Relating Petroleum System & Play Development to Basin Evolution

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Summary

Most oil and gas provinces are becoming increasingly mature with respect to exploration. Therefore, our understanding of petroleum prospectivity of less well explored basins becomes more important. In such areas, the use of mature basins as analogues can contribute to the identification of new hydrocarbon discoveries. We anticipate that the use of analogues will become increasingly valuable in exploration.

The objective of this thesis is to increase the knowledge of interpreting basin data in order to facilitate prospectivity prediction in new venture exploration through the recognition of patterns of petroleum system- and play development in basin (cycle)s with similar tectonostratigraphic characteristics.

Our study area comprises the conjugate West African and Brazilian South Atlantic marginal basins. These show many similarities in their tectonostratigraphic evolution, as they all commenced as interior- rift or fracture basins, and during the opening of the South Atlantic, evolved into post-rift passive margins. Both margins are very prolific producers of hydrocarbons and are currently under active exploration, particularly in the deep offshore. However, both margins contain areas, which remain under-explored.

So far, the use of basins for analogue comparison purposes has proven to be potentially misleading, as all basins are built-up in an unique way. We propose to break basins down into more standard components, allowing us to make comparisons that would not be possible between basins considered as a whole. Our methodology is based on the basin classification as developed by Kingston et al. (1983), in which basins are subdivided into relatively standard tectonostratigraphic cycles and/or stages. The major elements that dictate basin history are (1) basin-forming tectonics, (2) depositional or sedimentary processes, and (3) basin-modifying tectonics. Some simple basins have experienced only one tectonic episode and hence contain only one cycle. But most rifted basins contain more than one cycle and are called polyphase basins (Ziegler & Cloetingh, 2004; Cloetingh & Ziegler, 2007). To support this analysis and associated methodology, we have developed in cooperation with Statoil R&D (Bergen) a computer program called the Basin Data Illustrator (BDI). This program contains several tools that illustrate tectonostratigraphic development, as well as allow the geologist to more easily compare (the development of) petroleum systems and plays. In our analyses, we have made extensive use of these tools and the associated figures can be found throughout the thesis.

The South Atlantic marginal basins studied in this thesis are recognized as polyphase basins as they pass through successive cycles/stages of basin evolution. The 5-phase geodynamic model as developed by Cainelli & Mohriak (1999), as well as their subdivision of the tectonostratigraphy into four basin cycles or megasequences (pre-rift, syn-rift, transitional and post-rift), form the basic framework for the further analysis in this thesis. By examining these relatively standard tectonostratigraphic basin cycles/megasequences, we can review the parameters that are important for the development of petroleum systems and plays in standard cycle types rather than in the entire basin, thereby considerably expanding the scope of analogue comparison and avoiding some of the issues that make comparisons between complete basins difficult. As the South Atlantic marginal basins experienced a similar tectonostratigraphic basin cycle evolution, many analogous (potential) source-, reservoir- and seal rock intervals were able to develop. The analogous source rocks in these basins give rise to seven different types of petroleum systems (PSTs). Along both margins, the lacustrine syn-rift PST is the most productive as the associated source shales are geographically most extensive and mature over large areas. The other types of petroleum systems are less productive or were only able to develop locally, due to local source rock deposition, limited thickness and/or quality of the source sequence or general immaturity caused by insufficient burial. Similarly, play development is also closely related to basin tectonostratigraphic evolution, with characteristic reservoir facies and trap types occurring in each basin cycle. Along both margins, the post-rift is known to comprise the greatest number and variety of plays: this cycle is characterized by the greatest variety in depositional environments occurring (and hence reservoir lithofacies) as well as by halokinesis, strongly deforming post-rift strata and determining patterns of turbidite- and fan deposition.

Our approach of relating petroleum system- and play development to basin cycle evolution by evaluating the main geodynamic drivers, the developed depositional sequences and the basin-modifying tectonics, has not allowed us to define any distinctly different basin families in our study area. Using the individual basin cycles for analogue comparison purposes is preferred. However, many issues have been raised that need to be adressed in future studies. On the other hand, we were able to obtain a proper understanding of the tectonostratigraphy and source- and reservoir rock development, which allowed us to comment on the remaining prospectivity in the (under-explored) basins along the South Atlantic margins. Similarly, we are able to point out the main risks for the successful development of particular petroleum systems and plays.

Furthermore, we have performed a more detailed case-study on the conjugate Gabon Coastal- and Almada-Camamu basins in which we apply the same methodology. The results of this particular analysis, allow us to point out potential petroleum systems and plays, which are known to exist in Gabon, but still remain undiscovered in Almada-Camamu. This case-study demonstrates the significance of this methodology as it provides a systematic approach to evaluate exploration opportunities in genetically-related basins, as well as raises new questions and/or suspicions important for directing further research.

The second case-study included in this thesis concerns tectonic- and

maturity modelling of the Campos basin. We tested several models to explain the observed tectonic subsidence after backstripping of seven wells. The best-fit model has been expanded to predict the maturity of several rock intervals containing organic-rich facies. This modelling demonstrates the importance of certain tectonic events on the distribution of mature source rocks. Our results show that the area with potential source rocks located in the oil- and/or gas-window may be larger than previously assumed (Rangel & Martins, 1998). Similarly, source rocks ranging in age from Early- to Late Cretaceous, and locally even to Oligocene age, were able to achieve a mature state with respect to oil generation. The greatest risk is formed by the actual presence, thickness and quality of potential post-rift sources.

To conclude, this approach provides a good first impression of tectonostratigraphic basin evolution and the related potential for petroleum system- and play development. By applying the methodology, geologists will be able to approach the evaluation of exploration opportunities in a more systematic fashion and to raise questions and/or suspicions that can be addressed by specific studies and practical tools such as seismic- and/or well data interpretations.