

Hydrodynamics in the Llanos Basin, Colombia

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Summary

Active hydrodynamics is a well-documented phenomenon in all sub-Andean basins. Pervasive meteoric water recharge and cross-formational flow cause complexities in the petroleum systems and exploration including biodegradation, remigration, flushing of traps and tilted oil/water contacts (OWCs). The Llanos Basin is an economically important sub-Andean Basin located in central Colombia (Figure 1). The Rubiales/Quifa area is the most extensively developed part of the Llanos Basin and provides a good case study to understand the role of hydrodynamics. This presentation will outline the theory and workflow involved in identifying, mapping and predicting hydrodynamically tilted OWCs and their importance in petroleum exploration and development.

Methodology

Dynamic Migration Modelling is used to identify and map tilted OWCs. This method combines water flow patterns, hydraulic gradients and fluid densities to determine tilted OWCs, displaced oil pools and potentially flushed structures. The Canadian Discovery proprietary method uses a force vector approach to determine direction and magnitude of water flow. To calculate the force vectors, maps of hydraulic head, water salinity and reservoir structure are needed (Figure 2). The force vectors can then be used alongside a tilt amplification factor (a factor that reflects the density contrast between formation water and oil) to calculate an oil/water tilt map. In basins that are hydrodynamically active, this workflow can help to determine migration and remigration pathways, flow intensities and predict the location and extent of present-day oil accumulations.

Observations and Conclusions

Previous hydrodynamic analyses of the Llanos Basin have shown that the basin is highly hydrodynamically active (Villegas et al., 1994). Meteoric water recharge occurs through direct connection to outcrops in the southwest and southern portions of the basin, as well as the eastern subcrop margin. Oil migration occurred primarily from west to east during the Oligocene with an assumed initial oil gravity of around 30° API. Due to biodegradation, present-day oil can be much heavier and has been remigrated in response to the current hydrodynamic regime of the basin. Based on the dynamic migration modelling workflow, hydrodynamically aided traps were confirmed within the Rubiales and surrounding fields. The original accumulation has been re-migrated downdip in the direction of flow—creating a “constructive flow” scenario whereby hydrodynamics has aided trapping capacity. By quantitatively determining the magnitude and direction of the tilted OWC, the extent of the re-migrated oil pool has been mapped and potential volumes determined.

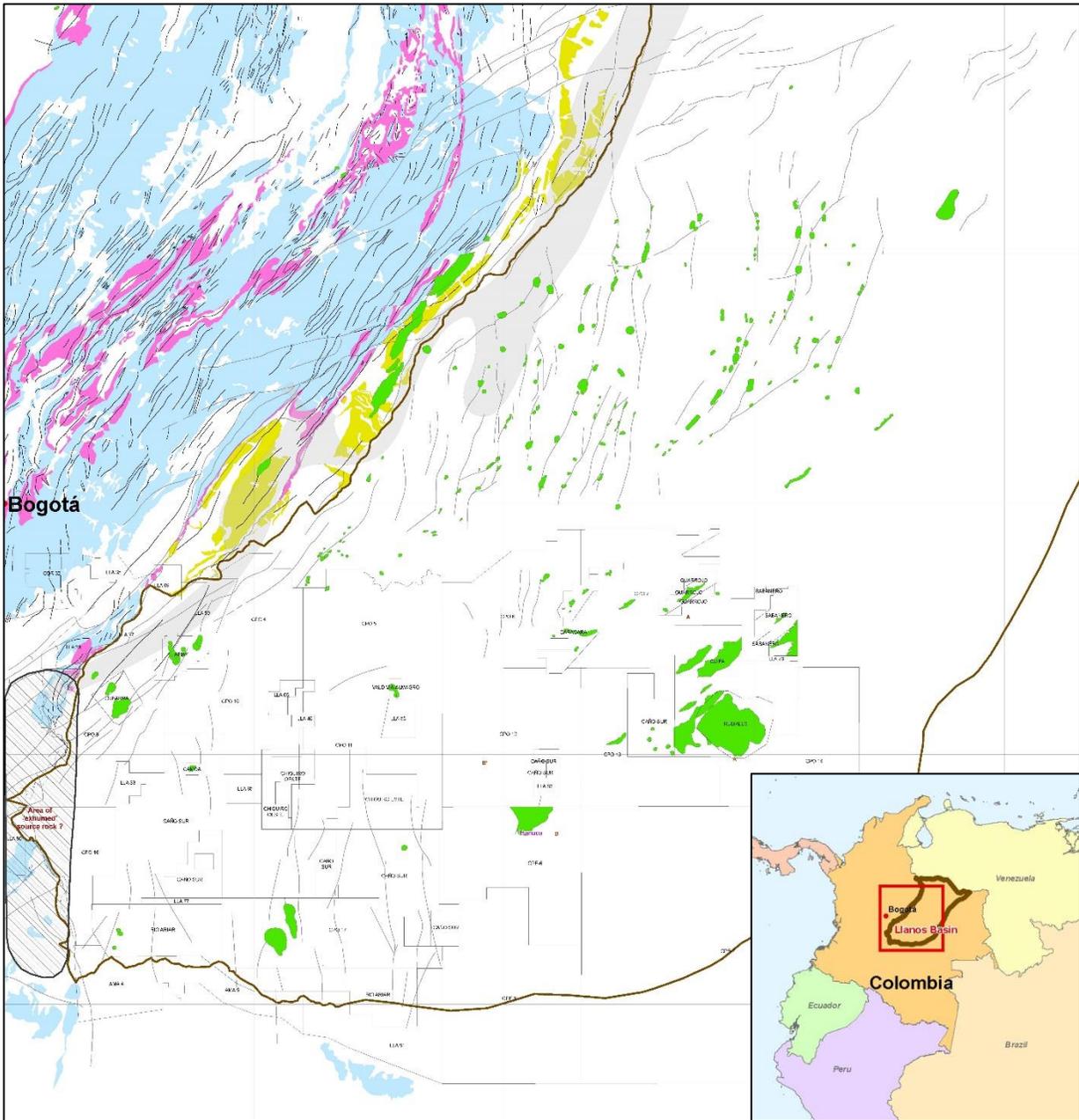


Figure 1: Location of the Llanos Basin

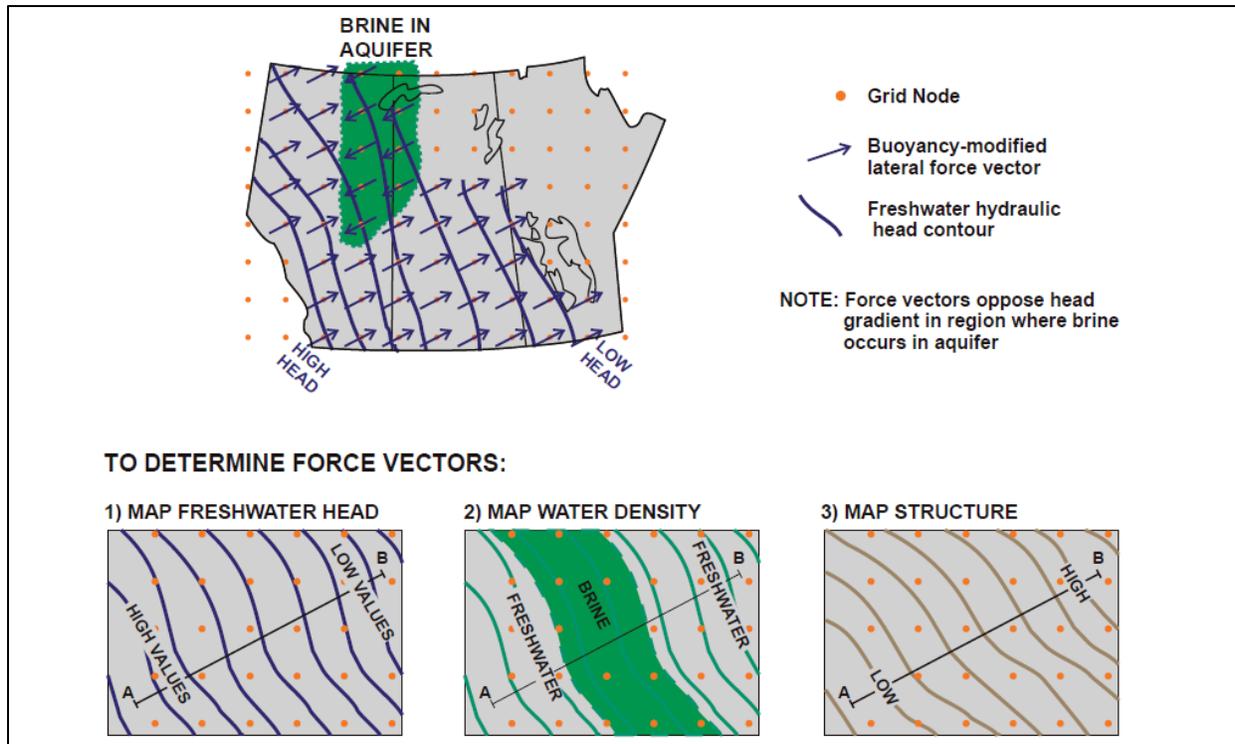


Figure 2: Determination of Force Vectors

References

Villegas, M.E., Bachu, S., Ramon, J.C., Underschlutz, J.R. 1994. Flow of Formation Waters in the Cretaceous-Miocene Succession of the Llanos Basin, Colombia. AAPG Bulletin, v 78, n 12, p 1843-1862.