

PROCEEDINGS, INDONESIAN PETROLEUM ASSOCIATION  
Twenty-Ninth Annual Convention & Exhibition, October 2003

**PROSPECTS TO RESERVOIR MODELS: STREAMLINE THE WORKFLOW**

**Dylan Mair\***  
**Christi Gell\***  
**Noel Lucas\***

**ABSTRACT**

Next generation 3D interpretation and reservoir modeling workflows provide order of magnitude gains for prospecting and development planning. New interpretation and modeling workflows take advantage of new methodologies and underlying technologies to use all available data instead of mimicking workflows that were designed around the limitations of earlier software and hardware, or were even derived from paper sections. Rapid identification and characterization of seismic anomalies enhances prospects identification and enables multiple realizations of each prospect model. Models are provided directly to the simulator and incorporated into an integrated asset-planning environment for portfolio risk analysis, automated well targeting and optimal field planning.

A four- to seven-fold decrease in cycle time has been proven worldwide for the seismic interpretation stage of a project, using this approach based on visualisation. Integrating this directly with reservoir modeling the asset team can now turn seismic data into reservoir models in days, rather than months. This enables a streamlined interpretation to simulation workflow within every asset team, and even provides reservoir models for those assets without a dedicated modeling specialist.

**INTRODUCTION**

Visualization is a new and powerful tool for data analysis that can shorten cycle time, reduce costs and increase accuracy. However, many companies and interpreters fail to take advantage of this concept. One of the most common reasons is due to a lack of

understanding on how to integrate visualization and interpretation into a collective workflow. One of the key workflows combines Geovolume Visualization and Interpretation (GVI) in a 3D seismic post-stack environment based around seismic interpretation and reservoir modeling. The steps involved progress from interpretation to internal reservoir modelling, with the final step addressing the fact (although not often admitted) that all interpretations are wrong. The important question that can be answered by combining volume interpretation and reservoir modeling is, "how wrong can the interpretation be and still find oil and gas?"

Historically, reservoir modeling has often been a complex process performed by an 'expert' outside of the asset team. The old modeling process created a time-consuming integration break between the G&G interpretation and reservoir simulation workflows.

Designing a next-generation earth modeling system to effectively cross the barrier between interpretation and modeling requires:

- direct integration with a fully integrated interpretation system;
- building models that can be run directly in today's reservoir simulators; and
- modern, robust management and sharing of the resulting models and the data from which they were built.

In many cases, it is only recently that these requirements became supportable by commercial hardware.

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\* Landmark Graphics (Malaysia) Sdn Bhd

## VOLUME INTERPRETATION

As there is an increasing amount of 3D seismic data worldwide volume interpretation is becoming the future of seismic interpretation for everyone, not just specialists in that field. It's core strengths center on its speed, the ability to handle small or large data sets and it's accuracy. Worldwide, there is a proven four- to seven-fold decrease in cycle time for the interpretation stage using this approach, with these numbers decreasing with each volume visualization technology advance. Companies thus need to target a decrease in prospect generation cycle time of not 2 or 3 times, but 10 times.

Perhaps more important than speed is the need for accurate interpretations. These are achieved through interactive data manipulation using advanced interpretation tools such as fault plane interpretation (vs. fault stick/segment interpretation), multiple attribute auto-tracking, and wave-form picking. Recent technological advances allow an interpreter to integrate many seismic attributes into geophysical interpretations. By examining a large number of attributes, the best set for characterizing an event can be selected. Once a set of attributes is chosen, it can be used to interpret complex geological features to help in distinguishing prospective vs. non-prospective areas. For a more detailed description of attribute definitions and techniques, see Harvey et al. (2000).

Figure 1 (Bulloch et al, 2001) illustrates a turbidite system with the attributes instantaneous dip and smoothed dip of maximum similarity, with the amplitude seismic volume and semblance shown in the background. The channel is moving down dip to the east and fans out as the slope of the regional event below decreases. Using these attributes gives a better visual picture when interpreting the depositional environment. Scanning through the data interactively confirms the interpretation of the various channels and fans.

Figure 2 shows a fault stick interpretation using the traditional line-by-line method on a semblance volume, which took about three days to complete. Notice that some of the interpretation is not complete or coherent. Fault A was interpreted as two faults and some of the fault interpretations were not completed. In contrast, Figure 3 shows the 3-D volume based fault plane interpretation, which took less than a day to complete. This utilized

simultaneous fault interpretations with interactive editing (which could be used to interpret multiple-Z value surfaces). By interpreting on a fault plane in the full volume, the interpreter could properly identify the faults and their correct extents.

Using the main techniques of geovolume interpretation, interpreters quickly generate regional interpretations and isolate areas of regional volumes for prospect investigation. These interpretations are completed accurately and quickly, and used to extract the maximum information from the seismic data with reduced cycle time. Some techniques employed are:

- using multiple attribute volumes for fault interpretation (i.e.: semblance) and surface auto-tracking (i.e.: amplitude and phase);
- data manipulation (scanning and slicing through regional volumes);
- full volume fault plane interpretation.

The finished interpretation products are then used in a streamlined "modeling-while-interpreting" workflow. Integrating volume interpretation directly with reservoir modeling, the asset team can now turn seismic data into reservoir models in days, rather than months.

## MODELING

Building reservoir models of interpreted prospects provides a different set of challenges to be met in order to enable order of magnitude improvement to the workflow. Streamlining the modeling workflow requires direct integration with interpretation data, both for model building and quality control. This also enables iterative modeling, unconstrained by the linear workflow of traditional modeling. Further speed improvement is gained through automated geological framework building, which reduces model building time even further.

Once prospects within the greater seismic volume have been identified, often using the power of the visualization center hardware and software, the requirements of reservoir modeling scale easily to the workstation environment. PC workstations are becoming increasingly popular in the oil and gas industry, both for performance and price and are rapidly becoming the platform of choice for reservoir-

scale work. Many oil companies around the world have implemented or are trying Linux workstations for exploration and development work, beyond seismic interpretation and seismic processing. While companies are cautious about publishing performance tests, lest they compromise their relationships with other hardware vendors, the PC platform has been generally very well received. Concerns about the stability of PC platforms often give way to a desire for greater performance.

Reservoir modeling incorporates many different data types; well data, seismic data, and interpretations of these data. To accelerate the modeling process, it must be possible to view and work with a wide range of data types as part of the modeling process. An example of a 3D viewer is shown in Figure 4 illustrating interpreted horizons and faults, two 3D seismic volumes and wells with logs and tops. Providing these data in a common database, used by the interpreter as well, ensures that the whole asset team is working with a single, consistent interpretation. Using a shared database ensures that new interpretations are immediately available for reservoir modeling. The different data types, including seismic and well log data for property modelling, can be directly incorporated into the model without reformatting or moving the data. Any editing required can be applied within the interpreter's environment. This ensures greater accuracy of the interpretation as well as avoiding duplication of data that leads to loss of integrity of interpretations and makes iteration of the workflow much more difficult.

Creating a topologically sealed framework using faults and horizons is traditionally a very labour-intensive process. It can take several days to accomplish. To overcome this limitation, automated tools can be used to shorten the construction time while still providing control over the results where required. The user selects the fault surfaces to be used for forming a sealed hierarchy of faults (also shown in Figure 4), and the software automatically forms a network of fault surfaces that cut and truncate each other as appropriate. The user provides quality control and adjusts the fault hierarchy if necessary by toggling the geological relationship between any pair of faults. Using this system, the fault framework can be constructed even for complex fault systems using very little user input, beyond specification of the desired grid azimuth and cell size. Surfaces within

the model are similarly fast-tracked, with automatic surface refinement around faults to overcome messy fault-horizon relationships that typically require considerable manual editing to repair.

Figure 5 shows a comparison of modeling done on a UNIX system compared with a PC system. Such a comparison demonstrates significant disparity between the two workflows. However this disparity is a result of both the hardware and the modeling process. Processes are at least three times faster on the PC and this initial difference might be attributed to the hardware, which was not a "state-of-the-art" system. The traditional workflow fares much worse in the data loading process, and slightly worse for structural modeling. This workflow was actually hindered further by datum issues that took much longer to resolve during data loading. These issues should not exist when there is direct integration with the interpretation data. The marked difference in property modeling would appear to be software related, although the workflows in this case were quite similar, using comprehensive geostatistical solutions.

Integrated reservoir modeling opens up the possibilities for iterative reservoir modeling, moving back and forth from modeling to interpretation to refine the result, incorporate new interpretations and potentially model multiple scenarios to fully qualify geological risk. Workflows beyond interpretation and modeling can also be accelerated through generation of "simulation ready" earth models and integration with development planning. Once rapid modeling is possible, models can be quickly updated throughout the life of the drilling and field development programs.

## CONCLUSIONS

3D volume interpretation and 3D modeling technologies provide valuable clues to companies in their quest to squeeze more oil from reservoirs. The workflow presented here is a major improvement over earlier techniques that only specialists outside of an asset team could apply. The old interpretation and modeling processes created a time-consuming integration break between G&G interpretation and reservoir simulation workflows. Integrating visualisation with interpretation and reservoir modelling in a collective workflow has bridged this gap, yielding major benefits in efficiency by

drastically reducing cycle time whilst improving results.

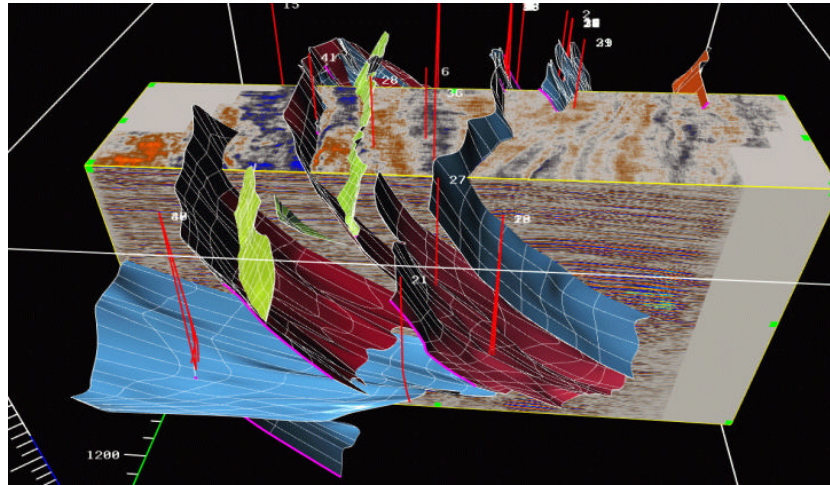
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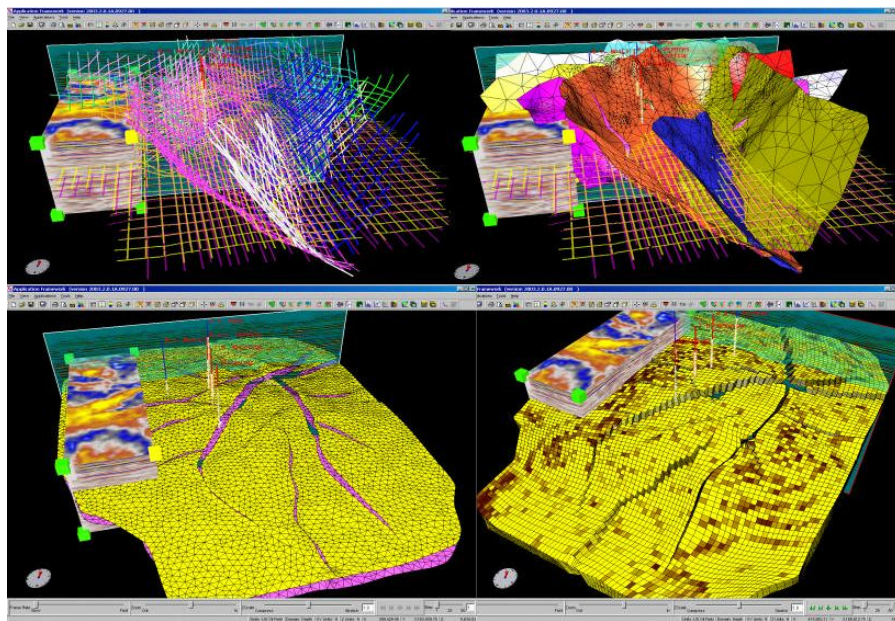
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**Figure 3** - More accurate fault plane interpretation created in a 3-D volume.



**Figure 4** - Iterative modeling environment. Interpretation data is displayed directly and any modification required is done using all of the tools available to the interpreter, to the original interpretation. This enables iterative (non-linear) workflows. Automated fault heirarchy, surface refinement and geostatistical property and facies modeling accelerate the workflow from months to hours.



<i>Task</i>	<i>Independent UNIX modeling</i>	<i>Integrated PC modeling</i>
Data Preparation	120.00*	2.00**
Fault Modeling	1.00	0.12
Structural Assembly	1.00	0.35
3D Geocellular Model	1.00	0.16
Seismic Extraction	1.00	0.35
Well Extraction	1.00	0.35
Facies Modeling (2 realizations)	48.00 (weekend)	0.16
Porosity Modeling (kriging)	48.00 (weekend)	0.16
Porosity Modeling (co-kriging)	48.00 (weekend)	0.16
Quality Control of the Model	16.00	16.00
<b>Total HOURS</b>	<b>285.00</b>	<b>19.81</b>

\* ASCII export/import of well and seismic data

\*\* Backup/restore of interpretation database

**Figure 5** - Next generation performance (Lucas 2003, unpublished). This table summarizes the time taken (in hours) to build the same reservoir model using the traditional workflow (using an independent modeling application) compared with an integrated workflow (linking directly with the interpretation environment). These differences result from both hardware and software factors. The model comprised 4 million cells with five faults and three structural horizons. Backup and restore of the interpretation is not necessary if all hardware exists on the same network.