A 4-D PETROLEUM SYSTEM MODEL IN A SOUTHERN AREA IN THE SANTOS BASIN, BRAZIL

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The evaluation of petroleum systems of the Santos Basin represents an exploratory challenge due to the little geologic information on the pre-salt section that comprises only two wells drilled near the shoreline. Considering an offshore area of about 215,000 km^2, in general, the characterization of the petroleum system has remained quite controversial.

Marine oils from 35^o up to 60^o API and gas were discovered in petroleum fields in the southern portion of the Santos Basin (Cerqueira, 2004). Concerning the oil quality and presence of gas, a high level of maturity of source rocks surrounding the petroleum accumulations has been deduced. Nevertheless, the marine source rocks sampled have recorded initial oil window evolution. To investigate this discrepancy, a 4-D modeling was carried out using Temis-3D to test a different scenario considering a more optimistic approach related to the marine source rocks richness and heat flow history.

In a bathymetry between 118 and 1,752 m, a geological model of 6,900 km^2 was constructed using 13 seismically-mapped stratigraphic horizons adjusted chronostratigraphically with wells drilled near the investigated area. Additionally, 15 stratigraphic horizons were interpolated to refine the geological framework.

The presence of thick layers of evaporites up to 5,900 m and an average thickness of 675 m tends to increase the degree of uncertainty with regards to the effectiveness of the petroleum generation from de pre-salt source-rocks because the thermal field is extremely affected by the relative increase of the salt deposits in the sedimentary column, and the rising columns of salt. The vertical salt movement was important up to the end of the Cretaceous, corresponding to 90% of the salt rise through younger sediments, and is less important for the remaining rise of the salt column that moved up to the seabed.

The basic rock package that was loaded in the model comprises three megasequences: the Neocomian-Barremian non-marine syn-rift megasequence, the Aptian transitional megasequence that includes a sequence of evaporitic rocks, and the marine megasequence consisting of shallow water Albian carbonate rocks that grade into siliciclastic sequences up to the present day (Pereira and Macedo, 1990). The maximum overburden may reach up to 10,300 m seismically mapped in local mini-basins.

Although no positive geochemistry correlation of the petroleum with the pre-salt lacustrine source rocks was possible in the adjacent areas, those rocks could be similar to Aptian source rocks of the Campos Basin. Source rocks with geochemical characteristics similar to those verified in the late syn-rift shales (oil-prone type I and type II kerogens) of Campos Basin (Trindade *et al*., 1995; Mello and Maxwell, 1991; Guardado *et al*., 2000) were defined. The working hypothesis is that the syn-rift source rocks in this portion of the Santos Basin could have been deposited under an earlier marine influence, which would explain the absence of lacustrine precursors. Despite the low organic richness of the basal Albian source rocks, it was estimated an average of 2% of total organic carbon.

To evaluate the petroleum generation volumetrically, an unusual heat history was assumed. The heat flow history was calibrated using vitrinite reflectance and present-day temperatures. The peak of heat flow was achieved at 112 Ma, followed by an exponential decay up to the last 1 Ma, and by an abrupt buildup necessary to fit the present-day thermal field.

Both source rocks, Aptian pre-salt and marine Albian, achieved high levels of maturity, resulting in 10% up to 20% of the modeled area in the gas window. The peak of expelled volume of petroleum from both source rocks was reached in the Upper Campanian, with 5.4 billion barrels of petroleum expelled per million year from the Aptian source rocks and 2.3 billions of barrels per million year from the Albian source rocks. The total petroleum charge expelled from the older source rocks was twice as large as that from the Albian source rocks.

The migration of the petroleum expelled from the pre-salt source rocks is primarily dependent on salt windows and subordinately controlled by the network of faults above the salt layer. The expelled petroleum from both source rocks, from 44 Ma up to the present day, comprises an important front of secondary migration focusing through faults and permeable pathways. The three gas-oil fields discovered into the modeled block were reproduced, although the only petroleum charge contribution was provided by the Albian source rocks. The mass of petroleum migrating from the pre-salt source rocks was focused to the south of the modeled area due to absence of salt windows near the fields, located in the northern part. Unless salt windows exist outside the modeled block, there is no local evidence of draining of petroleum up to the discovered fields from the pre-salt source rocks.

References

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