Case study: A large 3D wide azimuth ocean bottom node survey in deepwater GOM.

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Summary

We present the P-wave processing and imaging of a large 3D ocean bottom node survey, consisting of 1628 node locations, in deepwater Gulf of Mexico over the Atlantis field. The data quality is good, and the preliminary imaging results using both the primary reflections and the receiver ghost appear promising.

Introduction

In the fall of 2005 Fairfield Industries was the primary contractor of a large, wide azimuth survey (Ross and Beaudoin, 2006) for BP over the Atlantis field in the deepwater GOM. The water depth in the area varied from approximately 1400 metres to 2300 metres. The survey used 902 four-component ocean bottom nodes (Mitchell and Grisham, 2006), which BP commissioned Fairfield to build. The purpose of the survey was wide azimuth, sub-salt imaging using P-waves (Beaudoin and Michell, 2006).

The shot coverage was also on a hexagonal grid with a 50m spacing over an area of about 730km². The survey was acquired in two patches, with approximately 1700 node placements in total. The time between shots was 11.2 seconds, with a 12 second trace length, although the nodes actually recorded continuously.

The nodes were placed on the seafloor using an ROV. A dual Hydroacoustic Aided Inertial Navigation (HAIN) system (Marc et al, 2006) provided a positioning accuracy of approximately 0.5% of water depth (about 10m in this case). The node spacing was ~400m in both the x and y directions, using a hexagonal grid (Bardan, 1997) and covered an area of about 250 km².

Once placed on the seafloor the nodes were completely autonomous. The battery life and memory capacity were sufficient for about 28 days of continuous recording at a 2ms sample rate. The geophones were fixed (non-gimballed) and orthogonal, and the nodes were placed as much as possible on horizontal ground, such that one component was approximately vertical.

Discussion

The preliminary processing of the data to date has all been performed on common receiver gathers. Each gather is well sampled, and contains approximately 160,000 traces per component. The processing flow was very basic: node positioning, noise removal, quality control, geophone orientation, PZ summation and difference, and common receiver wave equation depth migration.

The overall positioning accuracy of the nodes was very good (Figure 1). Using the direct arrival to determine the node locations confirmed the positions derived from the HAIN system to within 10 metres for 95% of the nodes, and to within 20 metres for over 99%. About a third of the nodes had a bulk time shift due to a clock synchronization error, but this was easily detected and corrected.

Figure 1: The difference in the positions of the nodes calculated by a least squares inversion of the direct arrival times and the positions calculated using the HAIN system on the ROV.

Random noise was attenuated by spectral thresh-holding and balancing in the time-frequency space (see program tldnoise at http://www.freeusp.org). Care was taken to avoid damaging both the direct arrival and the receiver side water bottom multiples. The direct arrival was of particular importance as it was used for positioning the node, orienting the geophone components, and for the PZ summation. As will be discussed later, the receiver side multiples were also important for imaging.
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Figure 2: Example raw hydrophone data for a shot line from a receiver gather.

Figure 3: Example raw geophone data for a shot line from a receiver gather. The geophone component is oriented approximately vertically.

Figure 4: The PZ summation result for a shot line of a single receiver gather. This section contains predominantly up-going energy, so the direct arrival is attenuated. There is still some residual down-going energy at the farther offsets.

Figure 5: The PZ difference result for a shot line of a single receiver gather. This section contains predominantly down-going energy. In the shallow section we see only the direct arrival and the source reverberations.
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The vector infidelity correction method (Dellinger et al, 2002) rotates the geophone data to the vertical, East and North directions, and corrects for any scaling discrepancies between the components due to differences in gain or coupling, for example. The vector fidelity of the geophone data was excellent. In practice, for this dataset, the scaling effects were negligible and so the correction matrices were straightforward rotation matrices. The good vector fidelity results also confirm the accurate positioning of the nodes and the shots (Clarke and Dellinger, 2004).

The PZ summation and difference process (Barr and Sanders, 1989) combines the hydrophone data (Figure 2) and vertical geophone data (Figure 3) to give the up-going (Figure 4) and down-going wavefields (Figure 5). In this initial processing we performed the PZ summation using a single filter per receiver to match the vertical geophone data to the hydrophone data. The matching filter was designed on the direct arrival and the near offsets, so theoretically the process provides optimal receiver side multiple removal at near offsets, degrading with increasing offset. In practice, we see quite good results even at far offsets.

Additionally, source side water bottom multiples can be removed by wavefield extrapolation and adaptive subtraction (Xia et al, 2006).

![Figure 6: For the mirror migration the receiver position is reflected by the sea surface so that the receiver ghost now has only a single downward propagation path and a single upward propagation path and can be migrated with the usual algorithms.](image)

We depth migrate the up-going wavefield using reciprocal wave equation shot migration (i.e. receiver migration). This is particularly efficient for OBS node data with a sparse receiver grid and a dense shot grid. Each receiver is migrated separately on a different computer, with the whole migration taking under a day to complete in BP’s High Performance Computer center. Additionally, the individual output images allow us to run further decimation tests to help design future surveys.

Traditionally the up-going wavefield is then migrated to form an image, while the down-going wavefield is discarded. We also migrated the down-going wavefield using “mirror migration” (Verm, 1987, Ebrom et al, 2000, Shoshibaivili et al, 2005), where the node positions are mirrored by the sea-surface, effectively unwrapping the propagation into a form which can be migrated with the usual migration algorithms (Figure 6).

The image produced from this mirror migration (Figure 8) complements the usual image (Figure 7) using the primary reflections, particularly with improved illumination of the near surface. Further more, we can see that the PZ summation was effective as residual primary reflections would have migrated into the water column.

Conclusions

We have presented the successful use of a large 3D survey with ocean bottom nodes for wide azimuth subsalt P-wave imaging in deep water Gulf of Mexico over the Atlantis field. The data quality was very good. Depth migration of the receiver side ghost has also allowed us to image the shallow subsurface with the sparse node spacing.

References


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Figure 7: Initial depth migrated image using the PZ summed data. Only basic preprocessing, and no post migration image enhancement, has been applied. The poor shallow section is due to the sparse spacing of the nodes.

Figure 8: Initial image from the mirror migration of the receiver ghost with the PZ difference data. Only basic preprocessing, and no post-migration image enhancement, has been applied. Note in particular how the shallow section is greatly improved, while the deep section is also well imaged. Note also the lack of events in the water column indicates that the PZ sum process worked well.
EDITED REFERENCES
Note: This reference list is a copy-edited version of the reference list submitted by the author. Reference lists for the 2006 SEG Technical Program Expanded Abstracts have been copy edited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

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