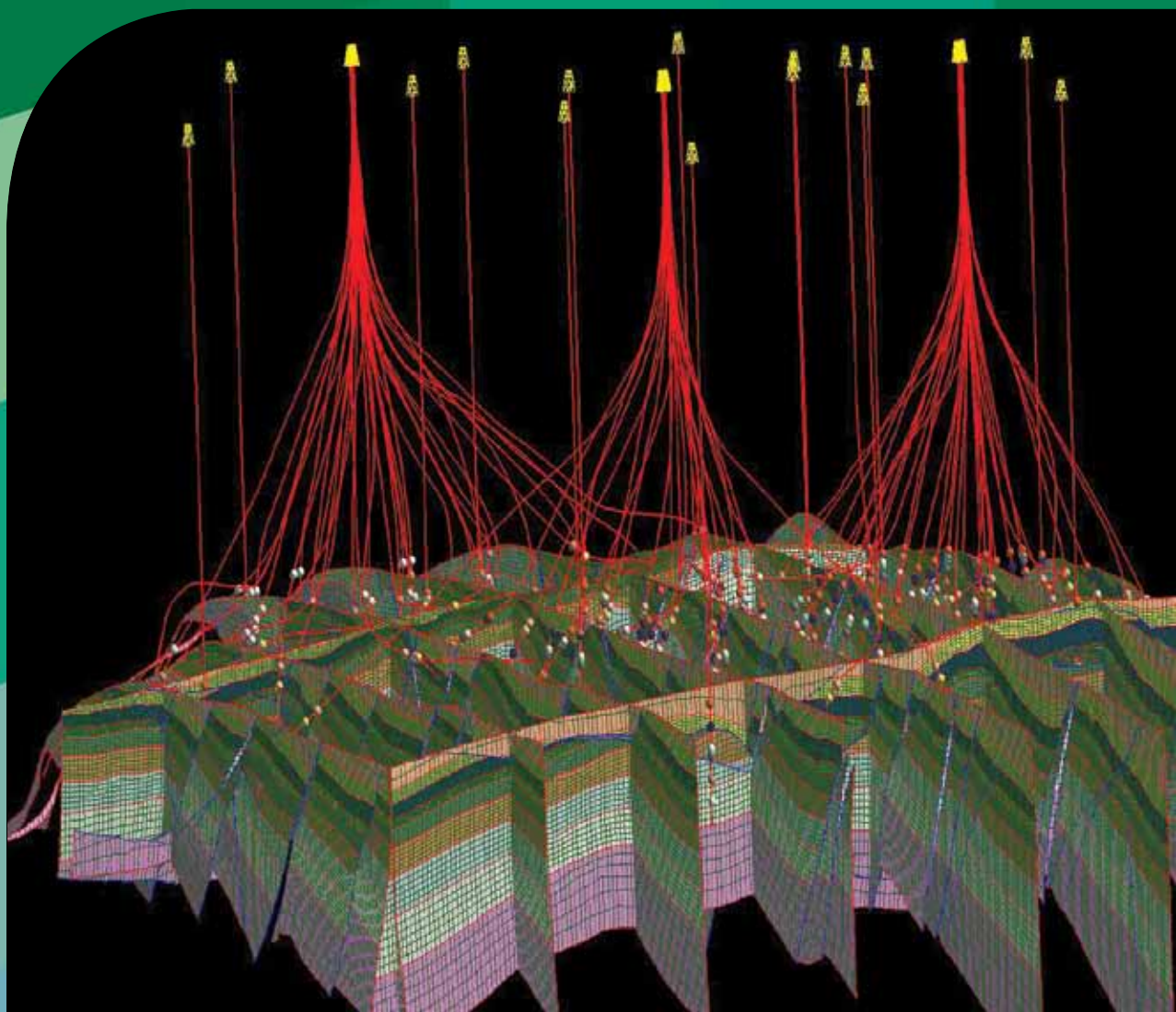
Interpretation and Modeling

Paradigm®

Redefining Geological Interpretation

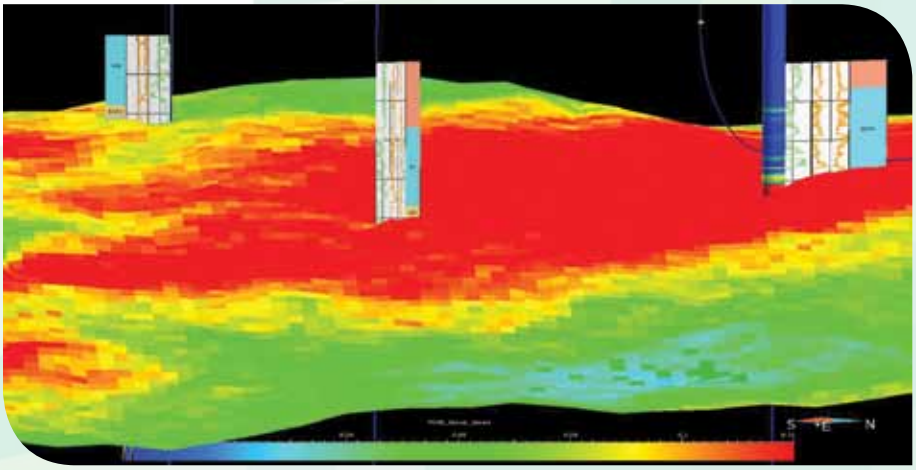


Paradigm Redefines Geology

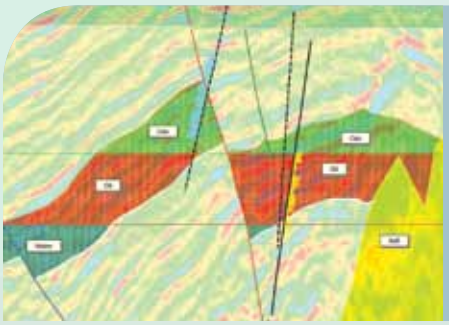
The art of geology relies on assembling sparsely-sampled data at vastly different scales, and using stratigraphic as well as geometrical logic, supported by field analogies, to populate areas where no objective data exists. Today, of course, it is rare for such a process to take place without some support from seismic data. While seismic is of lower resolution, it does offer uniform sampling in all three dimensions, and as such is invaluable in guiding correlation and modeling activities, as well as helping to develop structural, characterization, and direct property information.

Modern geological software combines applications that take geological information as a primary data input, and attempt to generate geological knowledge and parameters out of diverse data sources. The power of today's advanced computers, coupled with broad data integration, allows geologists to apply a wealth of science and technology to achieve geologically-consistent results. These can be evaluated and qualified for the uncertainties that are inherent in both the input data and the variability of geology. Paradigm's unique geological software capabilities are based on a number of powerful foundations:

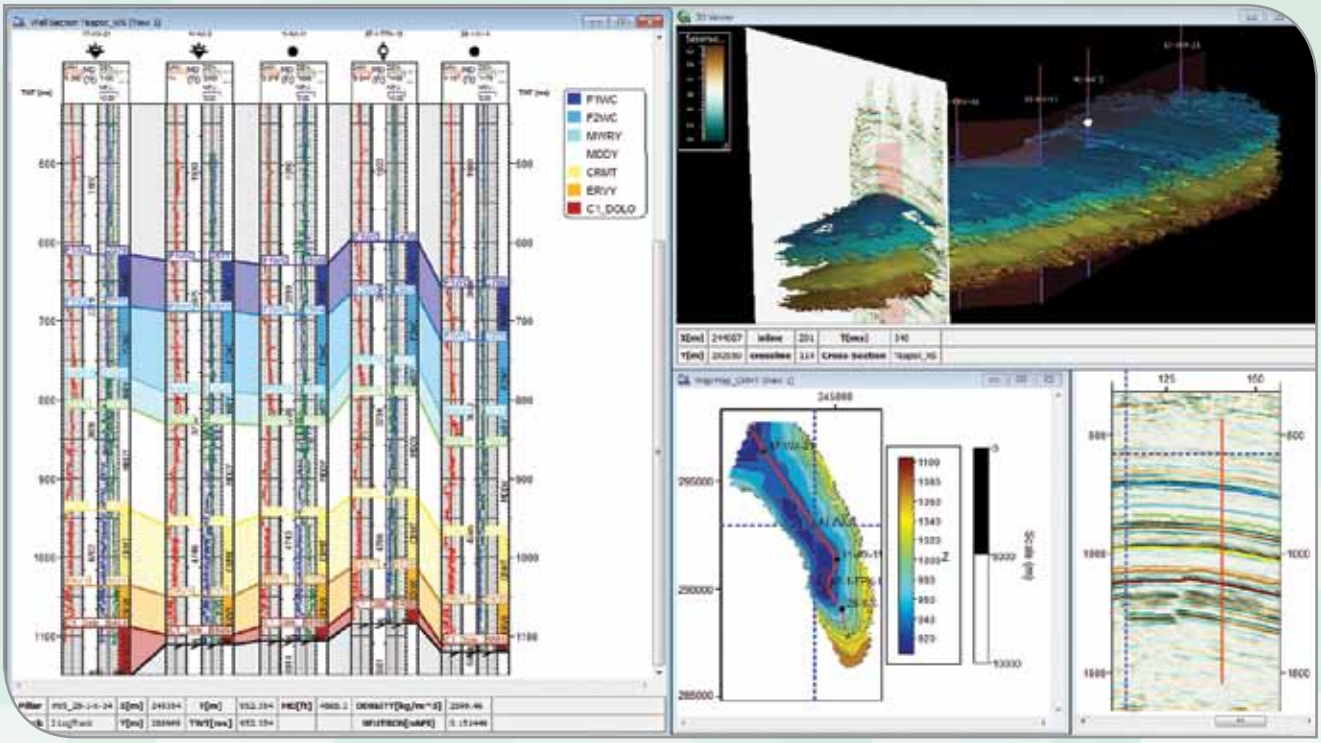
- The highly efficient and thorough processing and interpretation of well measurements for optimal formation evaluation, thereby gaining maximum information from well data
- Unique modeling tools, guided by geological constraints, used to construct structural and stratigraphic models, in order to validate interpretation utilizing a wide range of structural analysis tools
- The capacity to handle any amount of complex faults, avoiding compromises and simplifications
- Multiple geostatistical methods to assess and mitigate uncertainties
- Seamless integration to seismic, field production and other data sources that enrich geological workflows, and a direct process for generating geocellular simulation grids, free from pillars



3D well correlation



Continued success in exploration and production activities stems from a combination of innovative technologies and the efficient integration of data, disciplines and workflows.

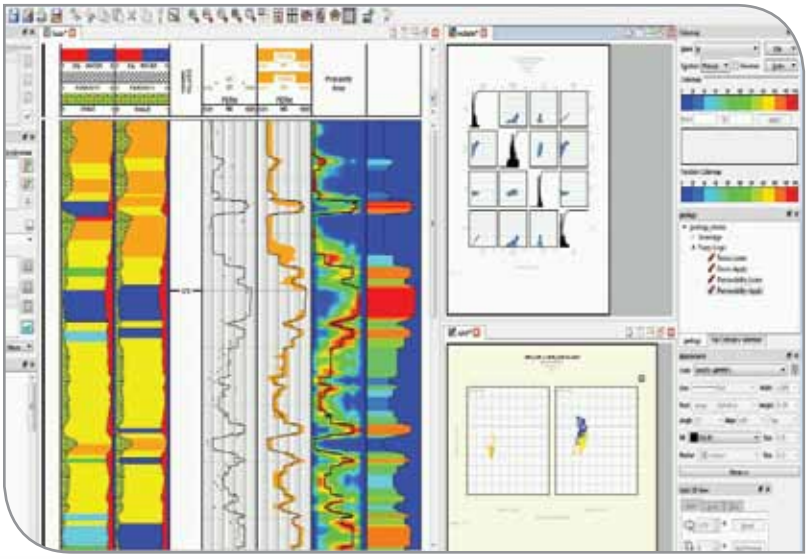


Integrated geological interpretation

Innovation is the Key

Through our culture of ongoing innovation and our close collaboration with leading energy companies, Paradigm™ now offers a mature and versatile geological software suite, designed to easily handle any project, from a simple, small-scale survey to a large, multi-disciplinary study involving challenging geological scenarios. The Paradigm Epos®-based product integration enables tight, iterative workflows that make it possible to study and compare different scenarios, estimate uncertainties, and develop ranked strategies to guide the decision-making process.

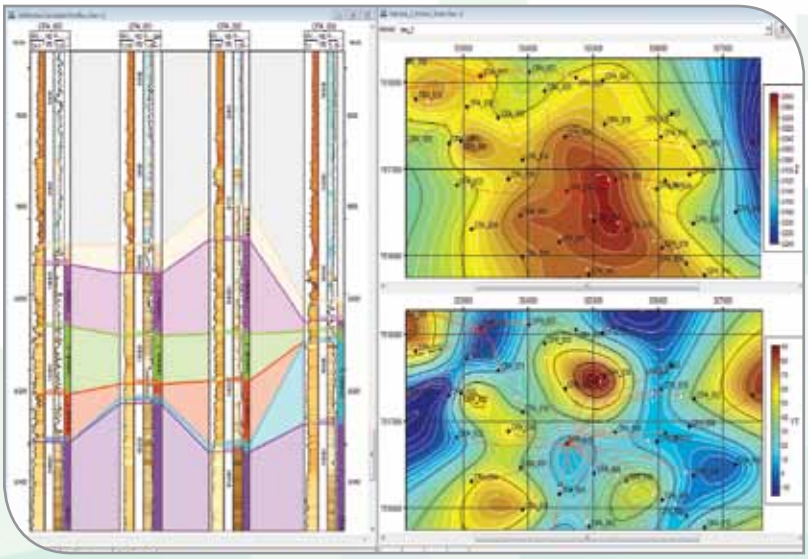
With over 200 scientists and programmers, Paradigm is a known innovator in many domains



Geolog workspace showing log display, crossplot and multiplot views

The Initial Data: Formation Evaluation and Petrophysics

Facies classification, borehole image interpretation, mineralogy, core interpretation and saturation determination are some of the functionalities that a geologist will find inside the industry-leading Geolog® formation evaluation system. Extendable with the customer's proprietary characterization algorithms, and able to process and generate multiple log types on many wells, Geolog serves as a platform for providing the best set of logs for use in well-to-well correlation, seismic-to-well correlation and reservoir model construction.



Marker correlation and associated elevation and thickness maps in the StratEarth® well correlation system

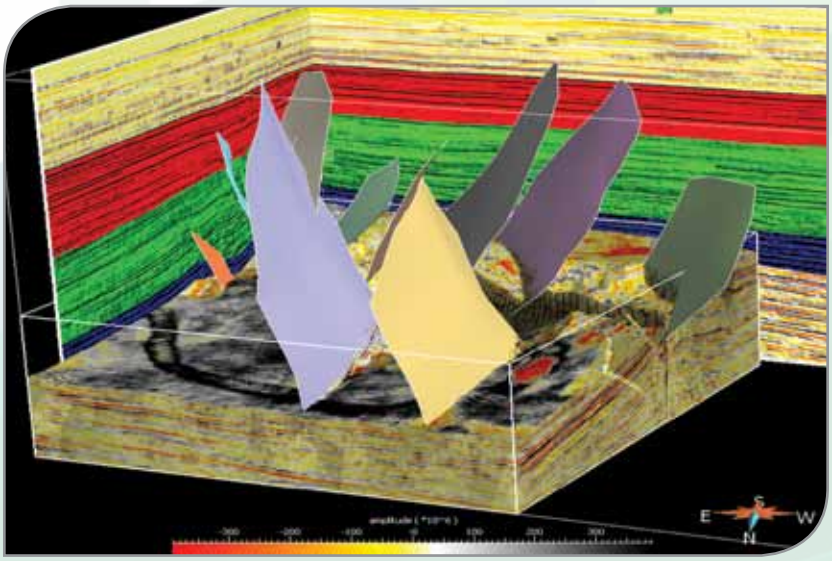
Building The Framework: Correlation and Cross-Sections

Taking logs directly from the petrophysicist, well sections can be constructed that display all the tracks needed to perform stratigraphic correlation, while incorporating seismic data (when available), interpretation and production information in the same section. Multi-scenario marker correlation can be constructed to evaluate uncertainty. Net pay thickness maps are constructed automatically while markers are interpreted and pay zones identified, using a variety of data analysis tools. Erosions and fault gap information are provided to construct TST and TVT sections. Stratigraphic information created while interpreting is then used directly for the construction of the 3D stratigraphic model.

Collaborative software allows petrophysicists, geologists, drilling engineers and well site staff to evaluate critical situations and discuss remedial action. This is of particular importance for horizontal drilling.

Building the Earth Model: Advanced Structural Modeling

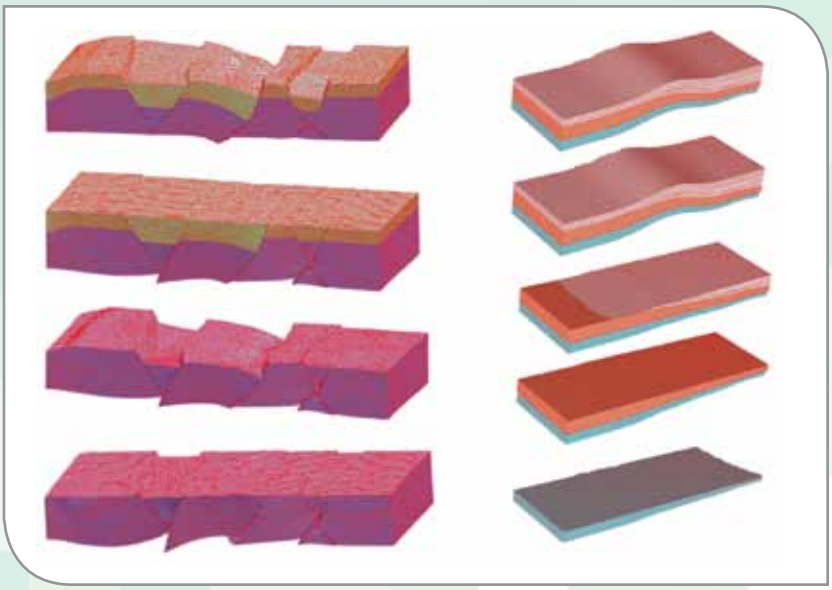
Based on the stratigraphy column, interpreted faults and salt bodies, the structural model is constructed automatically, finding fault-fault and fault-salt contacts and building horizons following sequence stratigraphy rules. Horizons and faults are constructed in order to automatically create a sealed model that can be used to generate 3D consistent maps, velocity models, geological grids and flow simulation grids. The 3D model, constructed using a 3D unstructured mesh and the UVT Transform®, has none of the limitations of pillar-based models. It can handle any kind of faulting, and can represent any stratigraphy between horizons.



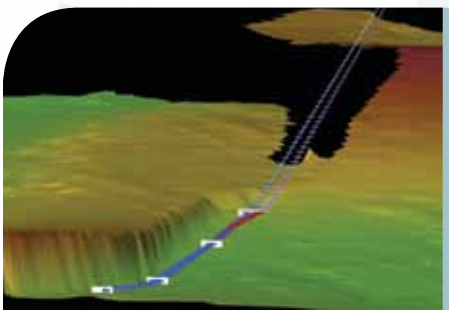
Faulted chrono-stratigraphic slice inside UVT model highlighting stratigraphic features

Unraveling Geological History: Reconstruction Processes

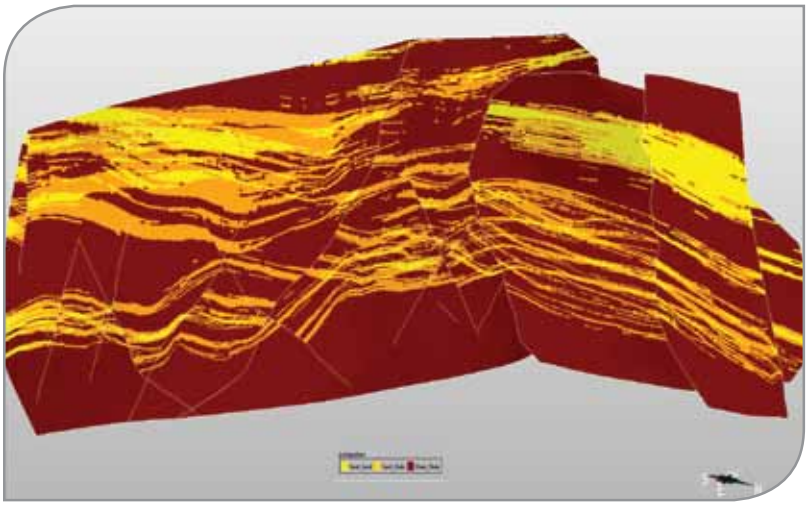
The unstructured mesh and associated UVT Transform contain the information needed to perform 3D restoration of the present-time model using a geo-mechanical finite element technique. Eliminating the need to construct a series of finite element models, each layer of the 3D model can be sequentially uncompacted and automatically uneroded. Along with the restoration of the 3D structural model, a 4D basin grid can be created in order to study basin maturity and fluid migrations.



Sequential restoration of 3D models inside the Kine3D-3 restoration application



Paradigm geological solutions can rapidly integrate real-time Logging While Drilling (LWD) data from the rig using the WITS-ML data transfer protocol. The new data is accessed by all applications and can be visualized and used in all relevant processes.



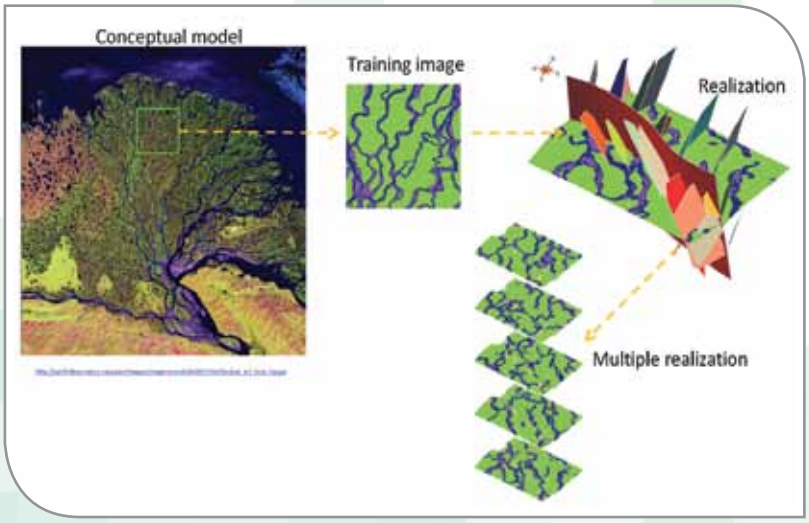
Facies juxtaposition and branching faults on a fault surface, computed on a geological grid

Understanding the Trapping Mechanism

From the stratigraphic faulted model, reservoir juxtaposition or fault traps can be studied. Juxtaposition maps and displacement maps can be constructed, and fault displacement analysis can be performed. The UVT Transform contains all the information needed to compute information such as Smear Gouge Ratio, or weighted Smear Gouge Ratio, which takes into account the smearing potential.

Populating the Model: Geostatistics

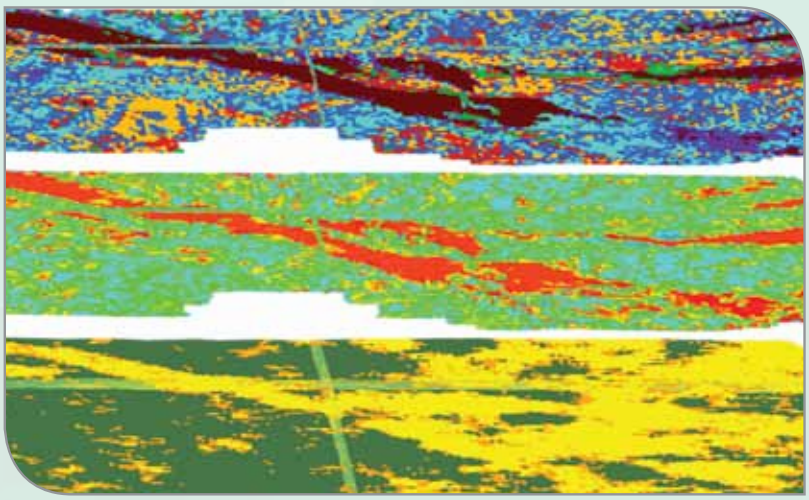
The 3D model and UVT Transform contain information about the paleo-geography coordinates of all the cells of the geologic grid created inside the 3D model. Geostatistical algorithms are then run inside the paleo-space in order to undo post-deposition deformation. Contrary to pillar-based models, the UVT Transform conserves paleo-distance, a necessary condition for proper geostastitical computation based on distance. Using a dynamic uncertainty workflow, the user constructs a reservoir property model by first performing a facies distribution per layer, using a complete set of categorical simulation algorithms, including MPS. For each facies, it is possible to populate the petrophysical parameters using krigging or simulation methods.



Multi-realization of an MPS simulation derived from a conceptual model

Populating the Model: Seismically-Derived Properties

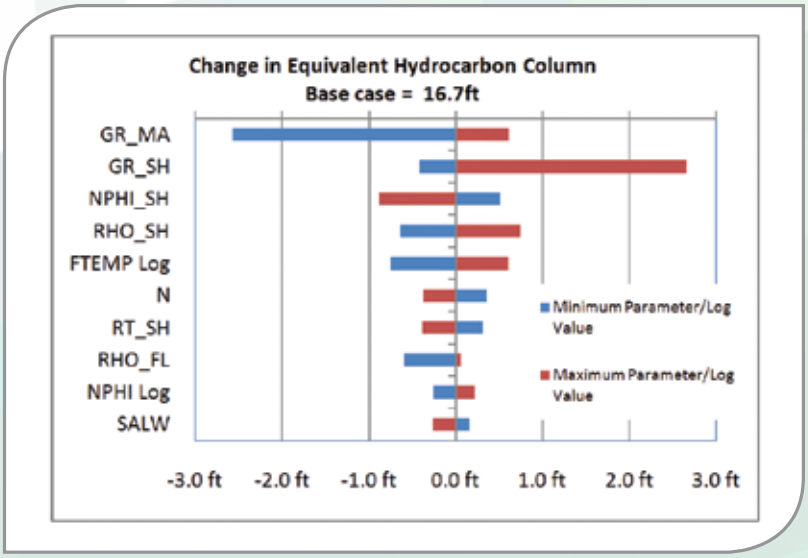
Using the seismic data or seismically-derived trend as secondary data inside the reservoir model, and combining different attribute volumes to constrain geological facies, simulation is easily performed using various seismic-to-well calibration tools. Uncertainty about this calibration can be incorporated in the model to study the overall "value of information" brought by the seismic volumes.



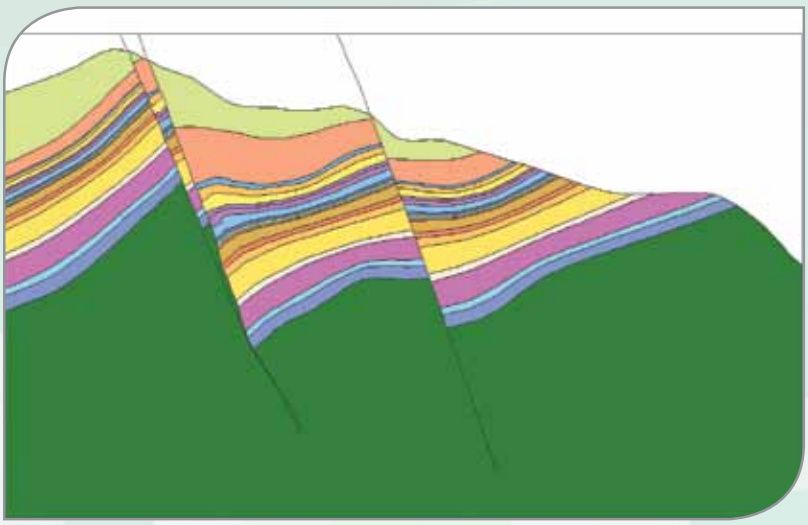
Combined seismic and petrophysical facies to generate a reservoir model

A Uniform Approach to Uncertainties in Petrophysics, Structure and Properties

Uncertainty is everywhere in geology, as information is sparse and very interpretative. Uncertainty is not only present in the algorithm that the modeler chooses to use, it is also in all the parameters of those algorithms. Uncertainty about correlation coefficients, variogram range, or porosity distribution mean that all can be input and analyzed for sensitivity studies. When dealing with uncertainty, the most important factor is to know which parameters are behind it, so that the workflow can be optimized and steps can be taken to reduce this uncertainty.



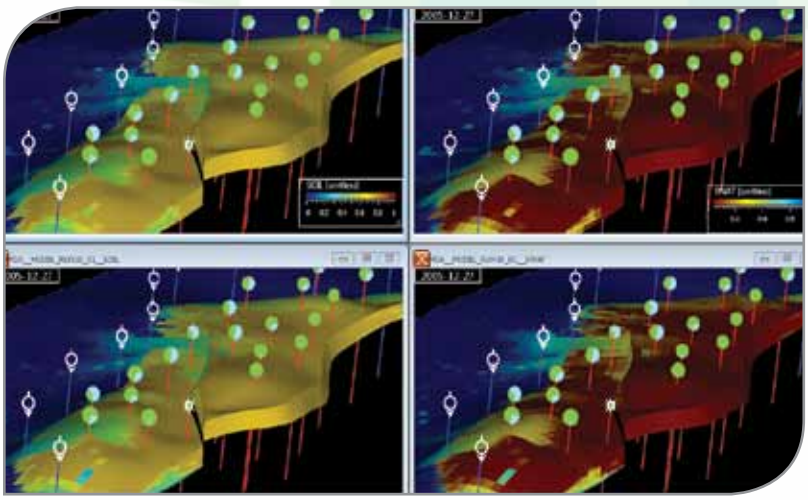
Tornado chart indicating most influential uncertainties



Geological cross-section as computed and displayed in SKUA®

From Static to Dynamic: A Mathematical Transform

The 3D model and UVT Transform can be discretized to automatically construct a flow simulation grid, where all necessary faults are taken into account and all cell geometries are optimized for high-performance flow simulation. The UVT Transform also guarantees the spatial integrity of the upscaling between the fine-scale geologic grid and the coarser flow simulation grid.



Multi-scenario comparison of flow simulation results

Reservoir Simulation and History Matching

A reservoir flow simulation grid can now be constructed in any geological setting, without compromising on fault geometry or fault inclusion in the flow simulation model. The incorporation of all the faults needed to perform acceptable history matching can be crucial in many reservoirs.

Workflow Management

All modeling processes are encapsulated inside workflow guides to help the occasional user, as well as to store all the parameters used to construct a model for auditability and QC purposes.

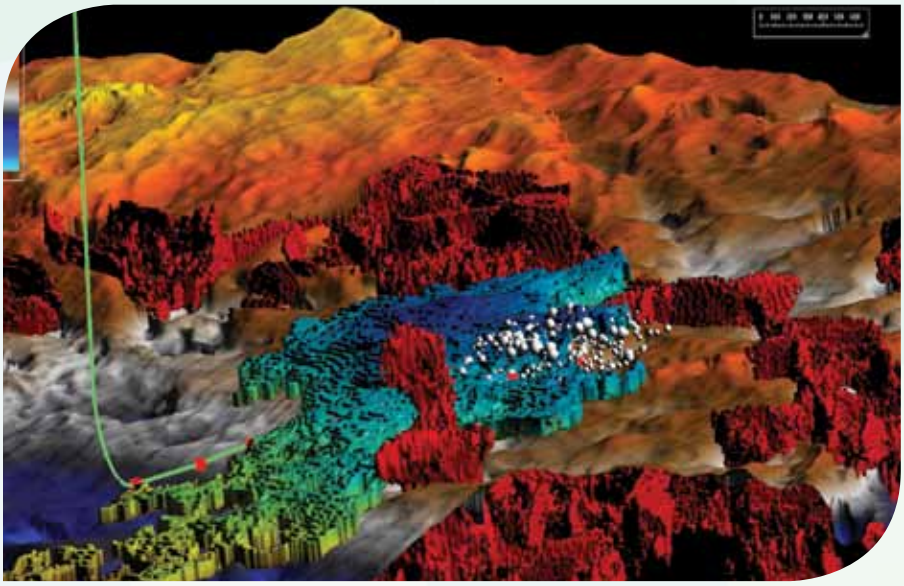
Data Management

The Paradigm application suite is built atop a multi-user, multi-site and multi-OS data management platform. Bulk data can be shared between different projects to minimize storage requirements. Access to specific data is controlled by administrator-defined security rules. The importance of a mature data infrastructure and a suite of effective services built around it is increasingly important to multi-disciplinary projects, bringing together large amounts of data of different vintages, from a variety of sources, and in some cases using different reference systems and units.

Building on the Paradigm Open Framework: Development Capabilities

Paradigm applications are open, allowing outside vendors to add proprietary or third-party technologies to Paradigm solutions. This can involve the development of plug-ins that have full access to the data model.

The open Paradigm framework provides a very fast prototyping environment that lets developers create new commands and dialog boxes, and insert them into existing menus. For customers or third-party technology companies, there is also a possibility to add Epos connection capabilities to existing proprietary applications, in order to access Epos data repositories and make use of services such as cursor tracking. This makes it possible to combine existing applications with Epos-based workflows in a seamless manner, and with minimal data replication. Some Paradigm solutions offer a high-level programming language to add new algorithms and processes directly within the user interface.



Integration of time-dependent micro-seismic data into the Paradigm 3D visualization window

Interoperability

All Epos-based applications enable interoperability with third-party datastores, including:

- OpenWorks® 2003.12, R5000
- GeoFrame® 4.5
- OpenSpirit® 3

System specifications

- 64-bit, for x64 architecture processors
- Microsoft® Windows® 7, XP, Vista
- Red Hat® Enterprise Linux® 5.3 and above, 6.0 and above

The Paradigm Advantage

+ Paradigm solutions allow the user to refer back to the original field measurements if needed.
+ A unified, mathematically rigorous modeling architecture ensures across-the-board subsurface consistency.
+ Every Paradigm geological solution delivers both depth and breadth of proven, efficient technologies.
+ A new, customizable user interface provides superior ease of use.
+ Dual-platform support ensures unparalleled flexibility in deployment and usage.