Design, Acquisition and Processing of Wide Azimuth 3D Land Seismic Data Utilizing Offset Vector Tiles

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Abstract

In 2008, a wide azimuth 3D land seismic survey was acquired in the Percheles area south of Santa Cruz, Bolivia. The survey was designed to properly populate offset vector tiles (OVT), which are composed of common mid points (CMP) with similar source-receiver offsets and azimuths. An acquisition design program was used to analyze OVT offset and azimuth distributions for the proposed acquisition plan. The seismic acquisition contractor successfully acquired the data with a minimal difference between pre and post acquisition plots. The data was then processed using an OVT pre-stack time migration (PreSTM) followed by correction for azimuthal velocity anisotropy using a proprietary surface-fitting technique. The final results showed a significant improvement in the seismic image quality when compared to the conventional processing results.

Introduction

The Percheles area is located about 60 km southwest of Santa Cruz, Bolivia. Percheles is a producing field operated by Chaco S.A. In 2008, the Percheles (PCH) 3D wide azimuth seismic survey was acquired. The total area for the survey was 250 km^2. The objective of the survey was to image a deep (approximately 3600 m TVD) recently discovered gas-condensate field in the Lower Carboniferous Tarija Formation formed by an anticline trap associated with a thrust fault. The Tarija Fm. presents a complex of huge straight glacial valleys and low sinuosity fluvial incised channels which lie either within the valleys or in the intervalleys. The discovery well confirms the fluvial nature of the reservoir sands and the presence of glacial sediments (tills) acting as seals.

Previous processing experience in Bolivia demonstrated that the seismic data quality is adversely affected by the presence of seismic velocity anisotropy (Fry et al., 2008). This anisotropy was generally expected in Bolivian sedimentary basins in which the sediments have been buried, compacted and subjected to significant compressional forces associated with the Andean orogeny. It was decided that the acquisition and processing of the seismic data should consider utilizing a technique which would address the structural dip associated with the data as well as allow measurement and correction of the seismic velocity anisotropy.

Seismic Velocity Anisotropy

Horizontal transverse isotropy (HTI) can be the result of vertically aligned fractures, or unequal horizontal stresses, or both (Thomsen, 2002). For example, for a single set of vertically aligned fractures, the fast NMO velocity will be parallel to the fracture strike, and the slow NMO velocity will be perpendicular to the fracture strike. Whereas, in the case of unequal horizontal stresses, the fast NMO velocity will be parallel to the maximum horizontal stress direction, and the slow NMO velocity will be perpendicular to it. In either case, the result is an azimuthally varying velocity field (Figure 1).

Unfortunately, traditional seismic signal processing techniques often either ignore the effects of azimuthal velocity anisotropy or degrade the azimuthal information. Williams and Jenner (2002) showed that ignoring the effects of azimuthal velocity anisotropy during the processing of wide azimuth seismic surveys can result in interpretation issues such as a loss in seismic image quality and a decrease in signal bandwidth. These issues are further compounded by the presence of structural dip in the data. Like azimuthal velocity anisotropy, structural dip also introduces an azimuthally varying time shift signature into the data. However, for typical seismic velocities, the dip effect is much less when comparing degrees of dip with percent anisotropy (Figure 2). When both azimuthal velocity anisotropy and structural dip are present, the effects will be combined in the data. Therefore, the structural dip component must be removed from the data prior to azimuthal velocity analysis.

OVT Acquisition and Processing

Migration is routinely performed to correct for the structural dip effects in seismic data. However, conventional common offset PreSTM does not preserve the azimuthal information so that post-migration azimuthal velocity analysis is not possible. On the other hand, performing PreSTM using vector offset bins (Vermeer 2002; Cary 1999) preserves the azimuthal information through migration and allows subsequent azimuthal velocity analysis using techniques such as surface-fitting (Jenner et al., 2001). The OVT approach is a natural extension of the binning used for 2D surveys to 3D and utilizes a Cartesian coordinate system of vector offsets aligned appropriately with the survey CMP grid (Calvert et al., 2008). Offset vector tiles are a collection of CMP bins with similar offsets and azimuths for a particular source and receiver line cross-spread (Figure 3).

Analyzing an acquisition design for OVT processing is different than for conventional processing methods because the dimensions of the vector tile are based on the source and receiver line spacing (Calvert et al., 2008). For each vector tile relative to source and receiver line cross-spread, the acquisition grid is analyzed using CMP trace fold distribution within each vector tile. Each CMP bin, within a vector tile, is marked for specific source and receiver combinations for various source and receiver cross-spreads (Figure 4). Evaluating all cross-spread combinations leads to complete CMP bin analysis of the acquisition grid for this specific vector tile. The objective is to have complete CMP bin coverage for each vector tile within the acquisition area.

For the PCH 3D acquisition design, modifications were made to the design to ensure the complete CMP bin coverage for each vector tile (Figure 5). Some CMP bins had zero or double trace density, but the majority of the bins were covered by one trace. Criterion was established to minimize the impact on the trace distribution when shots were skidded to avoid surface cultural features. The seismic contractor successfully acquired the data according to the proposed design, resulting in minimal difference between the pre and post acquisition plots.

The seismic processing contractor began the OVT PreSTM analysis by performing conventional post-stack migration of gathers corrected for azimuthal velocity anisotropy. In addition, OVT PreSTM followed by azimuthal residual moveout (RMO) analysis was performed on the data. The azimuthal velocity anisotropy attributes calculated from the pre and post stack migrations were compared and were found to be different. The difference was attributed to the removal of dip artifacts in the pre-stack gathers by the OVT PreSTM process. Additional studies are being conducted to further verify these observations. However, in general, OVT PreSTM followed by azimuthal RMO not only resulted in properly migrated data, but also provided an additional improvement in image quality and signal bandwidth by accounting for the effects of azimuthal velocity anisotropy (Figures 6 and 7).

Conclusions

Previous processing experience in the vicinity of the Percheles area demonstrated that the seismic data quality is adversely affected by the presence of seismic velocity anisotropy. A wide azimuth 3D survey was designed such that the offset and azimuth distributions would be appropriate for performing OVT PreSTM followed by azimuthal RMO. The results showed a significant improvement in the seismic image quality when compared to the conventional processing results.

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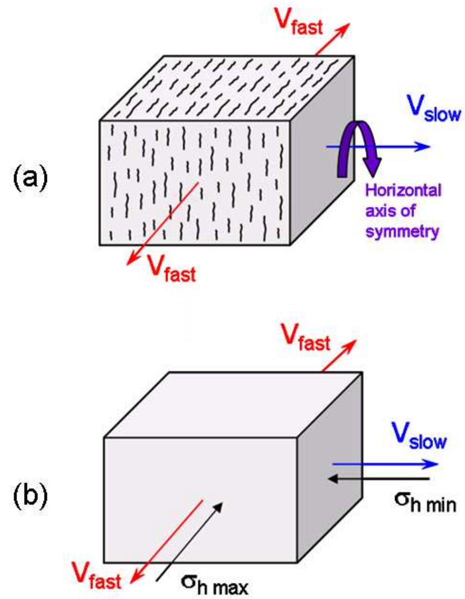

Figure 1: Horizontal transverse isotropy (HTI) due to: (a) single set of vertically aligned fractures; and (b) unequal horizontal stresses.

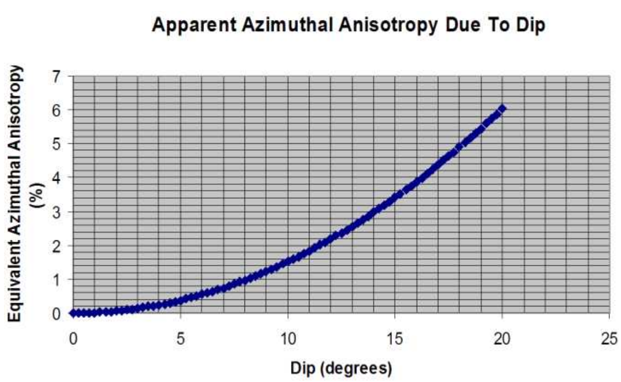

Figure 2: Dip effect versus equivalent azimuthal velocity anisotropy.

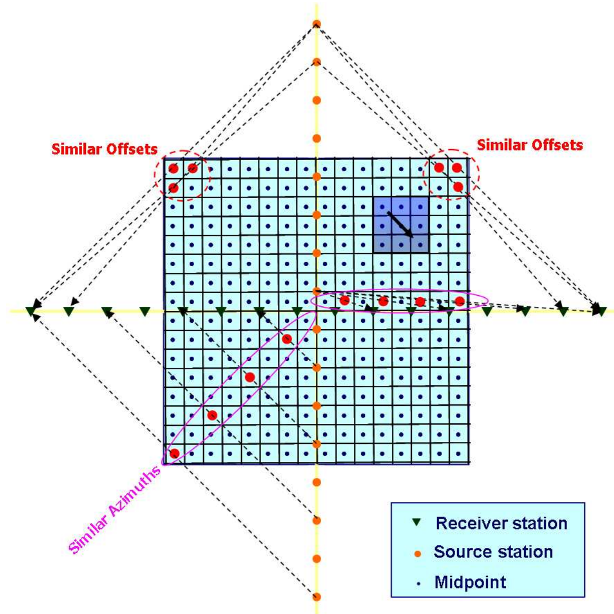

Figure 3: An orthogonal land survey can be considered the sum of a number of subsurveys each consisting of a single source-receiver line pair (or “cross-spread'). The single fold CMP grid is shown for a given cross-spread. Note that source-receiver offsets vary concentrically while source-receiver azimuths vary radially. A rectangular “tile” of CMPs defined by a limited range of inline and crossline offsets (blue shaded rectangle) would have similar azimuths and offsets (Calvert et al., 2008).

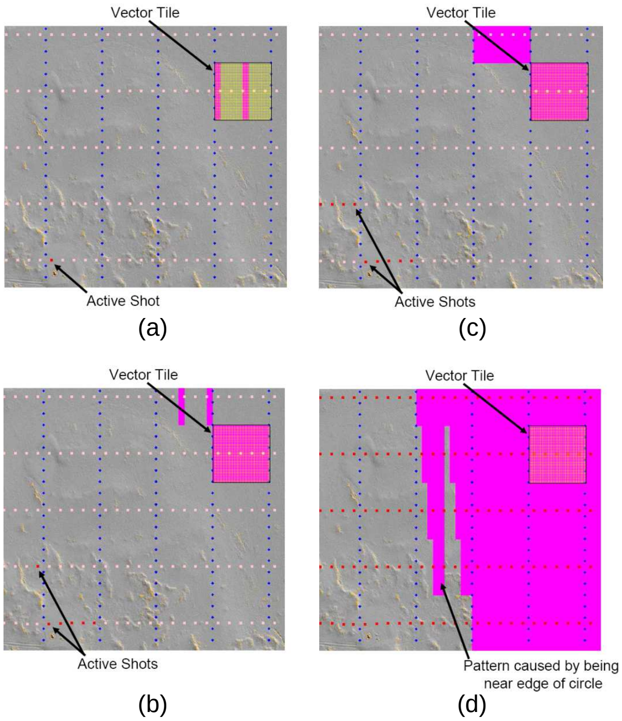

Figure 4: Single fold CMPs are shown for one active shot, where the CMPs are distributed in two bands for two cross-spread combinations (a). Using all active shots between two receiver lines completely populates the vector tile (b). Another shot line creates a different vector tile location (c). All shots provide a complete coverage for a specific vector tile in the cross-spread configuration, except at the edge of the survey (d).

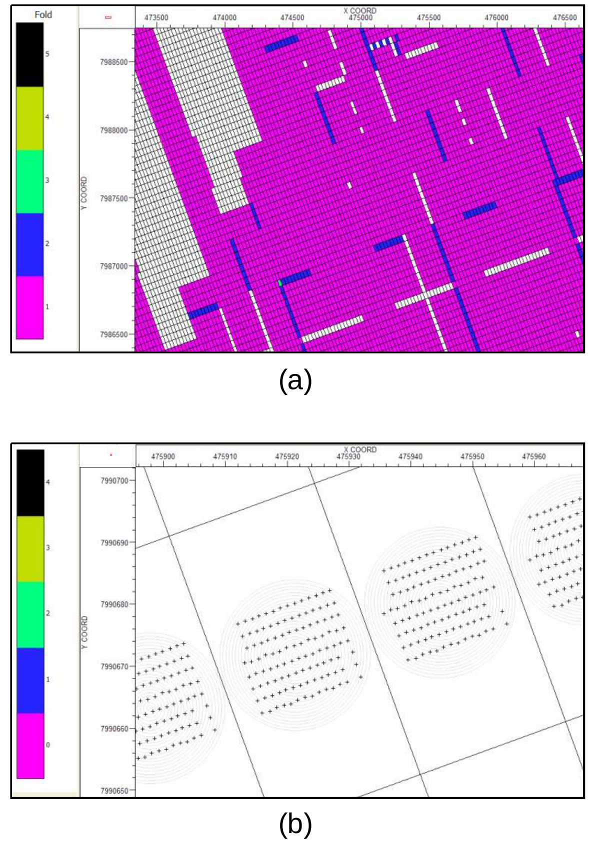

Figure 5: The trace fold in each CMP bin is shown for a specific offset vector tile for the PCH 3D seismic survey (a). The effect of the edge of the survey is shown where CMP bins have no traces. A close up of CMP bin shows its trace contribution for all offset vector tiles (b).

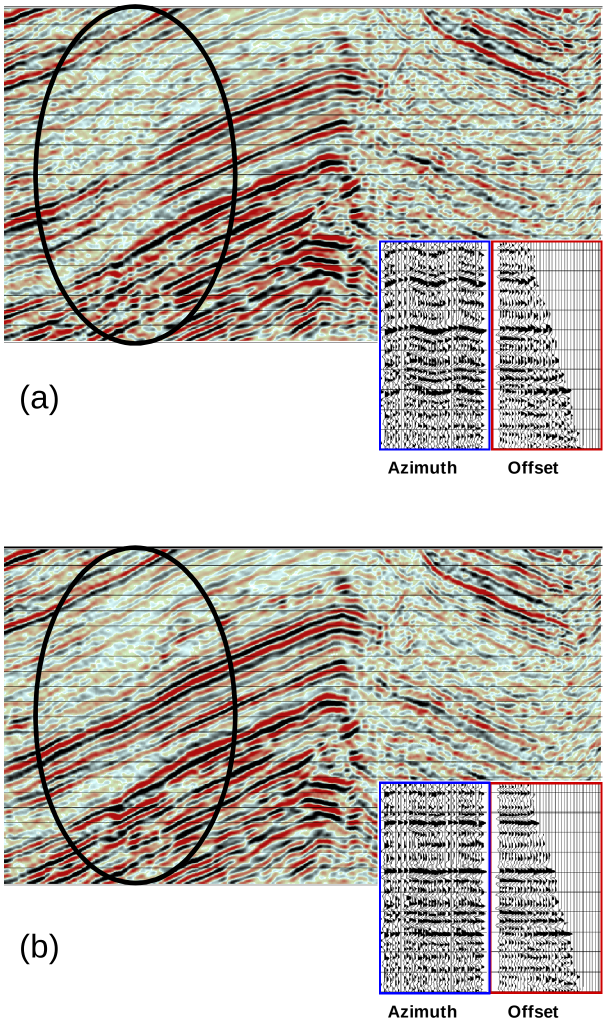

Figure 6: Vertical section from PCH 3D survey with inset azimuth and offset sorted gathers for: (a) isotropic OVT PreSTM; (b) isotropic OVT PreSTM with post-migration azimuthal RMO.

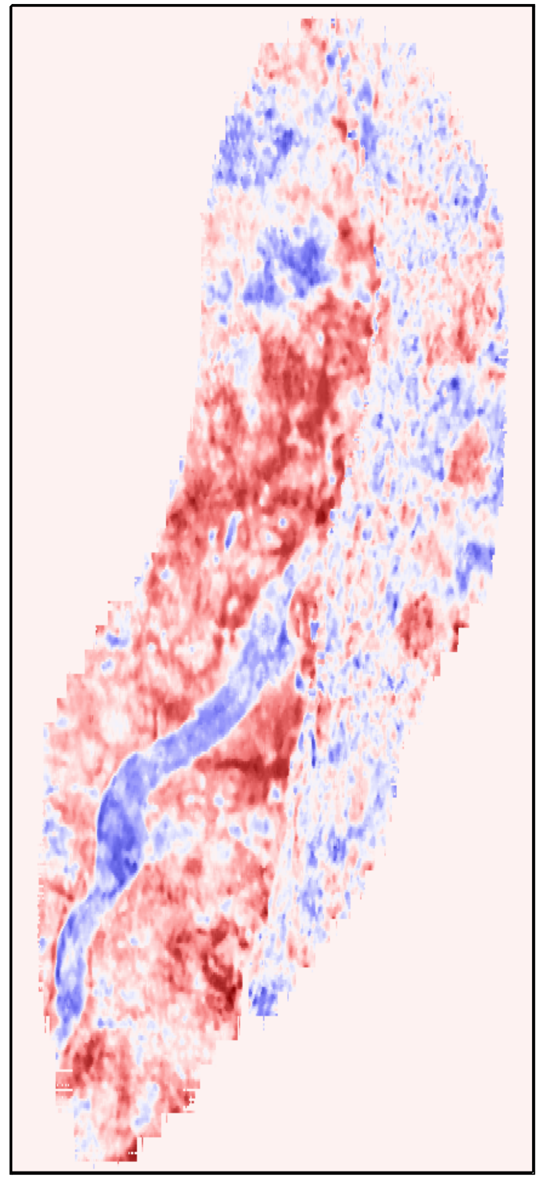

Figure 7: Horizon time slice from PCH 3D survey shows a good example of a low sinuosity fluvial incised channel in the Tarija Fm.