The question: Of what use is uncalibrated seismic and scattered log data when the customer needs answers to where and how to drill? This thought underlies a major prospect identification project offshore Western Australia. Schlumberger and WesternGeco collaborated to give their customers what was wanted and needed.

The project began when the Australian Government was planning to offer for leasing a large offshore region lying between the Io/Jansz and Scarborough gas fields on Australia’s Northwest shelf. WesternGeco committed to perform a 5,000-sq-km (1,950-sq-mile) 3-D seismic multicitylent survey of the area in advance of the lease sale. It reasoned that potential investors would purchase the data to help make investment decisions.

However, searching such a vast volume using seismic data alone is costly and time-consuming. WesternGeco worked with Schlumberger Data & Consulting Services (DCS) to determine that a well-calibrated gas-sand probability cube could be derived from amplitude vs. offset (AVO) inversion outputs. Using advanced visualization techniques, the data could then be interrogated to highlight several direct hydrocarbon indicators and potential prospects, an evaluation tool that could offer exceptional value to prospective investors.

That was only the beginning. DCS showed that a large number of useful products could evolve from the process benefiting precise target identification, as well as petrophysical and geomechanical answers that would resolve critical questions for the explorationists. Clearly the investors did not need data; they need accurate information upon which to base bid decisions, which could be tempered by the estimated drilling and development costs.

The project, named Keystone, made use of all available data to enhance its acquisition design. Among these were pre-existing 2-D seismic surveys and well log data from two previously drilled wells. One of the wells, Jupiter, was a gas discovery that had never been produced. The other well, Mercury, was dry. Log data from Jupiter and an additional eight others outside the project area were particularly valuable in calibrating time/depth conversions from seismic data to prospect identification and drilling models.

The integration of seismic and petrophysical data and data processing in this typical workflow illustrates the valuable answers that can result, benefitting investment decisions as well as subsequent drilling and completion plans. (Images courtesy of Schlumberger)
as well as creating models for each output domain in the seismic inversion, including acoustic impedance and compressional velocity/shear velocity ratio. The procedure derived mutual benefit from the seismic velocities, which were used to constrain the models and capture geological variations between the wells. The customer is happy to have the well data, but what is really wanted is knowledge of what is between the wells. Seismic, calibrated to well information, provides this.

**Decisions from data**

The **Western Trident** towed eight 5-km (3-mile) streamers energized by a dual air gun array. Simultaneous AVO inversion was performed on the data to compute seismic elastic attributes, which are used to generate lithology and fluid properties. The inversion used a proprietary nonlinear 3-D globally optimized approach implemented through simulated annealing. At the same time, the well log data from Jupiter, Mercury, and their eight “satellites” were conditioned to influence the tie to seismic and consequently the quality of the estimated wavelets. Since neither of the two wells inside the survey area had shear log data, essential for AVO inversion, shear was estimated, parameterized, and calibrated using shear wave data from the satellite wells.

Seismic volumes were calibrated to log data from the Jupiter and Mercury wells located inside the survey area, and multi-well wavelets were estimated for each angle stack using angle-dependent reflectivity logs. By using a different wavelet for each angle stack, it was possible to compensate for minor phase and frequency changes. Since the inversion window was fairly large, a vertically varying wavelet was used to account for changes in amplitude with depth. From the angle stack data, acoustic impedance and Poisson’s Ratio cubes were derived which, when combined with a rock physics model, yielded a gas sand probability cube. The logs were also instrumental in providing necessary low-frequency data outside the bandwidth of the seismic data. This information, in combination with velocity trends that follow the structural model, is essential to be incorporated into the inversion process in order to predict absolute rock properties.

High gas sand probability was predicted for a region that was subsequently penetrated by the Yellowglen well.
Rock physics and lithology prediction

Using acoustic impedance and Poisson’s ratio calculated from the 10 wells, the logs were cross-plotted to evaluate the relationship between the elastic log responses and petrophysical data such as clay volume, porosity, and saturation. The goal was to assess the seismic data’s ability to differentiate gas sands from other lithologies. A probability density function was derived that allowed estimates of uncertainty to be made. Calibrating on the known gas sand in Jupiter, it became apparent why Mercury, drilled on old 2-D seismic data, was a dry hole. Its trajectory intersects a structural high in an area where no gas sands are predicted, to one side of a minor fault.

With the hindsight of the new 3-D seismic data, it can be postulated that gas-bearing sands are to be found just to the west of the Mercury well. The ability to detect gas sands from AVO inversion and rock-physics interpretation was furthermore confirmed when the Yellowglen well was drilled. The gas discovery is situated directly in an area where a high gas-sand probability is predicted.

With the hindsight of the new 3-D seismic data, it can be postulated that gas-bearing sands are to be found just to the west of the Mercury well. The ability to detect gas sands from AVO inversion and rock-physics interpretation was furthermore confirmed when the Yellowglen well was drilled. The gas discovery is situated directly in an area where a high gas-sand probability is predicted.

Added value

Having developed a 3-D seismic volume from the Keystone data along with a calibrated prospect identification and gas sand probability cube, it was time to turn to drilling and development plan input. This included planning well trajectories to exploit target prospects together with drilling specifics such as optimum mud weight, presence and orientation of faults and natural fractures, and prediction of potential wellbore breakouts.

A 1-D mechanical earth model (MEM) derived from well logs was insufficient, but a 3-D MEM solved the issue through the integration of seismic. Through collaborative effort the company was able to develop answer-products to reduce drilling risk and cost, reduce turnaround time for customers’ exploration campaigns, and build a “communications model” for geoscientists and engineers.

Within Schlumberger, the project showed how through active collaboration, viable business products could be developed for sale to investors. It showed how geophysical and petrophysical knowledge could be successfully integrated using Petrel as the common software platform and how, by combining existing technologies, an efficient and effective workflow could be developed that is unique in the industry. And it demonstrated that the principal benefit of product integration and technical collaboration is the ability to deliver exactly what the customer needs to carry out exploration and development of hydrocarbon reservoirs—not a survey, a log or a drill bit, but an efficiently drilled borehole steered precisely through the reservoir sweet spot.

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