NOTAS GEOLÓGICAS

INTEGRATED SEQUENCE STRATIGRAPHIC MODEL FOR C1 UNIT (OFICINA FORMATION, MIOCENE), PETROCEDEÑO FIELD (JUNÍN), ORINOCO HEAVY OIL BELT, VENEZUELA

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FAJA PETROLIFERA DEL ORINOCO - VENEZUELA

INTRODUCTION

PetroCedeño Field is located within the Junín area, belonging to the Orinoco Heavy Oil Belt, at the southern margin of the Eastern Venezuelan Basin, South America (Fig. 1). The Orinoco Oil Belt is oriented parallel to the Orinoco River/ It has approximately 460 km long and between 40 and 80 km wide, with a total area of 55,300 km2, containing the biggest extra heavy oil reserves in the world.

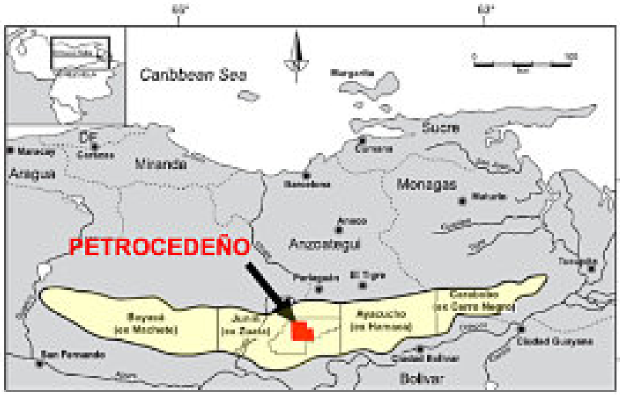

Figure 1: Map of northern Venezuela showing the location of the Orinoco belt (yellow) and PetroCedeño field (red).

Inside the Junín area, the PetroCedeño project was in the past, a Joint Venture between Pdvsa, Total, and Equinor (former Statoil). They started producing extra heavy oil (8.5° API) in 2000. The accumulation is mainly stratigraphic, in a thick volume of Early Miocene sediments, onlapping sedimentary rocks of Cretaceous age and or Cambrian. In some areas to the south, the Miocene sediments cover directly, crystalline rocks from the basement.

The Petrocedeño project is located along the foreland bulge on the south side of the eastern Venezuelan foredeep basin. Its hydrocarbon is derived mainly from marine source rocks from the early Paleocene to the Miocene, where traps are mostly stratigraphic.

DATABASE

PetroCedeño field has available 2D seismic lines and two 3D seismic cubes of 390 Km2 and 91 Km2 that were melted in one. Despite the extra heavy oil content of this field, located inside the Lower Oficina Formation (Morichal Member), mobility is enough to produce the oil by long horizontal wells. For many years, the pattern of these horizontal wells was radial and during the last six years such a pattern was changed to a fork pattern. The total number of horizontal wells has reached about 1500 and the typical length is about 1400 meters (4600 feet). The sand record was set in a well with 1694 meters (5555 feet) of continuous sand. All the horizontal wells were logged while drilling (LWD) with GR and resistivity.

The Fig. 2 shows the study area subdivided into small polygons called clusters or "macollas", in which the geometric center is the central point to place the production platform, making a development in a radial way or a fork trend, with some variations depending the geometry and orientation of the main sandbodies to be produced. The field also has an important number of vertical wells with stratigraphic purposes or observation purposes for about 200 wells. Also, the field has about 250 inclined wells, whose purpose was the investigation and delineation of the reservoirs, and at the same time to be the guideline as control points for horizontal developments.

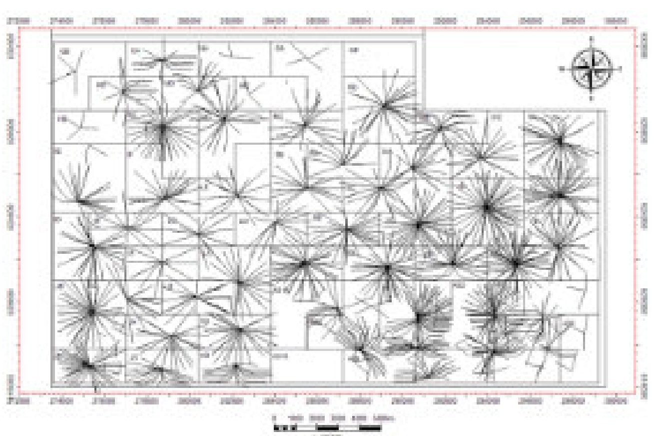

Figure 2: Study area, showing the cluster subdivision and the 2D projection of all horizontal wells drilled inside Oficina Formation. A radial pattern can be observed from the center of each cluster and a late pattern (fork type) in some clusters.

PREVIOUS WORK

Regional studies were made by numerous authors [1, 2, 3, 4] who interpreted the Orinoco Heavy Oil Belt as part of a peripheral bulge, that was not affected by the oblique compression between the Caribbean plate and the South American plate. Over the igneous-metamorphic basement, there are remnants of sedimentary rocks from the Cambrian age (Hato Viejo & Carrizal Formations) and Cretaceous rocks (Tigre & Canoa Formations), both tilted and partially eroded (Fig. 3). At the beginning of Tertiary time, sedimentation resumes, depositing Merecure Formation (Oligocene) to the north and the Miocene age, Oficina Formation, which were feed thought a depositional system moving sediments from the Guayana shield located to the south. Oficina Formation then, creates a thick clastic wedge to the south of a foreland basin within the Eastern Venezuelan Basin [5].

An important amount of core material is available; inside and in the neighborhood of the study area, for a total of about 40 cores, spanning different parts of the stratigraphic column of Lower Oficina. With this core information, several lithofacies and facies associations were defined and integrated with biostratigraphy and ichnological studies. The facies and facies associations were widely described and interpreted in [5, 6, 7] for this sedimentary section.

The structural framework of the PetroCedeño area was interpreted from 3D seismic cubes and revealed that a main fault runs east/west, along with some very small subsystems, described in [5, 6]. Fig. 3 shows a seismic line, oriented north-south, with the main seismic markers in the study area, and some of the operational stratigraphic units defined.

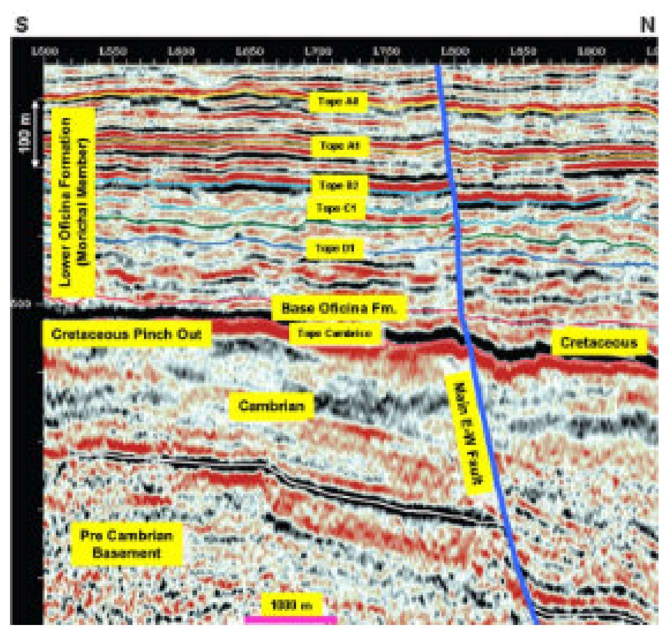

Figure 3: North-south seismic section across the study area shows the stratigraphy and the main interpreted seismic markers, along the operational units defined in the field. The main structural feature is an east-west fault crossing the entire field. Modified from [5].

During the last 15 years, some sedimentological and stratigraphical models have been published in the Junín area. The most important were [5, 7, 8, 9]. The first one [5], made a detailed sedimentological description of the Oficina Formation and the vertical stacking pattern, beginning with a fluvial setting at the base of the column, overlaid by a deltaic system that was progressively drowned and transformed into an estuary system, ending with a maximum flooding surface. Above this sedimentary system, they described a progradation with deltaic plain sediments tidally influenced, ending the Lower Oficina Formation (Morichal Member) cycle. References [5, 7] based their model (Fig. 4) in:

1) Recognition of key stratigraphic surfaces, correlated within the study area and definition of informal units or reservoir zonations.

2) The interpretation of the facies association and reservoir architecture based upon cores and its vertical stacking pattern, along with biostratigraphic data.

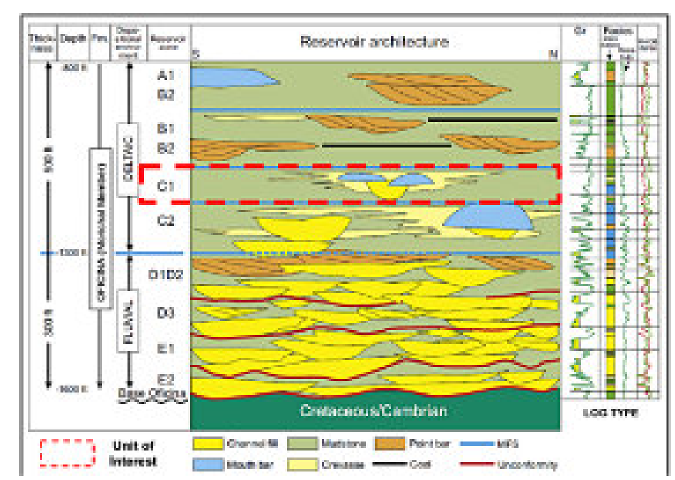

Figure 4: Stratigraphic model modified from [6, 7] with the operational subdivision and the architecture for Lower Oficina Formation (Morichal Member). Reference [6].

Later on, [8] in an unpublished Master Thesis, modifies parts of the previous model [5, 7], using a bigger study area, including some regional seismic, but unfortunately, with few wells and core data. With this data, the author [8] identifies three big system tracts, within the Morichal Member, starting with:

1) A lowstand system tract (LST) at the base of the Oficina Formation (composed of Units D, E, and F). This LST is associated with a relative sea level drop close to the limit of Oligocene-Miocene, where fluvial braided deposits filled the topographic lows over the sequence boundary and aggradated, probably reflecting a fast increase in accommodation space. This system tract in both models [5, 7, 8, 9], has the same interpretation.

2) A transgressive system tract (TST), where a fast rise of the eustatic level, moved the coastline to the south of the basin, depositing a big deltaic to the estuarine system (composed of C2 and C1 units, Fig. 4 and 5). References 8 and 9, interpreted this system tract as a continuous transgression. Hence, the difference in both models is that [7], proposed deltaic environments progressively drowned by the transgression, and in [8], it was proposed that the entire system is exclusively estuarine. The top of this transgressive system tract in both models is defined by a regional maximum flooding surface (MFS), at the top of the C1 unit, that can be traced hundreds of kilometers across Faja del Orinoco [6, 7, 8, 9, 10].

3) Finally, for the Morichal Member, both authors described a high stand system tract (HST) above the MFS, composed of fluvio-deltaic progradational pattern tidally influenced (composed of Units A and B, Fig. 4 and 5).

BIOSTRATIGRAPHY OF THE LOWER OFICINA FORMATION

There are numerous biostratigraphic internal reports in the area, with the resulting analysis from different cores. Reference [11] represents a good summary of them, showing the analysis of 76 samples for 15 different cores in the study area, to obtain geological age. Those analysis results shows that Lower Oficina Formation (Morichal Member) in the study area, may correspond to palinological zones T1 y T2 (Early Miocene).

In a more extended and detailed study [12, 13, 14], working with the core material regarding nanoplankton and palynology for the study area, the authors concluded that Lower Oficina Formation corresponds to T1 palynological subzone [15].

TIMING OF THE SEQUENCE STRATIGRAPHIC UNITS IN THE STUDY AREA

An approximation of geological ages using biostratigraphy for some key surfaces defined in the study area was published in [16]. As is shown in Fig. 5, the age assigned for these authors to for example top of unit B1 is about 16.8 Ma, and the age for the base of Lower Oficina Formation is about 23.8 Ma. The difference between both gave us 7.0 Ma, which is classified (using [17] hierarchies) as a depositional sequence of 2° order (unit range), containing several system tracts and parasequence sets in that period.

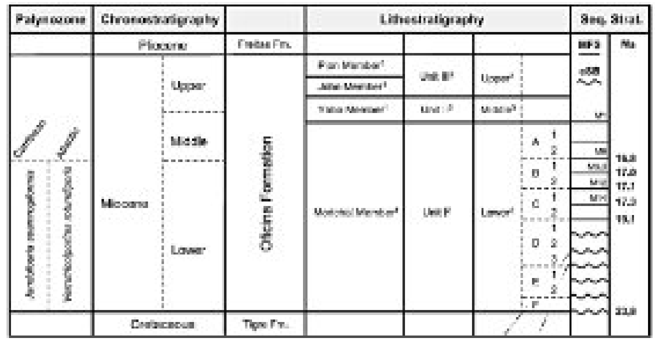

Figure 5: Stratigraphic column at Faja del Orinoco, and geological ages. Modified from [15].

Taking another example from Fig. 5, the LST defined by [7], [8] and [9] is located between the base of Oficina Formation and top of unit D1 (the span between 19.1 and 23.8 Ma), so the difference is about 4.7 Ma, placing the duration of this LST as a 3° order cycle, where sedimentary deposits, (parasequences and parasequence sets), basically fluvial in origin, fill and aggradates. The vertical stacking of repeated facies and facies associations in this system tract reflects a fundamentally aggradational setting.

All the previous analysis allows to conclude that the Lower Oficina Formation (Morichal Member) is a depositional sequence of 2° order, composed of different system tracts of 3° order, and the internal operational units defined for the study area, like B1, B2, C1, C2, D1, D3, E1, E2 and F (Fig. 4 and 5) are interpreted as 4° order parasequences or parasequence sets, according to the biostratigraphic dating [16].

RATIONALE FOR A NEW MODEL

The idea to review the current sequence stratigraphic model is based upon two major key points:

1) A lot of new data was acquired between 2012 and 2020, in the PetroCedeño field, with new vertical and inclined wells, hundreds of horizontal wells, and new core material, all inside the study area, that has to be incorporated into the stratigraphic model.

2) The previous models failed to explain or predict, some features in the sequence stratigraphic evolution of the Lower Oficina Formation, within the study area, mainly in the C1 operational unit or parasequence set C1.

The "Channel Problem" in the Operational Unit C1

The current models cannot explain in a sequence stratigraphic context, the presence of anomalous thick channelized sandstones with an apparent erratic distribution in the upper part of an interpreted transgressive system tract (C1 unit). Reference [18] in an unfinished and unpublished internal report, stated that in future work, evidence of relative sea level fluctuations has to be explored, as a possible explanation of some thick sandbodies located inside C1 and in the upper part of the C2 operational unit. Reference [18] also mentioned that looking at the 3D seismic, there is not enough resolution to interpret incised valleys and further investigation must be done with the 3D seismic to test that idea.

A study published in [19], focused only on the operational unit C2, where that stratigraphic section is composed of the vertical stacking of three parasequences (C21, 22, and 23). In some stratigraphic sections, the authors mentioned the possibility of incised valley fills based on the deep erosion probably produced by some sandbodies above C2. In 2008, one of the authors (Casas, J.), made an unpublished net sand map for the C1 operational unit within the PetroAnzoategui field, located just northeast of the study area and showing an important isolated sandbody with a NW/SE orientation (Fig. 6), almost perpendicular to the depositional system trend in the area for all the parasequence sets in the stratigraphic column [7, 9]. This thick sandbody was correlated with all available well data and interpreted stratigraphically, as part of the operational unit C1.

In this area, the anomalous sandbody is up to 24 m (80 feet) thick, and about 2.5 to 5 km wide. Outside this sandbody, the wells around showed net sand values close to zero (Fig. 6). This is strong evidence, very close to the study area, about the presence of an incised valley fill (IVF) system in the area. Using this analogy, the main channels observed in C1, within the study area, will be interpreted as an incised valley system (IVF) and discussed in detail, in further chapters with new evidence. References [7] and [9] mentioned in a general sense, that the C1 operational unit shows a change in the orientation of the sedimentary trend. At that time, the author did not realize this was probably related to the superimposed incised valley system over the previously interpreted transgressive system tract (TST).

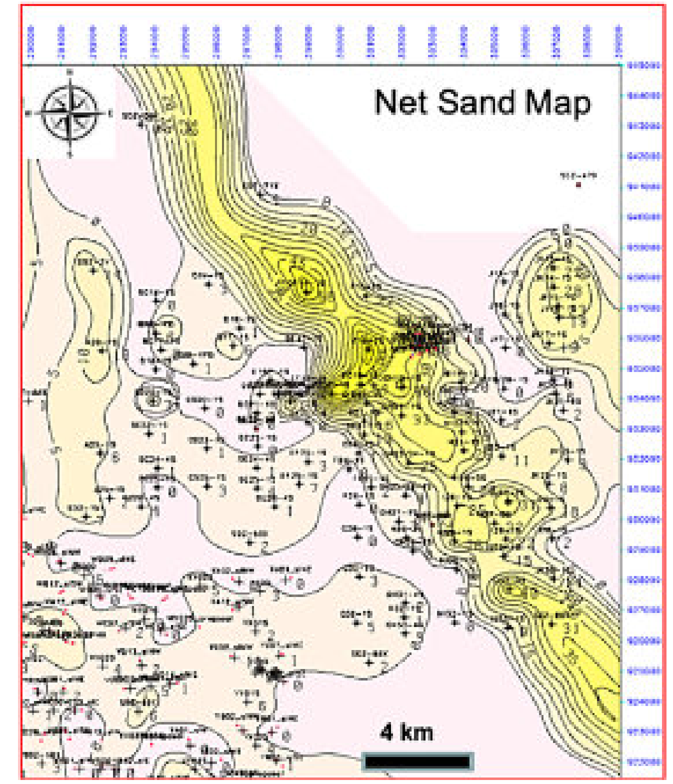

Figure 6: Net Sand Map from operational unit C1 at the northeast of the study area. Reference [9].

All the previous ideas exposed, have strong implications and changes in the previously published sequence stratigraphic models [7, 10], because both only defined a continuous transgressive event for the C2-C1 units, ending with the MFS at the top of C1. The possible explanation to account for these anomaly thick sandbodies in the C1 operational unit is related to a relative sea level drop, to decrease the amount of accommodation space, allowing an important incision process. This event also can be associated with a minor tectonic rise pulse, suggested by the change in the paleosedimentary trend [9]. The hypothesis of the tectonic pulse has to be further evaluated with a regional study, so by this time, the relative sea level drop is the simplest explanation with the available data within the study area. All this changes the previous sequence stratigraphic reference, because a new sequence boundary, never described in this area, has to be included in the sequence stratigraphic model [9].

SYSTEMS TRACTS IN THE C1-C2 UNITS

A. The Original Transgressive System Tract

Over the fluvial deposits that filled the lowstand system tract (LST), mentioned in [5, 6, 7, 8, 9], the first indications of estuarine and marine influence appear in the sedimentary section. Also, for the first time some thin coals, aerially extended, are well noticed. They all point to the beginning of the first transgressive system tract (TST). The presence of these continuous coals and coaly shales at the very top of D1/base C2 operational units can be interpreted as the response to the rise in relative sea level and the rise of the phreatic level in a more continental setting [20].

The transgressive system tract (TST) is composed from base to top of operational units C2 and C1, each of them formed by the vertical stacking of parasequences (mostly with a sandier upward trend), but at the same time all together with an apparent vertical transgressive pattern [7, 9]. In the sequence stratigraphic model, this TST ended with a regional MFS at the top of the C1 unit.

B. The New Lowstand System Tract and the second Transgressive System Tract

During TST late development, a relative sea-level change must occur, because of the interruption of the transgression. Once the relative sea level drop took place, a series of incisions were developed across the entire study area and beyond. Different pieces of evidence point out the existence of this incised valley system, but the main ones are:

1) Anomalous sand thickness (sandbodies up to 24 m thick) close to the top of a previously interpreted TST.
2) These thick sandbodies pinch out laterally in only a few hundred meters.
3) Some well logs show anomalous responses compared with the normal transgressive vertical stacking pattern of C2/C1.
4) The mapping of each anomalous sandbody shows geometries and orientations rather than the sedimentological trend of the rest of the operational units or parasequence sets (NE/SW).
5) Outside the study area, it has also been suggested for the C1 unit, the existence of thick anomalous sandbodies with quite different sedimentary geometry and orientation.

Figure 7 shows a possible interpretation of the sequence stratigraphy events and the system tracts involved in explaining the thick oil-bearing sandbodies in some wells for the C1 and C2 operational units in the southern part of the study area (LC-LA-AS11 clusters).

During the evolution of the C1 parasequence set, a relative sea-level fall might create an erosive surface, cutting deep and narrow valleys, probably filled during the LST and later filled up when the transgression resumes, creating a second TST. This new TST ended quickly, placing an interpreted MFS for the entire Orinoco Heavy Oil Belt area [9].

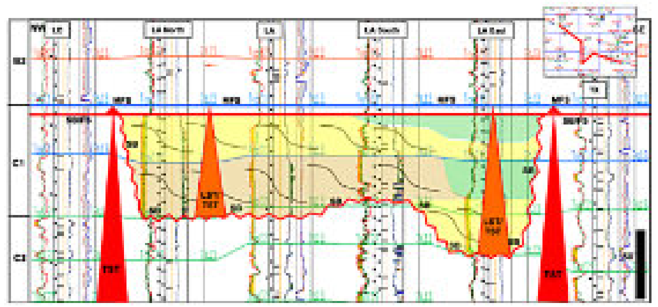

Figure 7: Sequence stratigraphy interpretation for clusters LC/LA/AS11, showing the presence of an interpreted incised valley, cutting the normal TST vertical pattern for C2/C1 units observed in wells LC and TX. The cross-section spans about 6 km between both wells. The datum corresponds to the MFS at the top of the C1 unit. (Green color = shaly fill, yellow/brown color = sandy fill). Reference [9].

The existence of an incised valley system cannot be an isolated feature in the study area. It must be a regional event that should be recognized in other areas of the Orinoco belt. When the key stratigraphic surfaces interpreted in the study area were extrapolated into the neighborhood field to the northeast (PetroAnzoategui), the correlation indicates that the anomalous sandbody mentioned before (Fig. 6), truly corresponds to the C1 unit, below the regional MFS. In this PetroAnzoategui field, a core cut in the C1 unit (well 171) was analyzed and interpreted, confirming the existence of a sequence boundary within the C1 unit [9].

As can be observed in Fig. 8, the core/log description and interpretation from well 171, allowed the identification of different key surfaces like a SB at 2218'8'' (Venezuelan standard units for well-core depths are in feet and inches), represented by a sharp contact between medium to coarse-grained fluvial sandstones above, and a tidally influenced succession below (Fig. 9). Above the sandy filling of the incision, a TSE was interpreted at the contact between a 30 cm coal layer and a 60 cm overlaying sandy siltstone, fully bioturbated by Asterosoma (Netto, R. 2019, personal communic.). References like [19] suggested that a coal at the top of an incised valley fill may represent the flooding surface (FS) associated with a transgression. Still, in this example, Reference [9] interpretation placed the TSE immediately above the coal layer, at 2173'2'' (core depth), where the fully bioturbated sandy siltstone appeared, probably representing the first truly brackish to marine influence in this area. Above that section, an interpreted MFS ends the transgression, confirmed with the core information, corresponding to a high GR peak (Fig. 8) in that well log.

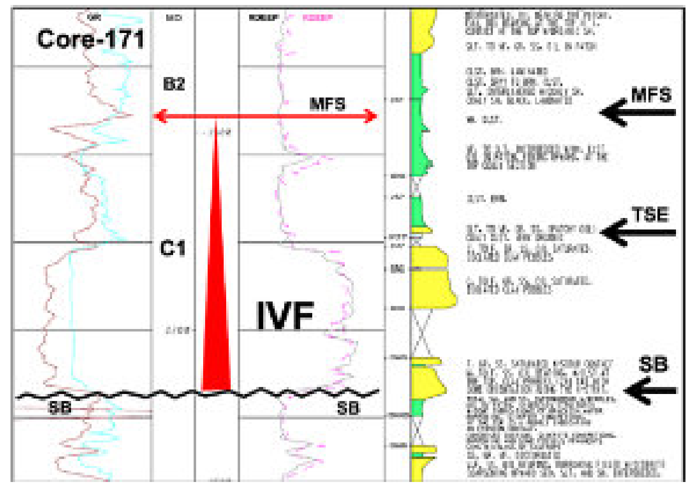

Figure 8: Well log and original core description (author unknown) of Core-171 showing the sedimentary section interpreted as an incised valley fill (IVF), within the C1 operational unit. Notice the interpreted SB at the base of the fluvial channel facies and the MFS upwards in the core section, coincident with the GR peak response (high radioactivity).

The following Fig. 9 shows core photos from the mentioned cored-well 171, highlighting the sharp contact between interpreted fluvial sandstones (above) and interpreted tidal successions typical from the C2 unit. This sharp and erosive contact (Figure 9, right side) is interpreted as a sequence boundary (SB) originated during C1 unit time.

Fig. 10 shows the conceptual model modified from Reference [18] and created to explain the system tract distribution in this section of the stratigraphic column. This conceptual model would explain the presence of abnormal sand thicknesses and its areal and localized distribution within the operational unit C1. As it is shown in the same Fig. 10, the sequence boundary (SB) in places, may have eroded deeply both C1 parasequences (C11-C12) and may even have reached the upper part of the underlying C2 unit [9].

After de SB, produced by the relative sea level fall, and the creation of an incised valley complex, a new transgression occurred, filling the incised system and ending with a regional maximum flooding Surface (MFS), identified as top of the C1 unit (top of parasequence C11). Examples showing this MFS, are recorded by many cores inside and outside the study area. The MFS also corresponds most of the time to a maximum peak in the Gamma Ray (GR) log response, calibrated with the presence of many cores, of biostratigraphic abundance and diversity content, around this MFS surface. Fig. 11 exemplifies this important surface definition based on cores, well logs, and biostratigraphy. This is an important key surface that can be traced along the entire Orinoco Heavy Oil Belt. [6, 8, 9].

Figure 9: Core interval 2207´-2221´ from well 171, where the interpreted SB can be seen in C1 unit, with a sharp/erosive contact, and the sandy filling of the incision. Reference [9].

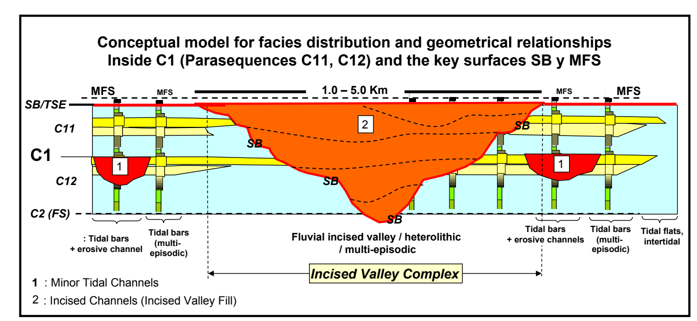

Figure 10: Conceptual model regarding the distribution of facies associations and genetic relationships, to explain the presence of an incised valley system complex in C1.

INTEGRATION OF HORIZONTAL WELL DATA INTO THE NEW SEQUENCE STRATIGRAPHIC MODEL

The development of PetroCedeño field, with its extra heavy oil reservoirs, was carried out with the drilling of long horizontal wells. Every horizontal well stars with a vertical to inclined section before reaching the landing point, where the proper horizontal section begins. This logged vertical/inclined section also provide valuable stratigraphic information in every cluster area. Also, during horizontal drilling, some stratigraphic branches would be necessary (up and down) to confirm the presence or absence of the targeted oil-bearing sandbody. These branches also provide stratigraphic control points, along the main horizontal section, and they were included in this study to obtain a more robust sequence stratigraphic model for the C1 unit [9].

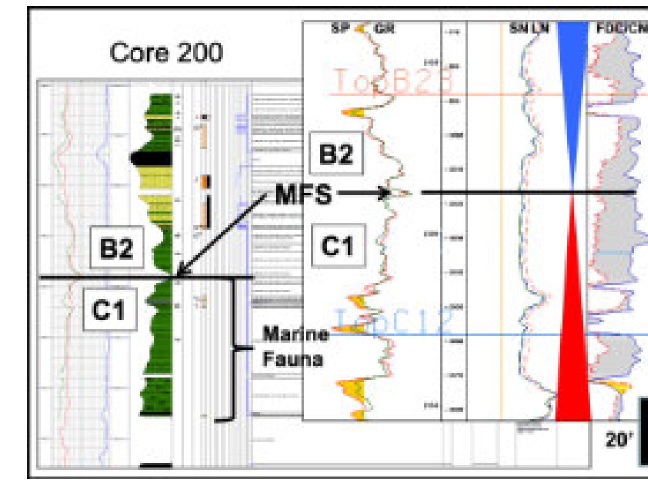

Figure 11: Core-log calibration for Well 200, showing the maximum flooding surface (MFS), ending the second transgressive system tract. Modified from [9].

Fig. 12 shows a seismic line and cross-section in LD cluster, both oriented SW-NE, along horizontal well Hor14 trajectory, with two additional control wells, RX and LD northeast. The horizontal well had as a target, the operational unit C2 Lower. In the logged sectio through the vertical/inclined trajectory of Hor14, it is possible to observe the development of a massive sandbody about 15 m (50 feet) thick, within the C1 operational unit. The sandbody is interpreted as a possible incised channel, or incised valley fill (IVF), that is not present in control wells RX and LD northeast, despite the close distance from the first one (about 200 meters). The seismic responses close to Hor14 are discontinuous and that may be is related to the presence of an incision, confirmed by the sandy presence in the inclined section of the well itself (Fig. 12).

Fig. 13, another example of a seismic line and cross-section (SE-NW) is shown, but now for cluster LA. Well LA and the vertical/inclined section of Hor 06, also crossed a thick sandbody in operational unit C1, interpreted as an incised valley. This sandbody is absent in control well LA East, which is 430 meters from the southeast. Again, in this seismic line, thick sandbodies in

C1 seems to correspond with chaotic seismic responses [9].

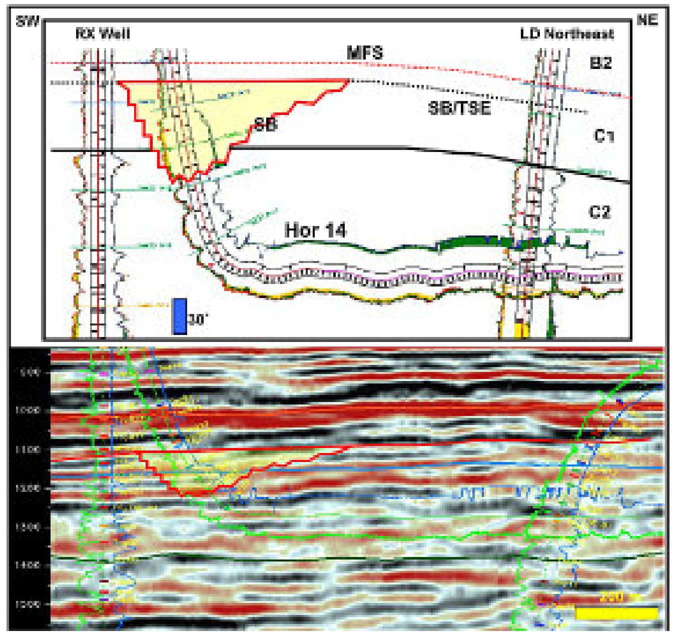

Figure 12: Well cross-section and seismic line from cluster SE showing horizontal well Hor 14. In its inclined section, the well crosess a thick sandbody (50 feet thick) in the C1 unit, which is not in the well RX (200 meters away). The sandbody is also absent in well LD Northeast. Reference [9].

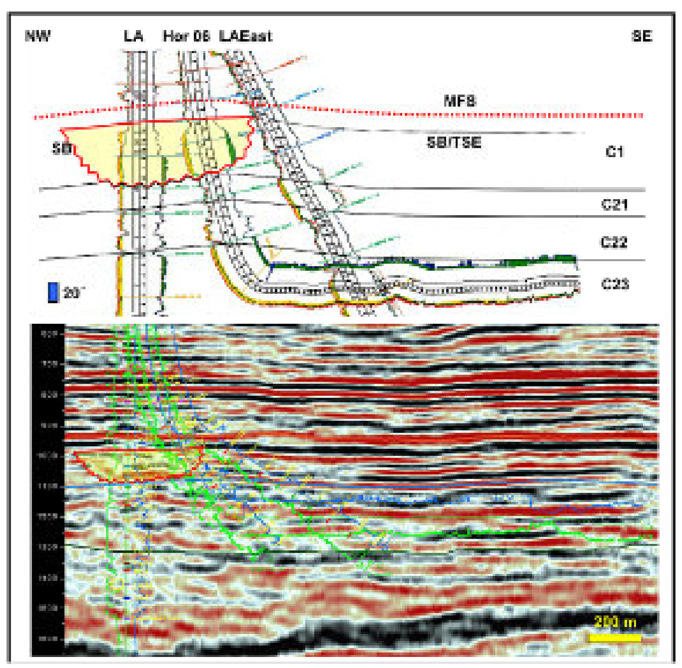

Figure 13: Example in seismic and well cross-section for cluster LA, showing wells LA and Horizontal 06 crossing a thick sandbody in operational unit C1. The sandbody is absent 430 meters away in control well LA East. Reference [9].

The Fig. 14 shows an arbitrary seismic line between SA and SB clusters (central area), following the trajectory of horizontal well Hor13, and targeting the C2 operational unit. This seismic line, is one of the best examples where apparently a perfect delineation of the incised channel, or incised valley fill (IVF) can be interpreted, cutting most of the C1 operational unit. This geographical location in the seismic confirmed the geometry and orientation interpreted in this cluster, using only well logs interpretation [9].

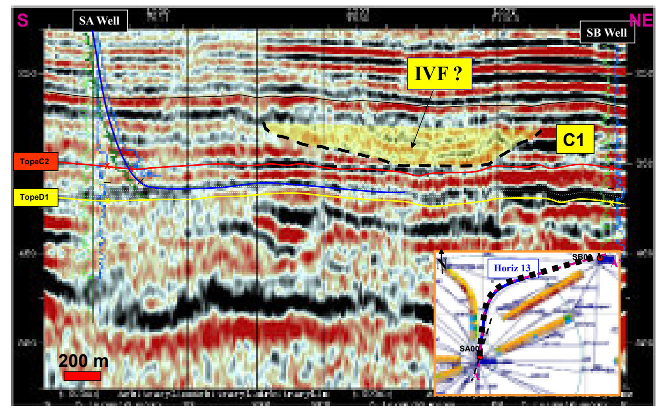

Figure 14: Seismic line along horizontal well Hor13 (black dotted trajectory), using as reference vertical wells SA- SB. Between vertical wells, an anomaly in seismic response can be seen and interpreted as a possibly incised valley fill (IVF).

2D MAPPING OF WELL AND SEISMIC DATA WITH THE INCISED VALLEY FILL (IVF) INTERPRETATION

From the interpretation of all wells (verticals, inclined, and horizontals), showing sedimentary bodies with features considered part of an incised valley complex, a stratigraphic interpretation was achieved regarding the possible geometry and orientation of such complex or system in the study area. Starting with the hypothesis that many of these incised valley features may be well connected, the interpretation emphasized geographical continuity between all the wells with incised valley interpretation. The interpretation of the valley system in some regions of the central study area, had excellent well control, allowing a good interpretation of the complex valley system, normally very narrow and localized, sometimes with strong sinuosity. On the other hand, some areas/clusters to the east, are highly interpretative because of the low density of wells, so more emphasis was placed on the seismic features observed [9].

In Fig. 15 the wells interpreted were placed over a time slice generated within C1 unit (50 milliseconds above the base of C1). The seismic slice did not show a clear image of the incise system along the study area, only some clusters in the south-central area showed morphologies that can be associated with a possible incision. Also, some seismic features in the eastern region, helped the interpretation, because the well density control was scarce. With the current 3D seismic quality, even working with different attributes, it was impossible to calibrate confidently, anomalous sand thickness or erosive features in the study area. More detailed work with different seismic attributes has to be done in the future, including drilling some additional key wells and cores, to prove better the hypothesis presented in Reference [9].

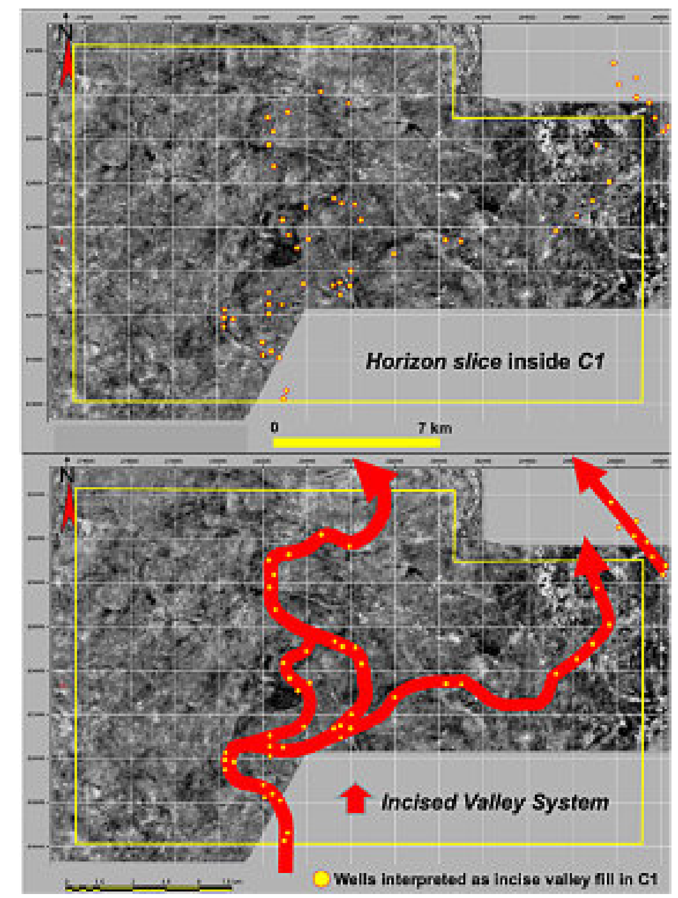

Figure 15: Time slice 50 milliseconds above the base of unit C1 (uninterpreted above). 2D interpretation of the incised valley system for the C1 unit (below) overlying the time slice. Notice the high sinuosity trajectory in some places, and its interpretation outside the study area to the northeast. Yellow dots in both images are wells interpreted as valley-fill sediments. Reference [9],

CONCLUSIONS

The sedimentary deposits of the Lower Oficina Formation (Early Miocene) at the study area (Junín Block), represent a depositional sequence of 2nd order, composed of several systems tracts of 3rd order, which in turn are composed of several transgressive/regressive cycles of 4th order. Most of these cycles corresponded to parasequences and parasequence sets, that in the past were referred to as informal operational units (reservoir zonation) and termed A1, A2, B1, B2, C1, C2, D1, D2, D3, E1, and E2, from top to bottom.

The great number of vertical wells, slanted wells, and horizontal wells, as well as numerous cores and the 3D seismic in the study area, yield the definition and confident correlation of a series of key surfaces traced along the study area and beyond. Adding the detailed core descriptions and interpretations over the years, and the amount of biostratigraphical studies created a robust base for establishing a sequence stratigraphic framework in the Lower Oficina Formation (Morichal Member) for this part of the Orinoco Heavy Oil Belt.

Close to the end of a parasequence set, with a clear transgressive pattern (C2/C1), a relative sea-level drop occurred in the area, generating a sequence boundary (SB) and an incised valley system. These incised valleys show great complexity and sinuosity, creating a narrow and localized system in the study area.

With a new relative sea level rise, some fluvial facies were preserved inside the valley system, deposited probably during the LST time. The facies association them, gradually became more and more transitional towards the top of the valley, until a transgressive surface of erosion (TSE) was placed across the area, eroding in some places the SB. The TSE was confirmed in a few cores outside the study area. This TSE marked the change between the LST (preserved mostly inside the valley system) and the new transgressive system tract (TST) period. This new TST ends with a well-defined MFS (calibrated with wells, cores, biostratigraphy, and seismic as C1 Top), along most of the Orinoco Heavy Oil Belt.

Integrating 3D seismic, vertical, inclined, and horizontal well data into the sequence stratigraphic model has been crucial to delineate the geometry, orientation, and continuity of the main sandbodies, especially in the case of the incised valley complex, at the C1 operational unit. The information obtained by the inclined landing sections in many horizontal wells, allowed in several clusters, defines a very complex incised valley system.

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