

# **Oligocene Unconformity and Depositional Model Update: Application for Hydrocarbon Prospectivity, Llanos Basin, Colombia\***

**Ignacio Iregui<sup>1</sup>, Alexis Medina<sup>2</sup>, Ivan Becerra<sup>3</sup>, Martin Morales<sup>3</sup>, and Diana Quinche<sup>3</sup>**

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<sup>1</sup>Cepsa Colombia, S.A., Bogotá, Colombia ([ignacio.iregui@cepsa.com](mailto:ignacio.iregui@cepsa.com))

<sup>2</sup>Cepsa E.P., S.A., Madrid

<sup>3</sup>Cepsa Colombia, S.A., Bogotá, Colombia

## **Abstract**

Data integration from sequence stratigraphy, biostratigraphy, chrono-well correlations techniques among others as log signature, thorium/potassium ratios, and fluid analysis suggests that Early Tertiary sand deposits presence - C9 formation - (former Eocene Mirador Formation) is controlled by an erosional surface named Oligocene Unconformity (OU), acting as the base of these reservoirs and defining the deposit geometry from Upper Cretaceous to Lower Tertiary sequences. It became necessary to use 3D seismic surveys available that, combined with new well data, made possible to adjust interpretation and seismic attributes that allowed to map the C9 Formation (main reservoir), the OU and the Cretaceous Guadalupe K Formation (secondary reservoir) for the first time, usually bypassed regarding to previous models. The OU seems to record and control both reservoirs geometries (dendrite geoforms associated to an estuarine environment) therefore useful to determine presence and/or absence of Lower C9 Formation but also and more important, of Guadalupe K Formation, recognized as the main reservoir for neighbor areas but never tested inside the area of study. Given the drawback of low seismic resolution due to relatively thin reservoirs and the OU presence, the use of seismic attributes was determinant to guide the detailed horizon picking, also key tool to overcome the notable difficulty of following the nearly plan parallel unconformity surface (paraconformity). All these results were used as main inputs for a complimentary project which involves quantitative interpretation methodology (seismic inversion, spectral decomposition, seismic facies classification) out of the scope of the present work, to complete the final prospectively assessment. It can be concluded that the Upper C9 Formation is present everywhere inside the study area with some slight thickness variation and corresponds to amalgamated siliciclastic sandstones genetically related to estuary environment of low accommodation. The Lower C9 Formation is very similar to Upper C9 but confined to the channels and mostly absent outside of them with some exceptions. Finally, the Guadalupe K Formation is partially or totally truncated/eroded by Lower C9 Formation incision, corresponding to “lows” and it is found where the paleo-topography of the OU exposes its shoulders or “highs”. The latter opens the floor to a new regionally unexplored stratigraphic play of a world class reservoir.

## **Introduction**

On previous studies, a new nomenclature for Oligocene basal units has been defined lying unconformable over the Oligocene Unconformity (OU). (Mondragón et al., 2016). They were the solid basement for the present study which aims basically to review and finally update also the geological model below the OU finding new exploration opportunities not taken into account before inside the area. However, there is work to do regarding biostratigraphy because there still exists a lack of certain data that can confirm the new hypothesis.

## **Geological Setting**

The Colombian foreland, specifically the Llanos Basin, has been the country's most prolific one during the last century (Figure 1). The common play type proven by nearby analogues is related to normal faults dipping eastwards (Antithetic faults), in other words, a conventional trap of monoclines closing in three ways against these structures. Nevertheless, recently some structures dipping westwards (synthetic faults) with clearly non-closing contours against the fault have proven hydrocarbons also opening the floor to the next step in exploration around the area. The lateral facies changes seem to allow oil and gas entrapment on this basin therefore a solid geological model is fundamental to drive the new exploration horizons.

Carbonera Formation (Tertiary) is an alternation of sand and shale Oligocene sequences (C1 to C9 members) of a fluvial-estuarine depositional environment lying over an Oligocene Unconformity (OU) which separates them from the Paleocene shaly formations (Cuervos-Barco Formation) as well as Cretaceous formations (Guadalupe Formation and Gachetá Formation). Recognized reservoirs located above and below the OU are within these formations representing the center of the study (Figure 2).

The geological model has evolved through time. First, the re-naming of Oligocene basal reservoirs to distinguish them from foothills Eocene sands formerly treated as the same, and also extending the Paleocene and Upper Cretaceous presence from a restricted western area to a full extent with only local variations. This model update increased the number of opportunities covering from combined to pure stratigraphic plays.

## **Results Discussion**

One of the key inputs for the present results is the OU interpretation. Not only angular truncations and incisions seen on seismic were used to obtain it. A detailed picking along with seismic attributes such as coherency and spectral decomposition served as a mapping guide. Seismic well tie of 14 wells and correlations of the main units were reviewed (Figure 3).

The basal Oligocene and pre-Oligocene reservoirs geometries (estuarine dendritic drainage system) are evident in seismic horizon slices due to the impedance contrast of shaly (Paleocene) and sandy levels. This can be only possible with a full coverage of a 3D seismic able to resolve reflectors above 80 ft. in this case. The basal Oligocene transgressive sandstone levels are lying unconformable over Paleocene and Upper Cretaceous deposits. There is no evidence of Eocene deposition around the area; this suggests that the Oligocene erosive action was made directly to Paleocene which had a sub-aerial exposure hence probably paleosoils development giving a chance to provide lateral or top seals (Figure 4).

The previous model defines the OU in a lower position honoring the palynology data (Oligocene) but leaving inconsistencies regarding the horizon correlations.

For the new approach, electric logs signature as well as the seismic principle of isochronology of a horizon, allowed us to raise a question mark on biostratigraphy results obtained for well D (Figure 4). Reviewing the correlations it was possible to change the OU original position and honor the logs and seismic data despite the palynology of only one well. The possible mixture of cuttings or errors in the sampling procedure could explain the reason why the age reported was not Paleocene as expected.

### **Conclusions**

The geological model update provided a new portfolio of opportunities thanks to the interdisciplinary work after step by step progress in the integrated knowledge.

The gathering of more precise biostratigraphy data could provide higher certainty for the model proposed on the study. However, the proven pre-Oligocene sandstone from the analogues, no matter its age, was not identified before in our area and brings an added value to the lot.

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Figure 1. Location map, Llanos Foreland Basin, Colombia.

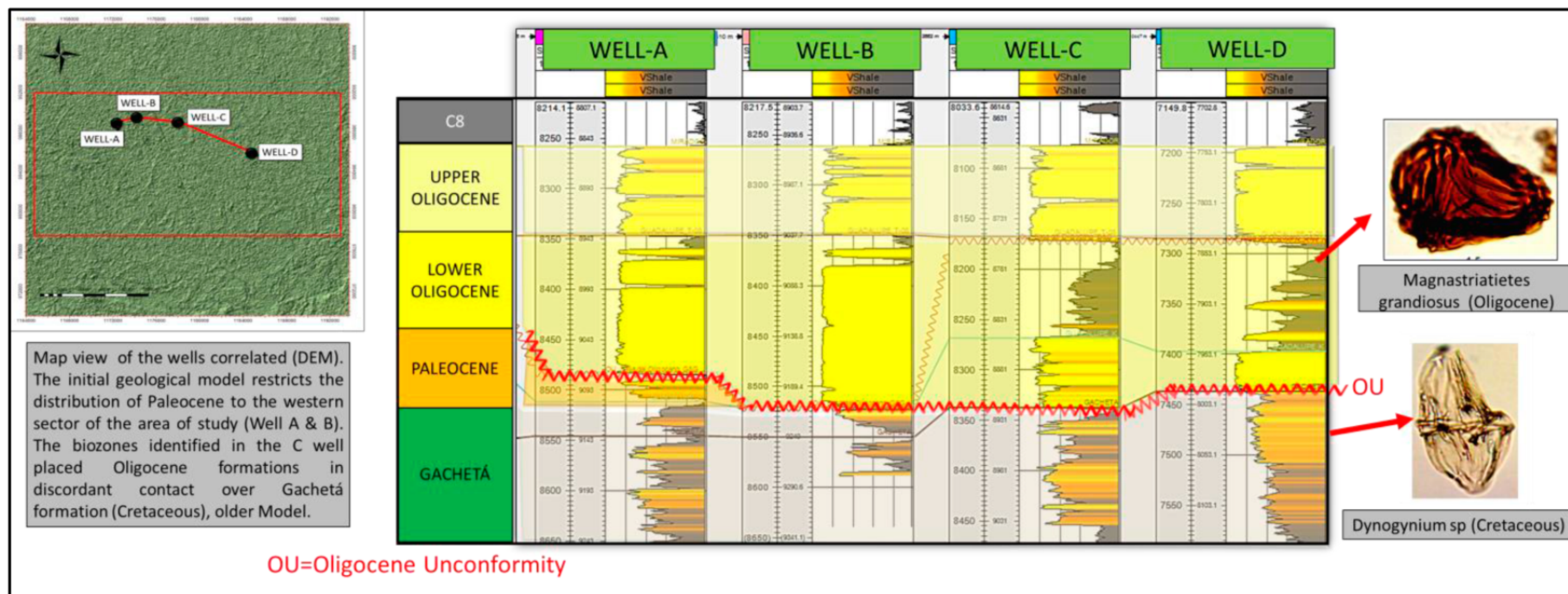


Figure 2. Wells correlation, previous model.



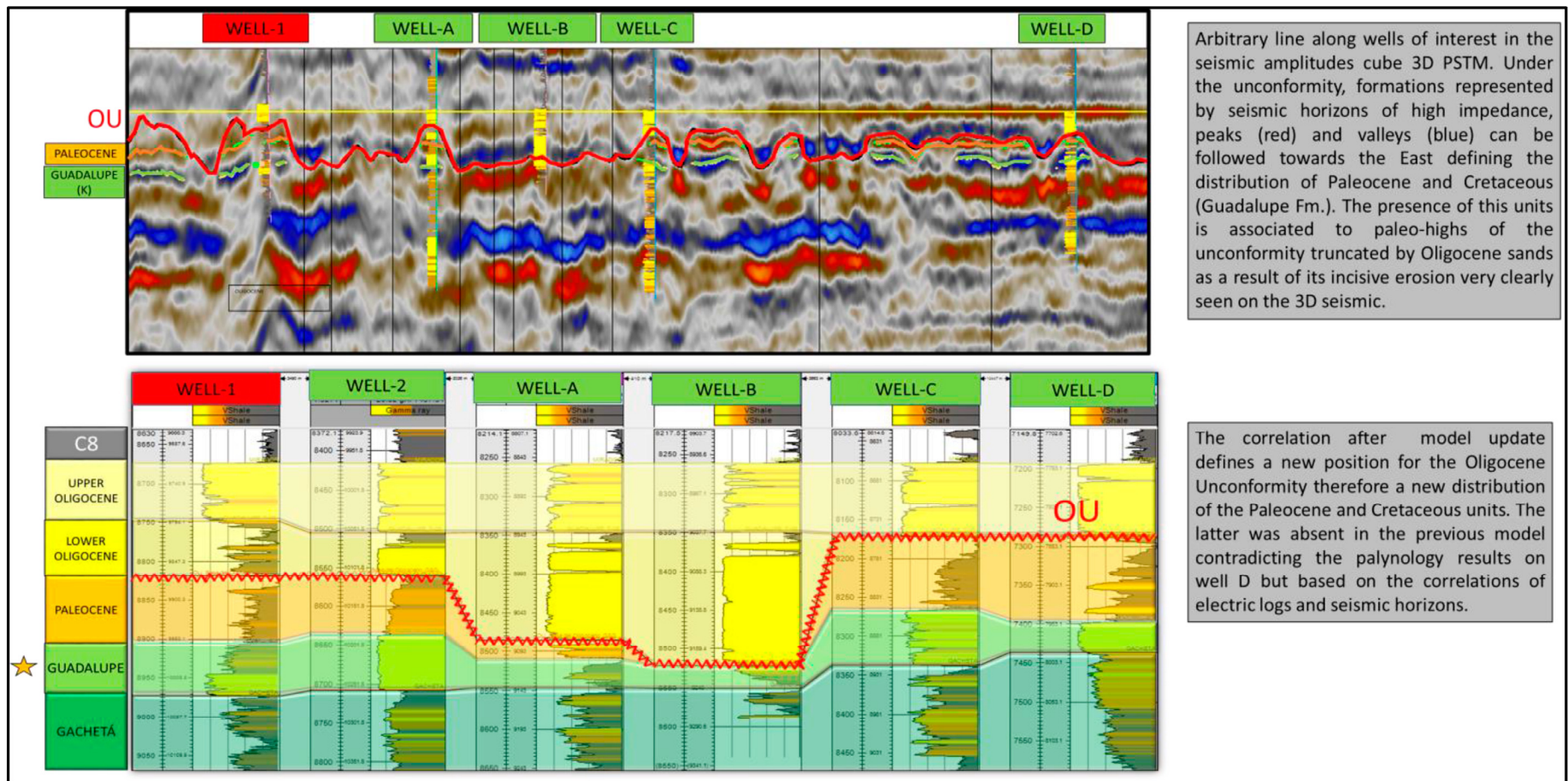


Figure 3. Wells correlation and seismic line along wells. Updated model based on seismic and log signature concept coherency, however disagreeing with palynology results.



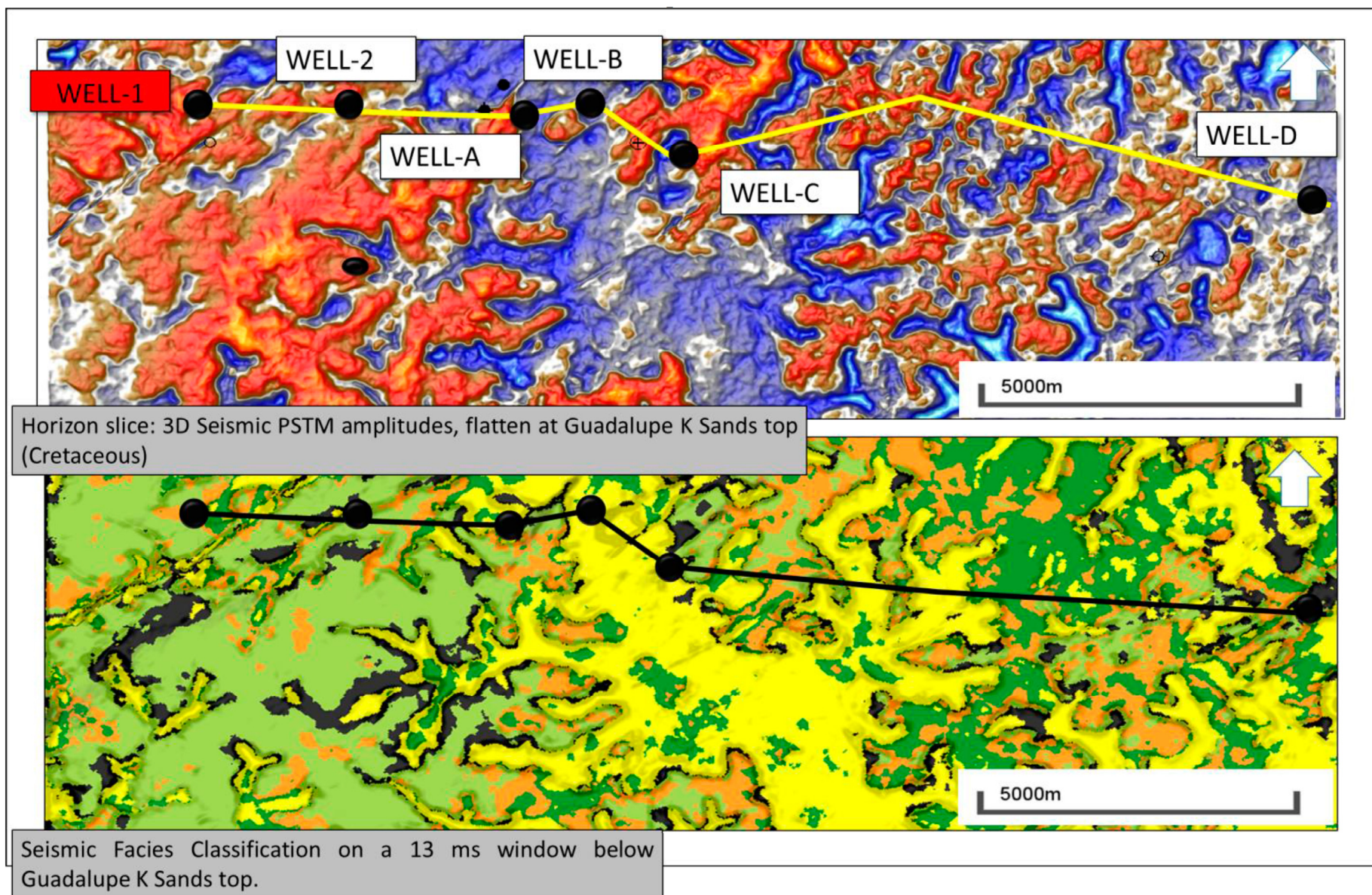


Figure 4. Seismic Amplitudes and Seismic Facies classification horizon slices at Guadalupe K Sands level.