International Gas Union Research Conference 2011

DEVELOPMENT OF GAS CONDENSATED MATURE RESERVOIRS IN SAN JUAN FORMATION, SAN JOAQUIN AREA IN THE EASTERN OF VENEZUELA. BILATERAL COOPERATION BETWEEN VENEZUELA AND RUSSIA

Author: *E. Vera*
Co-Authors: *Y. López, G. Bisignano, F. Merchán*

PDVSA Gas, Puerto La Cruz, Venezuela.

ABSTRACT

The República Bolivariana de Venezuela to undergo as increasingly accelerated strong social, political and economic changes, it is foreign policy develops to matching with the new reality of the country, with a profiling and consolidation of a geopolitical model to agree with the own strategic benefits for a oil country. Assuming that, the main strength to Venezuela are the great account of gas and oil reserves, the energy potential of the country is being used as a tool to promote a new model of strategic alliances between the Russian Federation and Venezuela, being two big oil and gas powers, which has common interests and share the vision of a multipolar world. The idea is to promote the establishment of a multidimensional balanced and international relations system in the XXI century. In this regards we propose to deepening the energy internationalization with the objective to increase the exploration capacity, integral production and marketing energy, through regional energy integration initiatives with foreign investment by controlled no for the hegemonic axes, using the figure of oil mix resources companies and then promoting the establishment of production technology exchange areas. In the framework of a bilateral cooperation between the Russian Federation and Venezuela, proposed the joint venture to development of mature fields San joaquin, El Roble and Guario located in eastern venezuela. the most important oil producers sands in the area are Oficina from Miocene and Merecure from Oligocene , however, from -9000 feet is located San Juan sand, divided into three main members (A, B and C) representing the cretaceous sediments, where the condensate gas has been developed from 1.974 with 7.6MMBBL of condensate produced and 897.9 MMMSCF of gas produced and remaining reserves of 1,33 MMMSCF of gas and 25,1MMBBL of condensate. San Juan sand represents an opportunity for the exchange of knowledge, technological and scientific cooperation between Russian and Venezuelan specialists in geoscientist to development our potential in the efficient operation and production of the energy resources because joint ventures.

TABLE OF CONTENTS

Introduction

Anaco Fields are part of Eastern Venezuela Basin comprising the states: Guarico, Anzoategui, Monagas and Delta Amacuro extending to Deltana platform and the south of Trinidad and Tobago. The most important structural element of the area is the Anaco Slipping. This fault divides the area of this study in two big blocks called Area Mayor de Oficina (AMO)-block depressed – and Area Mayor de Anaco (AMA) -block up-(Figure 1). The direction of this fault is northeast and dip average of 45 ° to the northwest. On the north side of the fault (block up) are the El Toco dome, elongated dome of Santa Ana has 4 domic completions minor in San Joaquin field are three completions and a decline Domica northeast in Guario Field, more to the northeast stands the Santa Rosa dome. These domes are dips between 25-27 ° on the south side in contrast to only to 2 -5 ° in the northern flank specifically in El Roble field and those are the main structures where are the oil Cretaceous deposits and will be studied in this report.

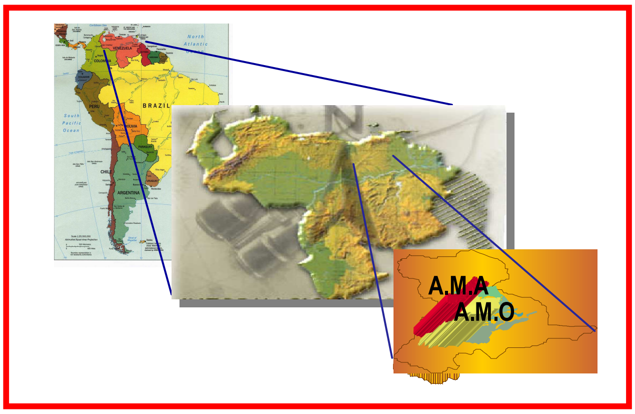


Figure 1. *Location of study area*

The study of the San Juan Formation, was conducted by applying a new methodology discussed and approved jointly by the professionals of Servicios Venrús (Gazprom) and PDVSA Gas. This approach includes descriptions and core analysis, use of GR Spectral for correlations, similarity seismic analysis (seismic cube), petrographic and petrophysical analysis.

Technical background

The Formation San Juan of Cretaceous age, has been divided into 3 sequences, known in this area as A (SJ-A), B (SJ-B) and C (SJ-C). From the standpoint of stratigraphic sequence, these sequences are separated by unconformities or sequence boundaries, widely recognized in the basin or their correlative conformities. This training has a proven gas remaining reserves of 2.1 TCF and 45 milion barrel for oil in the official reserves at the end of year 2010.

San Juan Formation in the fields of San Joaquin - El Roble - Guario East of the country, is officially characterized as a hydraulic flow unit stratigraphic levels labeled A, B and C.

The SJA has been developed at historically strong performance of gas production, as opposed to levels and SJ SJ-B-C, given the official status of the hydraulic unit of the sites that make up the training. On the other hand, there is a drop in gas production in line with the high volume of proved remaining reserves of gas exist in the San Juan Formation, which prompted an evaluation of the static and dynamic reservoir considered mature.

Geology

Using vertical stacking patterns subdivided the larger units A, B and C units in greater detail. Vertical architecture and the pattern of response records were obtained the following subdivisions:

- ✓ *A was subdivided into A1, A2 and A3*
- ✓ *B was subdivided into B1 and B2*
- ✓ *C was subdivided into C1, C2 and C3*

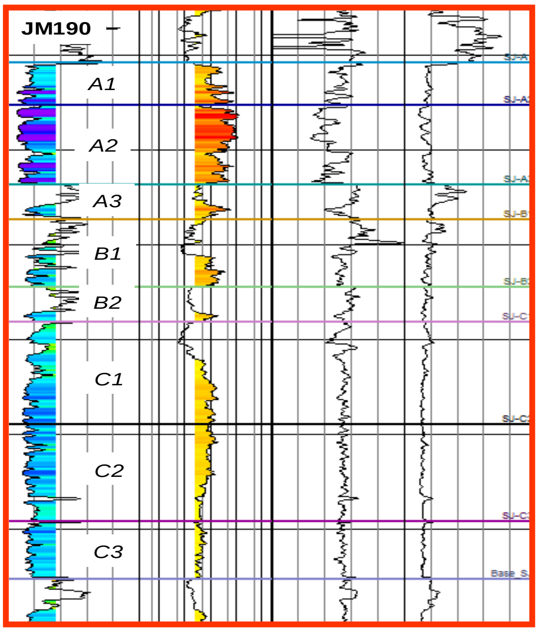


Figure 2. Stratigraphic subdivisión

To make the correlations used key wells. These wells are those with cores (3 wells) and those with registration GR_NGT Spectral (19 wells), this log was particularly helpful for correlating the larger units A, B and C, due to mineralogical differences that can be detected by the records, mainly thorium and potassium (Uranium also works in some wells).

Between A and B there is usually an increase in potassium content values, while B and C variations that serve geographically, but always showing vertical differences in the content of thorium and / or uranium (Figure 3). These vertical variations of the radioactive elements locally also helped locally in the internal subdivision of detail in the larger units of San Juan.

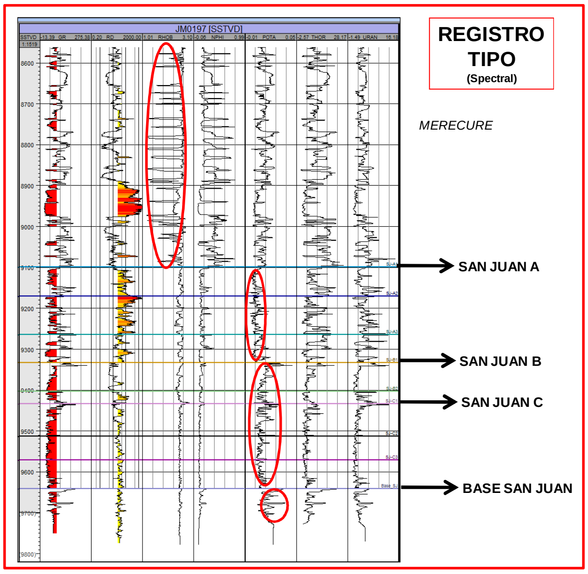


Figure 3. Record type showing stratigraphic divisions using Spectral GR_NTG Registration

Core Analysis

We performed a review of the cores from wells JM-191 JM-190 and JM-132 and detailed visual check of facies and facies associations previously described in 2000 and contained in sedimentary sheets.

Emphasis was placed on the key areas that separate sets of parasequences and parasequences (limits of sequences, minor erosional surfaces, bioturbated levels, flooding surfaces, paleosols, etc.). This being a key objective to corroborate the model stratigraphic correlations. As well as in bioturbated and its associations, its important meaning and help in the interpretation of sedimentological and stratigraphic pattern.

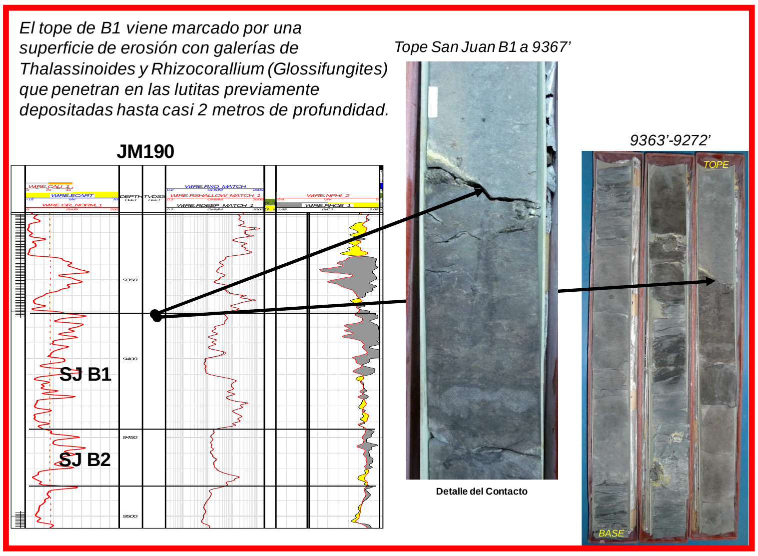
As most salient findings of the analysis must:

- *The tops of cycles granodecrecientes more developed fine-grained facies present and roots that indicate the presence of paleosols. Towards the base, the sandstone facies are medium to coarse grained.*
- *Basically, the sandstone facies and sedimentary structures present, cross-bedding sets and / or bioturbated facies.*
- *Bioturbation is intense in basically the entire core, indicating a very close environment of sedimentation shoreline. Dominate the large vertical component ichnofósiles SJA and SJB, while mastering the elements meiofaunales SJC, which indicate shallow marine or coastal sedimentation.*
- *Few natural fractures have been recognized in the cores and the highest density of them was found at the top of San Juan and preferentially facies fine-grained sandstones.*
- *Variations in the values of GR and / or massive sandstone resistivity Within The appearance in the GR, are in response to Change in grain size, intensity of bioturbation and the Presence of paleosols.*
- *Checked and calibrated stratigraphic interpretation that separates the cycle A1 A2, A3 and A2 through eroding surfaces and paleosols are interpreted as keys to stratigraphic correlation.*

- *The top of B1 is marked by an erosional surface with galleries and Rhizocorallium Thalassinoides (Glossifungites) that penetrate the shale / siltstone deposited prior to about 2 meters deep (Figure 4)*

- *The sedimentological criteria that separates B2 B1 in the nucleus shows that the sandstones of B2 are completely bioturbated while those of B1 have continuous cross-bedding sets with other types of bioturbation.*

- *The top of C1 is marked by an erosional surface with galleries Thalassinoides / Rizocoralium (Glossifungites) that penetrate shales previously deposited up to two meters deep.*



El tope de B1 viene marcado por una superficie de erosión con galerías de Thalassinoides y Rhizocorallium (Glossifungites) que penetran en las lutitas previamente depositadas hasta casi 2 metros de profundidad.

Figure 4. Stratigraphic contact between A3 and B1 subunits. The contact has a surface marked by erosive Glossifungites ichnofacies (well JM 190).

- *Variations in grain size and bioturbation hydrocarbon saturation control and physical properties of the rock (porosity and permeability).*

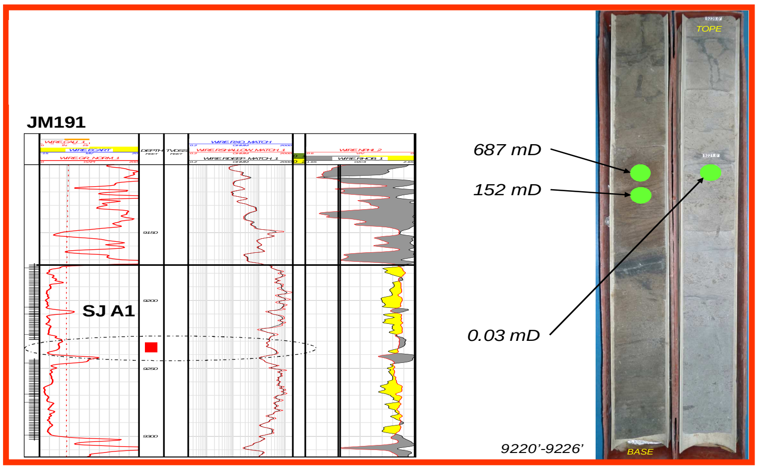
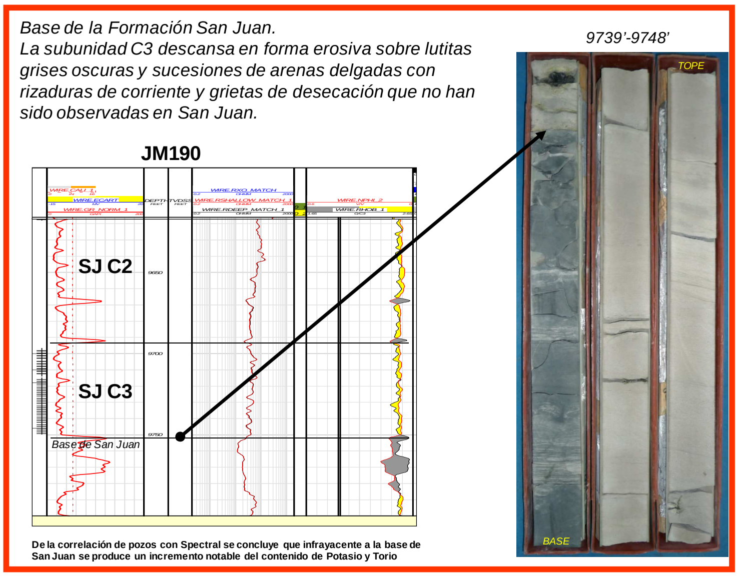


Figure 5. Significant variations in permeability due to changes in grain size and degree of bioturbation.

- *The contact between C2 and C3 San Juan is located in an erosive surface infrayace to shale dark gray, bioturbated, marine aspect and probably represent the remnant of the transgression.*
- *The base of the San Juan Formation rests on a dark gray shale erosion over a succession of sandstones and thin with ripple mark current and desiccation cracks that have not been seen in San Juan. based on observations in the core is thought to be the San Antonio Education San Juan infrayace which in this area, but biostratigraphic analysis are needed to confirm or rule this hypothesis (Figure 6).*


Base de la Formación San Juan.
La subunidad C3 descansa en forma erosiva sobre lutitas grises oscuras y sucesiones de arenas delgadas con rizaduras de corriente y grietas de desecación que no han sido observadas en San Juan.

De la correlación de pozos con Spectral se concluye que infrayacente a la base de San Juan se produce un incremento notable del contenido de Potasio y Torio

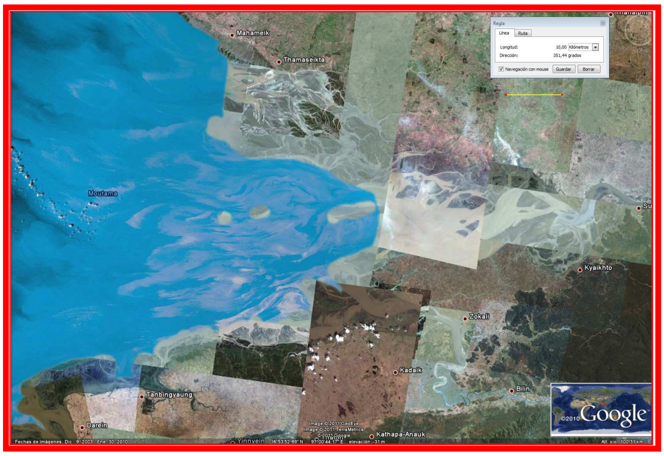
Figure 6. Erosive basal stratigraphic contact the San Juan Formation.

Sedimentary environments and depositional model

SJA sequence is composed entirely of channels/ bars facies associations develop on top of each cycle. The predominant sedimentary structure is high angle cross bedding indicating the migration of subaqueous dunes. There are bioturbations, but the type species, which is observed in some bodies, it is considered that due to the existing type of bioturbation, these massive and laterally extensive channels are probably near the coastline,although the river is completely domain. We defined at least 3 subunits or parasequences sets (A1, A2 and A3), where each represents an event of creating accommodation space and fill progradacional with subsequent abandonment, the latter based on the presence of paleosols at the top of each subunit and probably motivated the lateral migration of channels (figure 7).

Figure 7. SJA Level modern example showing the interlocking river systems development very close to the coastline. Sagavanirtok River (Alaska).

The sequence SJB present log responses showing both fining up sequence as coarsening up sequence, and which seem to correspond with facies associations of bars and tidal channels in a transgressive environment. Sequences of channels/ bars are observed in the cores with plenty of cross-bedding, enhanced by showing couples type oxidations tides and lots of vertical bioturbations type Ophiomorpha. The degree of bioturbation is quite intense in some sandstones in the particular body sand define as SJB2 subunit. This entire sequence is interpreted as a large estuary, consisting of bars and tidal channels (Figure 8).



Longitud: 10,00 Kilómetros
Dirección: 351,44 grados
☑ Navegación con mouse

Figure 8. SJ-B Level modern example analogue showing estuary environment. Moutama River, Martaban Golf, Myanmar.

San Juan C sequence (SJ-C) has been interpreted as shoreface facies associations with wave domain, based mainly on the coarsening up trend of the internal sequences in the Sedimentary facies mainly fine-grained and the presence of sedimentary structures typical of these environments, as swaley cross stratification parallel lamination and low angle planar cross-estratification. In addition, bioturbation characteristic of these sandstone in SJC sequence is basically type SJC meiofaunal or cryptobioturbation typical of these shoreface environments (Figure9).

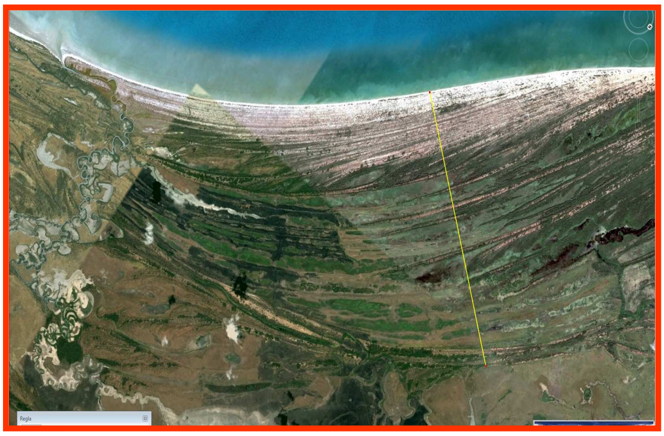


Figure 9. SJ-C level modern example of a prograding shoreface system (West Coast of Australia).

Sequential stratigraphic and biostratigraphic analysis.

The biostratigraphic study of Duran & Ramírez (2007) was used as the basis of these work for the chronostratigraphic framework in the Upper Cretaceous of the Area de Oficina in the absence of such analysis in the cores studied.

Of the selected intervals was obtained as a result, ages from Campanian (83.5My) and Upper Maastrichtian (65.5 My) covering 18 million years, which makes this interval can be classified as a sequence of comparatively order 2 (Vail et al,1991). and within it may have happened many cycles of order 3 and 4 (Figure10).

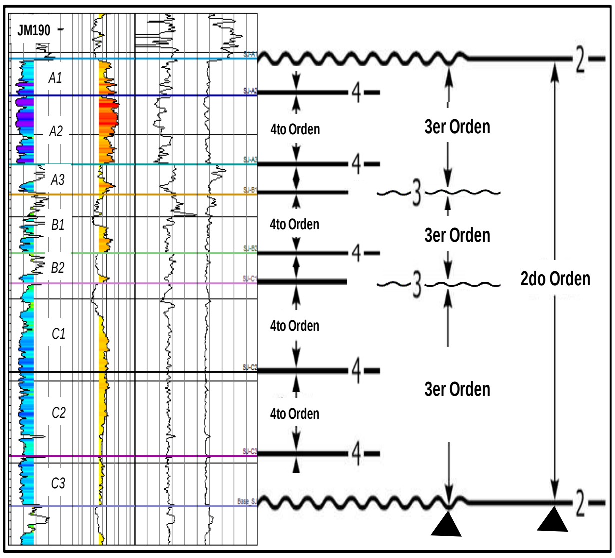


Figure 10. Organizational hierarchy in the sequence stratigraphy of the San Juan Formation.

Because we don't know the geological time lost caused by each sequence boundary, we must interpret each cycle or sequence in San Juan (A, B and C) probably has a 3 order sequence, may have lasted between 4 and 6 million years each.

This will allow us to infer that each existing subdivision within the 3 major sedimentary cycles defined for San Juan (A, B and C) be defined as sets of parasequences (which would be called A1, A2, A3, B1, etc), they could have lasted approximately 1 to 2 million years.

Figure 11 shows the interpretation and sequencial analysis in the well JM190 in terms of 3rd and 4th order cycles, where the blue triangles represent prograde (blueinverted triangles within the prograding pulses represent the creation ofaccommodation space on the train general progradation) and red triangles represent normal transgressions associated with the creation of accommodation space. It is note worthy that the surfaces that limit cycles of 3rd order is likely to be extrapolated outside San Joaquin, El Roble and Guario.

.

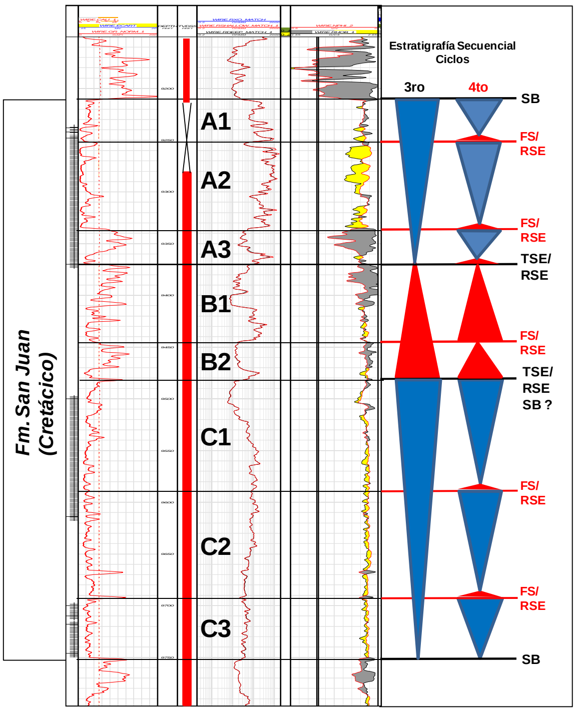


Figura 11. Organizational hierarchy in the sequence stratigraphy of the San Juan showing progradant/retrogradant cicles for 3 and 4 order.

Vertical Comunications, hidraulic units and compartmentalization

SJA has the sequence (June 2010), 832.7 Bcf of gas, while B and C together have produced 117.9 Bcf of gas. Previous studies claimed that all of San Juan could be a single hydraulic unit connected by fractures, based on the fractures observed in cores, pressure testing of training, production data and material balance. As a result of this study is presumed that this statement is partially incorrect because for example, the amount so poor systems of fractures observed in the nuclei, does not justify use the single causal factor for fractures as vertical communication observed through pressure data.

The well pressure data indicate that although there is vertical communication between units, this communication should not be assumed to be perfect, since the same pressure data also often reflected the existence of local barriers that affect the distribution of pressures. It is therefore not surprising that recent cases such as the JM-264 (located in a little drained historically), which found significant variations in pressure between SJA and SJB. This probably reflects the existence of areas where it is possible that the combination of local stratigraphic barriers and poor drainage, allowing it to appear cases such as the JM-264.

From the sedimentological point of view, vertical communication of fluids between the sequences of San Juan can also be explained due to the erosive nature of contacts between SJA and SJB SJB and between and SJC, which can result in many geographic areas sandstone contacts / sand between the units. And even if the presence of shale layers separating the units, the existence Glossfungites ichnofacies proven at the top of SJB and SJC, a factor that acts as a conduit for vertical communication facilitators.

Rock Quality

Petrographic analysis was performed of the San Juan Formation in the well JM-191. The sandstones sampled were classified as sub-arc cuarzoarenitas and (Folk, 1968). Quartz is the most common detrital mineral (69-82%) in the samples, with lesser amounts of feldspar (3-6%), detrital clay matrix (3-14%), lithic clasts (volcanic sand) and mineral authigenic (8-11%), among which the quartz overgrowths.

The samples show relatively low magnitudes of elements diagénesticos content (less than 11%). Diagenetic effects in descending order of importance, are: quartz overgrowth, authigenic clays, carbonates and pyrite. The quartz overgrowths are discontinuous, with very poor to poor development and tend to partially obstruct, the primary and secondary pores.

If you made a petrographic analysis of existing data for the entire San Juan Formation in the well JM-190, and plotted the main diagenetic effect reducing primary porosity such as overgrowth of silica, against the depth, which we note immediately measured the percentage of overgrowth diminishes in depth, which is totally contrary to the idea of increased diagenesis compared to SJC SJA, demonstrating that the precipitation of silica is not the cause of the declining quality of rock SJC as was thought to prior to this study (Figure 12). The samples show relatively low magnitudes of elements diagénesticos content (less than 11%). Diagenetic effects in descending order of importance, are: quartz overgrowth, authigenic clays, carbonates and pyrite. The quartz overgrowths are discontinuous, with very poor to poor development and tend to partially obstruct, the primary and secondary pores.

Making a petrographic analysis of existing data for the entire San Juan Formation in the well JM-190, and plotted the main diagenetic effect reducing primary porosity such as overgrowth of silica, against the depth, which we note immediately measured the percentage of overgrowth diminishes in depth, which is totally contrary to the idea of increased diagenesis compared to SJC SJA, demonstrating that the precipitation of silica is not the cause of the declining quality of rock SJC as was thought to prior to this study (Figure 12).

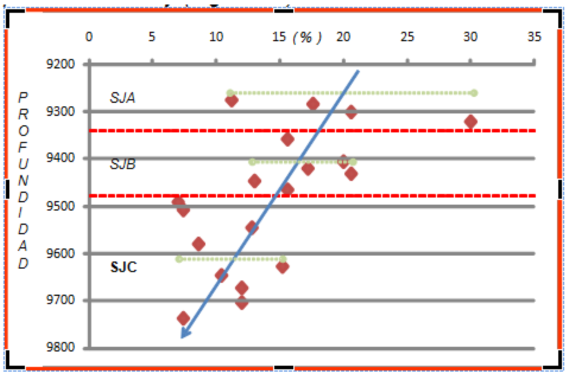


Figure 12. Quartz overgrowths Percentage distribution (Main diagenetic component of the San Juan Formation) in samples from well JM-190.

Based on conventional core analysis, a study of the variation of permeabilities in each of the sublevels of the San Juan Formation in order to evaluate the best interval in terms of quality rock, and, in Figure 13.A shows the variability in the range of permeability exhibited by different intervals of San Juan A. As shown, SJA2 SJA1 and about 40 to 50% of samples with good permeability between 100-1000 mD. Instead SJA3 and shows a decline in the same range at 29% and a marked increase in the percentage (54%) of sandy facies with bad permeabilities (less than 1 mD).

Figure 13.B shows the variability in the range of permeability exhibited by different intervals of San Juan B. As can be seen, and SJB2 SJB1 have very similar distributions with just 17 to 25% of samples with good permeability between 10-1000 mD. By contrast, SJB2 SJB1 and show a major proportion (62-79%)

in the percentage of sandy facies with bad permeabilities (less than 1 mD). This tied the greater the presence of fragments ductile and moderate to poor picking on the rock.

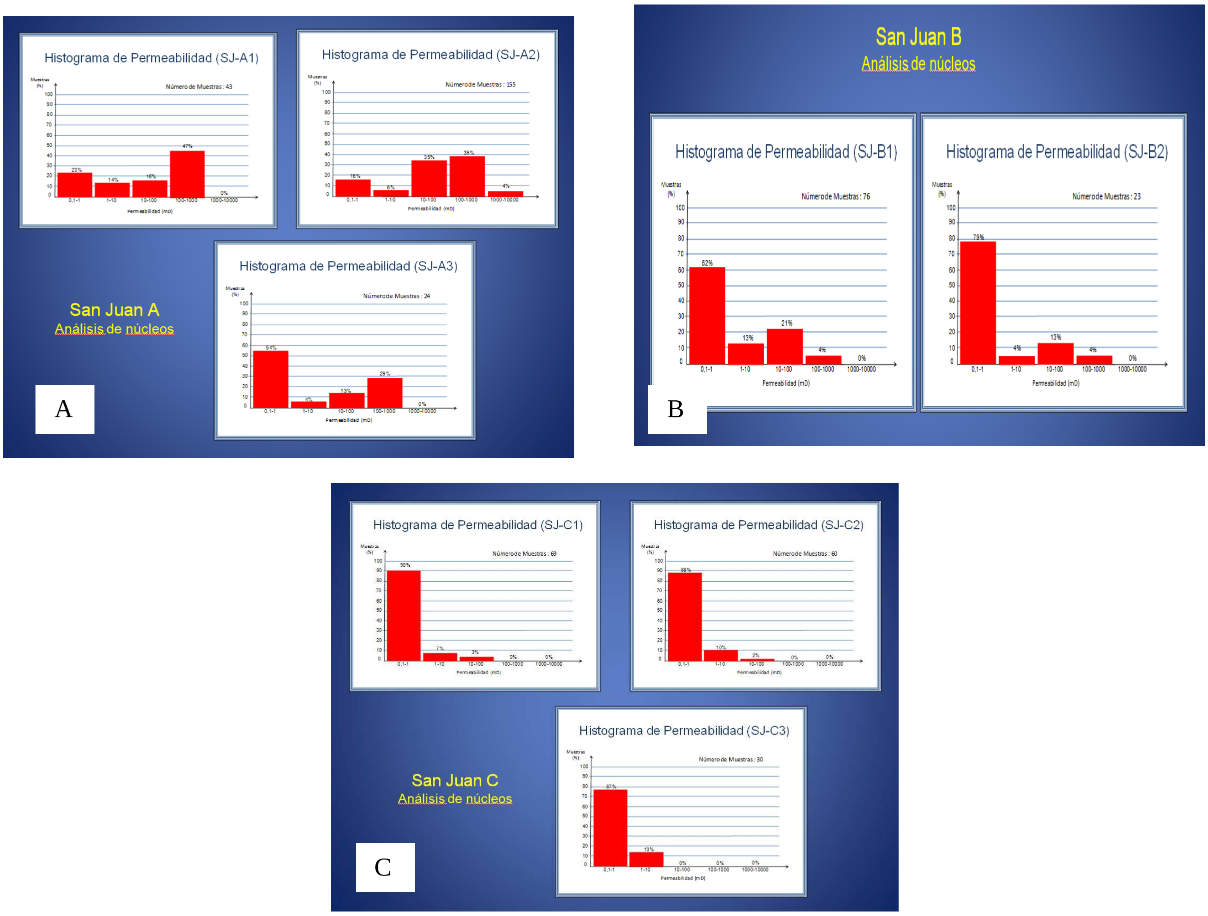


Figure 14. Permeability core ditribution by stratigraphics units (A.SJA B. SJB C.SJC).

Figure 13.C shows the variability in the range of permeability exhibited by different intervals of San Juan C. As shown, SJC1, SJC3 SJC2 and have very similar distributions with negligible percentages of samples with good permeability between 10-100 mD. In contrast with the sandy facies bad permeabilities (less than 1 mD), show an overwhelming majority (87-90%) within the population of the analyzed samples.
Figure 15. Distribution of permeability measured in core by stratigraphic unit (SJC).

Reserves

One objective of the interpretation of 3D seismic was to review new areas of interest may exist where large volumes of hydrocarbon reserves that were not visualized in previous studies. Thus, an evaluation algorithm using a seismic similarity (Michelena, R., Gonzales, E., Capello, M., The Leading Edge 17, 1998. Similarity analysis) which uses attributes that are linearly independent among them, and similar seismic facies is based on the location of a production well in the range of interest.

By producing well selected, you will extract the associated value in each depth using the selected attributes associated with the production. Then, that value is used to find similar seismic facies in each attribute, giving a 1 to a 0 similar area and not similar to the area. These "one's" are added and the similarity value will be associated with this anomaly.

This evaluation used 5 independent linealmentes attributes: Acoustic Impedance, RMS, Frequency, Polarity and phase Apparent. For the area of El Roble homoclinal selected well as RPN-75 is the only one who was punched to the sands B and has very good petrophysical characteristics. For sand pit C was selected by JM-132 show a good spread of seismic facies to homoclinal area.

A second evaluation was done using the acoustic impedance cube correlated with effective porosity values in 11 wells in the area, showing the correlation found by area, the regression line and the generated zone with 5% or more porosity. This is to support the possibility of mobility in the proposed area.

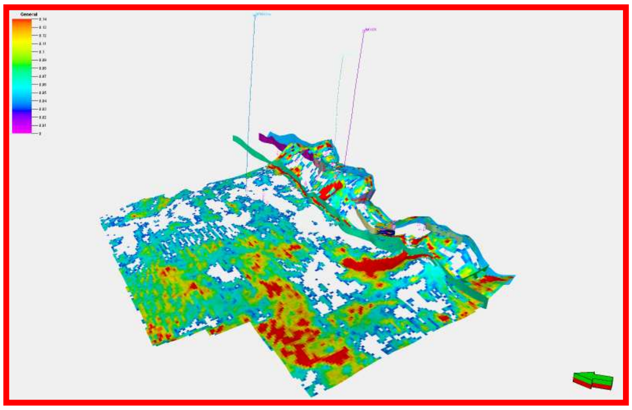


Figure 15. Impedance algorithm showing areas with PHIE> 5%. San Juan A.

Finally, using this new job methodology we included 500 MMMSCF of posibles reserves of gas in San Juan Formation in San Joaquin, El Roble, Guario fields.

Conclusions

- ✓ *The methodology integrating correlation from spectral GR logs, facies characterization from the description of cores and stratigraphic analysis - sequential seismic and pressure and production behavior of the wells indicates that levels SJA, SJB and SJC in the areas of San Joaquin, El Roble, Guario East of the country, are connected hydraulically in its entirety.*

- ✓ *Based on the analysis of cores from wells JM190, JM191 and JM132, the San Juan Formation can be subdivided into: SJA1, SJA2, SJA3, SJB1, SJB2, SJC1, and SJC3 SJC2.*

- ✓ *The production behavior of San Juan Formation is explained through the new geological model project outcome.*

- ✓ *The methodology used allowed us to identify new potential hydrocarbon accumulations in the levels listed SJ-A, SJ and SJ-B-C, with an expected increase in 500 MMMPCNG official GOES.*

- ✓ *The study identified the sites at pressures significantly above the current pressure for sand as SJA and extrapolated under the official views of the hydraulic unit to the sands and SJ SJ-B-C, this through hole at the JM-264 SJ-B drilled in February 2011.*

- ✓ *It confirms that the low resistivity in the San Juan Formation is associated with a condition of fluid mineral but a condition, according to the positive evaluation of JM-264 well.*

- ✓ *Petrographic analysis of the existing cores, allowed classifying the quality levels that comprise the San Juan Formation in diagenesis, picking grain and permeability, which is directly associated with the selection of production method that best suits each level.*

References

Bridge, J. *(2006) Fluvial Facies Models : Recent developments in Facies Models Revisited, edited by Walker, R. and Posamentier, H., SEPM Special publication # 84, p. 85-170*

Burfoot, W., I. Phillips, E. Delbos, C. Lindsay y B. Innes, 2001, Petrographic and Mercury Injection Analysis of Six-Sidewall Core Samples from Well JM-191 (San Joaquín Field), Informe de CoreLab 010506, 10 p.

Campion, K., Wagoner, J., Mitchum, R., Rahmanian, V. (2010) Parasequence associations in a shoreline succession : Blackhawk Formation, Utah. in Sequence Stratigraphy of siliciclastic systems edited by Abreu, V., Neal, J. and Bohacs, K. SEPM Concepts in Sedimentology and Paleontology # 9, 226 p.

*Casas, J***.** *(1997) Importance of bioturbation by interstitial meiobenthos in ancient sedimentary successions. Memorias I Congreso Latinoamericano de Sedimentología, Soc. Ven. Géol. Tomo I, Margarita, p. 157-160.*

Core Laboratories, 2002a, Sedimentología y Petrografía, JM-191 (Campo San Joaquín), PDVSA, informe interno, 21 p.

Core Laboratories, 2002b, Sedimentología y Petrografía, JM-190 (Campo San Joaquín), PDVSA, informe interno, 67 p.

Cross, T.A., and Lessenger, M.A., 1997, Correlation strategies for clastic wedges, in E.B. Coalson, J.C. Osmond, And E.T. Williams, eds., Innovative Applications of Petroleum Technology in the Rocky Mountain Area: Rocky Mountain Association of Geologists, Denver, p. 183-203

Dalrymple R., Zaitlin B & Boyd R. 1992. Estuarine facies Models: Conceptual basis and stratigraphic implications. Journal of Sedimentary Petrology 62: 1130-1146.

Di Croce, J. 1995. Eastern Venezuela Basin: Sequence Stratigraphy and Structural Evolution. Rice University Houston, Texas. Trabajo especial de grado, inédito, 225 p.

Durán I & Ramírez K. 2007. Estudio Bioestratigráfico del Campo El Furrial, Norte de Monagas. PDVSA-INTEVEP, Los Teques, CIT Nº11564,2007, Reporte interno, 88 p.

Gonzalez de Juana, C., Iturralde de Arozena, J. y Picard Cadillat, X. (1980). Geología de Venezuela y de sus cuencas petrolíferas. 2 tomos, ed. Foninves, Caracas, 1031 p.

Loset, T., Steel, R., Crabaugh, J. and Schellpeper, M. (2006) Interplay between shoreline migration paths, architecture and pinchout distance for siliciclastic shoreline tongues: evidence from the rock record, Sedimentology, 53, 735–767

Mial, A. and Miall C. (2001) Sequence stratigraphy as scientific enterprise : the evolution and persistence of conflicting paradigms, Earth-science reviews, Vol 54, 321-348

Michelena,R., Gonzales,E., Capello,M.(1998), Similarity analysis. The leading Edge.

McIlroy, D. (ed.) 2004. The Application of Ichnology to Palaeoenvironmental and Stratigraphic Analysis. Geological Society, London, Special Publications, 228, 29-62. Geological Society of London.

Pemberton, G., and Gingras, M (2005). Classification and characterizations of biogenically enhanced permeability. AAPG Bulletin, v. 89, no. 11, 1493–1517

Pemberton, G. MacEachern, J. and Saunders, T. (2004), Stratigraphic applications of substrate-specific ichnofacies: delineating discontinuities in the rock record From:
Miall, A. (1989) Stratigraphic sequences and their chronostratigraphic correlation, Journal of Sedimentary Petrology, Vol 61 No 4, 497-505

Rangel, M. (2010) Estudio Sedimentológico detallado de la sección cretácico tardío del Campo El Furrial, Norte de Monagas. Tesis de maestría UCV (Inédita), 184 p.

Vail, P.R., Audemard, F., Bowman, S.A., Eisner, P.N., Perez-Cruz, C., 1991. The stratigraphic signatures of tectonics, eustasy and sedimentology—an overview. In: Einsele, G., Ricken, W., Seilacher, A. (Eds.), Cycles and Events in Stratigraphy. SpringerVerlag, Berlin, pp. 617–659

Walker, R. y Plint, G., (1992) Wave and storm-dominated shallow marine systems in : Facies Models, Edited by Walker, R. and James, Geological Association of Canada, 219-238.