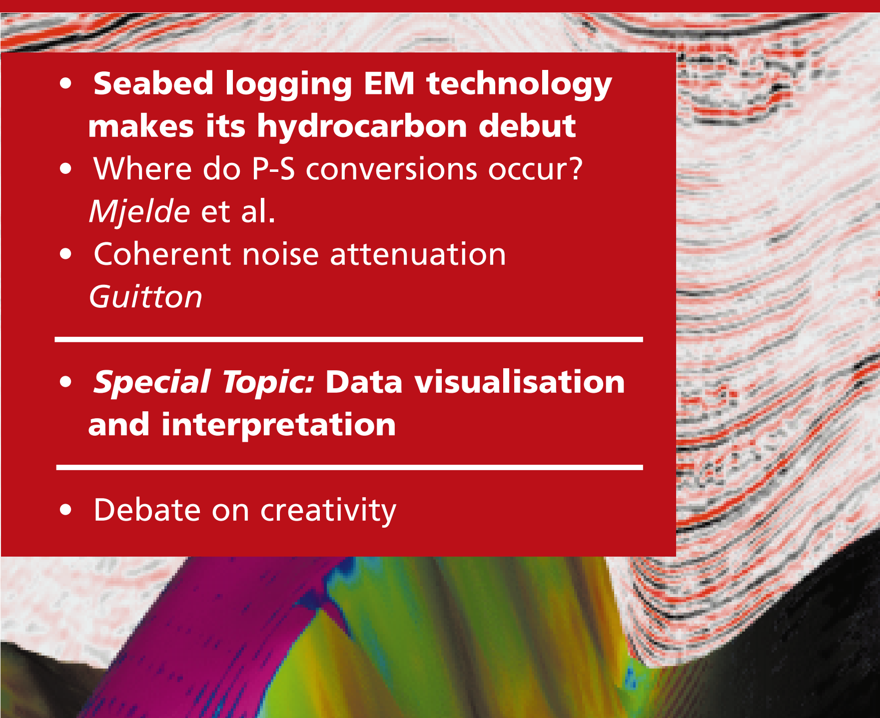
ISSN 0263-5046

FIRST BREAK

March 2002 Volume 20 Number 3

EAGE
EUROPEAN ASSOCIATION OF
GEOSCIENTISTS & ENGINEERS



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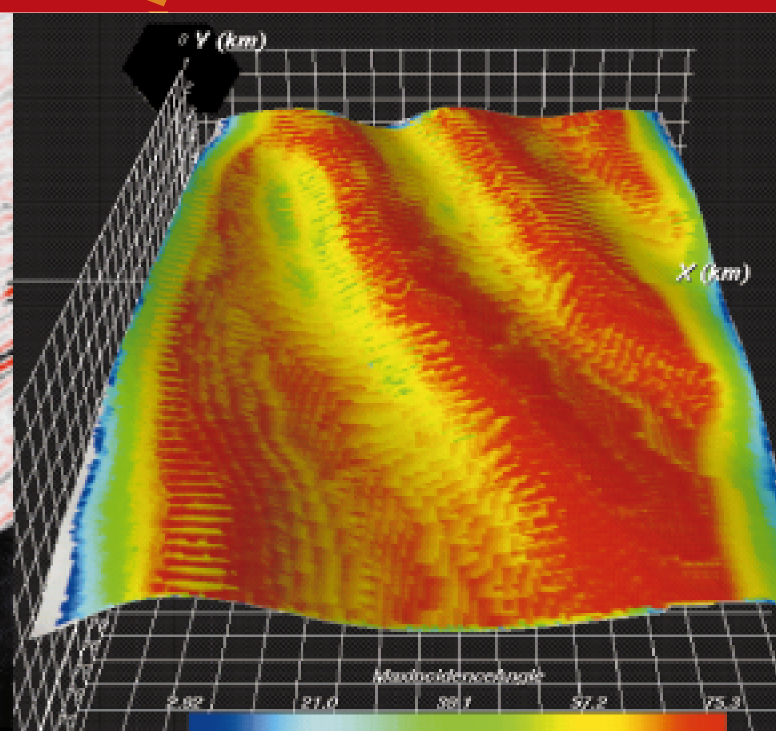

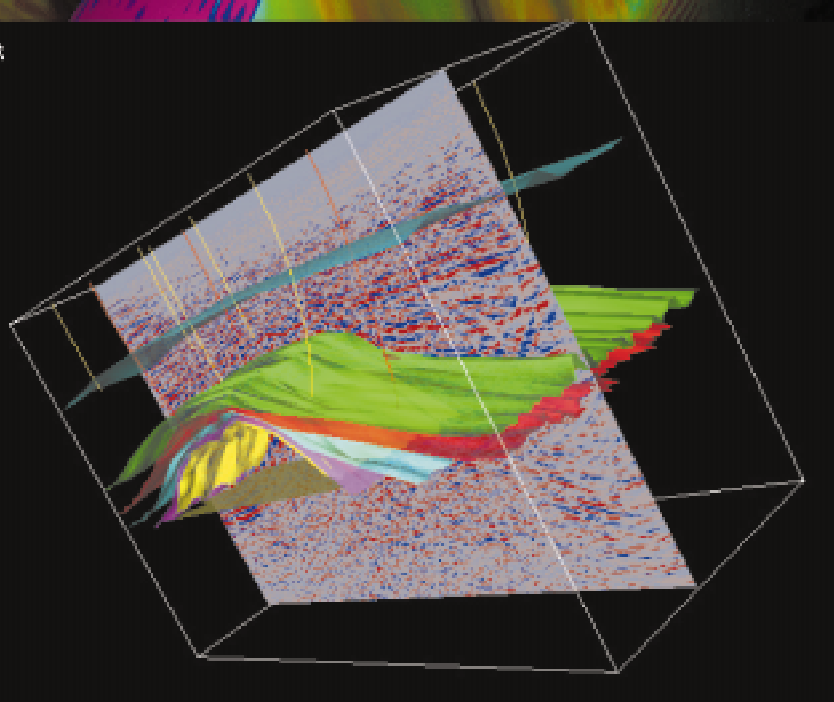

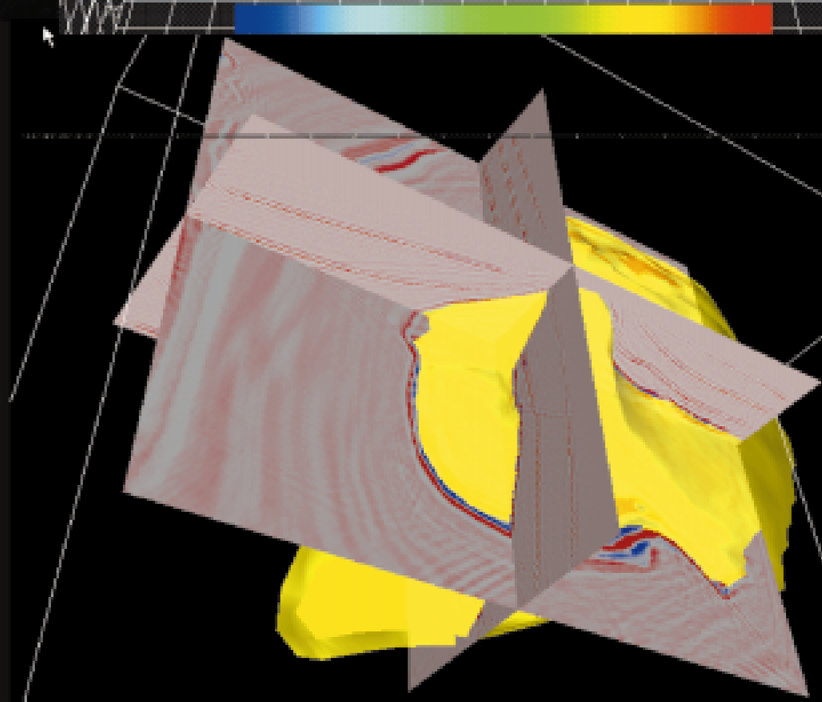

Data visualisation and interpretation

Will Internet seismic processing be the new paradigm for depth migration interpretation and visualization?

Dimitri Bevc and Alexander M. Popovici (3DGeo Development) and Biondo Biondi (Stanford University Exploration Project and the 3DGeo Development) discuss development work based on Internet technology which may make costly data visualization and interpretation processes more accessible to the exploration geoscience community

There have been many significant paradigm shifts in geophysics, and we are in the middle of another one with the industry-wide impact of the Internet. Internet Seismic Processing (INSP) provides the geophysicist with a set of globally accessible processing, interpretation, and visualization tools available on demand, as needed, without the burden of software upgrades, equipment purchases, and hardware administration.

Until now, the best visualization capability was available only on high-end graphic interpretation workstations. INSP brings this capability to any desktop and to all geoscientists. This capability is critical for depth imaging because depth velocity model building in complex areas is a highly interpretive task that benefits greatly from 3D visualization, QC, and collaboration – all of which are tied together through INSP.

This paper describes INSP and its impact on seismic processing interpretation and visualization. While the visualization and interpretation benefits alone should spur the proliferation of INSP, this paper also discusses other factors that will lead to the widespread adoption of INSP.

Technology and product offering already in place

INSP technology integrates a graphical user interface (GUI) with state-of-the-art software applications to give users a flexible and dynamic new solution for processing and interpreting geophysical data. Flexible client-server architecture is the foundation for the technology. The user can access the processing and interpretation system using a Java-enabled computer and standard Web browser connected to a local- or wide-area network. Server-side processing is used to control compute-intensive applications such as 3D depth migration, while the client builds processing flows and conducts interactive quality control, interpretation, and model building.

Java is ideal for intranet or Web-based applications, since the programming language was designed specifically for networking and is capable of dealing with security and parallel distributed computing, both of which are key issues for geophysical applications. The Java client-server design allows processing systems to leverage the 'write once, run anywhere' capabilities of advanced GUIs and process management tools, while using highly optimized seismic imaging algorithms running on specialized high-performance computers for the number-crunching tasks.

The essential components of a global system architecture for Web-based processing are schematically represented in Fig. 1. The key elements are the computational server, the client, and the Internet/intranet connection. Key features include platform independence, multi-user access, flexible security mechanisms (such as user authentication and authorization based on standard application programming interfaces), transparent encryption, data compression, and advanced user interface capabilities.

The server launches and manages the compute-intensive workflows. The seismic workflows execute program modules written in a computationally efficient language (such as C or Fortran) and are compiled for a specific platform. The processing modules are efficient in processing large amounts of data and can take advantage of parallel architectures and

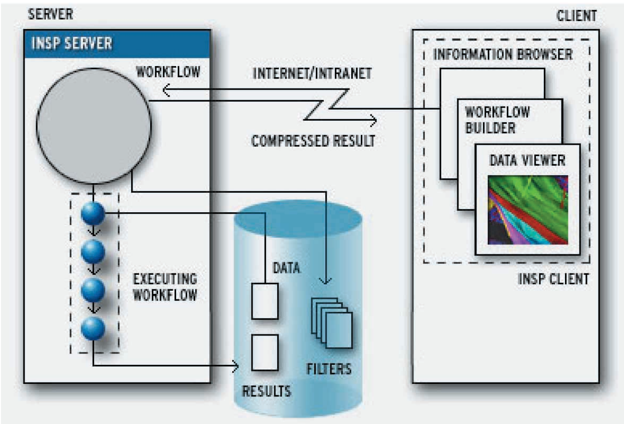

Figure 1 INSP global system architecture.

distributed computing.

The client is used to construct and manage (execute, interrupt, stop) work flows, as well as display seismic sections, velocity models, gathers and semblance data sets (as shown in Fig. 2), allowing direct data interaction such as picking and velocity model building and editing. As an intuitive GUI, the client masks all details related to the specific platform that the server and the interpretation modules are running on. The user interacts with a mouse-driven interface, where the projects and the seismic modules (filters) are organized hierarchically. The GUI gives users access to a dialog system, where they can enter or modify job parameters.

Universal platform for interpretation

INSP can speed processing turn-around time and optimize results because it allows the interaction of interpreters at all stages of data processing, and gives them the ability to make changes and alter the processing sequence as the job evolves. This is especially critical in building velocity depth models where interpretation input can be critical to obtaining the best depth migrated image.

INSP creates a software infrastructure that enables geologists and geophysicists in any organization to have direct control of depth-imaging projects and to have access to remote large-scale parallel computers. Internet processing reduces processing time with interpretation time by giving its clients the capability of setting, controlling and verifying the data processing jobs during run time. The oil companies can start interpreting data during the processing time and therefore shorten the time to the drilling decisions.

These resources can be globally available wherever there is Internet access. The geophysicist can be in the field, and use computing resources from a central location, or he/she can collaborate with geographically remote colleagues and team members by accessing and examining the same data files and processes. For shipboard processing, satellite data links can allow land-based geophysicists to QC and process data as it is acquired using the ship's computers.

Collaborative Internet seismic processing implements a new approach to collaboration for explorationists. There are competing technologies that attempt to achieve a similar result using a 'quick and dirty' approach. One such approach, commonly referred to as the 'thin client' model, uses the X11R6 Broadway extension of the X protocol, designed to work over wide area networks (WANs). Essentially, with such a configuration, there is a central geophysical application running on the server and there are thin clients accessing this application over the network. The thin clients are either standalone programs or web browser plug-ins that act as an X server that the remote central application uses to display its graphical output. While this approach has the advantage that the central application runs without modification, the severe drawback is that the network communication is extremely slow because a whole series of X events (such as mouse moves) is sent over the wire to and from the clients. If more than one client is involved, all clients must use the server as a relay, further slowing the interaction, making collaboration a slow and frustrating experience for users. It is important to note that this latency is a function of the number of connections along routers/relays in the Internet, and is a factor regardless of bandwidth: therefore it is a separate although related issue.

A better approach, and one used by INSP, is Java for network communication. Java was specifically designed for the Internet, and by its design overcomes the problems inherent in thin client applications. In this model, a certain amount of computing is transferred from the server to the clients. While the most significant amount of the processing is left on the server (an imaging computation, for example, is certainly

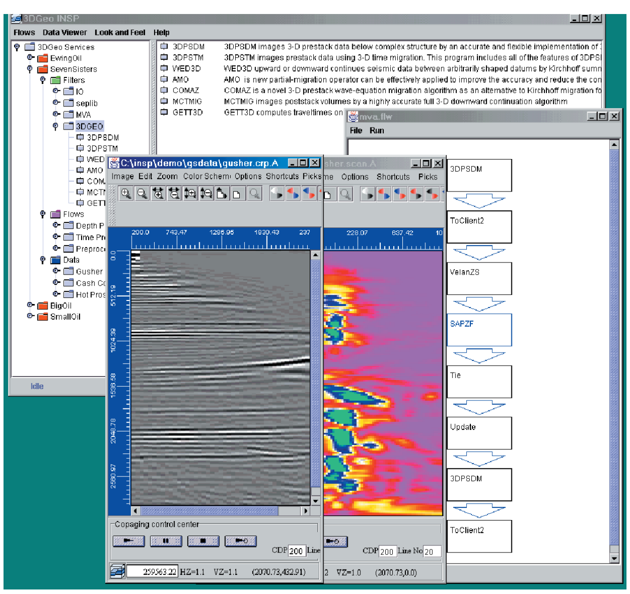

Figure 2 INSP client graphical user interface (GUI).

done on the server), the client handles most of the 'interaction' related tasks, such as generating the picks and moving the picks within the data cube or browsing locally through the data cube. When similar actions need to be performed on the peer clients, only the control information is transferred over the wire directly to the client(s), instructing it/them to replicate the actions. This results in faster communication and an almost instantaneous real-time experience.

Another advantage of 3DGeo's INSP is that if a network connection is not available, the user can still perform interpretation off-line and synchronize the result of the work with the rest of the team when the connection becomes available again. In the extreme case, the client can be used as a stand-alone interpretation tool, without relying on a network connection to perform basic functions. From this perspective, INSP clients can be seen as an interpretation and quality control (QA) tool with collaborative work features. This will be useful not only for collaborative interpretation, but also for applications such as remote QA of data during acquisition on land or offshore.

Platform for superior visualization

INSP's 3D visualization allows geoscientists to visualize and manipulate complex 3D bodies such as salt structures, complex over-thrusts, and intricate interpretive pick sets.

The bodies can be rendered in real time from existing 3D data sets, or imported as horizons and surfaces. Multiple data sets and bodies can be loaded into the viewer and superimposed simultaneously. Typically, shapes such as salt bodies or basalt intrusions are extracted from velocity models and viewed in 3D. The corresponding seismic image data can also be loaded into the viewer along in-lines, cross-lines, and depth sections. This is useful to validate the interpreted bodies against the seismic data. In the same way, loading picked surfaces or horizons into the INSP 3D viewer and comparing them with the seismic data allows processors/interpreters to insure consistency and geological validity.

The INSP 3D viewer can display well trajectories and velocity models, superimposing them onto the seismic data and 3D structures, giving a visual representation of complex 3D geometries. Horizons, bodies, pick sets, and seismic data can be made translucent so that other volumes can be seen through them. Colour maps can be changed for the seismic data, as well as the horizons, bodies, and pick sets. For the seismic data, the amplitude–colour relationship can be adjusted to emphasize seismic attributes such as areas of high reflectivity or bright spots.

In addition to the advanced visualization and QC capabilities, the INSP 3D viewer allows picking in the 3D volumes. The picking can be along seismic events, velocity surfaces, or any other bodies or sections that are loaded into the viewer.

The interpretive server and client have built-in capabilities for reservoir characterization by applying a series of amplitude and phase equalization and coherency enhancement operators to the migrated offset gathers. This includes Bayesian petrophysical inversion that is calibrated with existing well logs and is based on petrophysical principles, instead of being based on *a priori* statistical assumptions. The result of the process is a maximum likelihood estimation of the rock and fluid properties of the reservoir that can be effectively used to optimize production from existing wells and to plan drilling of new development wells.

The INSP 3D visualization software is written using the Java 3D API's so that existing and well supported 3D graphics rendering libraries can be leveraged. Java 3D runs on top of any hardware or OS specific graphics libraries such as OpenGL or DirectX, and makes use of them if they are available. Every element of INSP is written in Java, maintaining portability and ease of deployment over intranets and the Internet. It runs on any platform supporting Java, with Java 3D installed. Today, that includes any computer sold: if it runs a web browser, it can run INSP and the 3D viewer. Until recently, this type of visualization capability was available only on high-end graphic interpretation workstations. This type of capability is critical for depth imaging because depth velocity model building in complex areas is a highly interpretive task that benefits greatly from 3D visualization, QC, and collaboration – all of which are tied together through INSP. The following figures demonstrate the visualization that INSP can deliver over the Internet.

'Software as service' model

We have all read that perhaps the greatest advantage of 3D seismic imaging is that it can be used by the thousands of independent E&P companies to discover, rework, and extend the smaller yet prolific oil and gas fields, and to help them enhance the value of existing data. But how accessible is it to the average independent?

Let's face it, with all of the success and benefits of 3D seismic imaging, the technology remains extremely expensive and difficult to access for all but the largest E&P shops. A 100-

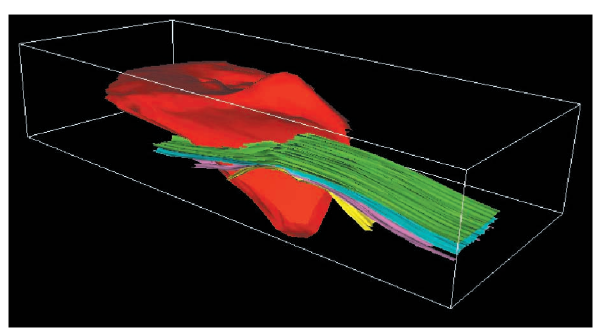

Figure 3 3D salt body (in red) and several interpreted horizons displayed in 3DGeo's 3D viewer.

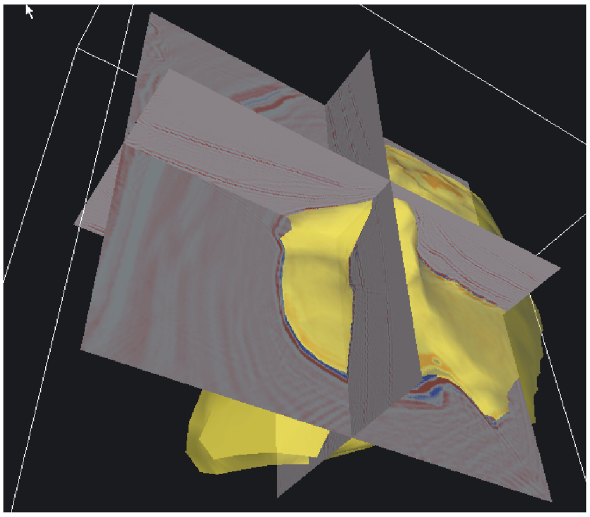

Figure 4 3D salt body with inline, crossline, and depth sections superimposed.

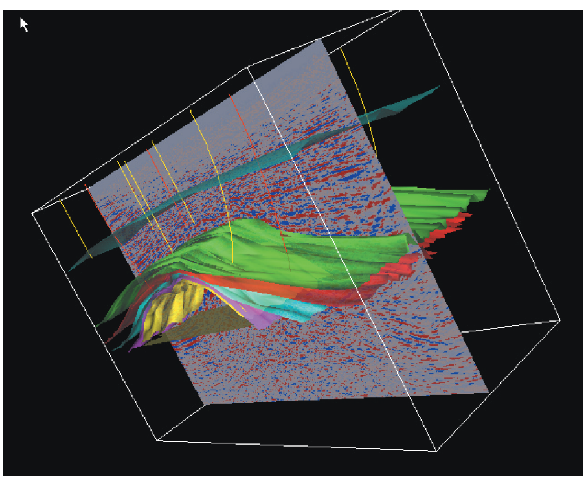

Figure 5 3D basalt top (yellow), seismic cross-section, and numerous interpreted surfaces and well trajectories.

block survey can cost up to $9 million just to load and process the data. The technology requires the use of very large and very expensive computer networks and processing units. Until recently, a popular medium-size 64 processors shared-memory parallel system, one of the more popular choices of supercomputers in the oil and gas industry, costs in the range of $2–$3 million. Maintenance of these networks and computers can easily cost additional millions of dollars per year, and provide tons of headaches. While some might point out that hardware capital costs have come down an order of magnitude with the introduction of Linux PC clusters, the administration and upkeep of these clusters (human cost) remains the same or has increased. Costs associated with transferring algorithms to the different systems, and parallel requirements of the PC clusters, also are far from trivial.

So with the high capital and operating costs, what's a small independent producer to do? Or how about a large oil company that realizes that seismic processing is not their core competency? The good news is that new Internet broadband technology combined with new service models can deliver 3D seismic imaging to more users without their up-front investment in capital and operating costs, and at the same time vastly improve collaborative efforts among the users. In the Internet world, a predominant new model of 'software as service' is rapidly evolving. Called application service providers (ASPs), these companies offer a business model where software users do not own or maintain the software, or the expensive hardware to run it. Instead, users access the software that the ASP maintains and hosts through the broadband Internet.

The 'software as service' model is the future. The importance of data and systems being maintained in remote locations with state-of-the-art security and mirroring capability, was one of the many grim lessons from the 11 September 2001 tragic attacks in New York City and Washington, DC. As shown in Table 1, even prior to 11 September, leading companies worldwide have shown their support for the new model.

Of 2000 companies worldwide surveyed by an industry consortium about the hosted services model:
- 23% said they are likely to sign-up to this model within 12 months
- 71% expecting to use an ASP within three years
- 70% said they would like to be contacted by an ASP about its offerings
- 12% of companies in Mexico, the US and France said they use an ASP
- 11% in Brazil and Canada, and 10% in Singapore said they use an ASP

There are thousands of independent oil and natural gas producers across the US, and thousands more world-wide. Most independent oil and natural gas producers employ fewer than 20 employees, and therefore have scarce in-house IT resources. This is the classic description of the ideal 'software as service' user base. The model is based on the economies of centralized software and data hosting that can be offered via the broadband Internet to a large user base that typically does not have the in-house capability or resources to manage and use high-end (expensive) internal client-server software.

According to the Independent Petroleum Association of America (IPAA), independent producers:
- drill 85% of wells in the USA

- produce 65% of the country's natural gas
- produce 40% of the oil (60% in the lower 48 states)
- increased their share of the lower 48 states petroleum production from 45% in the mid-1980s to more than 60% in 1995
- are expected to continue these trends

Conclusion

The potential of Internet-based seismic processing and interpretation, and the new 'software as service' model in geophysics is significant because it makes seismic depth imaging and other compute-intensive technologies accessible to a large community of users, while providing an efficient resource distribution and allocation to all potential users. Internet and intranet computing allows greatly increased interaction between the client and contractor, thereby increasing the quality of the final seismic image and in turn reducing exploration risk, and offsetting the high costs of exploratory drilling and reservoir management projects.