**Basin modelling applications in reducing risk and maximizing reserves**

**Introduction and review**

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The conference session was originally planned to address aspects of regional and reservoir diagenesis. However, at an early planning stage we decided that basin modelling was going to be the explorationists’ technique of the future and that a theme in the ‘Advances in Technology’ section incorporating basin modelling – but not excluding diagenesis – was more appropriate.

How prophetic: some 10 presentations were initially offered for the session, two of which were given in other sessions and two of which had to be withdrawn for reasons of commerciality. Of the six papers presented at the conference and included here, four use 3D migration modelling (all of them integrated with 1D and 2D), one is based on 2D generation and migration modelling and one integrates diagenesis, pressure prediction and...
and fluid migration. The papers encompass frontier exploration on the North Atlantic margin and hydrocarbon systems/ diagenetic modelling in the mature exploration areas of the East Irish Sea and the UK and Norwegian Central North Sea.

The 3D modelling papers all employ variations of ray-trace (or ray-path) modelling. From the efforts of our trawling and the resulting responses from oil companies and software vendors it would appear that no one has yet applied a full physics, grided 3D cellular basin model to case studies based in the NW European Shelf – or if they have it is too confidential to be presented. No doubt that dawn is not far away.

Ray-trace modelling provides a simple, computationally fast approach to modelling petroleum migration. The technique assumes that petroleum migration is driven by buoyancy, and it is the dip of the petroleum surface that dictates the migration pathway (Fig. 1). The result of this approach is that petroleum migration is very rapid and highly focussed – in effect the models produce inverted rivers of migrating petroleum. Given that geochemists tell us that petroleum migration is focussed into thin stringers of relatively high (>30%) saturation and that only <5% of the sedimentary basin is ever exposed to hydrocarbon migration (England et al. 1987; Larter et al. 1996; Schowalter 1979), then this approach appears to mimic our current prejudice of how hydrocarbons move in the subsurface. Thus the key parameter in this modelling approach is having an accurate structure contour map that reproduces the top surface of the carrier system (or the base of the regional seal). However, this fundamental pre-requisite appears to limit the usefulness of the technique to the more mature petroleum basins of the world such as the North Sea where the subsurface structure is seismically well defined. Frontier areas such as the Atlantic margin where the source horizons and migration routes are sub-basalt and cannot be seen on seismic, let alone structurally mapped, will remain the domain of 1D and 2D modelling until either technological developments allow these problems to be overcome or surfaces can be extrapolated mathematically. Also, the existing models use only the present-day structure contour surfaces and perform only 1D vertical decompaction – there is no structural restoration, although expect this capability to appear in the near future. With current developments, ray-trace migration modelling will soon be integrated with 3D petroleum and pressure generation engines (as CAULDRON now is), and will incorporate multi-carrier layer models, structural restoration and fault properties (Fig. 2).

Giles et al. provide a glimpse on the workings and output from CAULDRON, the in house SHELL 4D (3 dimensions plus time) simulator. This simulator has a linked 3D generation and migration engine, with the secondary migration based on ray-tracing. These authors show that heat flow is a true 3D process and significant errors can be introduced if only 1D approaches are employed. Jowitt et al. present one of two papers on the Atlantic Frontier, using PATHWAYS (Hindle 1997) to predict charge distribution and vertical migration. Holmes et al. show how geochemistry can effectively be used to

![Fig. 2. Multi-layer ray-path modelling of petroleum generation and migration in structurally restored volumes. The generation engine includes a pressure calculation. Bed geometries evolve through time. Migration takes place within and between carrier beds that change geometry through time as the basin develops. Faults are restored with inclined](http://pgc.lyellcollection.org/)

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constrain 2D models of petroleum migration in an example from the North Atlantic margin. Taylor et al. provide a regional study of the Central North Sea Graben Fairway trend using FINESSE, the in house Amoco ray-trace simulator, and demonstrate the importance of seal integrity in controlling hydrocarbon accumulations. Cowan et al. demonstrate how SEMI (Sylta 1993) can be used in a mature exploration province to reconstruct filling history through time and predict hydrocarbon phase type, in a model calibrated to known discoveries and the regional seal distribution. Effectively then, the papers capture a comparison of CAULDRON, PATHWAYS, FINESSE and SEMI.

Haszeldine et al. collate many of their ideas on basin scale diagenesis together to propose an integrated model of pressure development and diagenesis for the North Sea, employing 1D and 2D basin models to predict overpressure and fluid migration pathways. This approach is innovative, opening-up new avenues in the integration of diagenesis into basin models. Here the challenge is to provide both a spatial framework for process and diagenetic product distribution and for predicting porosity and diagenesis in unexplored parts of basins. Perhaps this type of approach will promote a renaissance in studies of sediment diagenesis.

The next advance for basin modelling will be towards quantitatively reducing risk in prospect evaluation – what is referred to as play modelling – incorporating statistical ranking of prospects and leads. With the rapid simulation times of ray-trace approaches the sensitivity of the petroleum system to any geological parameter – source-rock properties, carrier bed properties, seal integrity and petroleum phase type – can all be quantitatively assessed. No longer are we restrained by deterministic models. The explorationist can now ask ‘What if?’ questions. Indeed, Monte Carlo approaches to investigating sensitivities and volumetrics are already possible (Krokstad & Sylta 1996). Perhaps this probabilistic approach will herald a revolution in exploration and prospect evaluation.

References


