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Extensional Tectonics, Rifting, Formation of Sedimentary Basins, Cretaceous Volcanism, Emplacement of Dyke Swarms and Development of Hydrocarbon Pools: Case Studies from Peninsular India and Indian Ocean Region

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Prolonged extensional regime in peninsular India resulted in formation of rift and grabens, elongated basins and Gondwana sedimentation along them. Downward progression of rift related faults caused decompression melting, magma generation, volcanism and emplacement of dyke swarms. Spasmodic volcanism has given rise to several units interlayered with sediments. This unique volcano-sedimentary sequence is present in all the petroliferous basins in and around peninsular India. Interpretation of seismic profiles and drilling logs has confirmed the lateral continuance of this sequence to cover entire Bay of Bengal and eastern half of Arabian Sea. Uninterrupted Tertiary succession is deposited over this sequence. In intersectional regions of rift and grabens, thicker sediments are deposited and more rampant volcanism has taken place due to compounding effect. To obtain stratigraphic and structural information below these volcanic units has always been a challenge. Seismic profiles generated by Pre-Stacking and Depth Migration (PSDM) and Pre-Stacking and Time Migration (PSTM) processing techniques have great potential in mapping the basement faults and sediments below the basaltic units. The lithological logs from drill holes have provided point information, which not only confirmed the interpretation but also helped to extend sections in adjoining areas.The thickness and number of individual units varies in different basins, however, in most of the basins, they are present from the beginning to the end of the Cretaceous period. Furthermore, pre-volcanic upwelling heat seems to have provided kitchen for pre- Cretaceous sediments and flows sealed the cracks as epoxy to form formidable trapping mechanism. Volcanic units are also prolific producers of hydrocarbons because of primary, secondary and tertiary porosity and permeability. The original source for hydrocarbons could be from both older Mesozoic and older sediments, or the sedimentary horizons interlayered with the volcanic units. In most of the cases, bore holes in Cambay basin are drilled only up to top volcanic unit. It may be rewarding to re-enter suitable wells, to ascertain the hydrocarbon potential of older volcanic units and interlayered sediments.It has also emerged that the basaltic units are rift related and are not the product of hot spot activity. The disposition of basalticunits has played a significant role in the movement and preferential accumulation of hydrocarbons, both in underlying Mesozoic andoverlying Tertiary sequences. It has also been concluded that the basin forming and basin modifying tectonics, as well as volcanism hasprofound influence on generation and preferential accumulation of hydrocarbons. Very interesting disposition pattern of hydrocarbon pool within the sedimentary basins in on-land and contiguous off-shore regions are found. Pools associated with the rifts and grabens display very strong tectonic control and are elongated parallel to their axes. In all the basins deposition of source rocks, reservoir rocks as well as trapping mechanism are controlled be continuing basin forming tectonics. In nter-sectional areas of these structures, the pools arc parallel to overriding tectonics. Plotting ofhydrocarbon pools, depending on the geological ages of reservoir rocks has been very rewarding. It has helped in formulation of exploration strategy as well as progression of tectonics. An interesting example has come from theoffshore Bombay basin. Here the Paleocene, Eocene, Oligocene and Miocene pools have distinct relationship with geological setting. Paleocene pools s are elongated in N-S direction and appear to have developed during initiation of rifting from south to north.

Mapping of dyke swarms and integration with seismic and drill hole logs has been very useful both in our

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understanding the geological events, as well as for the exploration of hydrocarbons. ENE-WSW trending dyke swarm is largely enclosed within the Narmada-Tapti Tectonic Zone, while NNW-SSE trending swarm is located on the eastern shoulder of Cambay graben. The study has helped to identify two more dyke swarms from surrounding oceanic regions. The first one is located along the Gulf of Kutch and the other along the Lakshadweep chain of islands. Vertical gradient derivative of aeromagnetic data has helped to demarcate bifurcation and continuance across the graben. Parallelism of swarms with the rift and grabens has suggested that both are genetically related to each other and have developed during extensional tectonism. Exact similarity of major, trace and Rare Earth Elements (REE) in volcanic units and dykes are other interesting observations. Furthermore, location of effusive zones and centers, igneous complexes along and confined presence of dolerite and lamprophyre dykes, transecting coal bearing Gondwana sediments, within the rift and grabens, has also substantiated their mutual relationship. Characteristic shape and clustering pattern of effusive centers and emanating pattern of lava channels and tubes, have explained that there were volcanic fields. These fields were located at different levels and are closely aligned along major rift and grabens. The important fact that has emerged from this study is that the volcanism and dyke emplacement is rift related. Initial felsic volcanism was followed by tholeiitic and alkaline complexes and plugs and corresponding dykes. This has suggested that the magma was generated by decompression. At shallower depths melting of sialic lithosphere was the main cause for the felsic component. In turn this was followed by predominant tholeiitic units, as nearly vertical faults reached to deeper levels and finally gave rise to alkaline complexes and dykes.No evidences to support either the presence of hot spot or its trail are found. Ratherundisturbed continuance of rift and grabens as well as dyke swarms across the proposed trail further negates the idea.

Emplacement of swarms represents only ephemeral period during prolonged extensional tectonics. Petroliferous basins have developed both during earlier Mesozoic and post emplacement Tertiary successions. Giant hydrocarbon producing Ankaleshwar field is located in the Cambay graben and in the middle of ENE-WSW trending dyke swarm. In this field both source and reservoir rocks are of Tertiary period. Several fields in Krishna-Godavari basin are producing hydrocarbons from both Pre-Cretaceous and Tertiary sequences. However, fields in Kaveri basin are largely producing from underlying pre-volcanic sequences. Furthermore, nearly vertical fractures developed in pre emplacement period acted as conduits for upward movement of fluids and heat for distillation of sediments. Successive volcanic units also act as favorable reservoir rocks, due to both primary and secondary porosity/ permeability. Massive units have, however, formed oil seals for hydrocarbon trapping. Similar geological settings are also recognized in Mexican Gulf, Niger basin and several other basins around the globe. An integrated exploration strategy for such geological settings with dyke swarms and volcanic units is formulated for suitable utilization in comparable areas.