PETROLEUM SYSTEM EVALUATION OF THE JEQUITINHONHA BASIN (OFFSHORE BRAZIL): BASIN MODELLING AND RISK ANALYSIS

S. Kargl[1], F. Schneider[2] & I. Scotchman[3]

1 @ Beicip-Franlab, Rueil-Malmaison, France, sabine.kargl@beicip.fr; 2 @ Beicip-Franlab, Rueil-Malmaison, France, frederic.schneider@beicip.fr; 3 @ STATOIL, London, U.K., ISCO@statoil.com

Introduction

A 2-D basin modelling in Block BM-J-3 in the Jequitinhonha Basin, offshore Brazil, was undertaken to evaluate the petroleum system. The 2-D studied section is an interpreted line from a 3-D seismic survey covering the block. Potentially prospective sections are present in Upper Cretaceous and Lower Tertiary (Fig. 1).

The petroleum system analysis was performed as follows:

- Thermal and maturity calibration with 1-D software
- Time to depth conversion of seismic and horizons
- Structural reconstruction
- Study of the petroleum system behavior along the reference 2-D section including hydrocarbon generation, expulsion and migration using 2D integrated modelling techniques.
- Sensitivity analysis of the reference section varying key parameters.
- Testing of several scenarios due to the results of the sensitivity analysis.
- Risk analysis on hydrocarbon charge and trap potential, according to the uncertainties on the petroleum system components.

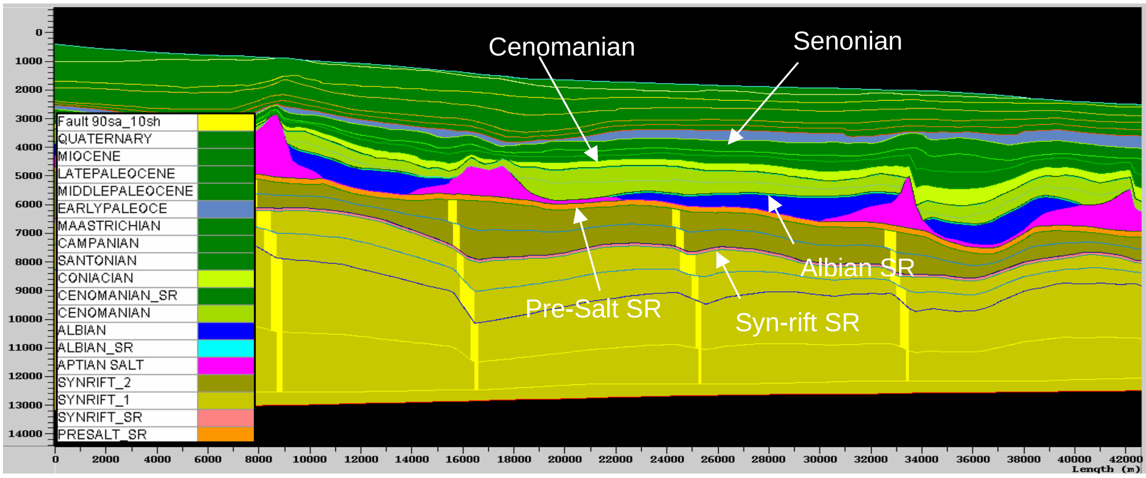

Fig. 1: Lithology distribution and main elements of the petroleum system of the studied section.

Known elements of the petroleum system

Regionally four source rocks are identified.

- Lower Cretaceous syn-rift freshwater lacustrine source rock comprising Type I kerogen.
- Pre-salt (Aptian) source rock with Type I kerogen with TOC values between 3 and 5%.
- Albian marine source rock (Type II kerogen) with a TOC of around 6%.
- Upper Cretaceous (late Albian to Turonian) source rocks with Type II kerogens. The Hydrogen Index is between 395 and 505. No oils have been correlated to this source, but it is potentially an excellent quality source if buried sufficiently in the deep offshore area.

Potential reservoir targets within the 2-D section are:

- Upper Cretaceous turbidites.
- Lower to Middle Paleocene channel system.

The present day temperature data available give an average thermal gradient of 32 °C/km in the western part of the section. The pressure regime derived from wells data show that the pore pressure is normal hydrostatic at present day.

The construction of the 2-D section

The 2-D section was built from an interpretation of an East-West oriented seismic line from a 3D seismic survey. The section has a length of 42.6 km and consists of 13 depth-converted seismic horizons with 12 internal layer subdivisions. The overall litho-stratigraphy was based on the ANP lithostratigraphic chart for the Jequitinhonha Basin.

The structural reconstruction was constrained by the software where only vertical deformation is valid. The salt thickness after deposition has a constant thickness, the onset of salt movement occurring after the deposition of the Albian carbonate with a main diapirism phase during the Upper Cretaceous (Senonian). At the end of the Paleocene the salt movement is assumed to be finished.

Reconstruction of the thermal regime

Temperature and maturity data can be reproduced assuming the following series of events: Rifting Phase between 142Ma to 125Ma, a drifting phase between 110Ma - 89Ma, followed by a thermal cooling phase with resultant slow subsidence along the basin. An improved fit of maturity is observed assuming a heating event during the latter phase (uppermost Cretaceous and Lower Paleocene). The known amplitude of erosion has no effect on the thermal maturity or temperature history of the basin.

The thermal boundary conditions from the 1-D calibration are assigned to the 2-D section with an increasing heat flow from West to East according to the increase of the extension factor along the margin.

Hydrocarbon Generation

In general, hydrocarbon generation begins in all four source rocks earlier in the eastern part of the section than in the western part. This is related to both increased heat flow and burial depth.

For the Cenomanian source rock, hydrocarbon generation started at end of Cretaceous in the eastern part and during the Upper Eocene in the West, while the Albian source rock started generation at the end of the Campanian in the eastern part and during the Middle Eocene in the western part of the section. The pre-salt source rock started generation at the top Santonian in the East and at the end of Paleocene in the western part.

For the synrift source rock, hydrocarbon generation started at end Cenomanian times. The potential of the synrift source rock is completely transformed by the end Paleocene.

Hydrocarbon Expulsion

Four main phases in the expulsion history are observed:

<u>Upper Cretaceous</u>: The deepest source rock (Synrift Source Rock) starts expulsion at the end of Cenomanian. The presence of salt controls lateral migration in layers below the salt.

<u>Lower Tertiary</u>: The pre-salt and even the Albian source rock start to expel in the eastern and deepest part of the section. Most of the potential of the syn-rift source rock has already been transformed. The salt window opening in the western part allows migration updip into the Albian.

<u>Eocene</u>: The Cenomanian source rock starts to expel in the East, while generation and expulsion continues for the other source rocks. Beneath the salt diapir the hydrocarbons are migrating laterally within the pre-salt layer.

<u>Oligocene to present day:</u> The potential of the pre-salt source rocks is depleted over all the section, except in the westernmost part. The Albian source rock continues to generate only in the central and western areas. The Cenomanian source rock starts expulsion in the central and western areas during the Lower Miocene.

Migration pattern in the central part of the section

For the potential Upper Cretaceous reservoirs, the migration pattern is dependent on salt movements and related drainage areas, which are 3-D phenomena. The hydrocarbon charge is controlled by the presence of salt (Fig. 2).

Prior to the Upper Eocene, the observed migration pattern shows that hydrocarbons are not sourcing the Albian and Cenomanian layers due to the presence of salt within the drainage system. Trap infill starts during the Upper Eocene/Lower Oligocene, hydrocarbon accumulation resulting essentially from an updip migration pattern.

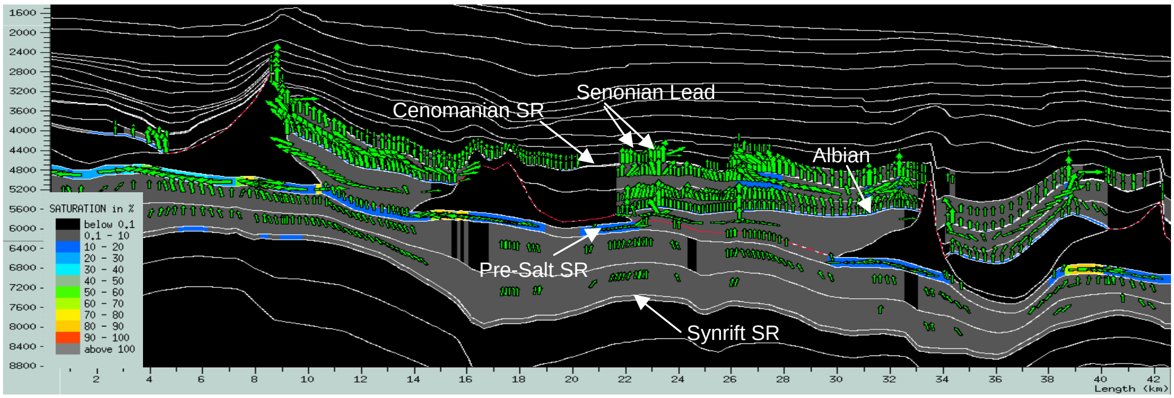

Fig. 2: Hydrocarbon saturation and migration pathways at present day.

Sensitivity and Risk Analysis

The sensitivity analyses showed that the main sensitive parameters concerning the hydrocarbon saturation are:

- The TOC of the pre-salt source rock,
- The TOC of the syn-rift, and
- The vertical permeability anisotropy of the Albian layer, which is an indicator of the vertical communication through the salt weld.

The results from the sensitivity analysis led to the analysis of further scenarios in order to test their impact on migration and present day accumulations. The objectives were to test: (1) the effect of the salt extension to the West, (2) the effect of a sand layer in the Albian, (3) the effect of the fault continuing a syn-rift fault through the Albian into the potential Upper Cretaceous reservoir layers. (4) the effect of the fault continuing together with the sand layer in the Albian, (5) the effect of changing the Albian source rock and lithology layers and (6) the effect of changing the Albian source rock and lithology layers combined with a syn-rift fault continuing through the Albian into the potential reservoir layer.

Conclusions

The observations on these tests showed:

- The salt extension to the West has an essential impact on the accumulation in the potential Upper Cretaceous reservoir: if the salt extends to the East, the migration pattern changes to such an extent that an accumulation in the reservoir is not possible. Moreover, the timing of the salt window opening is an important factor for the migration pattern.

- The Albian section containing a sandy layer and a source rock at the base also influences significantly the migration pattern through time: hydrocarbons get concentrated in the more permeable Albian sandstone layer and are migrating further through migration chimneys into the potential Upper Cretaceous reservoir layer.
- The change in the Albian lithology distribution, the stratigraphically higher position of the Albian source rock and the implantation of a sandy Cenomanian layer has no favourable impact on the migration pattern and charging system for the potential Upper Cretaceous reservoir layer.
- In all cases tested the continuation of major syn-rift fault upwards into the Upper Cretaceous section has no significant impact on the accumulation in the prospective Upper Cretaceous reservoir.