

CASE HISTORY OF OBS DATA PSDM PROCESSING AND REFINE FREQUENCY ENHANCEMENT

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Introduction

The Caspian Sea Area is estimated to hold the world's fifth largest gas reserves. With some experts estimating possible reserves of over 230 billion barrels of oil (estimate using 50% probability) and recent changes in the business environment of key neighbouring countries, it's easy to see why this area presents an interesting prospect for many oil companies. Although it has been producing oil and natural gas for many years now, the area is considered to have the resources to sustain production much greater than current levels with proven reserves already estimated between 17 and 33 billion barrels.

Improved seismic coverage and modern processing techniques on existing data are thought to hold the key to more successful discoveries within the region and annual growth is currently estimated at around a quarter of a million barrels per day. With many 3D surveys already shot within the region, the next natural step for many oil and gas exploration companies lies with high resolution surveys and depth imaging seismic studies.

In 2006 Spectrum was approached by one such oil company looking to pursue its interests in the region by enhancing its existing seismic. Their data consisted of a shallow water 3D seismic survey over a producing Caspian oil field, shot using the Ocean Bottom Cable (OBC) technique. The survey covered over 650 square kilometres and had been previously time processed by a competitor.

The Geology of the survey area consists of structured ridges and rows of sub-parallel folds formed by transpressional motion on a relatively broad continental shelf. Some of these folds contain shale diapirs. Overlying sediments contain extensive extensional faulting above anticlinal structures. The target horizons for this project were deep with good reflectivity off-structure but tended to show conflicting dips at the apex of the anticline where these dips are steepest. It was presumed that this effect was being caused by faults in the shallow section disrupting the ray paths. Gas chimneys, oil seeps and mud volcanoes were also known to be present in the area.

Oil and gas bearing formations in the survey area are said to lie in the Middle Pliocene series which is thought to have been formed in a shallow-water fluvial-deltaic environment. These formations are mainly composed of sands, sandstones, loams, shales, siltstones and unsorted rocks with each layer within being delineated according to the prevalence of each of these rock types.

Following successful tests on a small target line, the final objective of this work was to depth migrate the entire 650km²+ 3D OBC cube. The client was looking for significant uplift in key target layers compared to time processing as well as general improvement in the imaging of underlying sediments, faults and the general geology of the subject area. Inherent to the velocity definition of PSDM data processing, the client also expected an enhanced structural positioning of events. Spectrum was also instructed to present tests of any proprietary technology or techniques which had the potential to further improve the final image.

Pre-Processing

The project began with some pre-processing on existing CDP gathers which had been output at an intermediate stage of the previous processing. Testing showed that these could be enhanced for PSDM through amplitude balancing, simple bandpass filtering and random noise reduction techniques. Localised Amplitude Processing (LAP) was used to modify noise bursts appearing along the first breaks. Proprietary process "SNR" used a cross-correlation technique to reduce random noise aiding stack velocity analysis and improving stack clarity [Fig 1.].

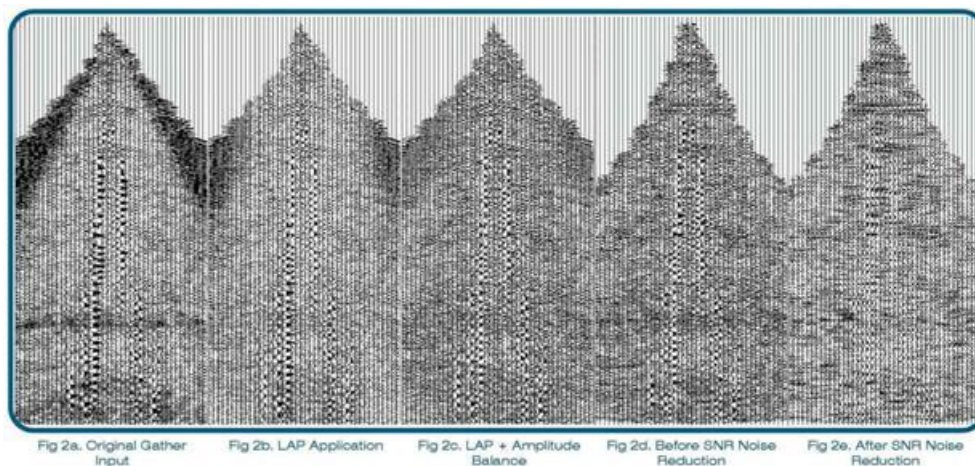


Fig 1. Pre-Processing Test Results

Finally velocities were re-picked to optimise the results of the noise reduction techniques. This immediately improved imaging, especially between 3 and 4 seconds.

After the CDP gathers were enhanced with signal to noise improvements, they were ready for PSDM processing.

Pre-Stack Depth Migration:

Initial velocities were picked as time (RMS) functions on a 2km grid then auto-picked down to a 0.5 km grid using rigorous QC procedures to check results against existing functioned used for the previous processing by a competitor. Numerous test results showed that Spectrum's velocities achieved significant improvement in the imaging of all areas of the survey.

These new functions were then input into Spectrum's proprietary Equator software program. Equator provides the ability to analyse each individual function and remove any picks statistically deemed mis-picked or out-of-trend. Velocity inversions were also removed where appropriate. After cleaning up each function Equator then smoothes them in x, y and z directions before converting the RMS (time) velocity values to interval (depth) velocities.

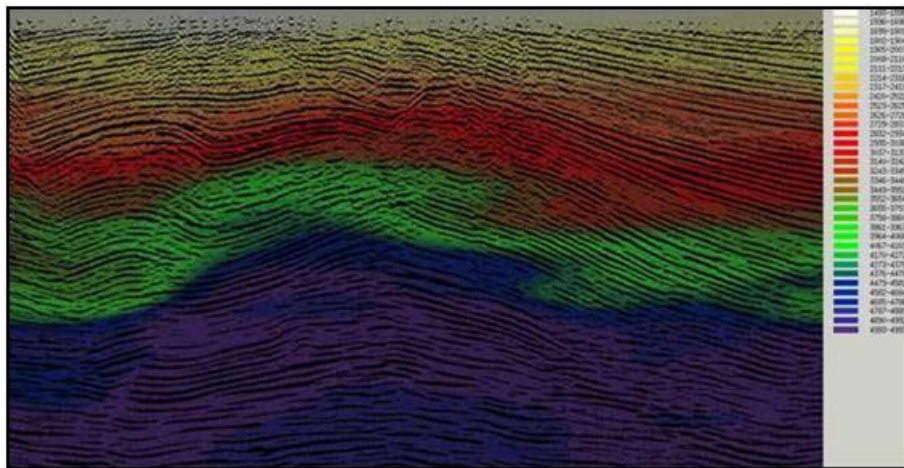


Fig 2. Final Time-Converted Interval Velocity Field

These enhanced velocity functions were then loaded into Geodepth software for generation of PSDM interval velocity modelling. This field is optimised through several iterations of PSDM and tomography; a standard procedure for updating sedimentary velocities for PSDM projects.

The first Kirchhoff depth migration was run using the enhanced velocities generated through the process described above. The output of this was then put through GeoDepth's grid tomography. This function of the program updates the velocity field such that subsequent migrations will produce depth gathers with flatter responses at all offsets. The output results from tomography tend to perturb the velocity model, producing more complex, and possibly distorted, velocities. Thus special attention must be paid to the velocities output after each Kirchhoff PSDM/tomography iteration in order to prevent these velocities from becoming too chaotic.

Tomography uses the intersection of horizon picks against output migrated depth gathers. If the output gathers trend upward at far offsets along a given horizon, then the velocity should be increased somewhere above the horizon at that bin location. If the output gathers trend downward at far offsets along a given horizon, then the velocity should be decreased somewhere above the horizon at that bin location. For this project the client provided 4 main interpreted horizons that were imported into GeoDepth [Fig 4.]. In addition, Spectrum interpreted 6-7 more horizons in the volume. A full coverage in x, y and z directions is needed to increase statistical calculations for tomography. Therefore, further horizons were added to give a more complete coverage.

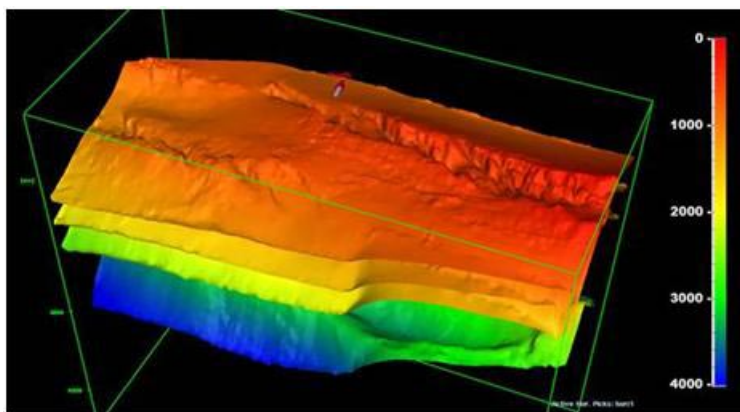


Fig 3. Horizons Used For Tomography Calculation

Each iteration of PSDM/tomography produced higher quality stacked images. Four migrations were appropriate for generating a velocity model that yielded good imaging results without the velocities becoming chaotic. The final velocity model was a slowly varying gradient. The velocities increased with depth, with slight variations laterally as the seismic imaging dictated.

Post-PSDM Processing

After the completion of the Kirchhoff PSDM processing, the volume was converted back to time; two distinct zones could now be seen in the data. The first was a shallow (0 – 2000 ms) zone of broader bandwidth (10 – 50 Hz), and the second a deeper zone of narrow bandwidth (6 – 25 Hz). The power spectra of the data show peaks at 20 Hz and 40 Hz, with a dip around 30 Hz. This is also seen to be present on the input gather dataset and on the existing PSTM stack data. It is assumed that this is a feature of the area. It was found in testing that the process of whitening the spectrum introduces noise in this 30 Hz region, which then has to be filtered back. The following was found to give optimal results:

- Deconvolution: This process reduces the ‘reverberation’ energy seen in the events and also whitens the spectrum, reducing the monochromatic look seen in the deeper events. The design window for the operator was chosen to include the higher frequency shallow events, and to avoid some of the migration artefacts appearing in the deeper part of the section. A long lag time was chosen to preserve the waveform of the deeper events, which are of low bandwidth.
- Time-variant bandpass filter: This was applied before coherency filtering, as tests showed this to give a slightly improved result for noise attenuation.
- Proprietary Coherency filter: Used to enhance the signal/noise and to mitigate some of the noise introduced in the 30 Hz region by the deconvolution. This is applied to both inline and crossline data in two passes.

Finally, as an additional service, Spectrum tested its REFINE technology on the post-stack data and the client approved its use on the full cube. REFINE combines different techniques to whiten the spectrum of the data in a time variant manner, using user specified windows, and frequency bands. Overall resolution is improved, although a little noise has been introduced at the 30Hz range due to the above mentioned data character. This was minimised by careful parameterisation through extensive testing. The power spectra displays show that the PSDM broadens the bandwidth between 8 – 25 Hz, and the REFINE process further broadens the bandwidth above 25 Hz [Fig 4.1 – Fig 4.3]

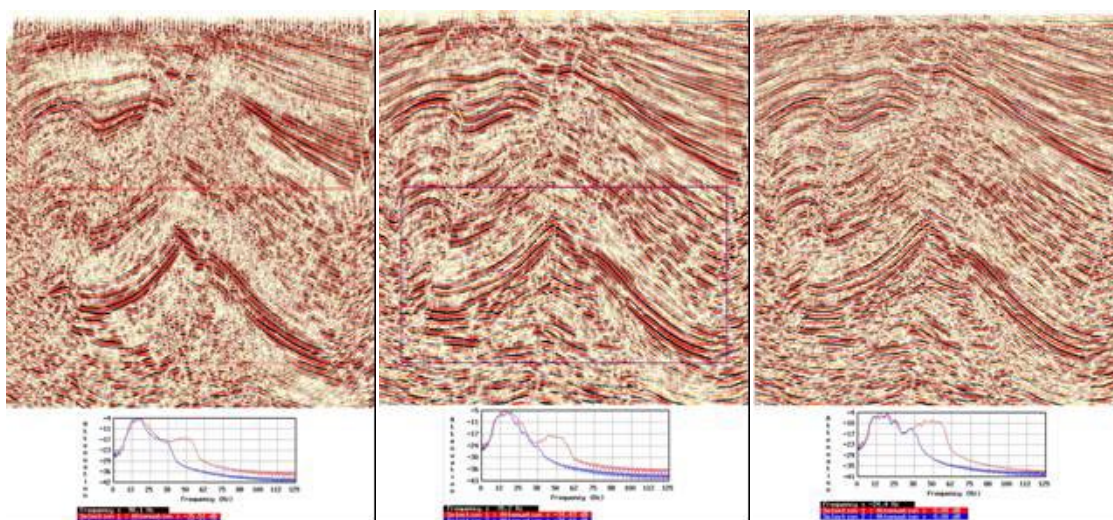


Fig 4.1, 4.2, 4.3. Power Spectra Displays: Original PSTM; Spectrum PSDM; Spectrum PSDM + REFINE

PSDM Conclusion

Kirchhoff pre-stack depth migration results showed considerable improvement as compared to existing time migration results. Notable areas of improvement included fault definition, structural details and improved resolution [Fig 5.1. – 5.6.].

Further enhancement of the image was achieved following application of REFINE technology to improve overall resolution and was especially effective on some of the weaker events. As such Spectrum achieved their objectives of producing a stack volume which would allow its client to more effectively resolve their reservoir model.

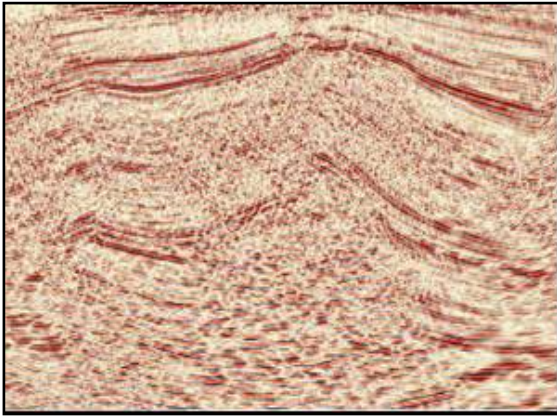


Fig 5.1. Original (3D OBC Time) Processing

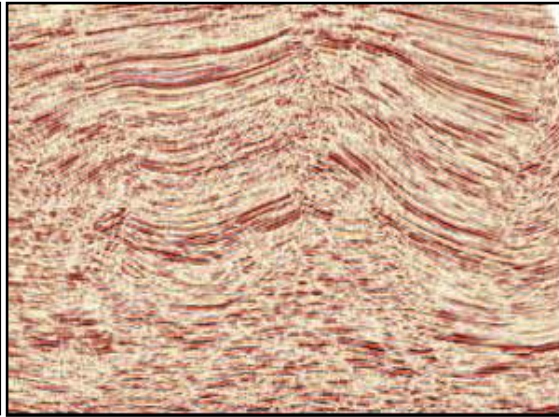


Fig 5.2. Spectrum (3D OBC Depth) Processing

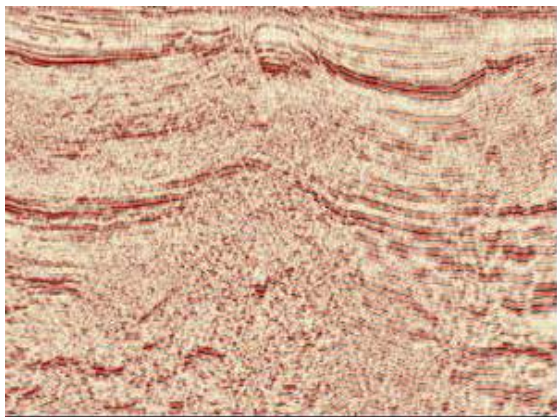


Fig 5.3. Original (3D OBC Time) Processing

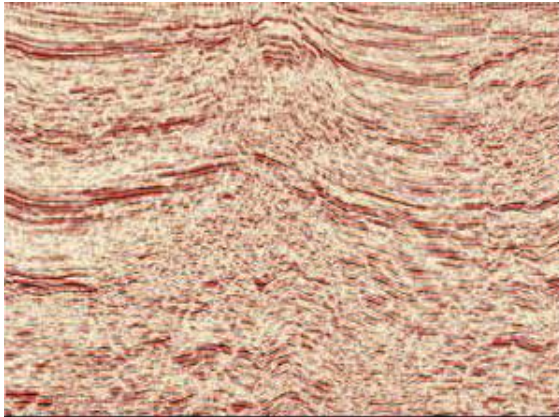


Fig 5.4. Spectrum (3D OBC Depth) Processing

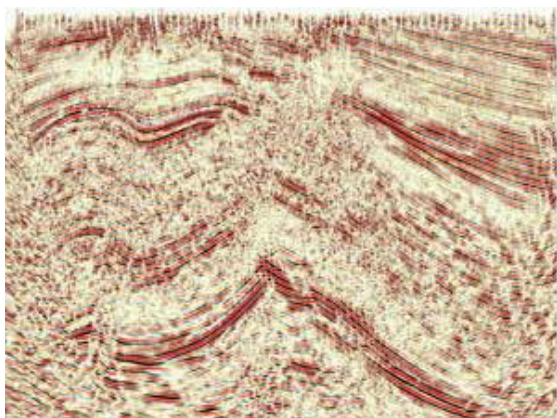


Fig 5.5. Original (3D OBC Time) Processing

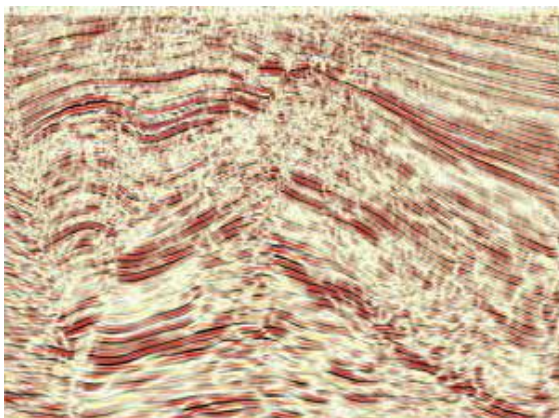


Fig 5.6. Spectrum (3D OBC Depth) Processing

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