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Petroleum Systems and Geological Modeling – An Overview:

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Summary

Petroleum systems encompass the history of entire process from generation of hydrocarbons to its preservation in a trap. The essential elements are the source, generation and expulsion, migration, reservoir, entrapment and preservation. Appropriate relative timing of development of the elements is, however, critical for a petroleum system to materialize. Petroleum systems depend on the type of basin architecture defined by tectono-sedimentary frame work and are often characterized by their distinctive source and migration drainage styles typical to the basin.

A comprehensive geological modelling of petroleum system includes that of the tectono-sedimentary frame work of a basin and the petroleum system and is known as basin and petroleum system modeling (BPSM). The BPSM model chronicles the complete hydrocarbon cycle- generation to preservation, by recreating through geologic times the dynamic processes like the tectonic evolution, temperature and pressure history, timing of generation, migration, accumulation, and loss(retention) of hydrocarbon. Advanced geochemical techniques such as biomarker correlations of petroleum to petroleum and petroleum to source correlations offer a slew of clues including the age, lithology and depositional environment of the effective source(s), timing of maturity, generation and expulsion. Combined with high resolution sequence stratigraphy model based on core, well logs and 3D seismic data, BPSM provides better assessment of the migration pathways, accumulation and retention of hydrocarbons, leading to more efficient exploration of hydrocarbon plays/prospects. Petroleum system modelling is also used as an important tool for risk analysis in evaluating hydrocarbon potentials of basins and prospects and can be employed gainfully at all stages of exploration.

Like all systems BPSM also has limitations. By far, the most contentious problem is the determination of the migration paths that consist of obscure elements like faults and their types, intensity and orientation of fractures and fissures, the permeable career beds and the unconformities in the overburden. Migration path is not a simple two dimensional connections between source and reservoir but is a more intricate network of three dimensional issues. This requires precise information of flow-path geometries in three dimensions with vertical and lateral permeability characters, the prevailing hydrodynamics and the paleodips at the time of hydrocarbon expulsion and migration. Another crucial issue is the difficulty in quantification of hydrocarbon expulsion (not generation) and of loss during migration on way which effectively determines the ultimate amount of hydrocarbon accumulation in the traps.

Explorationists are familiar with experiences of traps, drilled contiguous to or in a hydrocarbon bearing prospect and at structurally higher disposition and (presumably) belonging to the same petroleum system, being found water bearing. Instances are also plenty where hydrocarbon charging has taken place preferentially in only a few selected layers within the multi-layered reservoirs of a field. Redressal of these issues by BPSM leads to comprehensive understanding of the system and improve model prediction efficiency. Despite limitations, improvement in modeling accuracies can be achieved by knowledgeable and experienced interpreters having good grasp of the tectono-stratigraphic framework of the basin, the key to BPSM. Sensitivity analysis with varying geological and geochemical factors, leading to different scenarios, can be useful in effective application of BPSM in exploration and development of prospects.

Instances of producing oil fields of Mumbai High, Gandhar, Lakwa-lakhmani and Narimam are cited where the petroleum system may not have been fully comprehended. Inclusive understanding through revised geological and petroleum system modeling may help generate fresh ideas to find new hydrocarbons pools in these fields/basins to upgrade reserves and resources.

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