South Oman Salt Basin: High-Density Wide-Azimuth Land Seismic Acquisition and Processing

Petroleum Development Oman (PDO) : Richard Smith, Paul Zwartjes and Tom Van Dijk.
CGGVeritas : Richard Wombell, Nigel Benjamin, Teo Wah-Hong, Richard Cramp, Oleg Khakimov, Arthur McCarthy and Matthieu Bulteau

Introduction

The Ara play of the salt basin situated in the south of Oman was discovered by PDO in the 1970s. It consists of a number of phases of carbonate deposition (stringers) encased in Ara salt at depths that vary from 2500 to 6000 metres (see Figure 1). Conventional seismic surveys in this area have typically been unable to accurately and reliably delineate the stringers. The density of the sampling in these surveys has been insufficient to adequately sample the noise and signal, so that aggressive noise attenuation approaches have been required. These surveys have also been relatively narrow azimuth, resulting in poor cross-line noise attenuation and illumination problems.

![Figure 1: The Ara carbonate play of the salt basin situated in the south of Oman](image)

PDO’s ‘New Generation Seismic’ initiative was designed to make a step change in the density of seismic acquisition by recording well sampled wide-azimuth data in a cost effective manner (Sambell et al., 2009) with the objective of dramatically improving the quality of seismic imaging. The application of true WAZ algorithms to data with much better sampling should significantly improve the noise and multiple attenuation. The more uniform illumination from the WAZ acquisition geometry should result in a more accurate velocity model and improved imaging.

High-Density, Wide-Azimuth Acquisition

The high-density WAZ survey acquired in south Oman deployed 25000 channels with 288000 geophones along with 16 vibrators. This enabled a true land WAZ survey to be acquired with an
inline offset of 5km, a cross-line offset of 4km and a fold of 4000 assuming 25m by 25m bins. This can be compared to conventional narrow azimuth surveys in the region that typically employed narrow geometries with four receiver lines and a 50m inline receiver station, giving a fold of around 100. Table 1 outlines the acquisition parameters for this survey. Improvements in acquisition productivity, including a move to 24 hour operations, enabled the survey to be acquired in a cost-effective manner.

<table>
<thead>
<tr>
<th>Area</th>
<th>2500km²</th>
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<tbody>
<tr>
<td>Live channels</td>
<td>8000</td>
</tr>
<tr>
<td>Fold</td>
<td>4000 (25m x 25m bins)</td>
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<tr>
<td>Inline receiver spacing</td>
<td>25m</td>
</tr>
<tr>
<td>Receiver line spacing</td>
<td>200m</td>
</tr>
<tr>
<td>VP spacing</td>
<td>50m x 50m</td>
</tr>
<tr>
<td>VP/km²</td>
<td>800</td>
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</tbody>
</table>

**Table 1: Acquisition Geometry Parameters**

**Data Processing and Imaging**

The processing of such a high-density, wide-azimuth survey presented a range of challenges and opportunities. The wide-azimuth nature of the acquisition meant that all domains, including common-shot, common-receiver, cross-spread and CMP, were all truly 3D and the sheer size of the data volume, which was more than 140Tb, presented a major challenge.

Key elements of the WAZ processing sequence included 3D WAZ ground roll attenuation (Le Meur *et al*., 2008) and 3D Radon demultiple (Hugonnet *et al*., 2009). As can be seen from the schematic in Figure 1, there is significant structural dip on top-salt and deeper reflectors, which results in azimuthal variation in the velocity (i.e., dip-moveout related) even if there is no anisotropy present. Because of this, an azimuthally varying velocity field was required during the pre-processing for applications such as residual statics and 3D Radon, as well as to generate QC stacks.
Figure 2: 3D CMP gather (sorted by absolute offset) illustrating the processing sequence. (a) Raw, (b) ground-roll attenuation, (c) azimuthal velocity correction and (d) 3D Radon de-multiple.

For the velocity model building and imaging, the data were binned, regularized and migrated using common offset vector (COV) bins (Poole et al., 2009). COV bins are cartesian common-offset bins, defined by offset-x and offset-y, that allow the acquired offset and azimuth to be honored through the imaging process. The velocity model update was performed using multi-azimuth tomography and migrated using Kirchhoff pre-stack depth migration. After imaging, an azimuthally varying RMO was derived and applied (Lecerf et al., 2009) and the data stacked.

The processing sequence is illustrated in Figure 2 which shows a CMP gather at various stages of the pre-processing. Although the raw input data is significantly contaminated by ground-roll, guided-waves and multiples, it can be seen that the noise is well sampled by the high-density acquisition and can be very effectively attenuated. After the noise has been attenuated, some of the primary reflections show an obvious ‘jitter’ which is a result of the (pre-imaging) azimuthal velocity variations mixed together in a CMP ordered by absolute offset. Applying an azimuthally varying moveout correction effectively removes this distortion on the primary data prior to residual statics and Radon demultiple.

The combination of the new high-density wide-azimuth data and the use of true wide-azimuth processing algorithms that fully honour and exploit this data, results in substantially improved imaging. This is illustrated in Figure 3, where Figure 3a shows the image from a conventional narrow azimuth survey reprocessed in 2008 and Figure 3b the results from the new wide-azimuth data. There is a dramatic improvement in the signal-to-noise of the new image due to the better sampling. Top salt is now significantly better defined, as are the sub-salt events.
Figure 3: (a) Conventional narrow azimuth data reprocessed in 2008 and (b) WAZ acquisition and processing.

Conclusions

High-density wide-azimuth land seismic has been a combined effort of both acquisition and processing. A land ‘super-crew’ has yielded substantial improvements in productivity that enabled such a survey to be acquired in a relatively cost-effective manner. A range of true wide-azimuth processing algorithms that are able to exploit such well sampled data have produced significantly improved seismic imaging. It is likely that there will be continuing improvements in both areas during the next few years.

References


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