Sub-basalt hydrocarbon prospectivity in Kerala-Konkan offshore basin, India : A basin modeling approach

Somen Mishra #, Ravi Verma, Kenneth D'Silva, Smita Banerjee, Rabi Bastia, D.M. Nathaniel
Petroleum Business (E & P), Reliance Industries Ltd., Reliance Corporate Park,
Ghansoli, Thane-Belapur Road, Navi Mumbai-400701

Extended Abstract:

In this paper, we have put together a comprehensive understanding of the regional tectonic setup developed by integrating regional, seismic, well information and plate tectonic reconstruction studies to provide a basis for a robust petroleum system analysis in Kerala-Konkan (KK) offshore basin, India. A number of 1D models and a regional 2D model were built and simulated in the KK offshore region. The sub-basalt hydrocarbon prospectivity was then evaluated from the different types of modeling input scenarios (outcome of the regional assessment). The hydrocarbons are considered mostly to be in the gas window (of course in different depth ranges) as it is evident from high basalt heat flow and process of rifting.

The Kerala-Konkan basin in the southern part of the western continental margin of India has engaged much interest because of its probable hydrocarbon potential. The basin lies to the south of Bombay offshore basin, the major hydrocarbon producer of India and is adjacent to the Cauvery-Mannar basin (with established hydrocarbons). The South Western Continental Margin of India is characterized as a complex Volcanic Passive Margin.

Tectonic Reconstructions (Rogers and Santosh, 2001; D'Silva et. al, 2008) show that the Western Continental margin of India (WCMI) owes its origin to the Mesoproterozoic extensions of the Columbia Supercontinent (~1.5Ga) that were responsible for the formation of Morondova, Mascarene, Mahanadi and Pranhita-Godavari rifts (Fig. 1). All these mobile belts had been rejuvenated by related tectonic processes throughout geologic history, resulting in correlatable stratigraphy and some were taken advantage of during the ultimate breakup of Gondwanaland.

Gravity modeling of the southern Indian shield and offshore areas rule out any large-scale underplating or thicker magmatic crust (Radhakrishna et al., 1994; Arts et al., 2003) as generally observed along volcanic margins. Also, the increasing Effective Elastic Thickness (T_e) towards the south (Dev et. al, 2007) indicates that the volcanism decreases to the south. This indicates that this margin was already in a well advanced stage of rifting by the Mid-Cretaceous and the coast parallel eruptions seen in Madagascar (de Wit, 2003) and the dyke swarms in Karnataka and Kerala (Kumar et al., 2001) merely took advantage of the existing fault systems.

Restricted environment of deposition during early rift phase and the favourable thermal domain because of proximity of the basin to the spreading center and shallow mantle were conducive for development and maturation of source rocks. Despite these favorable elements of a petroleum system, most of the drilled wells in the basin were dry

Corresponding author: somen.mishra@ril.com

except some traces of gas in a few wells. Out of 15 exploratory wells, nearly 3 wells penetrated basalts.

Tectonic synthesis developed by integrating regional seismic, well information and plate-tectonic reconstruction studies indicate the existence of multi-episodic rifts coinciding with global anoxic events, thus providing a high possibility for the presence of Mesozoic source rocks along the south western continental margin of India (Mammo, 2010). The southern margin of India has no drilled evidence of Mesozoic source intervals. However, facies with restricted circulation suggestive of potential anoxic source development can be hypothesized for repeated intervals throughout the basin history. As the area was subjected to three phases of tectonism (incipient rifting, Madagascar separation and Seychelles separation), each stage can be projected as having possible restricted facies, both at sequence onset – with potential limited circulating conditions and in late phase development with stagnating conditions as the basin fills. Here we have taken the sources in Kimmeridgian, Albian-Aptian and Cenomanian-Turonian time periods. The basin is endowed with good reservoir facies as evident from the drilled wells in it and the horst-graben complex is likely to provide proper entrapment conditions.

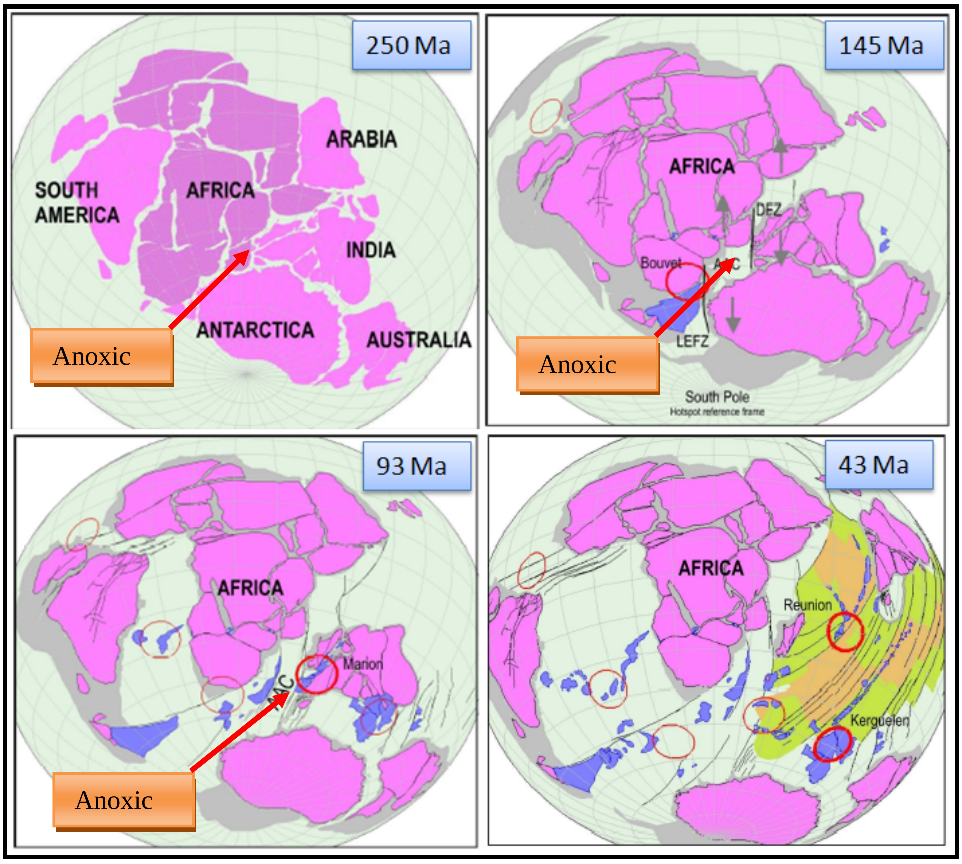

Figure 1: Plate Reconstructions during various geological events (modified after Reeves, 2009)

Corresponding author: somen.mishra@ril.com

Basin Modeling studies

Basin modeling studies were carried out to analyze the timing of maturity for different possible source rocks during the evolution of the offshore Kerala-Konkan basin notwithstanding the poorly constrained complex burial, thermal, and erosional history of the basin. The emphasis was also to determine the sensitivity of the modeling to variations in thermal and erosional history.

Quantitative one-dimensional 1D and 2D basin modeling (Figure 2, 3) were performed to evaluate the hydrocarbon potential of the offshore KK basin using the *Petromod* software of Schlumberger. The 1D modeling input parameters comprised of events or formations within the chrono-stratigraphy, deposition age, present and eroded thicknesses of formations and events, lithological parameters, kerogen types and kinetics and other geochemical parameters such as initial TOC%.

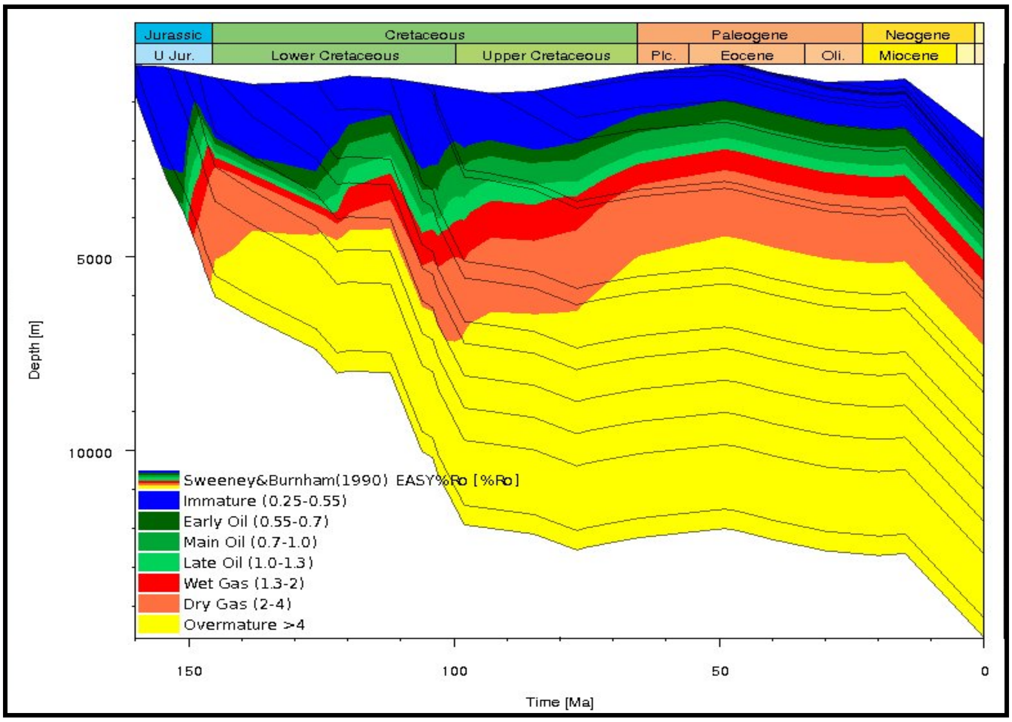

Figure 2: Maturity results of a 1D model : showing Oil and Gas window depth range

PetroFlow 2D in *Petromod* includes flowpath and 3-phase migration modeling with Darcy and hybrid Darcy simulators, the maps and cross-sections are primarily in two dimensions. Facies and lithologies are assigned for 2D models, as well as the source rock characteristics to simulate the generation of heavy oil, dry gas, wet gas, or other parameters. A number of other variables, such as HI, TOC, and Kinetic algorithms were input to the model. One two-dimensional cross-section is digitized in Petrobuilder module. Each layer is assigned the corresponding lithology and also the lateral variations of facies. The detail

Corresponding author: somen.mishra@ril.com

stratigraphy of the KK basin is known above the Deccan basalt. The nature of sub-basalt sediments was not known due to lack of well information and outcrops in onland areas of Kerala-Konkan basin. So the thickness of the basalt and sub-basalt sediments are based on the regional understanding combined with seismic interpretations.

Thermal history modeling was done by calibrating the modeled maturity profile against thermal indicators such as %Ro and T_{max} values. The Easy %Ro chemical kinetic model (Sweeney and Burnham, 1990) was applied for modeling systematic variation of %Ro behavior with respect to time and temperature. Integrating 1D and 2D modeling results (Figure 2, 3) provided us greater information about the petroleum system history of the province.

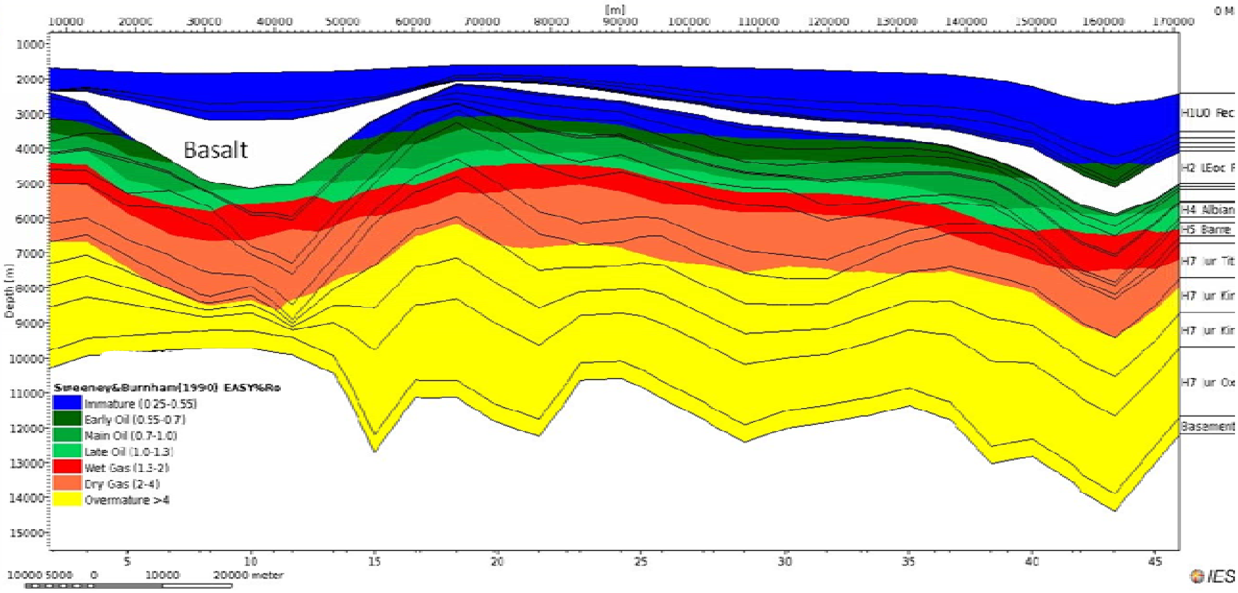

Figure 3: Thermal Maturity results of the 2D model showing Oil and Gas windows

We have simulated the 2D model in hybrid (both darcy and flowpath) as well as invasion percolation migration methods. We have assumed different scenarios by changing the type of lithology (homogeneous or mixed), fault nature in sub-basalt sediments.

Inferences

A closer review of the output shows that any source rock deposited before and during the Jurassic would atleast enter the oil window by the end of the Jurassic (Fig. 2). The late Jurassic being the age of the breakup of Madagascar-India-Antarctica from Africa though the dextral transtensional motion along the Davie Fracture Zone till the Aptian, is expected to be a time of synrift lacustrine environment of deposition.

During the Early Cretaceous, the Proto-Mozambique Ocean was a restricted basin with no open ocean circulation and hence very likely had an anoxic environment until the Falklands Plateau cleared the tip of Southern Africa (Fig. 1). Hence, this would be a

Corresponding author: somen.mishra@ril.com

favorable period for marine source rock deposition. The basin modeling studies show that any source rocks deposited during the Early Cretaceous would enter the oil window by the end of the Early Cretaceous while Jurassic source rocks would be in the gas generation window.

The Late Cretaceous was a period when the remaining East Gondwana fragments break apart. The Cenomanian-Turonian boundary is well documented as global anoxic event and it can be seen that any marine source rock deposited during this period would be in the oil generation window by the Paleocene-Eocene time period. The Early Tertiary reactivation of existing faults and structural inversion due to transtension along the Vishnu Fracture Zone could have lead to the remigration of hydrocarbon.

With the given geologic model, the output results of all the different simulation types confirm the possibility of gas in the sub-basalt sediments. The depth range of gas window varies across from one depocenter to the other. Thus the sub-basalt Mesozoics of the KK offshore basin is likely to have good hydrocarbon potential.

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Corresponding author: somen.mishra@ril.com