Improved image aids interpretation: A case history

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SUMMARY

The Oritupano-Leona 3D of Eastern Venezuela was originally acquired and processed during the period from late 1994 through 1995. Since that time, seismic processing technology has been advanced significantly. This presented an opportunity to determine whether the original imaging could be improved to the extent that it supported a more confident interpretation. To this end, a portion of the 3D (about 10%) was reprocessed in mid 1997. In the reprocessing, more advanced interactive velocity analysis and Q.C. tools were used to assure optimal stacking and migration velocity fields. New noise attenuation and surface-consistent deconvolution algorithms were applied during the reprocessing to ensure that maximum signal-to-noise (S/N) ratio, vertical resolution and wavelet stability were achieved. Pre-stack time migration was used to help generate the best possible time-domain image. The result of these steps was a significant improvement over the original processing, particularly in areas disrupted by faults. This enabled the interpreters to choose new well locations in the faulted zone and extend their success from neighboring areas.

INTRODUCTION

The Oritupano-Leona Unit is situated in the Maturin Sub Basin, Eastern Venezuela. The Consortium Perez Companc Norcen Corod was awarded the unit in 1994 in the second marginal field bidding round. A 684 km^2 3D program was acquired during 1994-1995 with its objectives to accurately exploit the existing fields and delineate new exploration prospects. To March 31, 1998, over 94 wells have been drilled on the 3D dataset.

Exploitation of the fields has been more than a simple infill program and has demanded a high level of expertise from the various disciplines to accomplish the task. For the geophysicists, it has required an extremely accurate picture of the subsurface as exploitation of the remaining reserves requires the successful navigation of the well bore and interpretation of stratigraphy and ultimately the derivation of reservoir parameters.

Production comes from the sandstones of the Tertiary Oficina formation. Faulting is predominately extensional with a major East/West fault trend broken by a NE/SW fault trend. Most of the fields have both a structural and stratigraphic component to their trapping mechanism.

SEISMIC PROCESSING

This 3D was acquired using shot and receiver intervals of 60 m and with a nominal CDP fold of 28. The quality of most raw records was moderate, with some poor shots in the more geologically complex areas. The original processing proceeded in stages during the course of acquisition, and in order to maintain consistency, the processing software used remained fixed during the project. The final result was satisfactory to base an interpretation on, but the S/N level and fault imaging were just adequate. To improve the imaging over the original, the following key new or enhanced technologies were used during the reprocessing.

1. MERIDIAN Network phase matching filter

In this 3D dataset, two different sources were used. The primary source (approx. 90% of the shots) was Vibroseis with a 10 s. linear sweep from 8 to 120 Hz. The remaining shots were dynamite using either a one or two hole pattern. These sources have significantly different phase characteristics which required compensation prior to summing traces from the two different shot types within the same common midpoint gather. A network phase matching filter was applied to raw dynamite shots to match the vibroseis phase characteristics. Dynamite shots and vibroseis shots were intentionally recorded at the same locations and these were input to the MERIDIAN process (Gray, et al, 1992) to generate a frequency-dependent operator used to reconcile the difference between the two sources. The operator was then applied to the dynamite shots in order to match the phase of the vibroseis data. An earlier version of MERIDIAN with most of the current features was used on the original processing as well.

2. BLAST Ground roll attenuation

Ground roll was a major coherent noise problem on this dataset. A frequency-dependent noise attenuation process was applied that detects anomalous trace amplitude levels within specified bands. Where the amplitude envelope of a trace within that band exceeds a threshold value a time-variant scaler is derived and applied. For this project, the application frequency range was from 0 - 25 Hz, with all signal above 25 Hz remaining untouched by the process.

3. SHAPE Band limited surface-consistent deconvolution

Conventional methods of spiking deconvolution attempt to design an operator at all frequencies up to the Nyquist, and may suffer from contamination of the amplitude spectrum by unwanted noise outside the useful signal band. The high frequencies are often characterized by random noise while the low frequencies are often dominated by linear noise related to ground roll or air wave. There is also the problem that most seismic sources, including vibroseis, are band limited with respect to the frequency range available from typical temporal sampling rates. The goal of deconvolution is to filter out the wavelet effects to produce a bandlimited representation of the reflectivity, which itself is not generally white in the spectral sense, particularly at low frequencies. This process functions by deconvolving using a wavelet shaped to a desired frequency band, resulting in output with better vertical resolution, a more stable phase and which better represents the reflectivity.

4. DMOFX

This algorithm performs DMO in the log stretch F/X domain with amplitude and phase compensation. It preserves amplitude and phase characteristics of the seismic data and is particularly useful for datasets where the offset distribution within common midpoint gathers is variable due to irregularities in shooting geometry (Wang and Cheadle, 1996). The original processing had used an unequalized Kirchhoff-based DMO algorithm.

5. MOVES prestack time migration

MOVES is a practical, cost-effective approach to prestack time migration (PSTM) which is suitable for large 3D volumes recorded in areas with gentle topography. The traditional Kirchhoff based PSTM accomplishes the moveout correction and positioning in a single step, but is too slow to handle large-scale volumes. The MOVES technique separates offset focusing and spatial positioning into separate steps, enabling very efficient algorithms to be used at each stage. Following NMO and equalized DMOFX, a series of zero-offset migrations is performed on common offset planes using a fast phase shift algorithm based on a single velocity function. The result at this intermediate point is a suite of PSTM gathers with some degree of error in the focusing and positioning of events. A residual migration velocity analysis is then done to improve the focusing. Because of the efficiency of the MOVES method, more effort can be expended on detailed interactive velocity analysis and Q.C. in the migrated domain. The PSTM gathers are then corrected using the spatially-varying velocity field and stacked to form the focused section. The positioning errors are then resolved by demigrating the focused section with the original single function followed by a remigration with the spatially-varying migration velocities to produce the final properly focused and positioned image.

GEOPHYSICAL INTERPRETATION

Being able to accurately image the trapping configuration and delineate the stratigraphy of the sand reservoirs is the objective of the geophysicists. In some of the fields, the fault shadowing under the main bounding fault and complex internal structuring dominates making the interpretation particularly difficult. Interpretation becomes model based as the structural configuration in a good area is used and integrated into the poor data areas.

To that point a 60 km^2 subset of the 3D was chosen in July 1997 as a pilot project for reprocessing with the clear objective of improving the image of the data at the reservoir level. This area that has been very active in the last twelve months and because of mixed results in the wells and an upcoming drilling campaign, the production team deemed it was necessary to improve the quality of the seismic data and the interpretation.

The results of the pilot project were significant in areas of S/N improvement, increased interpretability of reflectors and image beneath the bounding faults. These gains can be attributed to the application of new technologies (DMO, prestack time migration, noise attenuation and improved velocity analysis). Application of a Veritas' surface-consistent shape deconvolution resulted in a stable wavelet and as broad a bandwidth as possible. Interpretation of the pilot project led to the recommendation and approval in October 1997 to reprocess the rest of the 3D database.

In Fig. 1, well #1 is a vertical well drilled prior to Perez acquiring the unit. Time/depth data from a nearby well allows the calibration of the wellbore geology to the seismic. In general, the geology ties well except the major bounding fault cut which does not correspond to the seismic fault trace exactly. Well #2 was proposed by Perez and prognosed from the original 3D processing to target hydrocarbon bearing closures on each side of the bounding fault. Well #2 was economically successful although the main fault contact occurred shallower than expected.

Well #1 and well #2 were integrated into a re-interpretation using the prestack time migrated volume. Comparing the two interpretations, the following is evident:

1. Both well now intersect the seismic fault plane as expected. The faulting is clear and unambiguous.

2. Structuring is far more complicated. Horizons that were smeared on the original interpretation (Levels J & U) are better imaged and are now fault segmented. This has a direct impact on the producibility of the reservoir and development of the field.

3. A complete change in the structural interpretation at the economic basement level. The new interpretation is difficult to validate as the changes are below the last producing sand interval.

4. S/N improvement. Horizons have more continuity and are easier to interpret.

CONCLUSIONS AND DISCUSSION

Comparisons of the original and reprocessed sections are shown in Figs. 2 –5. The improvement of structural image is observed on the reprocessed post stack migrated section (Fig. 3). The image is clearer and sharper than that of the original processed section (Fig. 2). The S/N ratio and reflector continuity was increased noticibly, with the noise attenuation and band limited surface-consistent deconvolution contributing to the improvement. Another important factor was the use of new interactive velocity analysis tools which provided more accurate stacking and PSTM velocities crucial to the success of the reprocessing. Incremental improvement also can be noted from the conventional post stack migration to the section with DMOFX followed by post stack migration (Fig. 4). Further improvements were realized through prestack migration with the MOVES method(Fig. 5). Reprocessing with advanced seismic processing techniques yielded a better quality section on which a more confident interpretation can be based.

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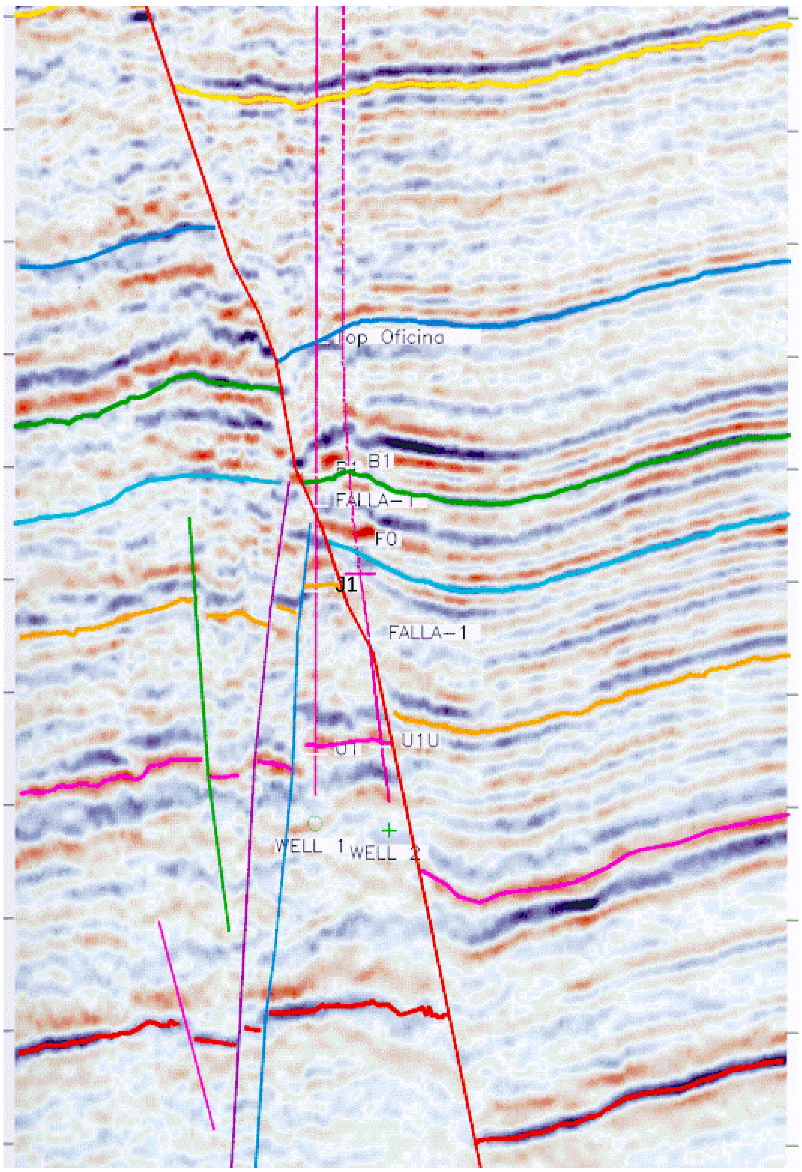

Fig. 1 Interpretation on the prestack migrated volume

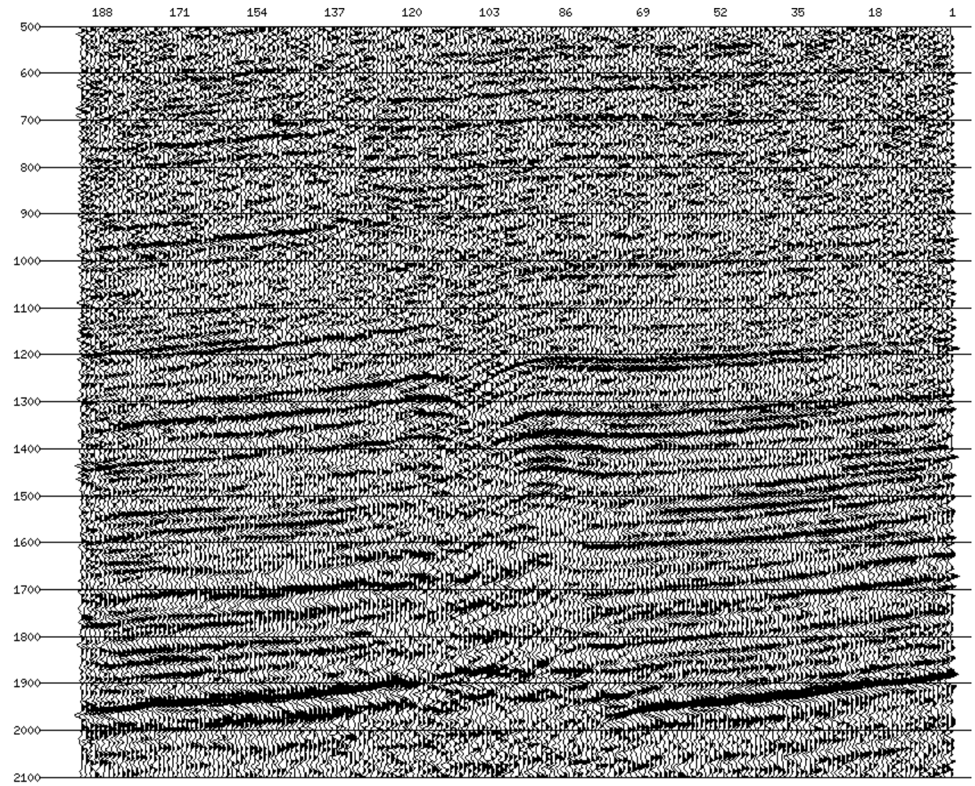

Fig. 2 Post stack migration of the original processing

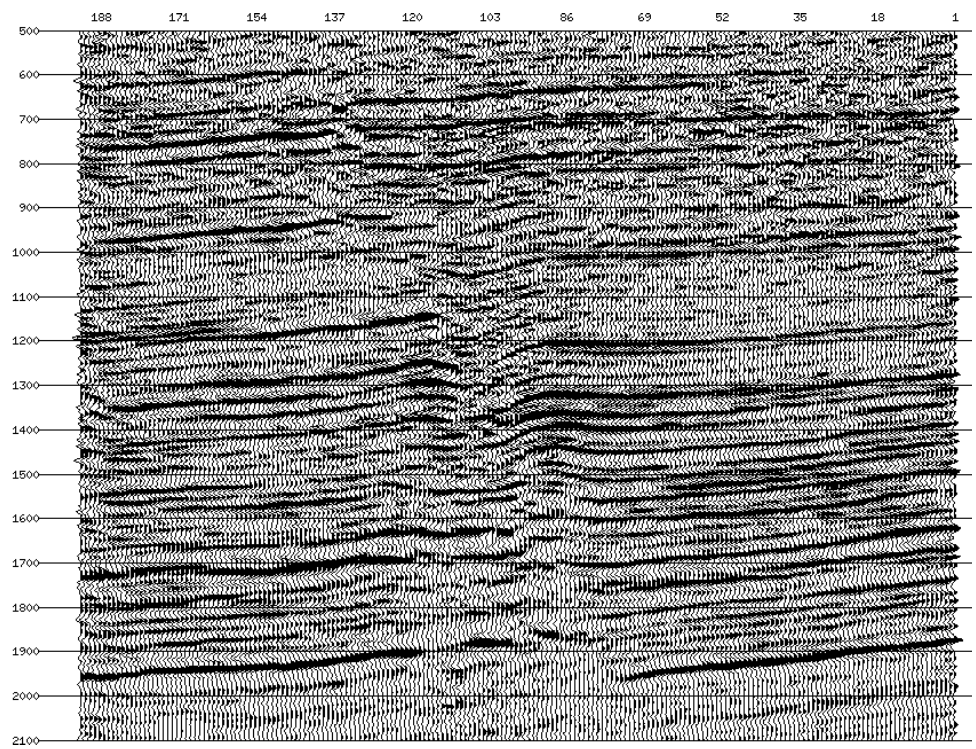

Fig. 3 Post stack migration of the reprocessing

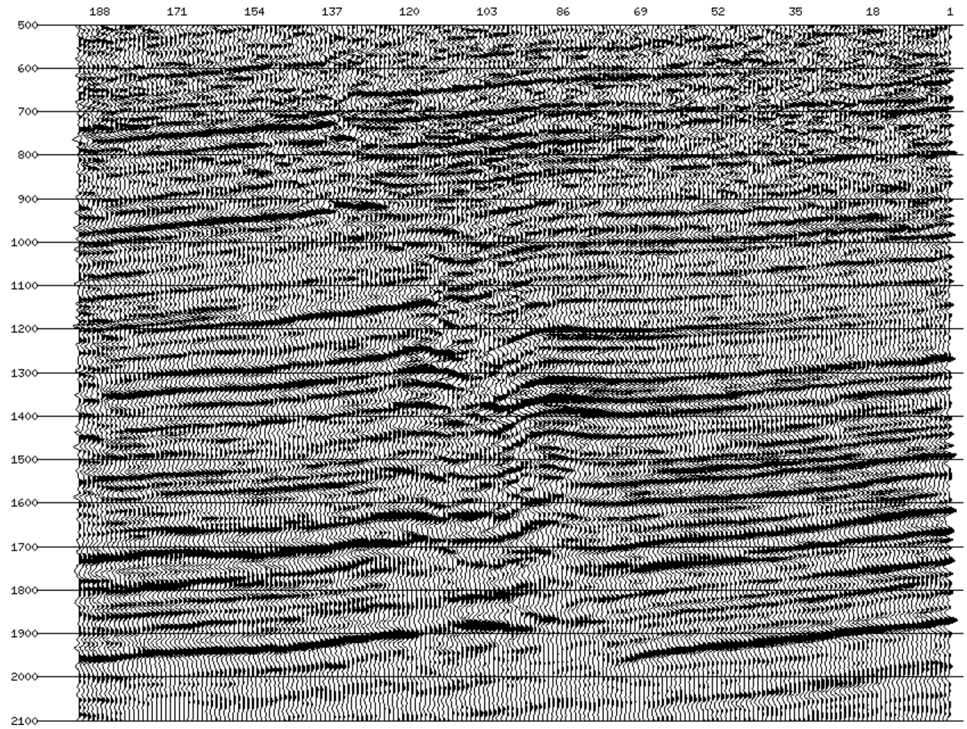

Fig. 4 Post DMO migration of the reprocessing

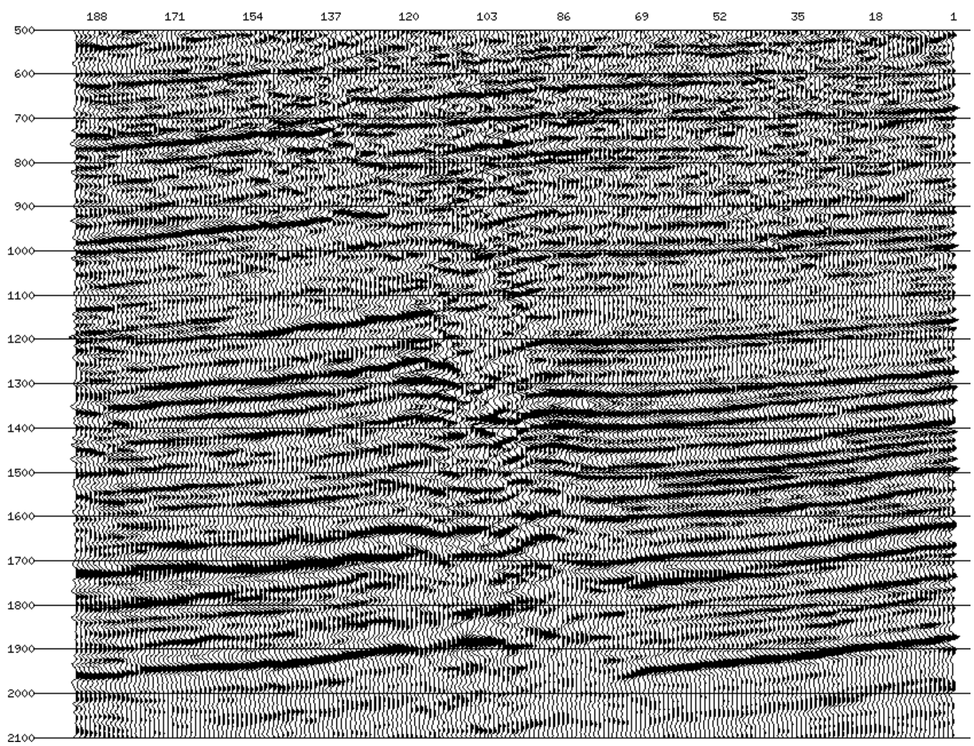

Fig. 5 Prestack migration of the reprocessing