUTHORS (FIRST NAME, LAST NAME): Yuqi Wu Wu¹, Keyu Liu², Chengyan Lin³, Chunmei Dong⁴

INSTITUTIONS (ALL):

1. Shandong Provincial Key Laboratory of Deep Oil and Gas, School of Geosciences, China University of Petroleum (East China)

2. China University of Petroleum (East China)

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ABSTRACT BODY:

Abstract Summary: The exploration and development of shale gas require accurate modeling and characterization of shale samples. Digital rocks have been widely used to characterize the shale samples, predict their petrophysical properties, and understand the pore-scale transport mechanisms in micrometer and nanometer pore systems. Previous studies from numerous geologists have indicated that the shale samples involve multitype minerals and multiscale pore systems. Therefore, such factors must be considered when shale models are constructed and characterized. Nevertheless, the imaging techniques such as X-ray CT scanners and FIB-SEM have to make a balance between high resolution and large field of view. In other words, current 3D imaging techniques either cover the large-scale structures at a low resolution or cover a small region at a high resolution. To address this issue, this study proposes a novel modeling technique, called process-based modeling, which combines the discrete element modeling method, quartet structure generation set algorithm, and morphology operation techniques. The proposed technique can generate various types of minerals (such as quartz, feldspar, calcite clay minerals, and pyrite) and pore structures (interparticle pores, intraparticle pores, and organic-matter pores) in shale samples. In order to evaluate the performance of the algorithm, multiple shale models were constructed. By analyzing the volume fraction of each component in the models and the pore/throat size distribution, average coordination number, and fractal dimension, and the tortuosity of the pore structures, the shale models were characterized. The modeling accuracy of the method was tested by comparing the petrophysical properties from the constructed digital models and experimental data. Based on the constructed shale models, the single-phase flow simulation of the gas was carried out using pore network modeling. In summary, this study presents a powerful digital core modeling algorithm. Compared with other modeling algorithms, the advantage of this method is that it fully considers multitype minerals and multiscale pore systems, and the constructed multicomponent and multiscale digital cores can be applied to the study of various petrophysical properties.

SESSION TITLE: Theme 5: Unconventional Resources

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Utilizing Borehole Images to Mitigate the Data Resolution Blind Spot of Subsurface Unconventional Reservoir Characterization

AUTHORS (FIRST NAME, LAST NAME): Andy Wray¹, Elia Haddad², Edgar Arteaga³, Juan Herrera⁴

INSTITUTIONS (ALL):

1. Schlumberger
2. Schlumberger
3. Schlumberger
4. Schlumberger

ABSTRACT BODY:

Abstract Summary: The vertical resolution of most existing downhole log measurement data is readily acknowledged to be insufficient in providing a representative characterization of thin bed properties that are common to unconventional reservoirs and can potentially have a significant influence on well performance. This data resolution blind spot can be mitigated by core analysis, but coring introduces an associated operational risk and additional cost to data acquisition programs. By leveraging the enhanced vertical resolution and wellbore coverage of borehole images, an innovative new workflow demonstrates how high-resolution characterization of thin bedded reservoirs can be achieved in a cost-effective manner with lower operational risk. The outputs of this workflow aim to enhance geological understanding, petrophysical evaluation and drilling & completion optimization. This case study shows how borehole image data is used to provide thin bed characterization of true stratigraphic thickness-corrected bed lamination density, average bed resistivity, adjacent bed resistivity contrast and per-depth bed thickness classification. In addition, the workflow also provides a dip-corrected borehole image-based, high-resolution facies model that captures thin bed lithology variations through the section. Finally, by integrating the borehole image data with an acoustically derived sonic stress profile, considering anisotropic properties, the workflow also generates high-resolution outputs of the closure gradient and unconfined compressive strength (including geomechanical property borehole images). These high-resolution geomechanical property outputs help to support drilling optimization of horizontal wellbores and more representative hydraulic fracture stimulation modeling. Together, these outputs provide a more representative subsurface characterization of unconventional reservoirs with respect to both vertical resolution (thin beds) and facies heterogeneity observed around the wellbore with the borehole images. Ultimately, the workflow aims to support optimized lateral target selection through an enhanced understanding of how thin bed rock properties impact reservoir quality and drilling & completion performance. By integrating the results of this new workflow with other available downhole data and calibration to core, it is considered that the existing data resolution blind spot encountered with characterizing many unconventional reservoirs can be significantly reduced.

SESSION TITLE: Theme 7: Critical Minerals for Energy Diversification

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

EXTENDED ABSTRACT: Reservoir Characterization and Fluid Identification of the Complex Aluminiferous Rock Series Using Advanced Logging Technologies, Ordos Basin

Yuting Hou¹, Yong Wu¹, Xiaoming Yang¹, Fangfang Wu², Xunqi Liu², Huayang Li², Jinlong Wu², Xianran Zhao², Shenzhuan Li², Xiao Gu², Zheyuan Huang²; 1. PetroChina Changqing Oilfield Company, 2. Schlumberger China

Summary

A breakthrough has been made in natural gas exploration of bauxite reservoirs in Permian Taiyuan Formation. Aluminiferous rock series is widely developed in Ordos Basin, and it was thought to be good caprock, but nowadays it had been proven to be good gas reservoir. This kind of special rocks can be identified easily by conventional logs with the characteristics of high GR, high neutron porosity, high bulk density and low compressional sonic slowness., however, it's a big challenge to identify the 'sweet spot' qualitatively and characterize the reservoirs quantitatively only using conventional logs due to special mineral contents and complex pore structures. And it's very difficult to identify the fluid types. To better reveal the reservoir quality and identify fluid types, advanced logging technologies were integrated to solve the problem, and achieved big success.

Introduction

The aluminiferous rock series is widely developed on the weathering crust of Lower Paleozoic carbonate rocks in Ordos Basin. Because of the Carboniferous transgression from southeast to northwest, the aluminiferous rock series is mainly developed in the Upper Carboniferous Benxi Formation in the northeast of the basin, and the Lower Permian Taiyuan Formation in the southwest of the basin (Gao Lan et al., 2014). The aluminiferous rock series is characterized by high GR (usually higher than 300 gAPI), high neutron porosity (usually higher than 40 pu), high bulk density (ranges from 2.4 to 3.2 g/cc) and low compressional sonic slowness (usually less than 70 us/ft), high uranium (usually higher than 50 ppm) and quite high thorium (usually higher than 50 ppm)(Fig.1), and it had been thought to be the regional caprock of the weathering crust gas reservoirs in oil and gas exploration (Fu Jinhua et al., 2021). Therefore, it didn't get much attention even though many wells showed high total gas values in the aluminiferous rock series, and no cores were obtained. To explore new reservoir types and discover potential gas bearing layers, the aluminiferous rock series attracted more and more attention. To better evaluate the reservoir, advanced logging technologies were applied, and an integrated reservoir evaluation was carried out by combining advanced logging data as well as core analysis data.

First, elemental concentrations of silicon, calcium, aluminum, iron, sulfur, magnesium, potassium, sodium, manganese and carbon et al. were obtained based on gamma ray spectroscopy data, and minerals were derived by oxide-closure method; second, lithology-independent porosity was calculated using nuclear magnetic resonance (NMR) logging data, and pore structure was analyzed; third, rock texture was classified according to high resolution electrical image data; fourth, 3D far field sonic data was used to identify features far away from the wellbore; fifth, fluid types were identified using innovative approach assisted with traditional methods. Moreover, the gas accumulation conditions were discussed by integrating source rock and reservoirs.

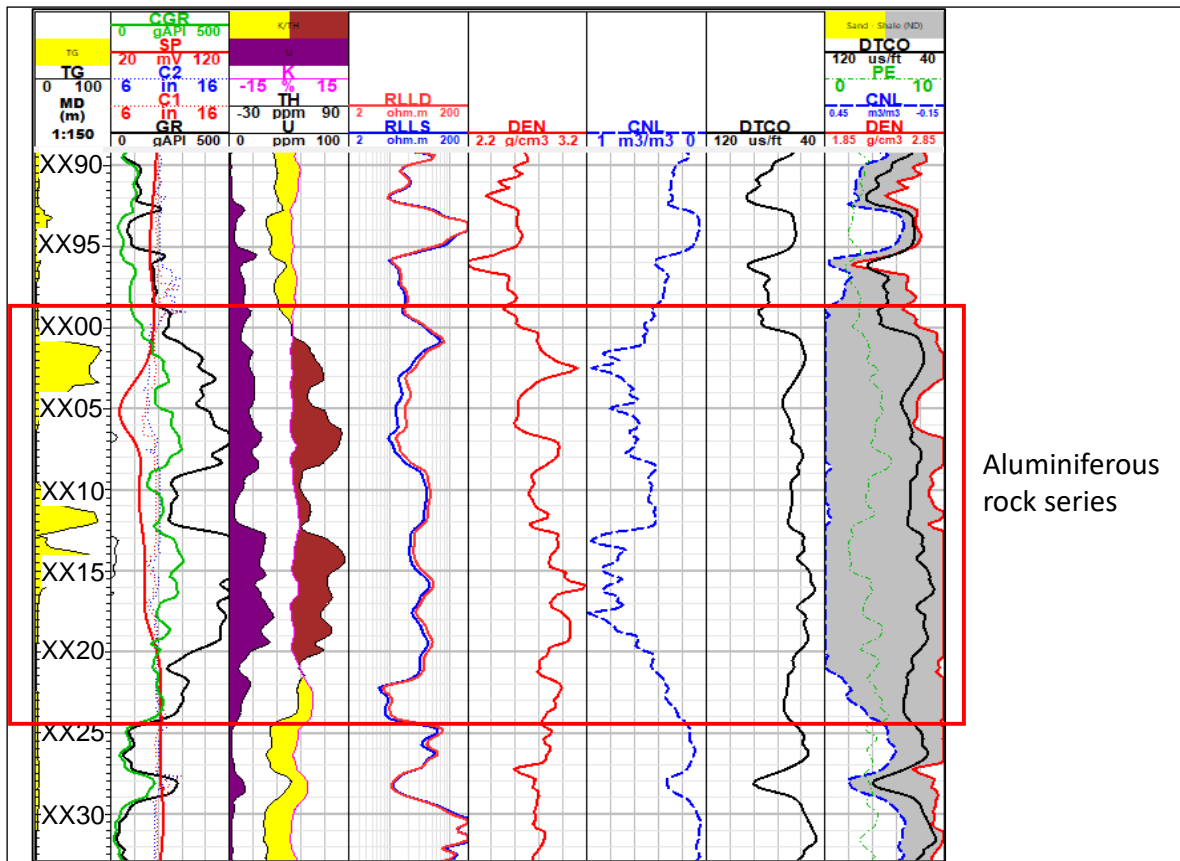


Figure 1-Conventional log characteristics of aluminiferous rock series

Lithology Identification

The aluminiferous rock series contains many minerals, including illite, kaolinite, quartz, feldspar, calcite, dolomite, bauxite, pyrite, siderite, et al. It's very difficult to get accurate mineral types and contents only by conventional logs. Gamma ray spectroscopy tool can measure more than 16 types of elements and can get more accurate mineral contents (Radtke, R. et al., 2012).

Based on the results of gamma ray spectroscopy data, the mineral contents of alumina, ferric oxide, clay, quartz & feldspar & mica, pyrite, siderite, calcite, dolomite and TOC were calculated using oxide-closure method. Based on the content of the elements and minerals, the lithologies were classified into three types, bauxite, bauxitic shale and carbonaceous shale. Bauxite has high aluminum and low silicon, high alumina, low clay, and low quartz & feldspar & mica; bauxitic shale has low aluminum, high clay and high quartz & feldspar & mica; carbonaceous shale has high TOC, high clay and low alumina (Fig.2). The aluminous rock series can be divided into 3 zones: the upper zone, the middle zone and the lower zone. The lower zone is mainly bauxitic shale with high content of pyrite and clay; the middle zone is mainly bauxite with high alumina; the upper zone is bauxitic shale and carbonaceous shale with high TOC and high clay.

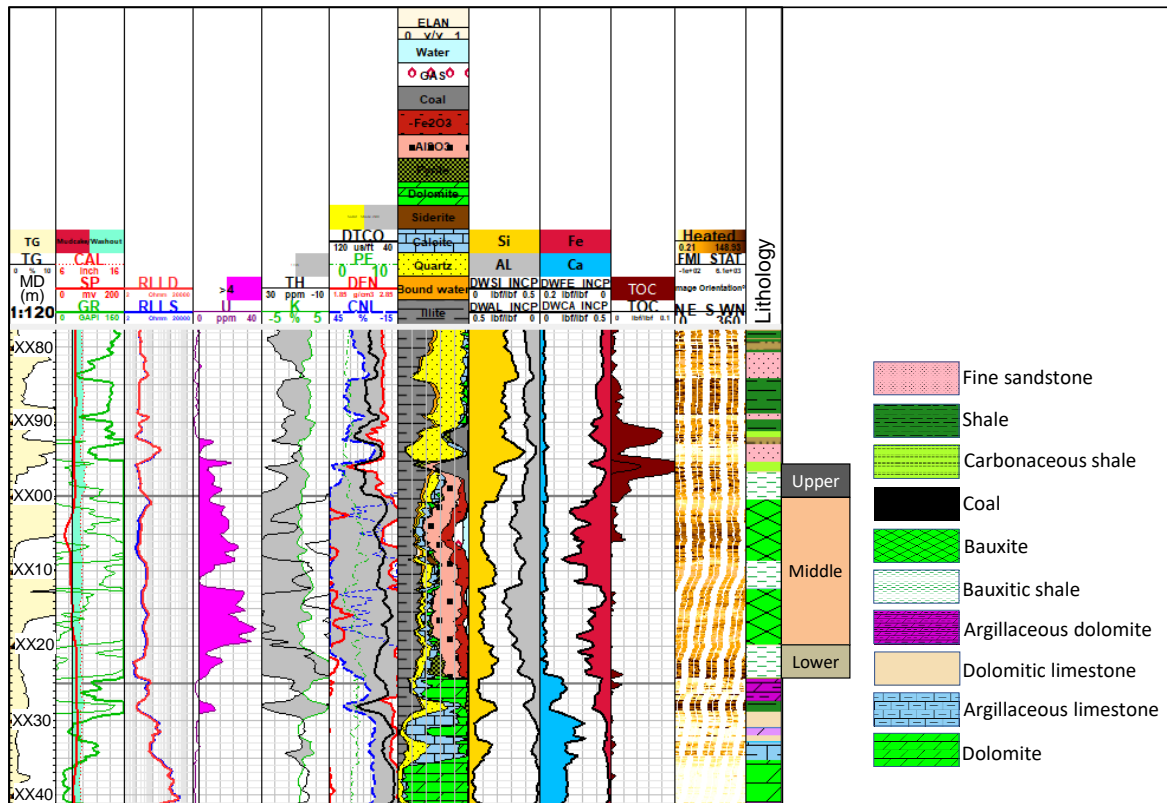


Figure 2-Lithology characteristics of aluminiferous rock series

Rock Texture Classification

Rock texture can indicate sedimentary environment or technic information, and different textures may have significantly different petrophysical properties. Based on the electrical images and cores, there are few natural fractures developed in the aluminiferous rock series. And the aluminous rock series can be classified into 5 types of textures, namely thinly layered, weakly layered, massive, patchy and psephitic (Fig.3). Massive texture looks homogeneous and has no beddings or fractures developed, it is usually formed in a rapid deposition or in a very stable sedimentary environment. Patchy texture has conductive heterogeneities developed on the relatively bright background, and it is formed due to some porous heterogeneities with dissolution pores developed. Thinly layered texture has very thin layers developed, which is usually formed in a very quiet environment with very slow deposition rate. Weakly layered texture has some relatively thicker layers, and the occurrence of the layers is not stable, which may be formed in a relatively strong hydrodynamic environment.

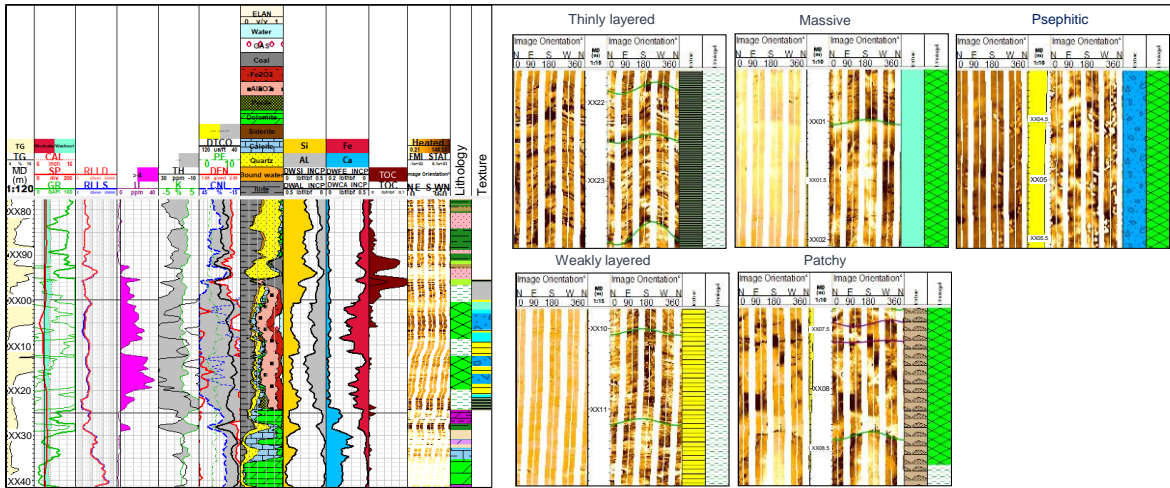


Figure 3-Texture classification of aluminiferous rock series based on electrical image data

Porosity Calculation and Pore Structure Analysis

Complex minerals result in various matrix properties such as matrix density, matrix neutron, and matrix slowness which are the keys for porosity calculation using traditional method. However, to quantify the matrix properties is quite challenging for aluminous rock series. One lithology independent approach, nuclear magnetic resonance (NMR) logging was used to evaluate porosity and pore structure. NMR can provide very accurate lithology-independent porosity and it is also the best choice for evaluating the reservoir pore structure (Kleinberg et al, 1994). 3 types of porosities can be obtained from NMR data, namely free fluid porosity (FFV), effective porosity (FFV_3ms) and total porosity (MRP). MRP and core porosity (CPOR) matches well in the aluminous rock series, and the interval of XX46-XX51m has the highest porosity in this case (Fig.4). Moreover, this Interval has high free fluid porosity and long T2 distribution, which indicates that there are lots of big pores developed in this Interval, and it has been proved by the cores (Fig.5).

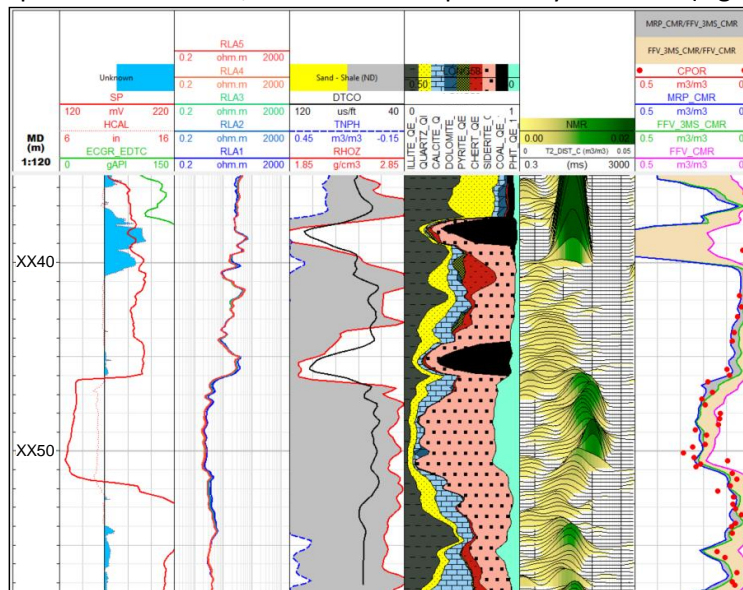


Figure 4-Comparison between NMR porosity and core porosity for aluminiferous rock series

Lots of dissolution pores were observed from the cores and thin sections at the Interval of XX46-XX51m (Fig.5). While the interval of XX53-XX54m has low total porosity and very low free fluid porosity, and there is only a few dissolution pores were observed in the cores and thin sections.

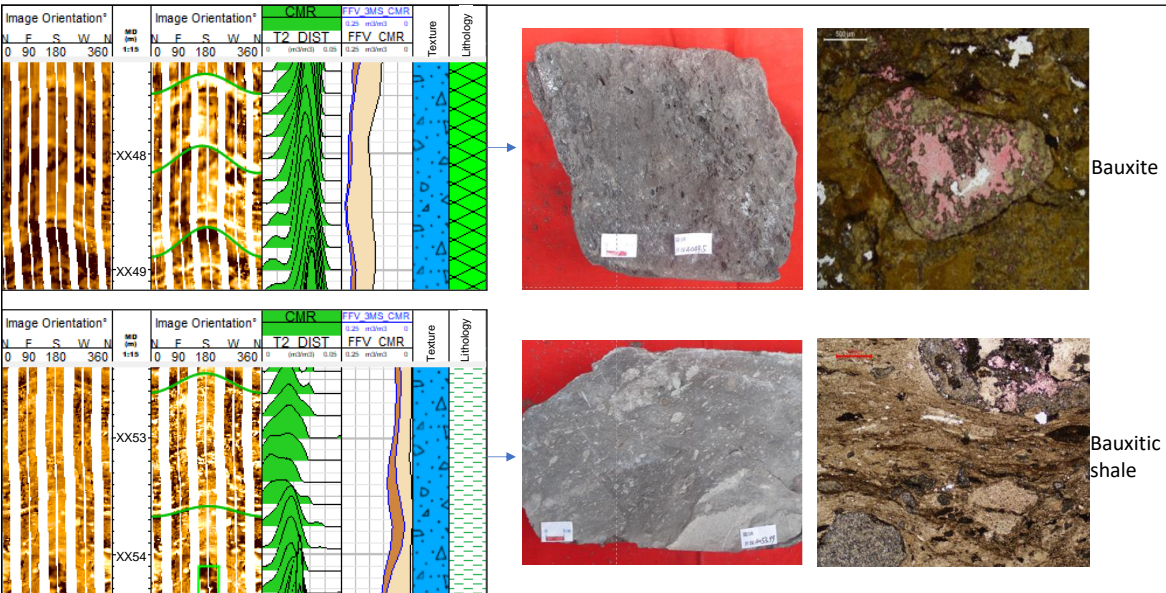


Figure 5-Pore structure analysis by NMR data and core data for aluminiferous rock series

To evaluate the pore structure in more detail, T2 distribution is usually divided into 8 logarithmic equidistance ranges, e.g. 0.3 ms, 1 ms, 3 ms, 10 ms, 30 ms, 100 ms, 300 ms, 1000 ms and 3000 ms, and the bin porosity for every range can be calculated and used for pore structure analysis (Coates et al., 1999). Based on the histogram of bin porosities, massive texture, thinly layered texture and weakly layered texture have low effective porosity, low free fluid porosity, mainly small pore size, and the pore structure is poor; psephitic texture has high effective porosity, high free fluid porosity and big pore size, and it has good pore structure (Fig. 6).

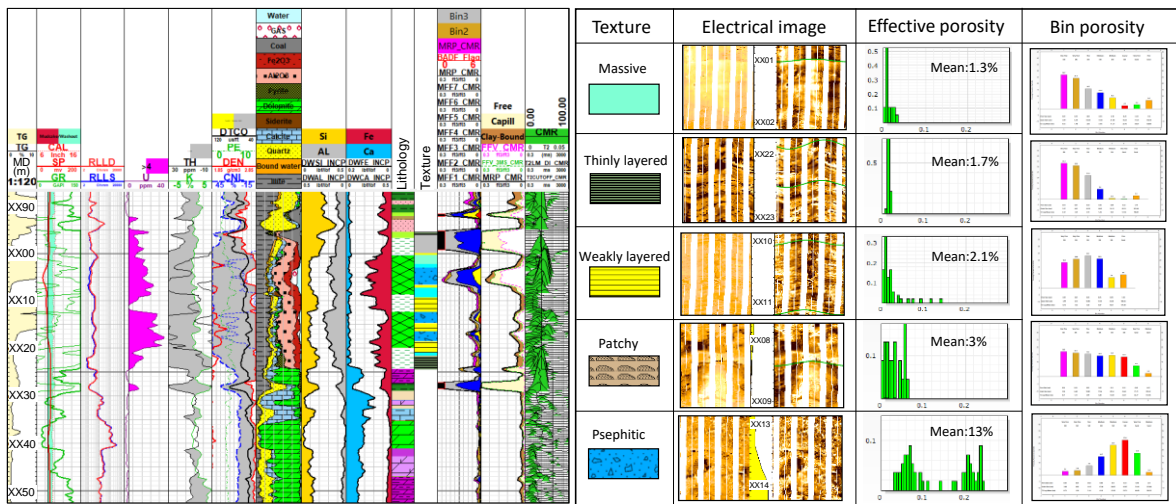


Figure 6-Pore structure analysis of different textures of aluminiferous rock series

Besides rock texture, mineral content also plays a very important role on reservoir quality. For the case in Fig.7, psephitic bauxite has many big pores and very high effective porosity, while psephitic bauxitic shale has small-medium pores and none free fluid porosity (Fig.7).

Good reservoirs are usually located in psephitic bauxite at the middle zone of the aluminous rock series. The average effective porosity of psephitic bauxite is 13%, and some intervals can reach 22%, which is quite better than most of the clastic reservoirs and carbonate reservoirs in Ordos Basin.

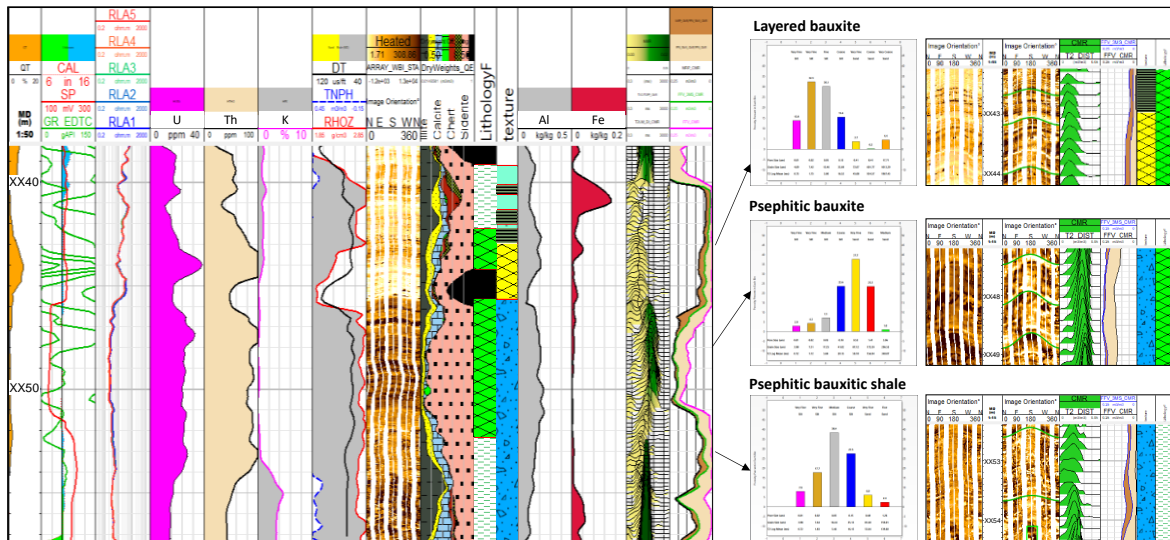


Figure 7-Pore structure analysis for different lithology

Far Field Feature Delineation

3D far field sonic processing quantitatively delineates sonic reflectors away from wellbore. It provides migration images of different azimuth, together with tadpoles indicating the true dip and azimuth of these reflectors (Bennett, N. et al., 2019).

Anomaly is shown in bauxite layer in 3D far field sonic data in this well (Fig.8). Discontinuous energy pieces appear in the migration image of different azimuth. 3D far field sonic processing indicates these events could be scattered sonic reflectors with dip angles between 70 to 80 degrees. And these possible reflectors are 20 to 45 meters away from the wellbore, which may indicate that the porous and permeable zones may have a good extension.

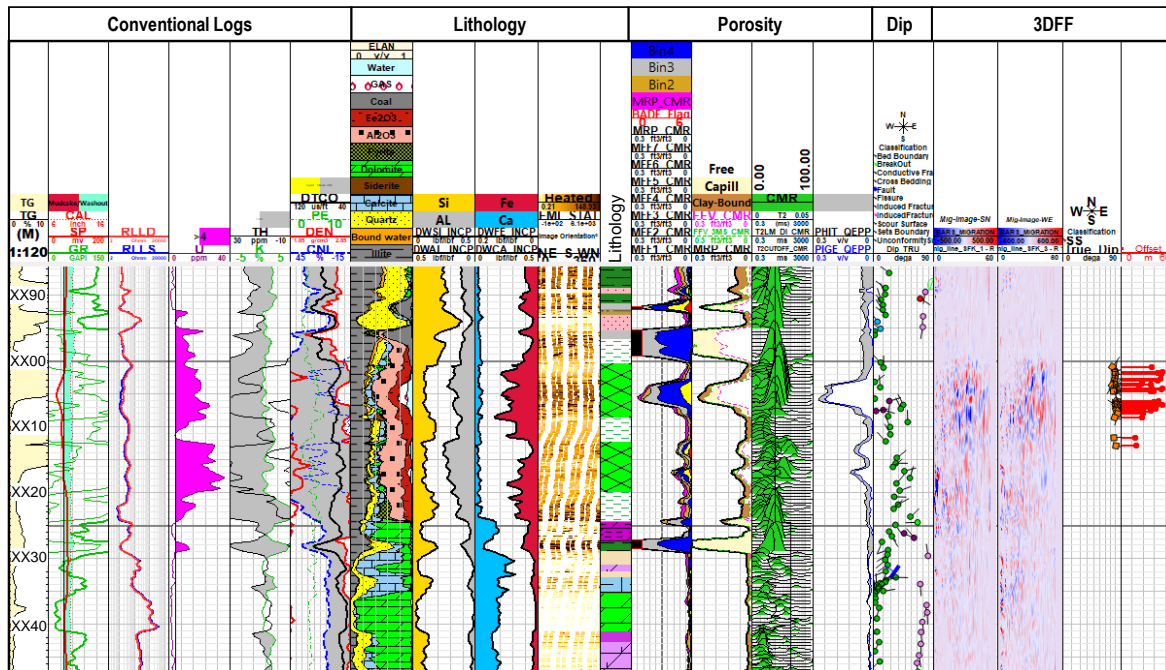


Figure 8-3D Far field sonic processing result of aluminiferous rock series

Fluid Identification

Triple combo logs are susceptible to such complex lithology, especially for fluid identification. The most important solution to this challenging mission is to use chlorine concentration (DWCL_INCP) from advanced measurement of gamma ray spectroscopy data. Chlorine has different characteristic spectra from the formation and borehole because of differences in gamma-ray scattering. And the shape of the borehole spectrum varies with the borehole environment. With the parameters of hole size and borehole fluid density, the chlorine yields were recombined and the borehole chlorine was determined by the algorithm which had been derived from 129 laboratory measurements and 2995 numerical simulations spanning a diverse range of conditions (Jeffrey Miles et al., 2020). And then the background was subtracted from the total chlorine yield to get the formation chlorine yield, which was converted into a formation concentration (DWCL). In the 22nd track of Fig.9, the chlorine concentration (DWCL_INCP) drops with increasing effective porosity (PIGE) in zone 14, which indicates gas bearing.

Water volume was computed with chlorine concentration, parameterized salinity, and total porosity. The calculated water saturation was shown in the 23rd track of Fig.9. It was observed that 3 gas zones (zone 14, zone 17, and zone19) had gas saturation ranging from 60% to 80%.

In addition, traditional saturation methods were applied in this case too. The quantitative saturation calculation with Archie equation involved resistivity and accurate porosity from NMR data. The gas saturation of 3 gas zones (zone 14, zone 17, and zone19) driven from resistivity ranges from 60% to 75%. And these 3 gas zones had relatively low PR (0.18-0.21) and VPVS (1.58-1.7) in comparison with other bauxite dry zones like zone 13, zone 16 or zone 20.

These 3 gas zones were perforated later premised on fluid integrated analysis, and the final natural gas production (67,400m³/day) was in accordance with our evaluation.

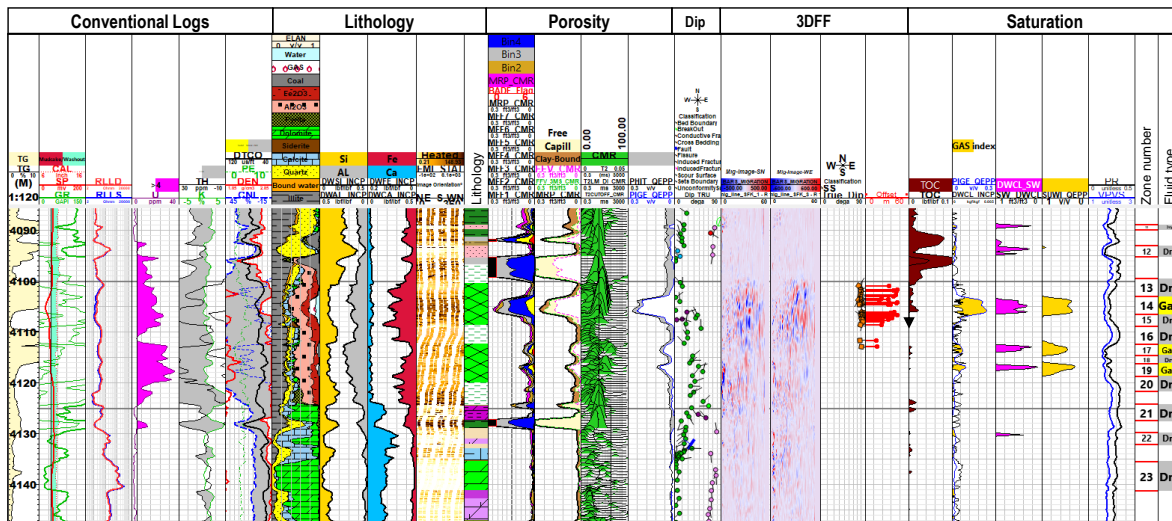


Figure 9-Fluid identification result for aluminiferous rock series

Natural Gas Accumulation Condition

The formation of bauxite gas reservoir results from many favorable conditions.

Lower Paleozoic carbonate rocks experienced about 14 million years of weathering and leaching process before the aluminous series rock deposited, which provide sufficient aluminous minerals for the formation of bauxite; tidal flat and lagoon sedimentary environment, frequent transgression and regression provide the proper environment for bauxite formation, and the lower part of paleogeomorphology is beneficial to form thick and high-quality bauxite; dissolution and leaching process formed lots of dissolution pores, including residual lattice dissolution pores, intragranular dissolution pores and matrix solution pores, which provide good storage space for natural gas accumulation. And according to gas source comparison, the accumulated natural gas was generated from the coal of Permian Taiyuan Formation and Shanxi Formation with high TOC ranges from 40% to 91%, and high Ro ranges from 2.4 to 2.66, which provides sufficient gas source for natural gas accumulation in aluminiferous rock series.

Conclusions

The aluminiferous rock series can be divided into 3 zones according to elemental concentrations and mineral contents. The bottom zone is bauxitic shale with high pyrite content; the middle is mainly bauxite with high alumina content; the top zone contains bauxitic shale and carbonaceous shale with high TOC content. Good reservoirs usually located at the middle zone.

The aluminiferous rock series can be classified into 5 types of textures according to electrical images and cores, namely massive, thinly layered, weakly layered, patchy, and psephitic. The psephitic bauxite has the best reservoir quality with high effective porosity, high free fluid porosity and more big pores.

Chlorine concentration method for fluid identification has a good application in bauxite reservoirs. High production wells usually have good source-reservoir configuration relationship and wide extension of high-quality reservoirs.

The achievements have dramatically improved geological understanding of the reservoir and provided valuable information for deployment of new wells.

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SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Integration of Carbon Capture Utilization and Sequestration to Develop A Sustainable Carbon Economy in India : A Review

AUTHORS (FIRST NAME, LAST NAME): Purnayan Mitra¹, Shubham B. Patel², Reddimi Sai Sampath Reddy³, Osama Shaukat⁴

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ABSTRACT BODY:

Abstract Summary: With Industrial Revolution happening in the 18th and 19th century, there has been a rapid increment in the usage of these fossil fuels as a source of energy in domestic, industrial, commercial and transport industry. However, huge amounts of gases like carbon dioxide, carbon mono-oxide, SO_x, NO_x, are produced during burning of these fossil fuels. The potential threats due to this gaseous emission include global warming, green house effect, bio-diversity degradation, ecological imbalance, climate change etc. The rising concern due to these threats have caused industries to look for ecofriendly technologies. Stringent rules have been framed to reduce the usage of fossil fuels and shift to renewable energies like solar, wind, tidal. But being natural sources there are chances of fluctuations in availability of the energies from these sources for power generations. Certainly therefore, the dependence on the fossil fuels couldn't be curbed zero due to unavailability of suitable alternatives. Therefore, the technology which got very popular is Carbon Capture, Utilization and Storage. In this technique the carbon dioxide produced is captured and then utilized in different forms or the captured carbon dioxide is stored for future applications. Many researchers have proposed that using this technique there are chances of net zero emissions of carbon dioxide in nature while we continue to burn fossil fuels. While many countries have already started utilizing this method to curb their carbon dioxide emissions, companies in India are still trying to adopt this technique. The carbon dioxide emission level has compounded annually with a growth rate of 3.1% in the past few decades in India primarily due to increased consumption of fossil fuels. So, adopting carbon capture utilization and sequestration (CCUS) technique is necessary to avoid the irreversible impacts of green house gas emissions. Utilization of carbon to produce methanol and other important petrochemicals gained high importance as a part of carbon capture, utilization and storage. Another popular application of CCUS is carbon mineralization. In this case study solution, we present a detailed study about the symbiotic relationship between Carbon Capture and Utilization (CCU) and Carbon Capture and Storage (CCS) and its market scope in India. We would also emphasize about how "Carbon to Waste Economy" is getting replaced with a "Sustainable Carbon Economy".

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: A Fracture Characterization Case Study from the Utah FORGE Enhanced Geothermal System Project, Utah, U.S.A.

AUTHORS (FIRST NAME, LAST NAME): Andy Wray², Juan Herrera¹, John McLennan³, Joseph Moore⁴, Pengju Xing⁵, Aleta Finnila⁶, Edgar Arteaga⁷, Erik Borchardt⁸

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5. University of Utah
6. Golder Associates Inc
7. Schlumberger
8. Schlumberger

ABSTRACT BODY:

Abstract Summary: The Utah Frontier Observatory for Research in Geothermal Energy (FORGE) is a full-scale field laboratory in south-central Utah, USA. The FORGE project is dedicated to advancing technologies, driving innovation, and growing expertise in Enhanced Geothermal System (EGS) development. The project is funded by the U.S. Department of Energy and managed by the Energy & Geoscience Institute at the University of Utah. The project aims to demonstrate EGS technologies that can be applied across the U.S.A. and globally, in hot, abrasive, low permeability rocks. Critical to the success of developing large-scale, economically sustainable EGS reservoirs is the ability to characterize, initiate and sustain the interconnected fracture networks required to extract heat in crystalline basement rocks over periods of 10s of years with small temperature declines. The granitic and metamorphic basement rocks at the Utah FORGE site have bottom hole temperatures close to 230 deg C, which pushes the limits of conventional wireline logging, drilling, and isolation tools. The application of through-the-bit conveyed logging technologies at Utah FORGE has proved effective at mitigating the downhole temperature challenge and provided for the logging of highly deviated injection wells. The integrated advanced analysis of resistivity and ultrasonic borehole image and dipole sonic data, including 3D far-field acoustic analysis, has provided a detailed subsurface characterization of fracture type, fracture intensity, fracture geometries and fracture apertures. These data have also provided the Utah FORGE team an enhanced understanding of the local stress regime and structural history, through borehole stress observations and fracture cross-cutting relationships. Ultimately, these fracture characterization data have been used to development a representative discrete fracture network (DFN) model, required for predicting the characteristics of the stimulated EGS reservoir. Simulations of the hydraulic stimulation of an injection well have predicted that existing natural fractures, represented by the DFN, could control the efficacy of the treatment and create a large volume of connected flow pathways in the stimulated region. This case study shows how existing technologies and expertise, developed from unconventional hydrocarbon reservoir characterization, are being leveraged to support subsurface fracture characterization and modeling in this pioneering geothermal project.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Venezuela as a Case Study: a short-term Roadmap for a Sustainable Future.

AUTHORS (FIRST NAME, LAST NAME): Marysol Mijares¹, Emilio Darriba², Gabriel Valdez¹, Melissa Delepiani¹

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ABSTRACT BODY:

Abstract Summary: Energy, as a key enabler for sustainable development, is a multidimensional issue that revolves around intertwined variables such as technology, society, environment, and politics. Energy resources are the biggest opportunity for rapid development that many poor countries have. Unfortunately, for many of them, it's been a missed opportunity. This is the case of Venezuela; despite its substantial available natural resources, the country faces a severe energy crisis that translates into a widespread shortage of domestic gas, transport fuel, and also frequent and unpredictable blackouts.

In addition, Venezuela is currently undergoing the worst economic crisis in its history: ongoing hyperinflation plus the lowest rankings of GDP portray the currency instability. However, this was not always the case, due to the oil-fueled boom of the 70s, the country became known as "Saudi Venezuela". Already by the 50s it had the 4th richest GDP per capita on Earth and was 12 times richer than China. Naturally, the rise and fall of this "Petrostate" shaped its particular energy context.

To propose a thorough solution to this complex emergency, the authors attempt to identify the root causes of the Venezuelan energy crisis by analyzing the evolution of its energy framework. To decode opportunities, the authors present a catalog of the Venezuelan energy potential of both non-renewable and renewable resources, compiled by research and collected data of well-known resources such as fossil fuels but also offering insight into neglected energy sources such as geothermal or nuclear. Furthermore, the authors examine the potential and limits regarding energy infrastructure projects in Venezuela, to identify priorities in terms of investment and a rapid yet feasible recovery from the crisis.

A short-term roadmap (30 years) of solutions is presented while taking into consideration cultural challenges, technological needs, socioeconomic priorities, environmental context, and viable policies. The discussion leads to the identification of multilateral strategies that must be implemented in a synchronized manner to be effective. Solutions are presented with a holistic approach, to help Venezuela recover from its most urgent socio-economic needs while heading towards a new stage of energy transition in which clean energy, science, and sustainable criteria lead the road towards prosperity.

Based on the 2nd place of the "Venezuela Energy Solutions for the Future" Case Competition.

SESSION TITLE: Theme 6: Intersecting Sustainability and the Geosciences

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Underground Natural Gas Storage: Evaluation of a Depleted Gas Reservoir – Rayoso Formation, Neuquén Basin, Argentina

AUTHORS (FIRST NAME, LAST NAME): Mercedes Perissé¹, Rayén P. Ferreyro Elizondo², Marcia J. Faviana³, Maria Victoria David⁴, Laura G. Constanzo⁵, Pablo A. Vázquez⁶, Álvaro E. Pose⁷, Damián E. Hryb⁸, Elanor Díaz⁹

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8. YPF S.A.
9. YPF S.A.

ABSTRACT BODY:

Abstract Summary: Underground Natural Gas Storage (UNGS) allows to store the surplus of gas production during low consume seasons (summer) and withdraw it during high demand periods (winter). They complement the development of gas fields (e.g. Vaca Muerta unconventional play) and optimize the transport capacity in main pipelines, increasing their use in summer for the UNGS filling and supplying specific markets in winter. Thus, they constitute the most effective and economic way to support peak demand. There is one UNGS in Latin America, which was established in 2001 and belongs to YPF: Diadema (Golfo San Jorge Basin, Argentina). Using the expertise gained in its development and operation, YPF started the studies in order to search new potential sites to convert to UNGS in Neuquén Basin, Argentina. This work focuses in the analysis of the Rojo Horizon, one of the gas-bearing layers of Rayoso Formation, as a potential reservoir for gas storage. For that purpose, a data acquisition plan, involving petrophysical and geomechanical laboratory tests in well cores, well logging, extended pressure test and continuous well pressure monitoring, was carried out. Based on the information acquired, the formation was evaluated with a multidisciplinary perspective, including the elaboration and calibration of static, dynamic, petrophysical and geomechanical models. The results of the volumetric analysis show that the Rojo Horizon has a working gas capacity of 250 Mm³ (million cubic meters), equal to 3 LNG carriers. Considering trap characteristics, seal efficiency, reservoir petrophysical properties and appropriate volumetric parameters, it is concluded that Rojo Horizon fulfills the technical requirements to be satisfactorily converted into an Underground Natural Gas Storage.

SESSION TITLE: Theme 2: Global Structural Styles and Kinematics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The characteristics of natural open fractures in the pre-salt reservoirs of the Barra Velha Formation, Santos Basin, Brazil.

AUTHORS (FIRST NAME, LAST NAME): Ole Petter Wennberg¹, Franceline De Oliveira Ramalho², Manuella Virgolino Mafia³, Fabio Laponi⁴, Alistair Stuart Chandler⁵, Luz Elena Gomez Cartesio⁶

INSTITUTIONS (ALL):

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5. Equinor
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ABSTRACT BODY:

Abstract Summary: Natural open fractures are common in carbonate reservoirs where they often have a large impact on fluid flow. Such fractures have also been reported in the Aptian Barra Velha formation in the pre-salt lacustrine carbonate reservoirs in the Santos Basin offshore Brazil. These fractures contribute to excess permeability in the pre-salt carbonate reservoirs (i.e., well test permeability is significantly larger than core permeability or log derived permeability) in combination with vugs and karstified layers. It is important to address these features to understand the fluid flow in the reservoir during production and injection, and also for well planning since they represent potential loss zones. Purpose of this presentation is to summarize the characteristics of natural open fractures in the presalt reservoirs and to discuss their distribution, occurrence and formation. The fractures have been interpreted in acoustic borehole image logs in 19 wells across the Santos Basin. The data quality is overall good and consistent so that results can be compared between wells. There are several methods for calculating fracture density from borehole image logs, and in this case the P21 fracture density, which is fracture trace length per area, was preferred. The carbonates in the Barra Velha Formation show various degree of silicification, and P21 fracture density show a strong correlation with volume of silica. Fractures are also frequent in fault damage zones, above and below cavities, and they are also associated with presence of vugs. The main orientation of the fractures is NNW-SSE which is in the same direction as the dominating fault trend, and this indicate a structural control on fracture formation. Natural open fractures are rare in high porosity rocks with a shubby or grainy texture, and also in intervals with a conglomeratic appearance in the borehole image logs.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Offshore Colombia: Crustal Structure and Evidence of Intra-Plate Spreading in the Central Caribbean

AUTHORS (FIRST NAME, LAST NAME): Kyle Reuber¹, Antara Goswami², Chuck Campbell³

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3. ACCEL Services Inc.

ABSTRACT BODY:

Abstract Summary: Recently reimaged seismic data from offshore Colombia has revealed previously unknown details of the central Caribbean and the active margin along northern Colombia. Approximately 60,000 line kilometers of 2D seismic, from a total of 18 legacy surveys, was depth-imaged as a single, contiguous survey. Much of the Caribbean Large Igneous Province (CLIP) is composed of a smooth-topped, 2-layer basement (~12 km thick) and is likely a result of sub-aqueous flows on Pacific-origin oceanic crust as the plate passed over the Galapagos Hot Spot (GHS). This integrated data set provides new evidence of intra-plate spreading within the central Colombian Basin. This region of rugose-topped, 3.5 km crust is flanked by the 2-layer crust of the Embera Hills in the west and the Beata Ridge in the east. These flanks show crustal thinning in the central Caribbean and have dipping magmatic flows (similar to seaward dipping reflectors) seismic packages dipping towards the thinned region. Through the incorporation of filtered free-air gravity data we identify a paleo-spreading ridge and a northern transform, striking SW-NE and sub-parallel to the Hess Escarpment. This expanse of new crust and the surrounding 2-Layer CLIP, are being obliquely subducted at the Magdalena Fan and the South Caribbean Deformed Belt (SCDB). The timing of the Embera Hills deformation and a Late Miocene unconformity that surrounds this region of thin crust is coeval with the docking of Panama in the western Caribbean. In this study we submit that a combination of: 1) the arrival of the Panama Arch; 2) buttress effects of the Santa Marta Massif; 3) the onset of the Andean Orogeny and; 4) the progressive easterly plate motion of the CLIP and slab tear all contributed to extensional stresses and subsequent oceanic spreading in the Central Caribbean. The limited amount of magmatic material encircling this area indicates that crustal breakup involved minimal igneous activity before progressing to normal oceanic crust production. The rugose fabric of the oceanic crust indicates that the spreading rate of the ridge axis was slow and created fault scarps at the ridge. The highly variable crustal thickness plays an important role in the nature of subduction along the northern South America margin. This study highlights that understanding regional distribution of Late Cretaceous sedimentary units and the Late Miocene Unconformity is critical to understanding the evolution of the central CLIP.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: A Geodynamic view of world-class deep-water oil provinces associated with Transform Marginal Plateaus in South America

AUTHORS (FIRST NAME, LAST NAME): Renato Darros de Matos Matos¹

INSTITUTIONS (ALL):

1. Guarini Consulting

ABSTRACT BODY:

Abstract Summary: The onset of magmatism combined with the distribution of lithospheric keels and scars inherited from Proterozoic cratonic collisions controlled deformation partitioning during the opening of the South Atlantic. Even though rifting was triggered by far-field stress, three plumes were active within the South American side: The Sierra Leone (SL) around the Demerara Plateau, the St. Helena (SH), partially inside the Borborema-Benin-Nigerian Province (BBNP), and the Tristan-Gough (TG) at the northern tip of the Austral Branch of the South Atlantic. Three LIPs are associated with each plume: The Sierra Leone in north South America, the Borborema LIP within the BBNP, and the Paraná Etendeka Magmatic Province-LIP between southern Brazil and Africa. Three Transform Marginal Plateaus (TMPs) are associated with the hotspot track of each plume: (a) The São Paulo TMP, associated with the TG plume in the Santos Basin; (b) The Pernambuco TMP, associated with the SH plume in Pernambuco Basin (NE Brazil); and (c) The conjugate Demerara and Guinea TMPs, associated with the SL plume. Two world-class deep-water oil provinces are associated with the São Paulo/Santos and Demerara-Guinea TMPs. (i) The oil-rich Santos Basin display large-scale basement-involved folding, with the presence of obliquely sheared active magmatic core complexes, which accommodated a large amount of extension through a large-scale accommodation zone between two competing rift/spreading centers that meet between the Santos and Pelotas basins. The margin was influenced by the thermal impact of the TG plume. Its transform boundary is the Florianópolis Fracture Zone. Proterozoic inheritance is the primary factor controlling deformation partitioning and the width of the Santos Basin. (ii) The Guyana/Suriname oil province is another example of a major oil reserves discovered around a TMP, but with quite distinct tectonic evolution and petroleum systems. The potential replication of the Guyana's success toward the Brazilian Equatorial Margin is discussed based on plate reconstruction, the nature of the crust and source rocks distribution. On the other hand, the so far oil deprived Pernambuco TMP, in NE Brazil, is an example of a TMP with no major oil reserves around it. It is associated with the hotspot track of the SH plume, when the continental crust was intruded and underplated. The Pernambuco TMP is bounded by the Kribi/Ascension fracture zones, at the junction of ocean basins of contrasting ages.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Influence of Sedimentary Patterns and Diagenetic Characteristics to the Oil Production, Eocene Kumaza Formation in the Southeast of the Gulf of Mexico

AUTHORS (FIRST NAME, LAST NAME): Jaime Rios Lopez¹, Abelardo Cantu-Chapa²

INSTITUTIONS (ALL):

1. PEMEX Exploracion y Produccion
2. INSTITUTO POLITÉCNICO NACIONAL

ABSTRACT BODY:

Abstract Summary: Historical production behaviors from some wells, it is evident that the conventional geological interpretation is not enough to reproduce the dynamic behavior of the reservoir. Some producing wells in Eocene manifests a wide range of production decline, from 1 to higher than 25% per month, which many times is not predicted.

Seismic data, well logs, cores, fluids, and reservoir pressure measurements from 5 oil Eocene fields. In order of scales, seismic data was used for areal distribution and subdivision of 1 to 3 units consistent with the correlative major lithologic units in the wells. Cores and drill cuttings samples from 50 wells helped to recognize units equivalent to the Bouma sequence with their respective lithological features and sedimentary structures in carbonate rocks, the microscopic explanation is reinforced with the particle sizes ranging. Within each major lithologic unit recognized with well logs, cyclicity in the sequences was observed. Eventually within the cycles there is gradation from calcirudites to calcarenites and back to massive calcirudites, this is due to the influence of energy peaks during sedimentary transport. Interrupted sequences were also identified due to abrupt loss of energy with the consequent deposition of fine sediments.

Once the sedimentary units and volumetric trends were characterized, the diagenetic events with high impact on hydrocarbon production were analyzed. Sedimentary patterns, diagenetic features, wellbore pressure measurements, capillary pressures and pore throat analysis, were articulated to assess those characteristics of the pore system that are favorable to oil storage and flow. In addition, qualitative analyses of oil content in rock samples were performed and their relationship with the intervals where porosity tends to be lost, to understand the causes and conditions of occurrence of these events, and consequently explain the productivity of wells.

With the results of this study, it was possible to give a geological explanation of the production behaviors of wells that were tested, and guide future production priorities based on: 1) Thicker sequence lobes, with high energy permanence in proximal zones of the deposit versus high cyclicity in distal or intermediate zones, 2) Units of greater textural maturity and granulometric selection, where porosity occlusion caused by cement precipitation is not significant, and

3) The flow condition enhanced by the presence of microfracturing.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Seal Risk Analysis Caribe Sur (Colombia-offshore).

AUTHORS (FIRST NAME, LAST NAME): Marcelo Garcia¹, Ricardo Zavala², Linda Montilla³, Sandra Montoya⁴, Darwin Mateus⁵, Antonio Velasquez⁶, Luis Gerardo Figuera⁷

INSTITUTIONS (ALL):

1. Ecopetrol
2. Ecopetrol
3. Ecopetrol
4. Ecopetrol
5. Ecopetrol-ICP
6. Ecopetrol Brasil
7. Ecopetrol

ABSTRACT BODY:

Abstract Summary: Abstract. Seal capacity assessment is currently a mandatory step in Ecopetrol's offshore exploration workflow. The objective of this technique is to predict how close the formation pore pressure is to the fracture pressure - in order to foresee the potential risk of leakage by mechanical failure. Some relationships must be established: overpressure, hydrocarbon (HC) column heights and seal, since a reservoir under low effective stress will stand a lower buoyancy force and consequently a smaller HC column. Pore pressure and fracture pressure values were available from logs in 13 wells, while in 12 prospects those were estimated from interval velocities calibrated with leak off tests (LOT) and MDT data. In addition, two regimes were identified in the Caribe Sur area, a low overpressured regime and a highly overpressured one, the later coinciding with the presence of gas clouds and chimneys. One last conclusion is that HC columns rarely reach leak off pressure, suggesting that capillary leakage is reached before fracture failure occurs. Understanding of how, when and why pressure-related seal failure occurs is critical to avoid drilling dry holes.

Keywords: Seal capacity, fracture pressure, pore pressure, hydrocarbon column, overpressure, effective stress.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Deep Waters of Pará-Maranhão and Pelotas Basins in Brazil – So far Away from Each Other, so Similar in Petroleum Geology and Potential

AUTHORS (FIRST NAME, LAST NAME): Pedro Victor Zalan¹, Mike Saunders², Eric Newman³, Joe Erickson⁴

INSTITUTIONS (ALL):

1. ZAG Consulting in Petroleum Exploration
2. TGS Houston
3. TGS
4. TGS Houston

ABSTRACT BODY:

Abstract Summary: The offshore Pará-Maranhão Basin (PAMA) is situated in the western part of the Equatorial Margin of Brazil. The Pelotas Basin (PEL) is the southernmost offshore basin in Brazil. They are 4,500 km (2,800 mi) apart from each other, having 14 other offshore basins in between them. Although distant in space they present very similar petroleum geology and potential, especially regarding the Marine Cretaceous Anoxic Shales–Upper Cretaceous Turbidites petroleum system. Another shared characteristic is the number of wells drilled in their deep and ultra-deep-waters; only two. Very large tracts of unexplored basins, presenting large thicknesses of sediments and having several geologically analogous areas with large oil and gas discoveries and production, are usually indicative of frontier areas ripe for great exploratory success.

The similarity starts with the source rocks. Turonian and Coniacian marine anoxic shales are the main source rocks in the deep waters of the Equatorial Atlantic conjugate margins. Aptian, Albian and Turonian marine anoxic shales are the candidates for hydrocarbon sourcing in PEL. Both deep water areas in the basins are devoid of rift sequences, their sedimentary section resting directly upon volcanic rocks; oceanic crust in PAMA, SDR's in PEL. The petroleum system, thus, is developed in the Drift Sequence. Both Drift Sequences are practically undisturbed by structural deformation, exception being gravitational cells. Turbidites are well developed in the Late Cretaceous sections of both basins, being stratigraphic traps the dominant accumulations envisaged in such situation. Migration routes are sub-seismic fractures and faults or visible faulting in subtle drape folds atop volcanic highs. An important secondary target in both areas, visible in new vintages of 2D seismic surveys, consist of Albian carbonate constructions developed on top of buried volcanos (atolls).

The similarity of these petroleum systems with other analogous proved petroleum provinces such as Ghana-Ivory Coast, Guyana-Suriname in the Equatorial Atlantic and Sergipe-Equatorial Guinea, Santos and South Africa in the South Atlantic are tremendous. The amount of leads visible in new 2D seismic data is high. It is only a matter of time that these two basins start yielding significant discoveries of stratigraphically trapped oil and gas accumulations.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Malvinas Basin, Argentina – A Closer Look at the Upper Cretaceous-Tertiary Stratigraphic and Structural Play of Turbidite Sand Complexes and Additional Springhill Leads, and Prospects

AUTHORS (FIRST NAME, LAST NAME): Randall Etherington¹, Eric Newman², Pedro Zalan³, Milos Cvetkovic⁴

INSTITUTIONS (ALL):

1. TGS
2. TGS
3. TGS
4. TGS

ABSTRACT BODY:

Abstract Summary: The oil and gas potential of the Malvinas Basin, with a proven petroleum system, has produced an exciting exploration hunting ground. Not only the regional understanding but also the identification of oil and gas leads has been accentuated by the addition of more than 14,000 km of long offset 2D seismic data. New 3D data builds on that knowledge and opens new windows of understanding with fantastic images of enhanced possibilities.

The Malvinas Basin formed during the Late Triassic-Jurassic break-up of Gondwana and is mapped as a triangular depocenter located offshore east of the Magallanes-Austral basin between the Rio Chico High and the Malvinas (Falkland) Islands with the North Scotia transform boundary forming the southern boundary.

The Malvinas Basin extends more than 300 km north-south and 350 km east-west at its southern boundary. The basin's history is complex and underwent multiple deformation phases due to the changing tectonic setting through time. Previous studies have identified several unconformity-bounded sequences and have grouped them into seismic units. The stratigraphic succession has been divided into four primary tectonostratigraphic units: the Jurassic syn-rift sediments; the sag phase beginning with the Springhill Formation; the Upper Cretaceous to Eocene transitional marine deposits; and the late Eocene-Pliocene foredeep deposits.

The sources for the hydrocarbon systems charging plays in the Malvinas Basin include lacustrine source rocks in the Jurassic Tobifera Formation, Early Cretaceous source rocks associated with the Springhill Formation, the Aptian to Albian Inoceramus Formation, and possibly the Turonian sediments.

Historically, the main exploration focus of the Malvinas Basin has been the prolific reservoir sands of the Early Cretaceous transgressive Springhill Formation. Many additional Springhill leads, and prospects have been identified and are yet to be tested. In addition, examples of new ideas will help open extra possibilities of the Upper Cretaceous-Tertiary stratigraphic and structural play of turbidite sand complexes.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Sediment Fairways and Gross Depositional Environments for the Cretaceous of the Guyana-Suriname Offshore Basin, Implications for Petroleum Systems.

AUTHORS (FIRST NAME, LAST NAME): Martín Pereira¹, Mariano Ragazzi², Estefania Tudisca³

INSTITUTIONS (ALL):

1. Pluspetrol
2. Pluspetrol
3. Pluspetrol

ABSTRACT BODY:

Abstract Summary: An analysis of the tectonostratigraphic evolution of the Guyana-Suriname offshore basin was carried-out from the integration of seismic interpretations, well data, bibliography and geological public information. This contribution focuses on Mesozoic evolution of the basin, which was controlled by three main global tectonic processes and local deformation responsible for the opening of a tongue-shaped depocenter towards the west and a submarine plateau, known as “Demerara”, towards the east. Each region had its particular evolution leading to different exploratory potential.

The western depocenter developed, especially since the Albian, as a deep marine basin characterized by a stepped slope with canyons in the south and an abyssal plain in the north. It constitutes the main pod for the Canje Formation source rock.

The Demerara plateau remained as a regional structural high during the entire evolution of the basin, where shallow marine to continental shelf sedimentation prevailed.

Four regional gross depositional environment maps are presented in this paper for the following second order sequences: Valanginian-lower Albian, intra-Albian, upper Albian-Cenomanian-Turonian and Coniacian-Maastrichtian. In the Early Cretaceous, thin offshore shale intervals and turbidite systems dominated in the western depocenter. On the other hand, in Demerara, this interval was characterized by a thick carbonate platform coexisting with siliciclastic deltas coming from the south, southeast and east.

During the Late Cretaceous a widespread transgressive phase affected the entire basin. Higher accommodation space developed in the western depocenter where long-distance sediment fairways have been recognized. submarine canyons and sediment bypassing characterized the shelf and slope, while in the abyssal plain turbidites and mass transport deposits interbed with shales.

In the Demerara plateau, this interval is characterized by an inherited topography that controlled the sediment pathways toward northwestern mini-basins. The presence of a shelf-delta system towards the south could have acted as the main source of sediments in a long-distance sediment fairway, but other short-distance sources could also have existed. Pelagic and hemipelagic mud interfingered with mass transport deposits and turbidite systems dominated in the area.

The mentioned processes, controlled the reservoir distribution and hydrocarbon prospectivity of the basin.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Ceará and Potiguar Basins – Seismic Image Highlights Exploration Leads and Prospects in this Petroliferous Underexplored Part of the Brazilian Equatorial Margin

AUTHORS (FIRST NAME, LAST NAME): Randall Etherington¹, Eric Newman², Pedro Zalan³, Mike Saunders⁴

INSTITUTIONS (ALL):

1. TGS
2. TGS
3. TGS
4. TGS

ABSTRACT BODY:

Abstract Summary: Oil production in the Potiguar and Ceará Basins is not new. The Potiguar Basin is the largest oil-producing region in equatorial Brazil along the onshore and near offshore areas of the basin with a cumulative production around one billion barrels of oil equivalent. Likewise, exploration activities in the Ceará basin commenced in the early 1970s that resulted in the discoveries of several moderate size fields discovered on the shelf and are producing to this day. The petroleum system of both basins contains proven lacustrine to marine prolific source rocks of rift to post-rift system and the highly expected yet speculative Albian-Turonian anoxic shales. Reservoir rocks range in age from Barremian to Eocene times. Seal rocks are observed throughout the entire stratigraphic column and are represented by intra-formational lacustrine shales, fine-grained argillaceous sandstones, shales, and thick deep marine pelitic rocks.

Ceará's Pecem discovery and Potiguar's Pitu oil discovery both confirmed the Aptian rift/syn-rift play in the deepwater. Both deepwater discoveries are characterized by half-grabens filled with lacustrine, fluvio-deltaic and fan-deltaic deposits.

The complete regional seismic data, solely in deep and ultra-deep waters, of the two basins helps to identify exploration leads and prospects of two main play types, specifically, the confirmed rift/syn-rift play and the greatly anticipated 'drift' Late Cretaceous-Tertiary turbidite sand play of channel and fan complexes. So, these two plays are extended and confirmed in deep and ultra-deep waters.

Turbidite channel and fan complexes can be identified with 2D seismic data, however 3D seismic data helps to image these features. Broadband, long offset 2D seismic clearly shows the Aptian 'Rift' play and evidence of the 'Drift' Late Cretaceous-Tertiary turbidite channel complexes and basin floor fans. However, the 3D data illustrates a much clearer seismic image and detail of the Cretaceous turbidite channel/fan complexes and Aptian 'Rift' structures. In addition, the 3D seismic attributes help identify exploration leads and provides the necessary data to create exciting prospects.

Transform faults have a dramatic effect on the basins and influences the potential play types. The leads and prospects of the Ceará and Potiguar basins have been greatly de-risked with the recent addition of regional 2D data and the newly acquired 3D seismic.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Linking the Pressure Behavior with Geological Features in the Oil Zone and Incorporated Aquifer in an Offshore Carbonate Reservoir, México

AUTHORS (FIRST NAME, LAST NAME): Jaime Rios Lopez², Francisco López-Rabatté¹, IGNACIO HERNÁNDEZ-CANO³, Erick Denogean⁴

INSTITUTIONS (ALL):

1. Pemex
2. PEMEX Exploracion y Produccion
3. FREELANCE CONSULTANT
4. PEMEX Exploracion y Produccion

ABSTRACT BODY:

Abstract Summary: The AT field delimitation was carried out 1.5 years after the discovery, logging a pressure of 7.8 kg/cm² lower than the result in the first exploratory well, within the same Mesozoic geological formation unit. After 6.6 years of drilling the extension well, it started exploitation observing a pressure drop of 14 kg/cm². These descents are due to the aquifer is regionally shared with other oil fields. Due to the extraction oil by development wells in the reservoir, an additional loss of 40 kg/cm² has been observed in 2021.

The pressure data that have been recorded in the wells since the discovery, throughout the productive life of the field, are used as control points to understand what happens in the porous system and interpret the static and dynamic behavior of the reservoir, as well as the effect of the exploitation of neighboring fields on the reservoir under study. The production and pressure behaviors respond to the features of geological units in the field, the regional connection through the aquifer and the extraction flow rate.

The geological, petrophysical and dynamic data of wells are studied: to maintain and increase the production, to monitoring the advances of fluid contacts and predict the oil displacement ratios by water injection, to considering the horizontal and vertical flow capacities of the geological units and the field compartments.

As a result of this analysis, the original and current pressure conditions of the field, the magnitude of drawdown both the oil zone and the aquifer were determined. Likewise, it is possible to make a zoning of the field: zones from highest to lowest drainage and bypassed zones.

To incorporating the dynamics data from two other neighboring fields, such as TK, UT, which were already depressed at the time of discovery, like the AT field, the depressing effect through the common aquifer is checked and complement the characterization of these reservoirs.

SESSION TITLE: Theme 3: Offshore Exploration and Production

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: The Argentine Basin and the earliest record of post-breakup tectonics and stratigraphy of the SW South Atlantic

AUTHORS (FIRST NAME, LAST NAME): Pedro Kress¹, Emilio A. Rojas Vera², Federico Spath³

INSTITUTIONS (ALL):

1. YPF S.A.
2. YPF S.A.
3. YPF S.A.

ABSTRACT BODY:

Abstract Summary: The Argentine Basin is the deep-water basin located along the slope of South America north of the Agulhas Malvinas fracture zone. The western part of the margin is underlain by thick igneous bodies and volcanic rocks known as seaward dipping reflectors (SDRs), fed by magmatism parallel to the future continental-ocean transition (COT) zone. However, the southernmost segment of the margin resembles a transform margin, where at the Agulhas Malvinas strike-slip fracture zone, faults were deflected northwards against the Patagonian craton, creating a transform margin segment. Transition between this segment and the magmatic divergent margin occurs over a short distance, the northernmost branch marking the onset of the magmatic packages of the SDRs. South to north propagation of the volcanic divergent margin occurred stepwise, where each magmatic segment was bounded by fractures zones, which could accommodate stresses during the rotation between Africa and South America. They did not propagate into the continent, but occasionally reactivated preexisting basement heterogeneities. Reactivation occurred along the Colorado fracture zone (CFZ) which marks the northern end of the oldest segment of SDRs and the Rio de la Plata Fracture zone (RFZ). The CFZ is characterized by a change in propagation from N-S to NNE-SSW and pervasive volcanic intrusions. Further north, where SDRs are best developed, several smaller fractures zones with a little continuity landward. They show strike-slip structures and initially constituted isolated depocenters, first to be flooded during the onset of marine transgression and prone to source rock preservation.

The RFZ is the northern first order boundary, with an counterclockwise offset of continental crust against oceanic crust and following another basement weakness zone. After breakup, a marine transgression occurred during Barremian-Early Aptian times. Transgression flooded first the fracture zones and then expanded onto the subsiding SDRs. Once the rate of transgression was outpaced by sediment supply, clinoforms prograded into a shallow water body (less than 300 m). A narrow shelf developed and most of the sediment bypassed the slope building up stacked levees and toe of slope turbidites, precluding basin floor fans and thermohaline reworking typical of deep-water environments. Deep water deposition occurred only after Cenomanian – Turonian boundary concomitant with the final separation between the Malvinas plateau and SW Africa.

SESSION TITLE: Theme 4: Geophysics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: A Workflow for Accurate Seismic Re-Depthing with Alternative Anisotropic Velocity Models in Structurally Complex Areas

AUTHORS (FIRST NAME, LAST NAME): Elive Menyoli¹

INSTITUTIONS (ALL):

1. Emerson Exploration and Production Software

ABSTRACT BODY:

Abstract Summary: Time-to-depth conversion of seismic volume is a required workflow when interpreting seismic data and defining the spatial location of a reservoir. This essential step is often approximated with vertical scaling method, which may only be valid for simple “layer-cake” geology. Consequently, in complex areas, it is very common to see disruptions and pull-ups in the depth converted volumes, which could result in missed targets, added costs, drilling hazards and delays in the subsequent exploration and production operations. In this presentation we will introduce a more accurate approach for re-depthing (time-depth or depth-to-depth conversion) of seismic volume in any kind of structural environment. The workflow is based on applying sequentially poststack RTM Demigration and poststack RTM Remigration. Demigration of stacked images is the reverse process of migration and generates zero-offset unmigrated seismic volume (time stack volume). The Demigration phase uses a depth migrated image and its corresponding anisotropic velocity model. After Demigration, the zero-offset time stack volume is remigrated with alternative sets of updated anisotropic velocity models. This approach allows interpreters to economically evaluate different interpretation scenarios in the velocity model, by incorporating their experience and knowledge of the field, maintaining consistency with available dataset such as outcrops and validating the viability of each scenario. This is particularly important to decrease imaging uncertainty in complex foothills areas where signal-to-noise ratio is poor, and reflectors lack continuity. The output of the workflow are multiple depth images and velocity models. Because the method runs both in anisotropic and isotropic modes, one can change any of the anisotropic parameters such as delta or epsilon, then use those as the updated model parameter.

Advantages: Because the method is based on RTM, it can accurately handle seismic data acquired over complex geologic media. No prestack gather is needed since it is a poststack process. The Demigration process need to be carried out only once but Remigration can be done as many times as needed, each time using alternative velocity models. There are no limitations on the dips of the formations, no requirement about smoothness of the velocity models, therefore, medium parameters within the layers can vary abruptly.

SESSION TITLE: Theme 4: Geophysics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Gas diffusion in a range of natural geomedia: Sample size and saturation effects

AUTHORS (FIRST NAME, LAST NAME): Xiaoqing Yuan¹, Qinhong Hu¹

INSTITUTIONS (ALL):

1. The University of Texas at Arlington

ABSTRACT BODY:

Abstract Summary: As the gas diffusion efficiency is key to understanding transport mechanisms in geomedia, this study is an attempt to understand how diffusion behavior are influenced with respect to granular size and water saturation to determine the relationship between diffusion coefficient (D_p , $m^2 s^{-1}$) and pore network (both geometry and connectivity). Diffusion chamber method with oxygen as the tracer gas were conducted on the six geologically different repacked sediments with six granular sizes. With decreasing of granular sizes, porosity measured, and diffusion coefficient calculated hardly fluctuates for the same sediment type, meaning the effect of particle size on pore network can be ignored for our six sediments. However, the obtained diffusion coefficient, varying in the magnitude of 10^{-7} to $10^{-6} m^2 /s$, could not be directly correlated to the changes in porosity, suggesting pore structure's complicated effect on gas transport. A decrease in diffusion coefficient after water saturation as observed in Grimsel Granodiorite with low porosity was attributed to the water blocking effect.

SESSION TITLE: Theme 4: Geophysics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Advanced analytics methods in seismic characterization: Teapot Dome Case Study

AUTHORS (FIRST NAME, LAST NAME): Veronica Perez¹, Felipe Melo² **INSTITUTIONS (ALL):**

1. GeoSoftware
2. GeoSoftware

ABSTRACT BODY:

Abstract Summary: In this work we calculate a net pay map and run an uncertainty analysis on the Frontier Formation of the Teapot Dome dataset. First, we perform a preconditioning of the seismic focusing on reducing errors from noise attenuation, spectral differences, residual move out and relative phase differences, and use those results to generate the partial stacks, perform the seismic well tie, wavelet estimation and run an elastic deterministic inversion. The volumes resulting from the deterministic inversion are used as input of a Deep Feed-forward Neural Network to predict volumes of porosity, clay, and water saturation. We then use those results alongside net pay at well locations, to run a multiple attribute map analysis and collocated cokriging to estimate the net pay map of the zone of interest. Finally, these results are used for the uncertainty analysis process where we perform stochastic methods to simulate several probable model maps to make quantitative predictions. These advanced analytics methods for seismic characterization allow us to go beyond the inversion results, providing us with valuable information about the reservoir productivity.

SESSION TITLE: Theme 4: Geophysics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Fracture Prediction of Carbonate Karst Reservoir Based on Anisotropy of PP-Wave and PS-Wave

AUTHORS (FIRST NAME, LAST NAME): Hongqiu Wang¹, Kang Chen², Qiyan Chen³, Jianhu Gao⁴, Zhe Yang⁵

INSTITUTIONS (ALL):

1. PetroChina Research Institute of Petroleum Exploration & Development Northwest
2. Southwest Oil & Gasfield Company, Petrochina
3. PetroChina Research Institute of Petroleum Exploration & Development Northwest
4. PetroChina Research Institute of Petroleum Exploration & Development Northwest
5. PetroChina Research Institute of Petroleum Exploration & Development Northwest

ABSTRACT BODY:

Abstract Summary: The stratigraphic deposits of the Lower Permian Maokou Formation in the south of the Sichuan Basin are located in carbonate shallow sea open platforms, and are mainly characterized by the development of intraplateau beach subfacies. At the end of the Middle Permian, affected by the Soochow Movement, the stratum was extensively uplifted, and the exposed carbonate rock suffered long-term weathering and erosion and atmospheric freshwater leaching and dissolution, and karst was very developed. In recent years, some wells have discovered karst fractured-cave systems in the syncline area (early exploration was concentrated in the anticline area) and obtained discovery of commercial gas, and exploration and development have shown that the degree of fractured-cave development is positively correlated with the level of gas production. Therefore, fracture-cave prediction is of great significance. Taking full advantage of the 3D full-azimuth and multi-wave seismic data in the YJ syncline area, the OVT domain (common offset pre-stack migration) and full-azimuth angle domain (common angle pre-stack migration) imaging of PP-wave were carried out. Based on these two kinds of gathers, fracture prediction is implemented by AVAZ method, and the PS-wave splitting is explored. Analysis showed that, compared with conventional OVT gathers, the seismic travel time and amplitude on full-azimuth common angle gathers shows more obvious anisotropic characteristics as the azimuth changes. Basic law of fractures distribution predicted by full-azimuth common angle gathers is better than that of OVT gathers, which quite conforms to the characteristics of karst reservoirs. The fast and slow shear wave separation finds that, the travel time of R component shows cosine characteristics and the T component has strong energy and polarity reversal phenomenon, meaning that the shear wave splitting phenomenon is obvious. After completing the analysis and correction of shear wave splitting in three time windows, the fast and slow shear wave time delay (indicating fracture development degree) and polarization direction (indicating fracture azimuth) are obtained, and the predicted fracture favorable development areas are better consistent with drilling results and geological regularity than result of PP-wave AVAZ, and the fracture azimuth prediction is basically consistent with the tectonic stress field and fault distribution characteristics, indicating that the prediction result is reliable.

SESSION TITLE: Theme 4: Geophysics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Improving seismic detection and resolution: spectral decomposition and extrapolation

AUTHORS (FIRST NAME, LAST NAME): Charles Puryear¹, Vsevolod Egorov², Raghava Tharimela³

INSTITUTIONS (ALL):

1. Spectral Geosolutions
2. GeoExpera
3. Spectral Geosolutions

ABSTRACT BODY:

Abstract Summary: In frontier exploration areas, seismic imaging enables geoscientists to observe the subsurface before wells are drilled. After drilling, it enables prediction of the distribution of play elements distal to the well location. The accuracy of characterization primarily depends on the detection and resolution properties of the seismic data. “Detection” refers to the capability of seeing a subsurface feature of interest, while “resolution” means being able to determine the vertical separation between the top and base interfaces (i.e. thickness), which is used for reservoir characterization and volumetric estimates.

Each of the three upstream stages of hydrocarbon prospecting - exploration, development and production - benefit from maximizing the resolution limits of the seismic data. An acceptable vertical resolution for seismic data at reservoir level is typically 15-30 meters. This value depends on the reservoir depth, rock properties, geological complexities and seismic data processing. Seismic bandwidth and peak frequency decrease with depth, while the velocity and wavelength increase. Thus, at the reservoir level, the vertical resolution can degrade to over 50 meters, while lateral resolution also diminishes.

Spectral extrapolation is a seismic method that is based on spectral (time-frequency) analysis of the seismic data. For spectral extrapolation, we apply a bandwidth extension technique using inversion that enables prediction of high frequencies outside of the original seismic band by extending the harmonic layer responses. The result can be used as input to seismic acoustic/elastic inversion, attribute computation, and rock and petrophysical properties prediction processes, thereby enhancing the interpretability of the data.

Spectral decomposition is a widely accepted attribute, primarily used for thin bed identification and fluid detection (such as low frequency shadows). We use a windowless inversion-based method to compute the frequency coefficients as a function of time, thereby maximizing the frequency resolution while maintaining the time resolution of the original seismic data. This method does not suffer from distortion produced by the Gibbs phenomenon.

This presented work discusses the principles of both spectral extrapolation and decomposition, with examples from seismic datasets acquired in Latin America. Through application of these methods, stratigraphic and structural details are enhanced.

SESSION TITLE: Theme 4: Geophysics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Improve the Accuracy of Channel Sand Reservoir Identification by Using the Amplitude Difference Between PP- and PS-Wave

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ABSTRACT BODY:

Abstract Summary: The SXM Formation in the Sichuan Basin is a favorable area for tight sandstone gas reservoirs. The channel sands are vertically superposed in multiple stages and are very different in exploration and development effects, so is urgent to implement the sand distribution. Log analysis shows that the V_p of sandstone is larger or smaller than that of the surrounding rock (mudstone), that is, V_p is difficult to effectively distinguish lithology, while V_s of sandstone is always higher than that of mudstone (sensitive to lithology), so multi-wave seismic data is beneficial to fine description of channel sand. According to the log interpretation results (V_p , V_s , density and porosity) of reservoirs, a porosity change model was established (porosity 5% to 14%), and multi-wave forward modeling was carried out. Forward modeling and actual multi-wave seismic data analysis show that for high impedance sand (porosity 5% to 7%), PP and PS peaks are at the top of the sand, with strong reflections, and PS amplitude is stronger than PP. It shows that both PP and PS can identify this type of reservoir, and the effect of PS is better. For medium impedance sand (good reservoir, porosity 7% to 10%), PP peaks are significantly weakened and even polarity reversal occurs, and PS peak is the top of the sand, and strong reflection, that is, PS is more conducive to identifying this type of reservoir, and PP is likely to miss this type of reservoir due to weaker amplitude. For low-impedance sand (high quality reservoir, porosity greater than 10%), PP peaks describe the bottom of sand (top is trough and bottom is peak), PS peaks still indicate the top of sand, and PP amplitude is significantly stronger than PS amplitude, indicating that PP is more conducive to identifying this type reservoir. In summary, the amplitude of PP changes with the porosity, and the peak of the high impedance (low porosity) is the top of the sand, while the polarity reversal (PP peak is sand's bottom) occurs at the low impedance (high porosity), and PS can indicate the top of the sand more stably with sand porosity changing (the phase remains unchanged). Therefore, the difference in the amplitude and phase of PP and PS can be used to characterize the porosity change and accurately predict the sand distribution. Finally, the maximum peak amplitude of PP and PS are extracted and combined with phase to describe channel sand distribution. The combination of PP- and PS-wave clearly identifies more sands than PP-wave.

SESSION TITLE: Theme 4: Geophysics

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

TITLE: Identification of intrusive body geometries from 3D seismic in a Pre-salt carbonate field, Santos Basin, offshore Brazil

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ABSTRACT BODY:

Abstract Summary: The Santos Basin is the most prolific pre-salt oil-producing offshore basin in Brazil. The basin has experienced several magmatic events and volcanic rocks have been found in Pre-salt exploration and appraisal wells. The presence, thickness and spatial extent of these volcanic rocks are challenging to predict from seismic, stemming from (i) the current degree of understanding the geometry and genesis of these volcanics, (ii) seismic quality issues and (iii) the limited well control. Typically, volcanics can act as barriers and can cause diagenetic effects in the carbonate reservoirs. In our study, two pre-salt carbonate reservoirs (Itapema and Barra Velha Formations) were investigated. These heterogeneous carbonates are located beneath a very thick salt layer (Ariri Fm.). The main reservoir consists of several hundreds of meters of bioclastic calcirudite facies (coquinas) and organic rich shales of the Itapema Fm., while the Barra Velha Fm. consists of in-situ facies (shrubstones and spherulestones) and reworked facies (calcarenite and calcirudite). Volcanic intrusions more than 500 meters in thickness have been found in both reservoirs. Petrophysical analysis established that these intrusive volcanic intervals typically display high bulk density, high velocity (hence high acoustic impedance), low gamma-ray and low neutron porosity values. The 3D seismic PSDM volume underwent a fit-for-purpose seismic data conditioning, in particular seismic noise cancelation and frequency enhancement, steered by zero-offset vertical-seismic profile data. Detailed mapping of faults using geometric seismic attributes and spectral decomposition, gravity and magnetic data revealed a complex tectonic setting including normal, strike-slip and regional transform faults. Manual fault mapping, 3D seismic interpretation and seismic facies analysis suggest that magmatism appears to be structurally controlled, possibly by deep seated faults. A deep neural network based acoustic impedance inversion, calibrated using several wells, conventional- and sidewall core samples. We adopted a neural network (NN) approach in order to (i) capture possible non-linear relationship between input data and targeted reservoir property and (ii) to generate higher vertical resolution volumes, which is attractive to image thin layers. This inverted volume was used to assist on identifying volcanic bodies from the 3D seismic, where volcanic cones, dikes, sills and probably laccoliths can be interpreted.

SESSION TITLE: Theme 8: Geodata Science and Artificial Intelligence

SESSION DAY & DATE:

SESSION TYPE: On-Demand Only

EXTENDED ABSTRACT: Development of python-based simulator for reservoir analysis and evaluation using CMG suite

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Introduction

Engineers require accurate performance predictions for a hydrocarbon reservoir under various operating conditions, which necessitates reservoir simulation. The reservoir simulation approach is becoming more widely used as a predictive tool in the petroleum industry. Its widespread acceptance can be attributed to advancements in computing facilities and numerical techniques for solving partial differential equations in simulators, which allow them to be used in modeling field cases. In regards to this, the pursued objectives were identified as follows; Static reservoir modeling of a hypothetical field under production with the help of python programming language; To investigate the results on the basis of the production data obtained from the python simulation; Reservoir modeling of a single flow of fluids from the proposed reservoir using the CMG suite; Comparison, evaluation, as well as the optimization of the simulation models thereby obtained.

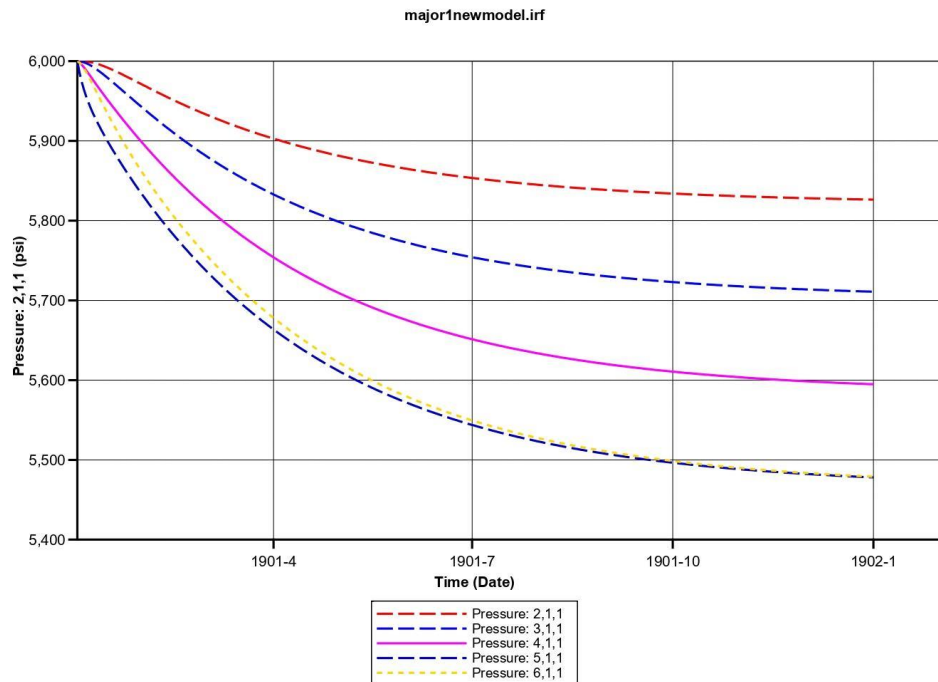
Adopted methodology and workflow

Reservoir models can be large and complex models, and their accuracy is dependent on the input parameters. Major steps taken for the simulation study are gathering input data, history matching, and performance prediction. The data, including the reservoir rock properties, fluid properties, and field production history, is gathered. Reservoir geometry, boundary conditions, well details (diameter, skin, location), and the well-operating conditions (flow rate, flowing borehole pressure) are also specified. Once these properties are determined, the gridding of the reservoir is done. To investigate the performance of the producing well from the reservoir simulation with the help of python, it is needed to model the solution to find out how the pressure varies in a reservoir as a function of space and time to obtain a comprehensive understanding of the fluid flow. A process/solver method is used to give a pressure solution in the most efficient path to irreducible oil saturation. This helps to model how saturation would vary as a function of space and time, giving the idea of the production in the well. These results are further verified from the simulations run in the CMG suite.

The model involved input parameters such as reservoir dimensions, reservoir properties like porosity, permeability, fluid properties, grid definition and production rate of the producing block. A block centered geometry was considered with the test case consisting of five blocks with one block put on production. Pressure values were determined for each time step followed by the generation of the overall pressure profile for each block in the two aforementioned cases using several python libraries like matplotlib, numpy and seaborn. This was followed by an

interactive visualization of pressure variation demonstrated with the help of animations for each block. Further analysis and interpretation were carried out by taking into account different rates of pressure depletion in the two cases. The output from the python-based simulation model had to be validated using CMG IMEX simulator. The input parameters included reservoir properties such as depth, temperature, initial pressure, bubble point pressure etc. along with fluid properties such as density, salinity etc. and grid properties with the reservoir being considered as homogeneous in terms of porosity and permeability. The time step for simulation and perforation intervals were kept the same as the python-based model. The input parameters resulted in the simulation of pressure in the range of initial pressure and the bubble point pressure followed by a 3-D visualization of pressure variation in different blocks.

Results and discussions



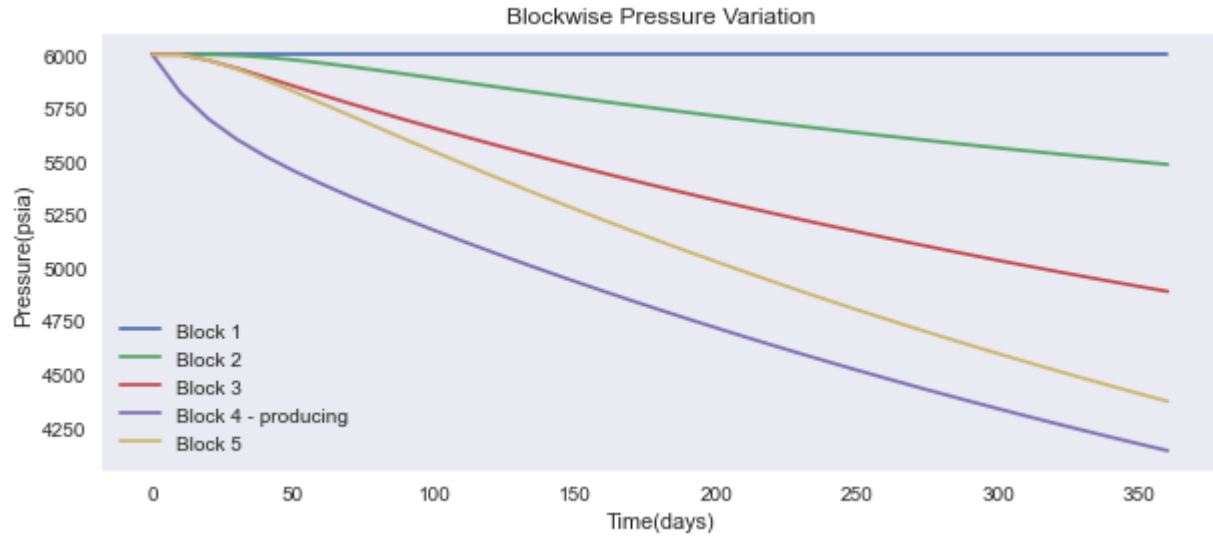
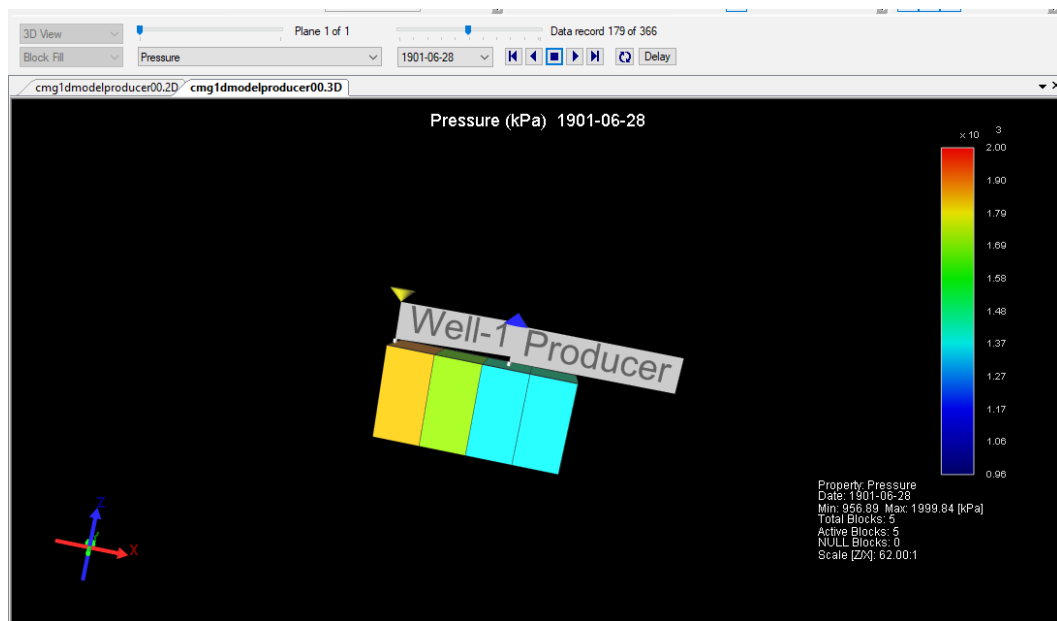


Figure 1. Block wise pressure distribution comparison of python based simulator and CMG IMEX simulator. a) block wise pressure distribution of CMG IMEX simulator. b) block wise pressure distribution of python based simulator



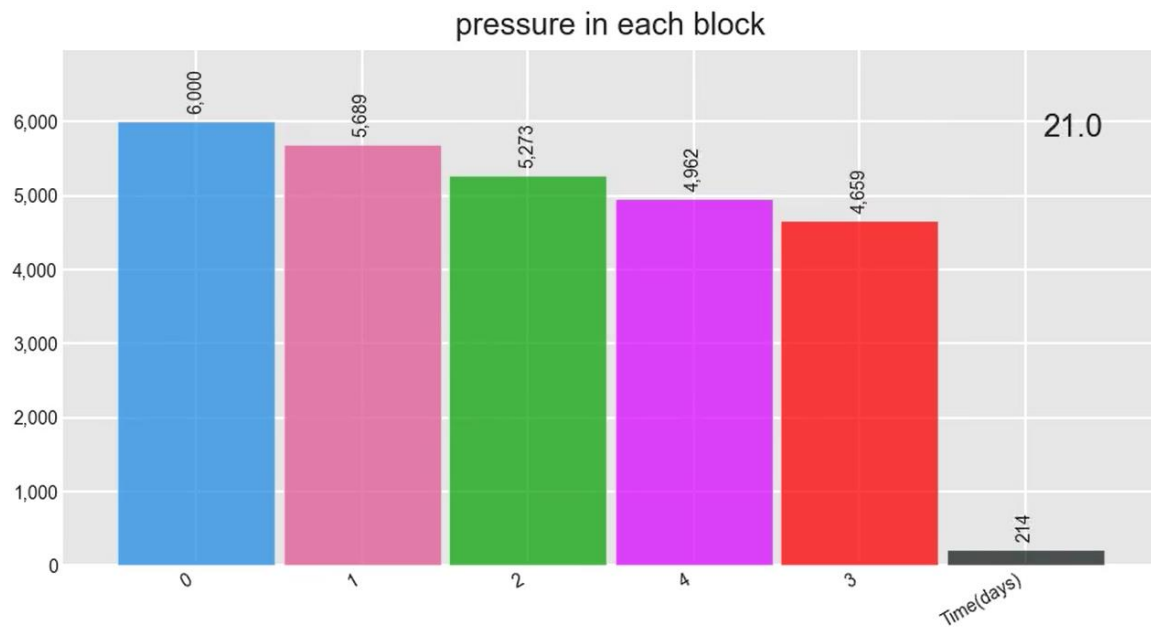


Figure 2. Simulation visualization of CMG IMEX simulator and python based simulator. a) 3D simulation visualization of a 1D homogeneous single phase fluid reservoir done on CMG IMEX simulator. b) Simulation visualization of a 1D homogeneous single phase reservoir done on python based simulation.

A 1D model for single phase fluid with constant pressure condition was successfully developed. The simulation results obtained through python and through CMG IMEX simulation were homogeneous. Block wise pressure distribution vs time is depicted in figure 1 for python developed simulator as well as for CMG IMEX simulator. Comprehensive comparison of the graphs show that python developed simulators give comparable results to the CMG IMEX simulator for 1D model. Further observations were taken:

1. No flow boundaries in any flowing porous reservoir can be modeled by assigning zero transmissibility at the edges of the porous medium.
2. When no flow boundary on the left side of the 1D reservoir is replaced by the constant pressure boundary the simulation results show greater pressure in each block centered grid because that boundary provides pressure support to the grid blocks containing the well.
3. We observed that Pressure calculated at different timesteps calculated at identical timesteps are different, depending on the timestep used in the calculation period. This concludes the approximation nature of the finite difference method.
4. Smaller timestep for calculation generally exhibits more accurate results when compared with the solutions of the original partial derivative equations.

