MODELING OF HYDROCARBON GENERATION AND MIGRATION IN THE GOLFO SAN JORGE BASIN, ARGENTINA

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Introduction

The Golfo San Jorge Basin (GSJB) is located in central Patagonia (southern Argentina), and covers an area of about 180,000 km^2 of which one third is offshore. The cumulative oil production of the basin is approximately 3,500 MMBbl, and the cumulative production of gas approximately 3 TCF. The oil production of the basin is about 38% of Argentina's yearly production.

Stratigraphy and basin evolution

The stratigraphy of the basin is composed of units ranging from Jurassic to Cenozoic age. The estimated maximum thickness is about 8.5 km above the top of the economic basement (Lonco Trapial Group and equivalents). The sedimentary fill is composed of clastic, volcaniclastic, volcanic and carbonate rocks. The evolution of the basin includes a rift phase (Jurassic to Early Cretaceous), and an extensional-transtensional phase (Early Cretaceous) followed by a sag phase (Early Cretaceous to Cenozoic). Neogene compression and uplift generated the almost north-south trending San Bernardo Fold Belt located in the western part of the basin.

Source rocks

Geochemical analyses of samples of the GSJB indicate the presence of source rocks within rift (Pozo A. A. Bandera and Pozo C. Guadal Formations) and the post-rift (Pozo D-129 Fm.) successions. In both cases the source rocks are dark organic-rich shales of lacustrine origin. Measurements carried out on several samples of the rift formations, almost all of them overmature, showed a maximum TOC value of 2.5% (Rodriguez and Littke, 2001). In the western part of the basin (Paso Rio Mayo sub-basin), some lacustrine source rocks, deposited during the rift phase, showed type I kerogen (Strelkov et al., 1994).

A set of measurements carried out on predominantly mature samples of the Pozo D-129 Fm. showed a maximum TOC value of 2.45% (Rodriguez and Littke, 2001) and hydrogen index values in the range of 200 to 500 mgHC/gTOC, representing kerogen types II, II/III, III and possibly I. Yllañez et al. (1989) measured values of TOC from 0.5% to more than 3% for early mature samples of the Pozo D-129 Fm. As is usual for lacustrine source rocks, there is strong variability in the geochemical characteristics. A general distribution, with the most hydrogen-enriched kerogen derived from algal material in the center of the basin, and more terrestrially dominated source rocks toward the borders of the basin, appears to be reasonable.

Reservoirs

The basin has an abundance of Cretaceous sandstone reservoirs interbedded with potential seals. The most important reservoirs are of Late Cretaceous age (Bajo Barreal Fm. and equivalents). These sandstones are mainly of fluvial origin, with varying content of volcaniclastic material (Hechem and Strelkov, 2002). Traps are mainly structural, with varying degrees of stratigraphic components. Reservoirs of minor importance are: Albian clastics and fractured pyroclastic rocks (Mina el Carmen and Castillo Fms.), and Barremian-Aptian rocks (Pozo D-129 Fm.).

Structure

Structurally, it is possible to recognize five major regions in the basin (Figari et al., 1999). In the eastern half, where an extensional style is dominant, three areas can be recognized: the northern flank, the center of basin and the southern flank. The three areas are characterized by block structures, which are limited by high angle normal faults arranged in W-E and WNW-ESE directions, with a complex pattern of synthetic and antithetic associated faults.

West of this area the San Bernardo Fold Belt, which has a NNW-SSE orientation, a length of approximately 600 km and a width of less than 100 km at most places, occurs. In the fold belt, the original extensional pattern has been inverted and compressional structures are dominant. The major faults are reverse due to the reactivation of older normal faults, with NW and NE orientations. The anticlines are often arranged in echelon and fragmented, e.g. by WNW-ESE oriented extensive and strike-slip faults.

A fifth region is the western GSJB, located further west of the San Bernardo fold belt, which is also dominated by extensional structures, although some inversion may have taken place. Normal faults have a WNW-ESE orientation.

Basin modeling

The evolution of the two main petroleum systems of the basin was modeled using 1D and 2D packages.

In the San Bernardo Fold Belt the oil generation began in the rift units between 130 and 100 Ma and between 110 and 80 Ma in the Pozo D-129 Fm. In general and at present time, the rifts units are in the gas window or overmature. The Pozo D-129 Fm. is still, or was until the Neogene, in the oil window.

In the basin center the generation of oil began between 130 and 120 Ma, and ceased at about 60 Ma. In the case of the Pozo D-129 Fm. hydrocarbon generation began between 80 and 110 Ma and became younger towards the rims of the basin. Gas generation began in the center of the basin at about 100 Ma and ceased at about 20-30 Ma. Except for some regions where the uppermost part of the Pozo D-129 Fm. remains in the gas generation window the source rocks in the center of the basin are overmature.

Along the flanks the generation of oil began between 120 and 100 Ma, and lasted at some locations until Neogene times. Gas generation started later and lasted longer at the margins.

Modeling results strongly suggest that a magmatic event between 20 and 30 Ma, combined with the maximum burial during Miocene times produced a very important pulse in hydrocarbon generation.

Different migration scenarios were evaluated, considering the variation in permeability of faults. The scenario that best depicts the present distribution of hydrocarbon accumulations was modeled considering permeability along fault planes. The principal high angle faults connected the deep source rocks with the reservoirs. In the center of the basin part of the generated hydrocarbons escaped vertically along faults. In the San Bernardo Fold Belt the tectonic inversion probably caused remigration of petroleum fluids previously charged.

East of the San Bernardo Fold Belt (northern and southern flanks), petroleum accumulations are charged mostly from the source rocks of the Pozo D-129 Fm. with minor contributions from the rift source rocks. The charge from the rift source rocks increase towards the western part of the basin, where the units are thicker. Due to the protracted history of hydrocarbon generation, several pulses of expulsion can be expected. Different mixtures of hydrocarbons and alteration processes explain the variability of petroleum composition in the basin.

The main reason for the diachronous distribution of hydrocarbon generation and migration is the thickness difference between center and flanks, which became progressively larger during Cretaceous times. This fact explains the regional distribution of oil fields in the basin.

The distribution of the petroleum fields in the eastern half of the basin shows a horseshoe geometry open to the east. This geometry with high probability completes giving an ellipse with the lesser explored offshore area to the east. Available seismic and well information support this point. The horseshoe distribution approximately coincides with the shape of the most recent “kitchen” of Pozo D-129 Fm. suggesting a pattern of migration strongly controlled by high angle faults, as has been modeled. The almost absence of fields towards the basin rim seems to be related with the predominantly short lateral migration, as the models suggest.

Due to the maturity reached by source rocks the present day center of the basin is interpreted as a mainly gas and light oil accumulation area. Geological risks seem to be mainly related to trap, preservation, and the poor quality of the reservoirs.

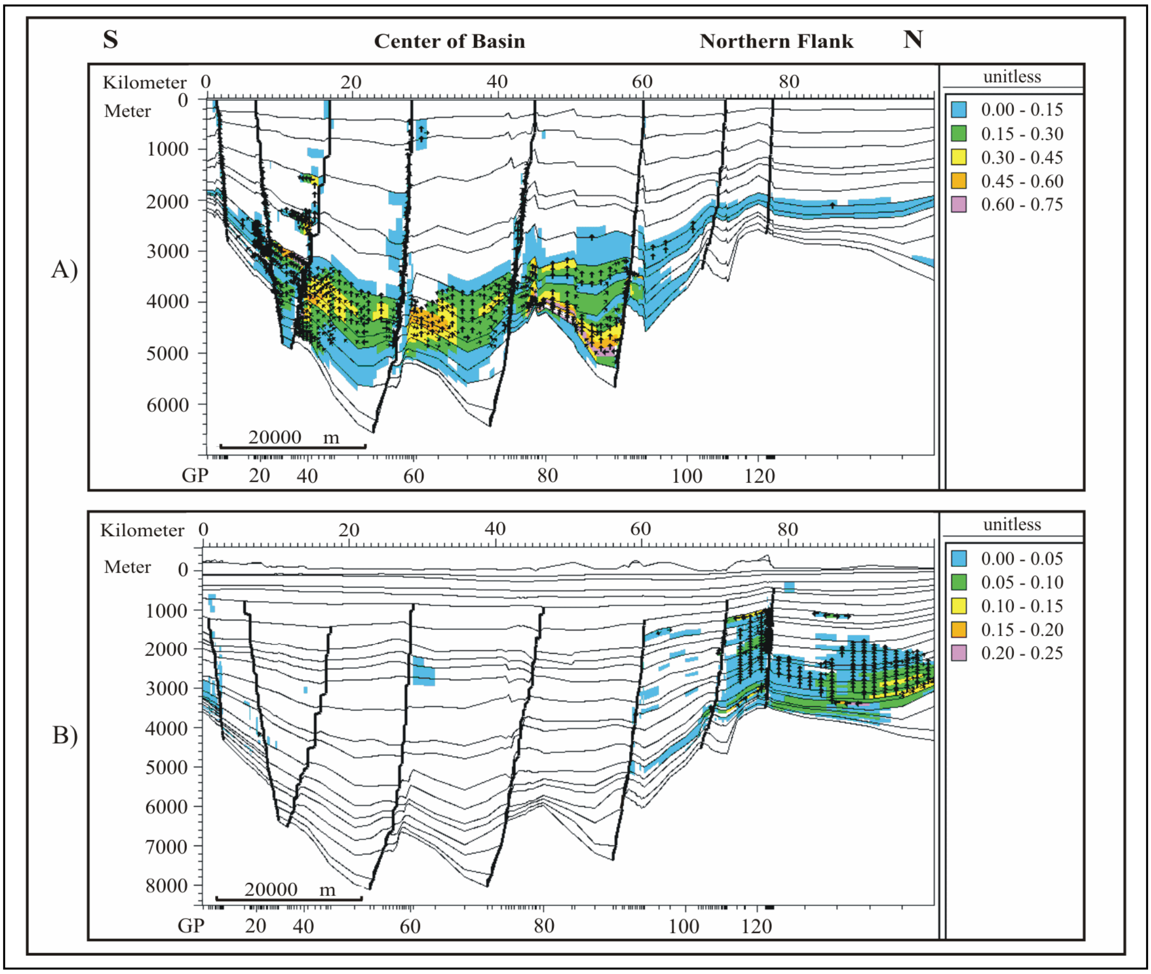

Figure 1. Migration and saturation of hydrocarbons along a N-S section located few kilometers to the west of Comodoro Rivadavia city: A) Late Cretaceous, B) Recent. Models with permeability along fault planes. Small arrows: migration of hydrocarbons.

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