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WHAT CAN WE LEARN FROM 2D BASIN MODELING? EXAMPLE FROM THE ESPIRITO SANTO BASIN, OFFSHORE BRAZIL

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Introduction

This 2-D study in the Espirito Santo Basin offshore Brazil was performed to evaluate petroleum system behaviour within the Block BM-ES-11. The 2-D section lies over the slope offshore Brazil, about 200 kilometers from land.

For the petroleum system modelling the following approach was applied:
(1) Reconstruction of the structural evolution.
(2) The thermal regime and maturity/hydrocarbon generation history was modelled.
(3) Petroleum system study including hydrocarbon migration reconstruction, which combines an interactive backward/forward modelling, thickness changes, thermal and hydrocarbon generation and subsequent hydrocarbon migration.
(4) Sensitivity analysis comparing the calculated hydrocarbon accumulation at various locations according to the variability of independent parameters driving the petroleum system.
(5) Test of different scenarios investigating the effects of salt welding, faulting and lithology on the prospective areas.
These last two items are not discussed in this presentation.

Petroleum System Elements

The four potential source rocks are:

- Lower Cretaceous syn-rift, lacustrine kerogen (Type I).
- Pre-salt (Aptian) Source rock, lacustrine / brackish marine kerogen (Type I).
- Albian Source rock, marine kerogen (Type II).
- Cenomanian - Turonian source rocks, marine kerogen (Type II).

Reservoirs are likely within Upper Cretaceous turbidite systems, with traps formed by salt diapirs.

The Construction of the 2D Section

The structural geometry of the 2-D section is based on seismic line 11072 oriented West-East across the block, with a length of 60km. The section consists of 29 horizons, where 10 horizons are depth converted seismic horizon interpretations. The remaining horizons were used to model salt movement and deformation, lateral movements being accounted for by replacement of other cell lithologies with salt.

The stratigraphy is based on the ANP Espirito Santo Basin lithostratigraphic chart. For the structural reconstruction only vertical deformation is used, therefore as salt movements are a 3-D phenomenon, no thickness preservation is considered for the salt. Timing of salt movements and welding were determined from the 2-D model.

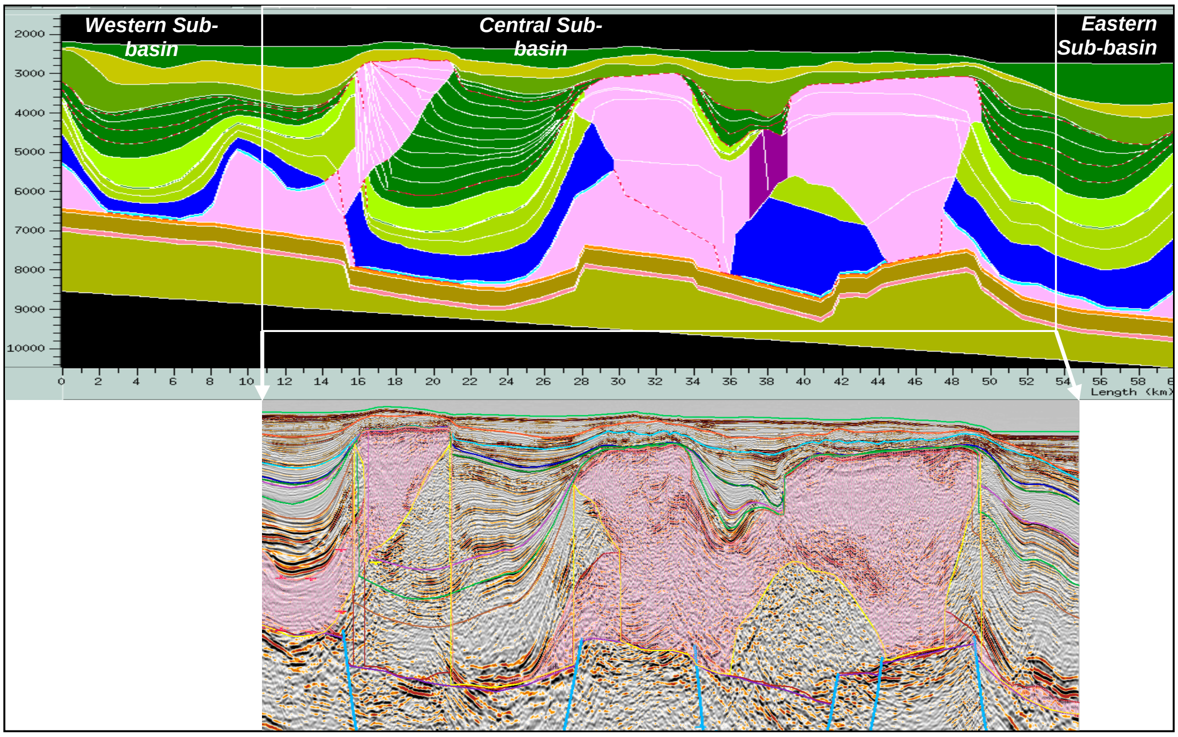

Fig. 1: Lithology distribution and main elements of the petroleum system of the studied section.

Thermal Regime

The present day temperature data available from 10 surrounding wells give an average thermal gradient of 32°C/km. The observed maturity evolution was calibrated to an average curve of regional vitrinite reflectance data.

Hydrocarbon Generation

The syn-rift source is completely mature present day with the onset of hydrocarbon generation in the western sub-basin at 84Ma (Santonian) and in the central and eastern sub-basin at around 98Ma (Top Albian). The hydrocarbon potential is transformed in the eastern sub-basin at the end of Santonian (83Ma) and in the western sub-basin at the end of Cretaceous (65Ma). The maturity of the pre-salt source rock is dependent on both the presence of salt diapirs and on the burial depth, with a hydrocarbon generation history similar to that of the syn-rift source rock except in the western sub-basin, where hydrocarbon generation started at 76Ma with a peak generation prior to the end of Middle Eocene (40Ma).

The maturity of the post-salt source rocks in the Albian and the Cenomanian is solely dependent on burial depth. Albian source rock hydrocarbon generation history in the central and eastern sub-basins is similar to that of the pre-salt source rock, occurring some 5 to 10 Ma years later, but hydrocarbon potential is not totally transformed at present day. In the western sub-basin the hydrocarbon generation started during the Campanian at 74Ma. The shallower Cenomanian source remains the less mature. Generally the hydrocarbon generation started at the end of Cretaceous, but does not attain a high transformation ratio.

Hydrocarbon Expulsion and Migration

Expulsion from the Syn-rift and Pre-salt source rocks began during the Cenomanian, the presence of salt impeding vertical and up-dip migration. During the Campanian, the post-salt Albian and the Cenomanian source rocks also started to expel. The migration pattern is dependent on the presence of salt, which leads to lateral migration below the salt all along the source rock layers below the salt seal. During the Maastrichtian welding begins to impact the migration pattern, leading to hydrocarbon accumulations present in prospective post-salt reservoir. The trapping mechanism is driven by lateral updip migration along the permeable Upper Cretaceous sandy formations into the structural highest positions and by vertical migration in the depocentres of the sub-basins. The Upper Cretaceous seals are effective and impede any migration further upwards.

Conclusions

2-D basin modeling was useful in building a consistent scenario for understanding the petroleum system behavior in this area. It allows the rapid evaluation of different scenarios that allow the testing of new hypotheses or ideas. However, in this part of the Espirito Santo Basin, the migration pattern, migration pathways and related drainage systems are a 3-D phenomenon, strongly controlled by the presence of salt and salt movements. 3-D basin modeling, a more time consuming and expensive study, would be required to fully investigate this, particularly as salt weld timing is a controlling component in hydrocarbon charging.