



Brief Report on Joint Workshop Organized by EAGE & SPG on “Broadband Seismic- Key to Understanding the Reservoir Potential”

EAGE and SPG, India jointly organized a workshop on “Broadband Seismic –Key to Understanding the Reservoir Potential” at hotel The Leela, Mumbai during 2-4 June, 2014. A total of 79 participants comprising 34 representing hydrocarbon E&P companies, 36 representing service companies, 5 representing the national oil & gas sector regulators and two each from academia and sister societies attended the workshop. A total of 17 presentations, a keynote address and a one day short course were spread over a three day workshop.



On Monday June 2, preceding the workshop, Mazin Farouki of PGS presented a one day short course titled: ‘*Broadband Seismic: A Platform to Understand, Measure, Compare and Exploit the Options Available Today and Tomorrow.*’ The course provided a comprehensive but accessible overview of broadband seismic. A key aspect is how the many processing and acquisition-based broadband solutions can be understood, measured and compared. The broadband concept also leads to a wider issue: full wave-field seismic, where the full primary and multiple wave-fields can be used to illuminate, image and characterize the earth far more comprehensively than today. The short course was well attended by 30 participants.



The keynote address was delivered by Narendra K. Verma, Director (Exploration) of Oil & Natural Gas Corporation Ltd (ONGC) the largest National Oil Company of India. He discussed in detail the challenges and opportunities that lies in the offshore sedimentary basins of India. He highlighted the role new and emerging technologies like broadband seismic can play in improving the subsurface mapping of complex geological environments.



The workshop comprised of six sessions and kicked off with Session 1 on Broadband Marine Seismic Acquisition that was chaired by Gareth Williams (Dolphin Geophysical) & Conrad Judd (CGG). This was an interesting session containing presentations on broadband data recorded with 3 different techniques. Maz Farouki of PGS presented the use of refractions, reflections and multiples in building a detailed velocity for PSDM on shallow data recorded with dual sensor streamer equipment. The refractions were used via FWI

to build a near surface model, the reflections used in tomography and the first order multiples used to build a detailed near surface model and image with a reduced acquisition footprint via mirror migration. The latter step was possible after using both the dual sensor data to separate the upcoming from the down going energy. In contrast, Chris Koeninger of WesternGeco followed this by describing some aspects of processing multi-sensor data including a cross-line accelerometer measurement to address spatial as well as temporal bandwidth. For example, gravity may be used to rotate the individual sensor data to vertical and horizontal data and the hydrophone low frequency data provides information on the wave height which may then be used to filter out noise. Examples of interpolation using the multi-sensor data on to a 6.25m crossline bin size were shown. In the final paper, Conrad Judd of CGG showed examples of recording broadband data with hydrophone only data with a variable depth streamer as well improvements to temporal bandwidth when incorporating a synchronized, 2 level broadband source. In the latter case, collapsing the bubble during processing becomes more important and it was reported that estimating this from the recorded near field hydrophone data is the most reliable way.

Session 2 on Broadband Marine Seismic Processing was chaired by Chairs: Sushobhan Dutta (Cairn) & Robert Soubaras (CGG). This post lunch Session started with the brief introduction of the session chairs by themselves. Before each presentation we as a session chair individually introduced about the speaker's background to the audience. The first speaker Mr. Ross O'Driscoll (ION GXT) presented about "Broadband processing of conventional marine streamer data". Speaker completed his presentation within his allocated time. The second speaker Matt Lamont (DugGeo) was introduced to the audience by Robert Soubaras. He presented on the topic "Ghostbusters". Presentation concluded with related technical Q/A. Last speaker Jason Sun was introduced by Sushobhan Dutta with his professional & technical background. He presented on "Processing of Variable Depth Streamer Data with Examples from APAC".

After each presentation there was a pre-defined schedule time for the useful technical discussion on the related topic and the speakers answered their questions acceptably. On behalf of EAGE the session chairs appreciated the individual speaker with a token gift and the session ends with vote of thanks. We are very much thankful to EAGE to consider us by giving this opportunity to act as session chair for this technically valuable workshop.

Session 3 on Broadband Seismic Reservoir Characterization was chaired by Manish Joshi (Essar Oil) & Lopamudra Roy (Schlumberger Geosolutions). First paper by Dr. Robert (CGG) was on the topic 'Filling the information gap with Broadband seismic.' With the advent of Broadband seismic we are able to achieve



low frequencies (as low as 2.5 / 3 Hz- two octane's gain) and higher frequencies (as high as 160/200 Hz - one octave gain). To achieve goal of filling the information gap as described by Claerbout (1985) a variable depth streamer data was acquired offshore West Africa and acoustic inversion was performed with the low frequency impedance model from the interval velocity model derived from rms velocities. The result

of this survey was validated by another survey acquired over West Australia offshore and elastic inversion was performed in similar manner. The result showed good mapping of gas sands between the three wells. Litho-classification computed from the impedance and Poisson's ratio.

Second paper 'Impact of ultra-low frequencies from Broadband data on seismic inversion – A collection of case studies.' By Dr. Anubhati (Schlumberger) put emphasis on the inability of conventional seismic owing to lack of broader spectrum towards low frequencies increases the dependency on the sparse log data for quantitative inversion hence increase in uncertainty. Filling the information gap (Claerbout 1985) remains the main problem here again. Various acquisition technologies such as over under, Sparse under, Slanted cables, Multisensor cables etc was discussed with examples from all technical service providers. Finally a case study based on a paper by Wallick and Gioldi (Interpretation, Nov. 2003) from Saudi Arabia showed the impact of broadband data on improved reservoir characterization and exploration. as mapping of reservoir was done with broadband seismic data which was a challenge with conventional seismic. The base of Khuff carbonates was used to map the reservoir top. Comparison of broadband with conventional seismic data was done for another case study from North West Australia (Bayly et. Al. 2011)

Third paper from the session was by Mr. Venkata Murthy (PGS) on 'The value of Broadband seismic data from Dual-sensor streamer for the interpreter and reservoir geophysics'. It followed the same approach of increasing the bandwidth and thereby achieving the objective of reservoir characterization for end users. The increase in bandwidth is achieved by removing the sea surface ghosts at the receiver end via principle of wave field separations and retaining the amplitude and phase integrity of the pre-stack data to carry out further analysis such as pre-stack inversion, AVO and Q studies. Increased bandwidth certainly have a positive impact on seismic interpretation and reservoir properties deviation where low side of spectrum contributes towards improved deviation of the absolute elastic properties such as acoustic and shear impedance whereas higher side of spectrum improves the shallower imaging and delineates thin reservoir layers. This certainly reduces our dependability on the well data which is always sparsely located.

All three papers were able to demonstrate the significance of broadband seismic in order to approach an inverse problem like subsurface imaging and reservoir characterization with more confidence. There was technical discussion after all the three presentations. The two major take away from this session was that Phase integrity is vital for successful inversion and accuracy of the velocity obtained from low frequency is very important for reservoir level inversion.



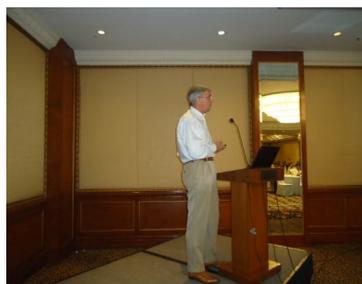
Session 4 on Broadband Case Studies was chaired by Christoph Koeninger (Schlumberger Geosolutions) & Soman Chacko (Cairn India). Gareth Williams presented a case history from West of Shetland that demonstrated that increasing the usable bandwidth is a question of improving S/N by one method or another during acquisition and then applying careful processing. This applies to both hydrophone only and

multi-sensor recording. The example from West of Shetland used a hydrophone only cable towed deep and with just a mild, linear slant. This simple geometry allows conventional de-multiple techniques to be used and pre-stack de-ghosting also allows conventional AVO analysis.

This was followed by a talk from Chris Koeninger where different acquisition geometries (flat shallow, flat deep, slanted and over-under streamers) from a real acquisition experiment and their associated de-ghosting techniques were analyzed and compared. While all the results were comparatively stable, specific acquisition geometries designed for notch diversity (over-under and slanted) together with the latest techniques on de-ghosting provided a consistent uplift in signal bandwidth over the more traditional flat streamer geometries.

The final paper of the session was presented by Sreedurga Somasundaram of Cairn India who discussed a novel technique to increase the resolution and interpretability of conventionally acquired and processed land data. The approach involves sparse layer inversion constrained by high resolution spectral decomposition that yields broadband reflectivity data. Very thin channelized reservoir units that are undetected or unresolved in conventional seismic data are resolved in the inversion data. The results allowed better understanding of lateral reservoir continuity leading to an improved reservoir model.

Session 5 on Broadband OBC & Land seismic was chaired by Philip Fontana (Polarcus) & Matthieu Retailleau (CGG). Criss (INOVA) gave a very good overview of advances in land technology on both the source and receiver side that have extended the bandwidth of land data, especially for the low frequencies which are so important to broadband imaging. Second presentation by Matthieu Retailleau (CGG) demonstrated how to successfully exploit the low frequency energy that can be derived from modern land acquisition. The broadband land seismic sections displayed during the talk were the first time I could not easily differentiate land from marine data. The third paper from Chris Walker (Fairfield nodal) was presented by substitute presenter Phil Fontana. The paper included a refresher on some of the differences in how the PZ summation is accomplished in seabed data compared to streamers. The discussion also extended the concept of "broadband" to spatial sampling considerations that can leverage with ocean bottom sensors. A case study of an ocean bottom node survey from the Gulf of Mexico provided an illustration of how high fidelity broadband spatial and temporal sampling can be achieved with ocean bottom receivers and simultaneous source technology.



Session 6 on Broadband Seismic - Future Trends was chaired by J.P. Paliwal (ONGC) and Rakesh Walia (CGG). Two papers were presented in the final session of the workshop. The first from Brian Barley (Reliance-BP JV) was titled 'Justifying Broadband Seismic Acquisition'. Brian emphasized that the geological significance of seismic data is easier to communicate using layer based impedance than it is

using interface reflectivity. In this context, he argued that improved bandwidth can be exploited practically and reliably in large data volumes using accessible workflows. This was well illustrated in a case history on the appraisal and development of a recent discovery off the East Coast of India. Brian also compared elastic impedance products based on legacy processing with results using in-house methods, which improve the S/N in gradient data at low and high frequencies.

A. K. Dwivedi (ONGC) presented 'Seismic Exploration: Broadband and Beyond'. He focused on the industry expectations from broadband seismic. He emphasized that future developments should be able to reduce turnaround time in data acquisition & processing, and should lead to better understanding and better utilization of full seismic wave-field. The emerging broadband seismic technology is expected to boost the capability of seismic inversion in describing and understanding key subsurface properties in more quantitative manners, and to accelerate QI application in exploration and development.

Overall, the workshop with high technical quality content received excellent response with some important take-home messages. Attendees have regarded the workshop as a value add and look forward to a follow-up workshop within the next one or two years.

