Integrating 2-D, 3-D Yields New Insights

By Tony Rebec and Tony Marsh

HOUSTON—The ability to utilize the abundance of legacy 2-D seismic data in North America today offers a realistic solution to the increasing exploration activity with the goal of quickly locating new drillable prospects.

With the industries focus on 3-D and 4-D technologies and powerful integrated workstations, legacy 2-D data typically have been left out in the cold. Not any longer. Conventional 2-D data can now be visualized and interpreted in 3-D space; the same 3-D space that 3-D seismic surveys are typically viewed in.

In fact, it gets even better. Those legacy crisscrossing grids of various vintages of 2-D data can now be integrated in the same 3-D space along with single or multiple 3-D surveys, if available. Figure 1 shows a large 3-D space covering hundreds of square miles, containing many 2- and 3-D surveys with multiple attributes and numerous wells.

So what effectively does this bring to the table?

The seismic interpreter can now, for the first time, view subsurface features present on 2-D lines in a 3-D space, and using value thresholding as a control, allow rapid recognition of such features as channels and fault systems as they are sampled in 3-D space by 2-D slices throughout the data sets. Figure 2, for example, contains an arbitrary section displayed from the multisurvey project shown in Figure 1.

But wait, there is more good news! Some of the more productive tools used for 3-D interpretation are now available for 2-D data as well, such as automatic smart horizon tracking through the different surveys and automatic fault tracking on sections, along with smart display technology.

Next-Generation Systems

Traditional 2-D interpretation ca-
bilities on a workstation typically use a series of section displays with interpretation performed on a section-by-section basis. However that is all changing with the introduction of the next generation of interpretation systems. Full production interpretation functionality is now at the interpreter’s fingertips for regional- and prospect-scale interpretation for single survey and/or multiple survey projects, including both 2-D and 3-D data.

Functionality includes data visualization in 2- and 3-D, survey balancing, and seismic-to-well ties. Classical manual interpretation and highly productive automatic horizon and fault interpretation tools are available, including mapping and plotting functionality, attribute generation, and horizon-based attribute extraction. Seamless combination of 2-D and 3-D view windows enables faster and more accurate interpretation in any geological environment.

Smart waveform-based horizon auto-tracking consists of propagating horizons through 2-D surveys offering hereditary path and threshold quality control tools similar to those used in 3-D surveys. Direct interpretation of multi-z horizons, such as occurs with overthrusting and salt overhangs, and auto-tracking tools as well as automatic triangulation of surfaces while picking can significantly aid interpretation.

One issue that is inherent both within single 2-D surveys and between multiple 2-D surveys is data misties at intersection points, either as time shifts or as response changes. Within the same survey, the data misties are typically the result of recording in both the dip and strike directions. The strike direction records data updip (shortest distance between shot/receiver and the reflector) and on the processed section, therefore, the reflectors come in at an earlier time.

Between multiple 2-D surveys, misties typically are compounded by multiple recording systems and different processing workflows, which results in both time and phase shifts. Many long hours of the seismic processor’s time have been spent analyzing and attempting to fix misties within and between surveys, in addition to many hours in meetings presenting test results prior to final application.

The good news is that these issues can...
now be fixed effectively on the fly and saved permanently for future work. Mistie analysis between intersecting lines can be performed with a click of the mouse, and a table and map (Figure 3) of intersections are displayed that show the time shift and phase characteristic measured. A quick selection of which one to normalize to, and the task is performed at the speed of light. Figure 4A shows a 2-D intersection prior to mistie correction, while Figure 4B shows the same intersection after applying with mistie corrections. Figure 5 shows the corrections applied using a smart trace zoom display.

**Horizon Propagation**

Although the actual horizon picking or reflector tracking component of the interpretation has traditionally been a very time consuming task, horizon propagation is an efficient, field-proven method that searches for optimal waveform correlation along a seismic reflector. Enveloping reflectors can be used to guide horizon tracking from initial seed points or grids, ensuring the construction of reliable horizon interpretations. Waveform-based horizon auto-tracking marks a significant step forward in computer-assisted interpretation, even in poor signal-to-noise areas.

Fast, true 3-D visualization, coupled with 2-D scanning, enables rapid quality control of interpretations. Auto-tracking can work at the regional scale by propagating horizons directly from data on disk at 8-, 16- or 32-bit data formats, or at the prospect scale utilizing threshold rendering. Threshold-based interpretation techniques can be used to reveal and place seeds on fragmented horizons with characteristic signatures, such as faulted channel systems viewed in 3-D space. Propagation workflows enable enhanced user control, especially in geologically challenging areas where other auto-trackers fail.

Total supervision by the interpreter over the handling of event character changes, for stopping at discontinuous events (faults, channels, etc.) and for methodical progress through areas affected by noise or other perturbing factors, is maintained. The quality control process is further enhanced by the concurrent visualization of well markers, faults and other horizons, ensuring that new picking is consistent with the structural framework.

This propagation in 3-D space provides the highest quality event tracking through subsample precision. With 3-D data, seed points are extended into picked regions by correlating trace shape and then propagating along the path of high-
est correlation, rather than enforcing a systematic, grid-based progression. This selective approach enables auto-tracking to be initially restricted to the highest quality seeds and correlations. With the trace shape analysis, doublets can be picked consistently, making the algorithm less prone to cycle skipping compared to amplitude-based auto-tracking.

**Quantum Leaps**

The interpreter can continue horizon picking by adding new seeds, or switch modes to edge propagation to grow the region using all horizon picks as seeds. Such workflows eliminate the typical requirement for extensive 2-D manual interpretation prior to running auto-tracking. This unique capability offers unprecedented benefits to both seismic data interpreters and processors alike, with quantum leaps in productivity and flexibility.

Another important capability is horizon auto-tracking on volumes larger than RAM utilizing efficient data caching from disk. Unprecedented speed and accuracy result in a major acceleration of the interpretation process. For very large regional projects, productivity and system efficiency can be increased dramatically by restricting project limits to user-defined areas or by culling 2-D lines dynamically, which frees memory. For rapid image visualization and efficiency, rendering is only performed on the visible part of the image. Display fidelity is preserved during data zooming using smart seismic trace decimation technology.

Viewing seismic data using 3-D visualization is an extremely powerful tool that can have an immediate impact on the interpreter’s understanding of the subsurface. However, this has not been exploited in the world of 2-D seismic until now. Not only can 2-D data be viewed in 3-D space, but they can be interpreted in the same space. This is extremely useful for viewing and interpreting complex stratigraphic features such as channels, as well as complex fault systems.

Channel features that are sampled on numerous 2-D lines can be viewed in 3-D space (Figure 6A) using numerical thresholding to determine the relative spatial changes (Figure 6B), and then interpreted in 3-D space with surface triangulation all within the same window to produce a continuous map of the channel feature (Figure 6C). This also is true for fault systems. A fault system can be viewed through the data, interpreted with projected intersections viewed in 3-D space on adjacent lines, and the interpretation finalized. The fault plane is then available in 3-D space for further analysis.

**2-D Attributes In 3-D Space**

Seismic attributes certainly are not new in the world of 2-D, but looking at them in 3-D space certainly is. The ability to rapidly change the viewed data from the seismic or from one attribute to another again allows the interpreter to visibly scan for anomalous features present within the 2-D sampled subsurface, especially when using amplitude thresholding to see through the volume from line to line. Certain attributes have tended to lend themselves to the 3-D seismic world.

The Coherence Cube™ technology originally made famous by Amoco and brought to the market by The Coherence Cube Company is one such attribute and has long been looked on as an exclusive 3-D tool. However, run in a 2-D mode and co-rendered back with the seismic or attribute data, it can bring new insights into subtle fault and fracture detection. And when used in conjunction with opacity, it can be an extremely useful tool for 2-D interpretation. Figure 7 shows the coherence attribute co-rendered with seismic on two intersecting lines in 3-D space.

The vertical signatures of features that can easily be recognized on 3-D seismic data from their spatial response can be observed on the 2-D data, which is very effective when simultaneously working both 2- and 3-D data in the same workspace (Figure 8).

There is little doubt that the exponenti-
tial increase in the number of 3-D seismic surveys in the late 1970s and early 1980s was the catalyst needed for developing early versions of 3-D interactive interpretation workstations, of which some had token 2-D survey capabilities. However, it was 3-D that dominated the advancement into the world of 3-D graphics, automatic tracking and visualization in spite of the overwhelming amount of 2-D versus 3-D data being worked for exploration.

With ongoing advancements in seismic interpretation technology, 2-D data can now be treated similar to 3-D data in three-dimensional space. Rapid scanning through parallel sets of lines can be achieved using line lists, whereby the interpreter can examine structural variations between lines or between 2-D surveys, just like one would do for 3-D surveys. By looking at 2-D data in the 3-D environment, basin-scale features can be visualized, as well as the introduction of regional aeromagnetic or gravimetric maps draped over the mapped structural time surfaces from the seismic. For long regional 2-D lines, parameters can be selected to allow the interpreter to roam along the regional line and identify the detail within the big picture, and the list of capabilities goes on.

Such capabilities are putting 2-D seismic in a new light and providing 2-D data sets with a renewed status in the interpretation world, especially with the ability to view and interpret 2-D surveys along with 3-D surveys. When both types of data are put in the same 3-D space, a symbiotic relationship comes into play, creating a new dimension for analyzing the subsurface by utilizing legacy 2-D seismic data.

Editor’s Note: The data set used to create most of the figures was supplied by the Victorian State Government, Australia. The cultural data are provided to Paradigm under license by IHS Energy, copyright 2006.

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