Report on EAGE Vienna 2006 workshop on marine multi-azimuth seismic

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**Introduction**

The EAGE conference in Vienna, June 2006 was the venue for a workshop on one of the most interesting developments in seismic technology in recent years. The subject was multi-azimuth and wide azimuth seismic surveying in the marine environment, with emphasis on its application in deepwater environments. The timing of this workshop was particularly appropriate with the introduction, since 2004, of several new technologies and methodologies to image below complex overburden in major deepwater oil and gas provinces. The workshop brought together a range of presenters from E&P companies and seismic contractors to present the state of play in the technology and discuss challenges for the future. It was the first of several sessions on the subject in 2006. The EAGE workshop was followed by the SEG/EAGE Summer Research Workshop on subsalt imaging and a special session on multi-azimuth and wide azimuth seismic at the SEG convention in October.

Below is a summary of the EAGE Multi-Azimuth workshop as an introduction to the papers in this special edition of First Break. The perspectives provided in the two authors’ keynote papers as coordinators of the workshop form the basis of this article.

**Why the need for multi-azimuth and wide azimuth seismic?**

In many of the world’s hydrocarbon provinces, overcoming significant subsurface imaging challenges is required to access and deliver the resources. These comprise overburden and reservoir complexity in established areas such as the North Sea, and increasingly, in deepwater environments where imaging below complex salt is necessary for success. New seismic technology is required to generate images of reservoirs from exploration through to production. Even in relatively benign geological environments, where good structural images of the reservoir are attainable, delivering seismic data quality required for development and production purposes is still a significant challenge.

One breakthrough in such environments in recent years has been the use of ocean bottom cable data (OBC) to increase the signal-to-noise ratio and illuminate the subsurface from a wide range of azimuths. Several early applications of OBC were for S-wave imaging below gas clouds, however increasingly we have seen significant benefit in wide azimuth P-wave OBC data to enhance imaging compared to conventional towed streamer data. BP has observed and published several examples of this improved data quality, such as at Clair in the UKCS (Kommedal et al., 2005) and Azeri in the Caspian Sea (Bouska et al., 2005). These are difficult reservoirs to image and required breakthroughs in the quality of the subsurface images for use in field development.

In deepwater areas such as the Gulf of Mexico (GoM), Angola, and the Nile Delta, reservoirs are obscured by salt layers of varying geometry and thickness. In the GoM and Angola, the allochthonous salt canopy has long wavelength variations on the top and base that generate large lateral velocity contrasts with surrounding sediments. In Egypt, the Messinian layer, formed of eroded anhydrite and marine sediments, generates much shorter wavelength velocity contrasts. Both cases, although at different scales, create significant reservoir imaging challenges that are difficult to overcome using conventional narrow azimuth towed streamer data. In practice we find that in these subsalt environments, narrow azimuth data are often marginal for exploration purposes and inadequate for field development and production. Even with the development of sophisticated processing techniques we still cannot achieve the data quality from narrow azimuth towed streamer data necessary to deliver subsurface images that meet the business demands.

**How these challenges are being tackled?**

A breakthrough in seismic imaging is therefore required, and from experience in seismic data quality enhancement with multi and wide azimuth seismic in shallow water through OBC, we can expect illumination and signal-to-noise enhancements from its use in deepwater. The issue becomes one of how to acquire the data as ocean bottom cables are generally not designed to operate in such water depths and are difficult to deploy efficiently. This leads to the need to develop new methods of acquiring multi-azimuth and wide azimuth data in deepwater environments for imaging below complex overburden. In the past, there have been several attempts at designing new techniques and methodologies. The vertical cable method (Krail, 1994) was such an approach that showed early promise but did not become a commercial success. Designs resulting from the SMART industry joint venture (Sukup, 2002) demonstrated ways of utilizing towed streamer technology for acquir-

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ing a wide range of azimuths although were never tested at scale in the field.

In 2003, BP placed a strategic focus on subsalt imaging with an objective of developing new techniques to meet the significant technical and business challenges encountered. This resulted in development of several methodologies for acquiring wide azimuth data in deep water (Fig.1).

These utilized existing towed streamer equipment in novel ways and led to the development of new ocean bottom solutions. In the Nile Delta, after a successful dual azimuth field test in 2003, BP contracted PGS to acquire the industry’s first six azimuth seismic survey to test the technique for imaging the Raven field. This technique proved very applicable to imaging below the short wavelength velocity anomalies generated by the Messinian overburden and provided significant uplift in data quality over single azimuth data. In the Gulf of Mexico, the industry’s first wide azimuth towed streamer (WATS) survey for subsalt imaging was acquired by BP over the Mad Dog field in late 2004 using Veritas DGC as the acquisition contractor. This provided significant uplift in data quality over the existing narrow azimuth data, the wide azimuth array well suited to imaging below the long wavelength velocity anomalies caused by the large salt bodies. Results of the multi-azimuth efforts in the Nile Delta are presented in this issue of First Break. Modelling of wide azimuth surveys for subsalt imaging in the GoM was presented at the workshop and has been documented in The Leading Edge (Regone, 2006).

Both the towed streamer multi-azimuth and wide azimuth methodologies have their place in the seismic toolkit and the appropriate methodology to use should be chosen by considering the imaging objectives, geological complexity, and operational environment. The benefit of these techniques is their use of existing acquisition technology in new ways and their scalability both in survey size and azimuths acquired.

Although in the examples cited the techniques were applied as field development tools, they are highly suited to exploration application where large surveys provide operational efficiencies.

In addition to these towed streamer methods, BP pioneered the application of new deepwater ocean bottom nodes systems for subsalt imaging. After successful equipment trials in 2004, BP commissioned Fairfield to manufacture 900 node units and acquire a survey over the Atlantis field in the GoM in late 2005. In order to deliver this survey, it was necessary to overcome numerous technical and operational challenges. The autonomous nodes were deployed and retrieved using remote operating vehicles (ROV) over a water bottom topography that varied in depth from 1300 to 2200 m with significant elevation variations over the middle part of the area. The survey was a great operational success and demonstrated that a field wide survey could be acquired safely and with excellent reliability (Ross and Beaudoin, 2006). Processing and evaluation of this survey is ongoing.

Each of these at-scale experiments has demonstrated the viability of acquiring multi-azimuth and wide azimuth data in deepwater environments to overcome significant imaging challenges. Delivering the required uplift in data quality at acceptable costs enables use of these tools to reduce risk and uncertainty in developing fields with considerable subsurface imaging challenges and where drilling costs are high. Proving their application at a field scale has been critical and has opened up opportunities to adapt and modify the techniques for exploration and appraisal purposes.

The challenges for marine multi-azimuth seismic and the EAGE workshop

All the above were presented in some detail at the workshop as part of the wide ranging discussion on various aspects.
of marine multi-azimuth seismic from shallow to deepwater. The workshop was structured to cover acquisition technology, operational requirements and processing aspects to understand the benefits and trade-offs associated with each method.

Marine Multi-Azimuth Seismic Workshop, Vienna, June 2006

- Wide Azimuth Seismic: From Shallow to Deep Water, Tim Summers, BP
- Development, Trends and Market View of Wide and Multi-Azimuth Seismic Methods, Phil Fontana, Veritas DGC
- Towed Streamer Multi-Azimuth Seismic, Eivind Fromyr, PGS
- Multi-Azimuth 3D for Improved Pre-Pliocene Imaging in the Nile Delta, Jim Keggin, BP
- Azimuthal Anisotropy, Fiona Dewey, Wintershall
- Multi-Azimuth Processing for Multi-Azimuth Acquisitions, Philippe Hermann, CGG
- Developing Wide Azimuth Solutions for the Deep Water Gulf of Mexico, Carl Regone, BP
- Experiences with Multi-Azimuth Acquisition in Ocean Bottom Seismic, Mark Thompson, Statoil
- Multi-Azimuth Seismic with Ocean Bottom Nodes: Feasibility and Processing Issues, Enrico Ceragioli, Total
- Applying OBS Node Technology – Beyond Atlantis, Steve Mitchell, Fairfield Industries
- Rich Azimuth Marine Acquisition II – Update, Mike Howard, BHP Billiton
- Challenge for Rich Azimuths – A Processing Opportunity, Jerry Kapoor, Western-Geco
- Realizing the Potential of Wide Azimuth Towed Streamer Acquisition, Bruce Verwest, Veritas DGC.

Starting with multi-azimuth towed streamer solutions, considerations on operational efficiency and cost effectiveness to deliver the field operations were followed by analysis of processing the data. A major benefit in this regard is that multi-azimuth seismic surveys are a collection of conventional surveys in different directions, and the established marine processing toolkit can be applied to each survey prior to combining into a single volume. The challenge is to optimally extract the signal and reject the noise from each survey as reviewed by Fromyr and Keggin. Furthermore in areas of significant azimuthal anisotropy, more complexity is introduced into the processing to generate combined volumes as discussed by Dewey.

Once we move away from multi-azimuth acquisition through conventional surveys in different directions to multi-vessel wide azimuth surveys, an increase in processing complexity ensues. This results in the need to re-consider processing options in the shot domain rather than the CDP domain we have been routinely using for many years. Hermann presented an overview of this thinking, linking to the afternoon discussion on wide azimuth methods that commenced with a discussion by Regone on modeling acquisition geometries required for subsalt imaging. A method of combining aspects of both multi-azimuth and wide azimuth towed streamer surveys was presented by Howard, demonstrating how we might achieve the benefits from both in a cost effective manner.

The more conventional methods of acquiring wide azimuth data are, as previously discussed, through ocean bottom systems. There are significant challenges in densely sampling data cost effectively through ocean bottom cable acquisition, although the benefits to data quality are evident as shown by Thompson’s review of Statoil’s extensive OBC program. This led to presentations on nodal systems, reviewing the ability to acquire equivalent data quality to cables, and on the operational requirements for deepwater environments. The issue of data quality was covered by Ceragioli, who showed comparison data from tests Total have carried out in West Africa. He demonstrated that the required data quality can be achieved using nodes and data from mixed acquisition systems can be utilized together. The complex operational aspects of deepwater node acquisition were presented by Mitchell in a discussion of Fairfield’s successful completion of the previously mentioned BP Atlantis survey.

The workshop demonstrated that multi-azimuth and wide azimuth marine acquisition have become a reality with significant investment being made in new technology by both E&P companies and contractors to meet the subsurface imaging challenges. This is the start of an exciting period that will require a much deeper understanding of the characteristics of the data and how they need to be processed in order to deliver best-in-class subsurface images. This discussion was started at the workshop with an introduction of processing opportunities by Kapoor. This was followed by some very interesting insights by Verwest into the characteristics of signal and noise in wide azimuth towed streamer data, and how multiples can be attenuated effectively through this acquisition style.

The future?
Data presented in the workshop from the towed steamer multi-azimuth and wide azimuth techniques and from the ocean bottom seismic surveys acquired up to that time all showed a significant improvement in image quality over previous data acquired in the same areas using narrow azimuth towed streamer techniques. This increase in image quality has generated a lot of interest across the industry in using these non-conventional marine acquisition techniques for a variety of applications in provinces all over the world. As more and more E&P companies decide that these types of non-conventional acquisition techniques have value in their exploration and development plans, the seismic contractors will have to gear up to provide the acquisition and data processing services in a timely and cost effective manner.

As mentioned above, the multi-azimuth streamer surveys require the use of a conventionally equipped streamer crew. The survey area is covered multiple times in multiple directions.
The time it takes to complete a multi-azimuth survey is directly related to the number of required directions. Therefore, the streamer vessel will be committed to the survey for significantly longer periods of time compared to a conventional survey.

In the case of towed streamer wide azimuth surveys, the acquisition configurations require multiple vessels. In the simplest case a wide azimuth streamer survey can be acquired with a single streamer vessel and an additional source vessel. But the time to acquire this type of survey with this minimal vessel configuration would be too long to meet decision-making timeframes for most exploration and/or development programmes. So, contractors are using multiple source and/or streamer vessels to help shorten the acquisition time for wide azimuth towed streamer surveys.

The use of a single streamer vessel on a multi-azimuth survey and the use of multiple source and streamer vessels on wide azimuth surveys will change the global availability of marine surface seismic resources if the contractors do not increase the currently available capacity. At this stage in the development of these techniques the big question for the future is ‘Will these types of surveys produce a large enough market to warrant the capital expenditure for a significant increase in marine seismic resources?’ The answer to that question will have a direct impact on the costs of such surveys and the costs will determine how the E&P companies will evaluate the value of these types of data.

There are similar economic decisions to be made by the contractors and the E&P companies relative to deep water ocean bottom systems. In the case of node type operations, a significant upfront investment in the nodes and node handling systems is required just to get into the game. Then, the daily operational costs will be mostly determined by the availability of ROV support resources. At this time, ROV operations are not an area where the seismic contractors generally have expertise or controllable assets. Those services have to be sub-contracted to third party companies that traditionally have business models based upon servicing other facets of E&P operations. So, similar to the towed streamer techniques, the cost, and therefore the perceived value, of deepwater ocean bottom seismic surveys will be driven by the availability of the hardware and operational assets required to conduct these types of surveys.

During the time following the Vienna workshop in June 2006 until the printing of this article, several of the major contractors have embarked on large wide azimuth data library projects in the Gulf of Mexico with underwriting from major E&P companies. There have also been tenders and inquiries for proprietary towed streamer and ocean bottom programmes in other parts of the world. So, it appears that the business models of the seismic contractors and the perceived value of these types of surveys by the E&P companies are currently aligned and suggest a bright future for these new ways of acquiring marine 3D seismic data.

References
Bouska, J. and Johnston, R. [2005] The first 3D/4-C ocean bottom seismic surveys in the Caspian Sea: Acquisition Design and processing strategy. The Leading Edge, 24, 910-912.