Ocean Bottom Nodes Fast Track PSDM

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Abstract

Deep water oceanic nodes are currently acquired with sparse receivers (e.g. 400-500m) on the seafloor and dense source carpet (e.g. 50m) on the surface. This geometry generates seismic data quite suitable to the SAE 3-D Pre-Stack Depth Wave Equation Processing, which provides high quality resolution imaging, even for sparse receiver geometry. The maximum frequency of these data is ruled by the bin size which depends on the shot spacing. Once applying pre-processing and proper wave-field separation, along with a previous knowledge of the sediment velocities, 3D common nodes gathers can be pre-stack migrated by 3D shot record technique assuming the principle of reciprocity. In order to speed up the imaging process, we limit the maximum frequency to allow us to enlarge the bin size (e.g. 25m to 50m). Thus, the whole data is processed with no trace decimation. The data volume of an area of 300km^2, 400x400m of nodes spacing with shots binned in 50x50m, can be processed with two velocity iterations and delivered within 45 days. This fast track provides the true final image of data, as well as the whole data scrutinization and quality control.

Introduction

The ocean bottom nodes (OBN) techniques with the proper geometry design provide full azimuth distribution for large aperture data being able to illuminate under complex geology. The true 3D nature of these data requires imaging techniques that have been optimized for many years. The need for an effective processing tool led to the development of the work flow to process 3D common receiver gathers which is based on the shot record migration using p-wave reciprocity (Sukup & Crawford, 2015).

Assessment of the OBN data at the first glance is difficult because of the nature of the OBN geometry. Convention fast track processing are difficult to achieve because of the large volume of data required to produce a single full fold line, and is not always sufficient to have the true assessment of the potential image of the 3D OBN data. Therefore, we decided to implement a special fast track work flow which consist of the same flow applied in the final processing for these data in Sukup & Crawford (2015). We can handle the whole OBN data with no trace decimation whatsoever on the data. In order to speed up the process we limit the maximum frequency of the data to allow us to double the natural bin size. Our fast track can produce true 3D wave equation PSDM lines after each line is recovered.

Fast Track Workflow

The OBN data are combed and sorted in common receiver gathers (CRG's) and quality controlled still during the acquisition – after the nodes are retrieved from the water. These four components CRG's are stored in either hard drives or tapes. From this point data are ready to start the fast track processing. Initially, conventional pre-processing is applied to the data:

- Separate pressure and vertical components;
- Vertical rotation;
- Spherical to plane wave correction (legacy velocity required);
- 50m x 50m binning;
- Deterministic deconvolution / gap deconvolution;
- Dual sensor summation and subtraction (up-coming and down-going field separation).

The rotation of the input geophone triplet XYZ by roll/tilt angles is applied to the data. Then spherical divergence correction or gain recovery is applied. Most of the deep-water nodes surveys are designed with shots spaced by 50m in both directions. Thus, the natural bin size in this case is 25m x 25m. In order to speed up the fast track work flow we limit the high frequency to allow us to enlarge the bin size. e.g. 50m x 50m. Although, the CMP fold increases in 1/4, the number of traces in the CRG's is reduced to 1/4. Therefore, "lighter" CRG's are generated to be submitted to shot record migration.

Far-field source signature and instrument response are used to generate the deterministic filter operator to be applied on the data prior to the GAP predictive deconvolution.

A shaping filter is derived to match P and Z data. The vertical rotated velocity sensor is matched to the pressure sensor data using a least-squares matching filter derived from a direct arrival window of the two sensors. Dual sensor adaptive summation and subtraction generates two datasets respectively: up-coming field CRG and down-going field (mirror) CRG (Fig.1). The shots are binned in grids normally double sized.

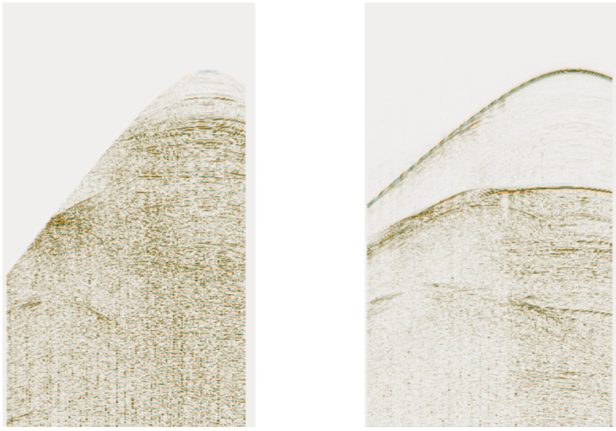

***Figure 1**: Up-coming field (left) and down-going mirror field (right) after the pre-processing.*

Fast-Track Imaging

The ocean bottom node technique migrates 3D records with full azimuth and large aperture data to a better structural image of the subsurface. Pre-stack migration is performed by the downward continuation (backward propagation) of the receiver wave-field recorded at the surface and followed by the forward propagation of the source wave-field using either a simulated source or the actual recording of the source wave-field (Fig.2). Imaging at a given depth level and image point are obtained by cross correlating the down-going wave-field with the up-coming wave-field and picking the amplitude (Claerbout, 1985).

Both up-coming and mirror fields are migrated. The up-coming field provides image close to the node position since the reflection point for this field is closer to the receiver. On the other hand, the mirror image provides illumination on a larger lateral extent since the reflection point for the mirror field is closer to the source.

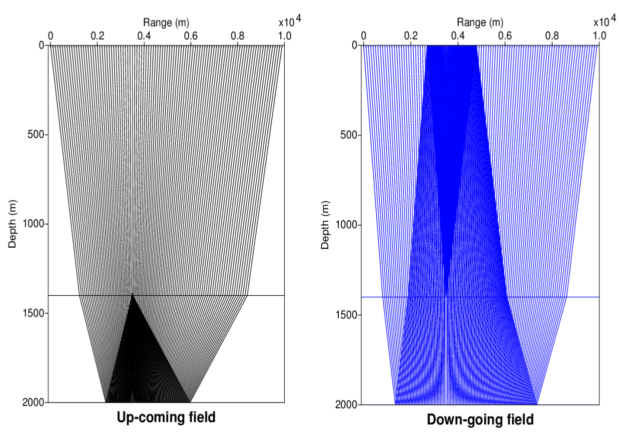

***Figure 2**: Simple example showing the up-coming field (left) illumination compared with down-going field (mirror). Notice the larger lateral extent of the down-going field.*

Legacy velocity model from previous towed streamed or oceanic bottom nodes survey are used to define the sediment velocities and as initial velocity model. The velocity focusing analysis is applied to determine the best imaging velocity by examining how the energy from a reflector "focuses" near the reflector location during the migration. If the correct velocity is used in the migration, then the downward propagation of the source wave-field and the backward extrapolation of the receiver wave-field followed by the cross-correlation will remove the right amount of time and the image of the reflector will be well resolved. If the incorrect velocity is used the energy will be moved either too fast (high velocity) or too slow (low velocity).

Depth focusing analysis is a practical velocity analysis for 3-D shot record migration where the image of each shot record is stacked to an image volume and the individual migrated records are discarded. Migration of the receiver records using a velocity that is in error will lead to "focusing" errors and a poorly resolved stacked section. This imaging error may not be apparent by examining a single migrated record but requires that we examine how the energy is focusing near a given image location as seen from several different source locations. The principle of pre-stack depth migration depth focusing analysis is based on examining at each downward continuation level a window about the t=0 imaging condition in the downward continued wave-field after applying the source term correction. These windows are stacked for all source records contributing to a given pre-stack migration and displayed in what I call a 'tau- deviation record'.

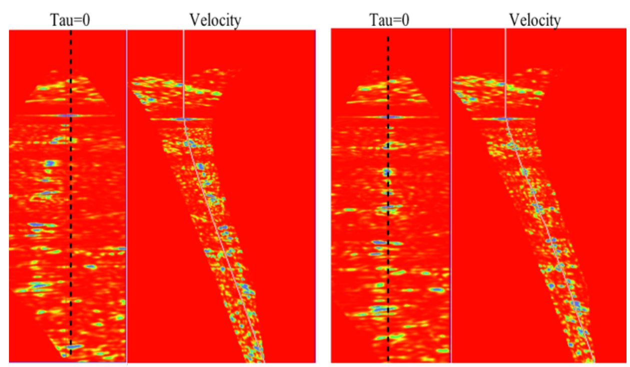

***Figure 3**: Velocity panels containing Tau deviation plot (left) and velocity coherent plot (right). The left panel is from an initial velocity model, where we notice the Tau=0 deviation clearly as well as the coherent velocities. The right panel corresponds to an updated velocity model.*

3D PSPI migrations are ready to be executed using an initial sedimentary velocity model. Subsequently, iterations of Focusing Velocity Analysis technique are applied to update the velocity model defining the top and bottom of salt as illustrated in Figure 3. Velocities vary from 1500m/s (water) to 4500m/s (salt). The final stacked 3D PSDM volumes for the up-coming and down-going wave-fields are generated. Both mirror (down-going field) and direct (up-coming field) migrations are adaptively summed up to generate the final compound image (Fig. 4). 3D PSDM migrated partial stacks are generated for initial QI studies.

A post-summed processing is applied on the data such as band pass filter, FXY Decon, spectral balance, etc.

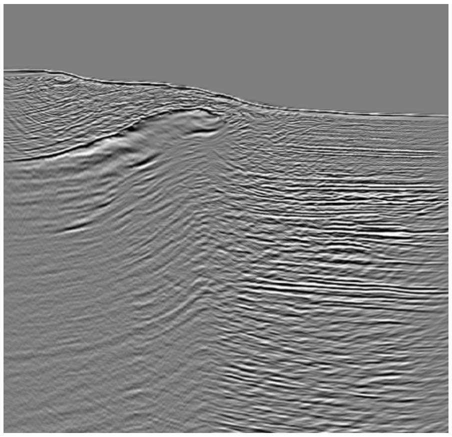

***Figure 4**: In-line extracted from the volume product of both mirror (down-going field) and direct (up-coming field) migrations adaptively summed.*

Example of 3-D OBN Fast-Track Workflow Turnaround Time

We have processed a OBN survey containing 800 nodes spaced by 400m x 400m in deep-water. The shooting area extended 8km outside the nodes area. The shots were spaced by 50m x 50m. Each CRG family has around 100,000 traces. The record length has 10s and sample rate of 4ms.

We used the sequence described above for the wave equation PSDM fast work flow. Shots were binned 50m x 50m. Regular rectangular bins were defined along the node lines and sources were assigned to the nearest bin center within a given tolerance and then a CMP correction was made to correct the source location to bin center using an assumption velocity.

Assuming no initial velocity was provided, we carried out three interactions of velocity analysis to construct the velocity model. Wave field separation and up-coming (direct) and down-going (mirror) migrations were applied on the whole volume.

We utilize for this benchmark a processing hardware in place in Houston, consisting of 4 x Cisco nodes, 2 CPU's per node, 16 cores per CPU, giving a total of 128 cores with 16TB of SAN high speed storage and an additional 60TB of NAS storage.

The final PSDM summed volume was delivered within 6 weeks after the CRG's were ready to process. Additionally, angle gathers, up-coming image, down-going image (mirror), post-processing and the final velocity model used in SGY were delivered.

Conclusions

This paper presented a fast wave equation PSDM workflow for nodes technology in deep-water. We tested the efficiency of the workflow in a survey with 800 nodes of 100,000 shots each. Data pre-processing was applied. The shots were binned 50m x 50m. Dual sensor summation and subtraction was applied to separate up-coming common receiver gathers (CRG's) and down-going CRG's (mirror). Shot record velocity analysis was carried to generate the velocity model. 3D wave equation shot record migration was applied in both fields.

The turnaround time to deliver the wave equation PSDM volume and angle gathers in a 3D deep water OBN survey was much faster than current fast track methods.

Acknowledgments

This paper was supported by SAExploration. We thank Breck Young for all the IT support.

References

Claerbout, J.F., 1985, Imaging the Earth's Interior. Blackwell, Oxford.

Howie, J., Mahob, P., Shepherd, D., and Beaudoin, G., 2008, Unlocking the full potential of Atlantis with OBS nodes, SEG, Expanded Abstracts, 363–367.

Holden, J.P., Drummie, S., Deeds, J., Mitchell, P.P., Brown, S., and Gosling, R.D., 2013, Deep water Ocean-Bottom Node Processing - A West of Shetland Case Study. 75th EAGE Conference & Exhibition incorporating SPE EUROPEC 2013.

Higginbotham, J., Brown, M., and Macesanu, C., 2010, Depth migration velocity model building with wave equation imaging, First Break Volume 28, p. 27-33.

Sukup, D. and Crawford, P., 2015, P-Wave Ocean-Bottom Node Processing in Gulf of Mexico: a test survey. SBGF.