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Linking Multi-Dimensional Petroleum Systems and Structural Modeling – Principles and Applications

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Many of the worlds' interesting petroleum exploration areas are characterized by structurally complex geologic histories. Structural or Tectonic Modeling techniques are needed to interprete and reconstruct these histories and Petroleum Systems Modeling can then be used to simulate hydrocarbon generation and migration in order to improve predictions of HC locations and properties. Integrating or linking these two techniques has obvious benefits.

Structural Modeling is used to interprete tectonically influenced geological models, especially in cases of salt, extensional and compressional tectonics, and the creation of paleo-models provides a check on the consistency of the present interpretation. Lateral movements of objects and geometries are controlled using surface or volume balancing and rules for the behaviour of rock units when stressed.

Multi-dimensional (2D/3D) Petroleum Systems Modeling is used to simulate hydrocarbon generation and migration processes in order to improve the understanding and predictions of hydrocarbon accumulation sites and properties. The models are dynamic, i.e. they provide a complete record of the changing geometries and properties through geologic time. The geological processes are mostly modeled as vertical movements of cellular or mapped geological objects which enable them to be followed through burial and uplift processes. Temperatures, pressures and hydrocarbon generation and migration processes including complex phase/component behaviours are simulated and one of the more recent important developments has been in incorporating advanced pvt-controlled multi-phase/multi-component models such as flash calculations which enable complex hydrocarbon component models to be more accurately related to hydrocarbon phases in the petroleum system.

Integrating or linking Petroleum Systems and Structural Modeling enables the simulation of petroleum migration and accumulation processes in structurally complex environments. The main application areas are mobile shale and salt modeling, and extensional and compressional tectonic environments. Several development groups have for some time been developing new integrated tools which combine both structural and petroleum migration modeling capabilities. The main potential advantage of the integrated approach is that feedback between both modeling processes could be ensured, for example of pressures to compaction to paleo-geometry.

However, fully integrated tools have some inherent disadvantages, the principle ones being a) the complexity of the integrated tool means that the functionality and reliability of both the structural and the petroleum migration modeling functions will always be limited compared to specialized tools, and b) structural geologists will have to change to new tools but as technical experts – like all software users - are always reluctant to change, the adoption and actual application of the new integrated tools will not occur, especially if the functionality of the new tool will never reach that of the specialized tool.

An approach which has only recently been completed for compressional tectonic modeling is to create links between separate high-end petroleum systems and structural modeling software tools instead of trying to create an integrated package. The main benefits are that users can continue to work with advanced special tools for both structural and petroleum systems modeling and the superior functionality of both tools is retained. A sequence of structural paleo-models controls the geometry of the model during processing with the 2D/3D petroleum systems modeling simulator, special grid transformation routines ensure that the geometries, properties and hydrocarbons in the system are handled correctly from timestep to timestep, and 3-phase, n-component migration modeling can then be performed in the thrusted models using advanced pvt-controlled phase/composition models such as flash calculations.

The presentation will elaborate on the advantages and disadvantages of both fully integrated and linked approaches, will provide details of the concepts and workflow of the linked approach, and will use a case history in a compressional tectonic environment to illustrate the key points.