Active Tectonic and Mechanic Interaction Between Cusiana and Yopal Faults Interpreting Seismic and Terraces Geometry

J.S. Carvajal Torres
Colombian Petroleum Institute
Bucaramanga, Colombia
juancarvajal.26@gmail.com

J. F. Gómez*
Colombian Petroleum Institute
Universidad Industrial de Santander
Bucaramanga, Colombia
josefernando.geo@gmail.com

A. Mora
Ecopetrol S.A.
Bogota, Colombia
andres.mora@ecopetrol.com.co

D. Costantino
University of Leeds
Leeds, England
D.Costantino@leeds.ac.uk

M. Reyes
Colombian Petroleum Institute
Bucaramanga, Colombia
martinreyesco@gmail.com

SUMMARY

Along the Colombian Llanos Foothills, different rock formations lie affected by tectonic movements, expressing geomorphological changes at the surface associated with subsurface geologic structures (anticlines and synclines). Some of them were created during the most recent tectonic movements throughout the last period of geological time. This evidence is plotted in the geological map of the area extended from the Colombian Eastern Cordillera to the Colombian Llanos Orientales basin (figure 1). There, folded and faulted Quaternary deposits can be observed. This is the case of the alluvial terraces in the study area (figure 1), which have been deformed due to the recent tectonic activity. Therefore, to test this theory, this study generates a three dimensional kinematic model based on serial balanced geological cross sections built by seismic, geological and well data. Hence, we can analyze the geometry of faults in the area (Cusiana and Yopal), with the geometry of the Alluvial Terraces deposited during the Late Pleistocene (0.2 Ma, ICP, (2009)). Consequently, it simulates the fault kinematics since the Quaternary Terraces deposition in order to quantify fault motion rates, thereby, assessing the age of faulting. Finally, in addition, this study, using PetroMod 1D models, appraises the age of the famous Colombian oil field called Cusiana. As a result, it demonstrates the continuous generation and migration of oil from the kitchen located at the Colombian Eastern Cordillera, to the Colombian Llanos Basin.

Key words: Colombian Llanos Orientales basin, Quaternary deposits, alluvial terraces, Cusiana and Yopal Fault.

INTRODUCTION

The western flank of the Colombian Cordillera Oriental resulted from the inversion of previous basins (Tesón et al, 2013). Mora et al, (2010); based on thermocronometers assessed the timing of this event, establishing Paleocene as the first stage of the inversion of the Mesozoic rift basin. This inversion created different structural styles along the Colombian Llanos Foothills due to the structural inheritance, (Jiménez et al, (2013)). In this paper, Jimenez et al, (2013); exposes 3 structural domains: (1) Northern, controlled by thin skin faults and duplexes; (2) Centre, transition zone between thick and thin skin and (3) Southern, where the thick skin faults controlled the structures.

In any case, due to the continuous seismicity along the Colombian Llanos Foothills, geoscientists interpret this as an active margin, (Sarria, (1990); Cooper et al, (1995)). The study area (figure 1), contains deformed Quaternary fluvial Terraces (0.2 Ma, ICP-Ecopetrol, (2009)), which support the idea of an active deformation in the study area. Thus, this study attempts to establish a cinematic model which explains how the fluvial terraces in the study area were deformed, and, find the tectonic interaction between the Cusiana and Yopal faults with the deformed Quaternary rocks by a tridimensional model. This tridimensional model is based on cross sections built from 2D seismic lines.

The kinematic model resulted from this study, demonstrates Yopal Fault and Cusiana Fault during the last 0.2 Ma with a deformation rate of 2 mm/year and 1.5 mm/year, causing the deformation of the Fluvial Terraces in the study area. Thus, it raises the question of how old the Cusiana Oil Field actually is.

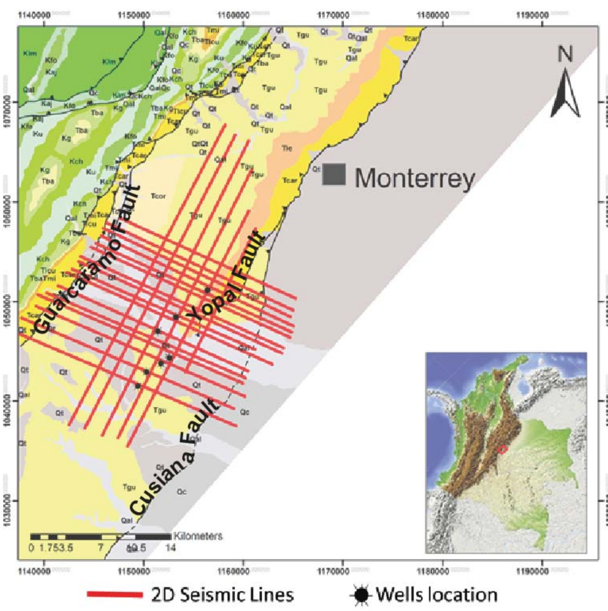

Figure 1. Location map of the study area showing the seismic lines and the well data used to build the tridimensional model.

METHOD AND RESULTS

22 (2D) Seismic Lines, were used to build the final model, all of them interpreted in time and converted to depth using information from 8 wells. Once converted, each seismic line was analysed as a cross section, therefore, balanced by the principles exposed in Dahlstrom, (1969), Suppe et al, (1985) and Wilkerson & Dicken, (2001).
In order to constrain the model, based on the assumption: "A restorable cross section is a balanced cross section", (Dahlstrom, (1969)), a termocrhonological sample and stratigraphic information was used to cinematically restore the cross sections, controlling the thickness of the rock layers and the temperature reached of each rock formation. As a prime result, all the constrained and balanced cross sections formed a previous geological model, so, the surfaces were constructed by the lines of each layer.

After, the analysis of the deformation of the Quaternary fluvial terraces took part, but first, based on ramps bisectors of the faults, the roll of each fault into the deformation of the Quaternary deposits was analysed. By that way, no fault could be discarded, both are currently associated with the deformation of the Quaternary at the study area. Then, their mechanic interaction was examined, along the study area, from south to north, Yopal fault increases its displacement as the Cusiana fault decreases its own. Thus, based on transfer zone concept of Dahlstrom, (1969), these faults are a good example of a transfer zone in the study area and both move simultaneously.

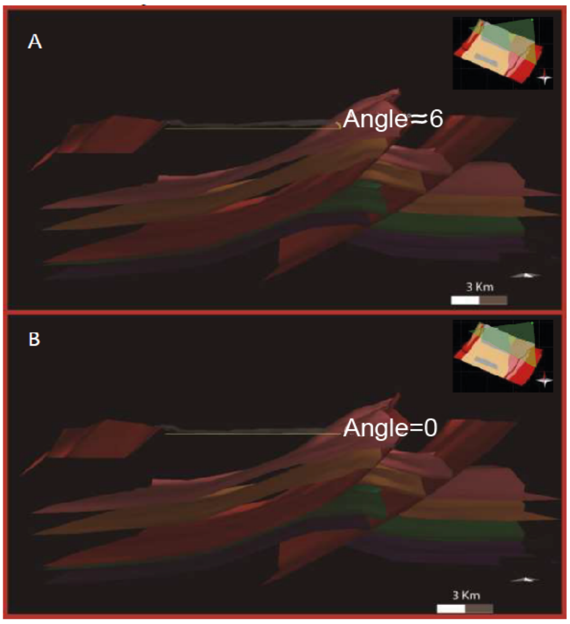

Figure 2. Kinematic restitution of the Yopal and Cusiana Fault until the Quaternary fluvial terraces were undeformed.

Finally, Yopal and Cusiana fault movement and displacement were estimated making a kinematic restitution until the fluvial terraces were undeformed, figure 2. Due to this kinematic restoration, this study encountered and measured the displacement of both faults throughout the last 200.000 years (Quaternary terraces age):

- Yopal Fault: 300 meters displaced during the last 0.2 Ma, its total average displacement in the study area is around 2000 meters.
- Cusiana Fault: 400 displaced during the last 0.2 Ma, its average total displacement in the study area is around 1200 meters.

CONCLUSIONS

Due to the geometric analysis of both fault planes (Yopal and Cusiana), bisectors show that both faults are related to the Quaternary fluvial terraces deformation, since these deposits are involved in the ramp bisectors domain of each fault independently. Thus, the hypothesis of one static fault was discarded. Also, the variation in displacement from south to north of each fault, brought the knowledge to establish the study area as a transfer zone between Yopal and Cusiana Fault, which allows the authors to infer a simultaneous movement of the faults during the last 0.2 Ma. Furthermore, by the kinematic model founded in this study 300 meters and 400 meters are estimated as displacement for Yopal and Cusiana fault. In addition, the absence of growth strata means Cusiana fault appeared 0.7 Ma whereas Yopal fault was formed 1.3 Ma. This implies that the Colombian oil field, Cusiana, is a very young oil accumulation, because of the fact that Yopal fault is part of the trap of the petroleum system, and the lack of oil appearance at the footwall of Yopal Fault means a quick filling of the 1.6 GB of oil recoverable reserves at the Giant Cusiana Field. The deformation of the Quaternary fluvial terraces demonstrate the active tectonics of the area and the youth of the oil fields associated with these tectonics movements and supports the hypothesis of the current active kitchen, which sent oil to the Llanos basin until faults as Cusiana and Yopal cut that connection.

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