THE SHARED EARTH MODEL RE-VISITED
A new generation of integrated models will actively add value to subsurface studies and reservoir management.

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Introduction

There is an earth model implicit in the work of every subsurface discipline. Seismic interpretation is guided by a constantly-reviewed mental model. A flow simulation model is a numerical abstraction guided by the engineer's feeling for the dynamic effects of geological features and rock properties. Sedimentologists and petrophysicists form a geological concept in order to make internally consistent interpretations of well data.

Mental models require an understanding that comes with experience; but currently, the industry is short of experienced people. Subsurface teams are overloaded, and as the emphasis shifts from appraising and developing large fields towards maximising recovery and locating additional reserves to utilise infrastructure, the demands on professionals of all disciplines can only increase.

However, new technology may be able to supplement mental models with computer models and bring the Shared Earth Model to a new role, obtaining maximum value from the available subsurface talent.

What is a Shared Earth Model?

In essence, our current idea of the shared earth model principle is unchanged from its first formulation 15 years or so ago. It is the use of computer modelling to link up the mental models, assumptions and specialised understanding held by subsurface professionals in different disciplines working on the same field or prospect. The idea is that what one person sees in his data can be an aid and constraint to the way another person interprets other data. All this leads to a more consistent picture of a reservoir, more efficiently reached, resulting in better support for field and business management decisions.

The shared earth model concept emerged in the mid 1990's from oil company majors Elf and BP (Gutteridge et al, 1993; Gawith & Gutteridge, 1994). Its aim was to bring together sub-surface people in different disciplines, including geophysicists, geologists, reservoir engineers and petrophysicists, using a common model of the subsurface, albeit expressed or realized in different ways. The benefits of such integration were clear: models of the sub-surface that were consistent with all available data and conceptual views would be closer to reality and hence more likely to make realistic predictions. Such models are often referred to as shared earth models and in practice, are based on geological 3D modelling software.

Shared earth models should be ephemeral, continuously changing. They should inform and constrain technical choices but also reflect our changing view of the subsurface during appraisal, development and production phases of a field's life. At first, this was difficult because all the available software programs were designed with the idea of an expensively-created and long-lived model. No-one could justify discarding a model with so much invested in it. What is more, software for each discipline continued to be developed separately, with only high-end visualisation systems attempting to bring things together.

However, in the last few years the increasing power and diminishing cost of computers have changed our working environment. We are now in a position where we can take full advantage of this and make a big leap forward. Today, models can be considered as disposable: built within a matter of hours to solve a particular business decision and updated instantly when new data becomes available.

Inter-disciplinary integration of models has benefitted from two connected developments. Firstly there has been a convergence of geological modelling and reservoir simulation, with fine-scale simulation requiring less up-scaling of properties. Secondly the improved data-handling capacity of desktop computers now brings 3D seismic attributes into the modelling domain and so makes the application of rock-physics-based methods in 3D geological models a practical proposition.

Rock physics holds the key to 'closing the loop' between reservoir simulation and seismic modelling, and to making fluid predictions from time-lapse seismic. Rock physics makes the connections between the realms of geology, reservoir engineering and geophysics, not only seismic but non-seismic methods such as EM and gravity.

How Far Have We Come?

Most reservoir models now have the static aspect of a simulation model created directly from a detailed 3D geological model, as the industry has realised that this is much more efficient than the traditional approach. The connection between seismic interpretation / analysis and the geological model is more indirect however. And in most cases the flow of information is one-way: interpretations and models are still not being revised sufficiently often. Nevertheless, we are making progress, and emerging technology is helping.

Fast and Flexible Model Building.

Models that integrate all available data and views are all very well but not very practical if the model construction takes a lot of time and effort to complete. We need to be able to make, re-make and update models continuously according to business needs. One way to achieve this is to make the model a 'virtual' one which is realised only where and when needed (Gawith & Gutteridge, 1999). The model description can be stored as a recipe and built 'on the fly' at an appropriate level of detail. A model building system that is grid-less can achieve this without difficulty.

Closing the Loop

During the history-matching process, it is possible for some aspects of the flow simulator model to depart from the geology, making predictions unreliable. With suitable models we are now in a position to use seismic modelling and real seismic to validate a flow simulation. Saturation and pressure changes from flow simulation time-step data can be used, together with rock physics, to build time-lapse synthetic seismic data. The synthetics can be compared to real 4D seismic to validate the flow simulation. If the seismic data confirms the simulator's results in the spaces between history-matched wells, greater confidence can be had in its forward predictions.

In feasibility studies, where 4D seismic has not yet been acquired, the time-lapse synthetics can help to determine at what stage there will be value to be gained in acquiring the next survey.

This is the simulator-to-seismic family of work-flows, implemented expensively by major operators (Watts et al, 1996). New modelling techniques, integrating rocks, fluids and seismic signals on the fly, will bring them into common use.

Reservoir Monitoring

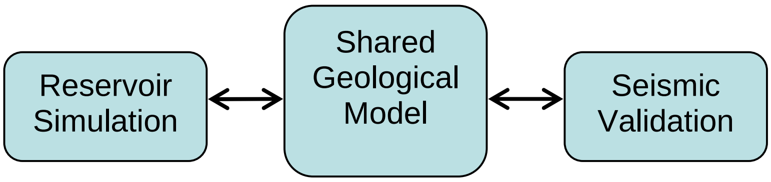
Sophisticated reservoir monitoring is important in maximising recovery. Inverting time-lapse seismic to reservoir fluid movements should be performed within the context of an integrated model to ensure that any changes predicted are consistent with the underlying geology (Gawith et al, 2005).

Again, a reliable rock physics model is an important part of this process; so is a willingness to change the model if the results are implausible. Virtual models, instantly changeable, will greatly reduce the cost of rebuilding our geological models in response to new observations.

The Near Future

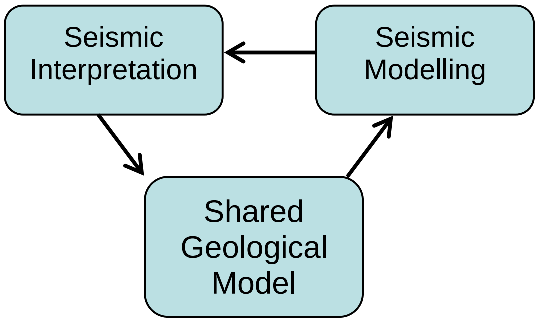
To conclude, let us imagine …

A reservoir engineer history-matching a simulation sees early water-breakthrough in the field which is not reproduced by the model; he postulates a high-permeability pathway from the aquifer to a particular well and inserts this into the model. Because this is based on a shared earth model, the geological elements required for this (e.g. channel geometry) and, through rock physics, the seismic expression can be evaluated and tested against geological analogues and observed seismic data. The engineer asks his colleagues: this will help the match – does it work for you? In this way an engineering-driven change to the field model is validated by the involvement of the whole subsurface team.



Or again …

A geophysicist is interpreting the reflections from a highly-faulted potential reservoir interval, hoping to delineate a satellite oil accumulation and develop a drilling target. As he correlates horizons and faults on one screen, a 3D geological model is added-to on another screen, so that the interpreter can see whether the picks make structural sense. Stratigraphy and rock properties are extended into the new 3D model region and on a third screen a synthetic version of the current seismic data view is shown for comparison, so that the stratigraphic sense of the picks can be confirmed.



These two scenarios have technology reinforcing human skill and judgement. This is what the Shared earth Model idea was really about.

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