Cerro Negro Field, Venezuela: Geological Images from a High Resolution 3-D Survey

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Following a pilot 3-D survey, Petrolera Cerro Negro acquired and processed a 3-D dynamite survey over the Cerro Negro Field in Venezuela. We designed the survey to achieve high frequency imaging at the relatively shallow (<1000 m) objectives in the Morichal formation.

The data exhibits usable frequencies in the 10-120 Hz range after migration. The results of the survey have satisfied the original objective of imaging the faults and basement structure in the field. Use of continuity measurements on the data has resulted in a photographic quality image of the faults at the basement level. The pattern of the faults indicates an unexpected degree of complexity, indicating a richer structural history than originally thought. The continuity data also shows depositional details in the Morichal, which is in accordance with the geological history of the area.

The operatorship is currently in the process of drilling many horizontal development wells. The patterns of the wells bores and variations in the rock types present a challenge to the usage of the 3-D seismic. The operatorship is working to raise the understanding and utility of the seismic data to another plateau.

INTRODUCTION

The Petrolera Cerro Negro partnership, operated by Operadora Cerro Negro, a wholly owned subsidiary of Mobil Oil Compay, has embarked on a project to produce synthetic crude oil from heavy 8-9° API oil in an area north of the Orinoco River (Figure 1). The geological trend in which the Cerro Negro area is located has over a trillion barrels of in-place reserves. The oil has to be produced, transported and refined in an efficient manner. This paper will present some contributions of geophysics to the production effort.

HISTORY

Petrolera Cerro Negro was formed in 1997. It is composed of Mobil Cerro Negro Ltd., PDVSA Cerro Negro, S.A., and Veba Oel Venezuela Orinoco GmbH. The partnership's goal is to drill and produce the heavy oil in the lease area as cheaply and efficiently as possible. To do this, a good knowledge of the surface and subsurface area is needed. Early production is scheduled to begin in August, 1999.

A pilot 3-D survey was run in 1996. The results of this pilot were encouraging, so a larger 330 sq km 3-D survey was shot in 1997. The processed results of the survey became available last year.

SEISMIC ACQUSITION

Source testing during the pilot survey indicated that the best source type and deployment was buried dynamite charges. The size of the charge and depth of burial optimize the bandwidth and noise characteristics of the data for the relatively shallow objective. The survey design produced 20 x 20 m bins of nominal 32 fold at depth. Source lines at 240 m spacing were shot at a 27 degree angle to receiver lines at 200 m spacing to produce a more even fold distribution.

SEISMIC PROCESSING

Seismic data processing steps emphasized preserving and using the bandwidth of the data. Careful attention to static solutions and stacking velocities achieved this goal. Wavelet processing results are excellent, producing a zero phase response at known reflectors. After migration we have usuable frequencies from 10-120 Hz.

GEOLOGICAL SETTING

The general geology and styles of faulting and depositon are well known, due mainly to the large number of wells. The main geologic objectives in the Cerro Negro area are the Lower-to-Middle Miocene Morichal Sands, the lowermost section of the Oficina Formation. These sands are composed of sediments transported from the Guyana Shield, which is located to the south. The sands have excellent reservoir characteristics with permeabilities of 3-14 Darcies. The Morichal Sands were deposited in a continental environment that became progressively more marine with time. Depositional features such as incised valleys are present in the area, but their detection requires special attention.

Underlying the Morichal Sands is a crystalline igneous basement. Basement normal faults are often reactivated and cut through the overlying sediments. The contrast between the Lower Morichal sediments with the basement produces a large acoustic impedance boundary reflection.

DATA EXAMPLES

Figure 2 shows a typical south-north dip section, and Figure 3 a typical west-east section. The top basement reflector is the strong amplitude event at the base of the organized reflectors and above the disorganized or random reflections within the basement itself. The wide bandwidth is apparent from the number of well defined reflection events within any specified time interval. For instance, there at least seven wavelengths of data within a 100 msec window at the objective.

INTERPRETATION

Well log correlation and forward seismic modeling indicated that there are no singular reflection events to be expected in the area except the top basement reflector and possibly the Top Middle Morichal, which is an exposure surface. Therefore, interpretation of the units and individual sand and shale units is very challenging. Nevertheless, there are interpretation techniques which use the seismic data and picked horizons to reveal details useful for the purposes of understanding the area and planning wells. Some of these techniques are discussed below.

We calculated seismic continuity to aid in interpreting the area. This technique has proven extremely useful in detecting and describing the basement fault patterns and patterns in other more continuous layers. A horizon continuity display at the basement shows the interconnection of the faults in extreme detail, even showing the en-echelon nature of some of the faults (Figure 4). This pattern may relate to strike-slip motion.

A horizon continuity display at an Upper Morichal level clearly shows valley features (Figure 5). The display further shows lateral changes within the valley, information which can be used in planning wells. Faults related to basement offsets also show up on this display.

We have further improved the quality of our works by careful pre-stack processing of the seismic data and editing and normalizing the well logs. Also a large effort is being put into better understanding the stratigraphic systems by recognizing and mapping incised valley systems in order to aim the wells to more productive targets.

Other ongoing efforts include acoustic impedance inversion and unsupervised neural network self-organizing maps. These techniques will render the seismic data in domains other than seismic amplitude, which should provide a greater degree of identification and separation of the objective units.

CONCLUSIONS

Three-D seismic data has already shown value to the drilling and producing operations at Cerro Negro. Continued study of the high quality seismic data will continue to provide guidance in well placement and reservoir description.

ACKNOWLEDGMENTS

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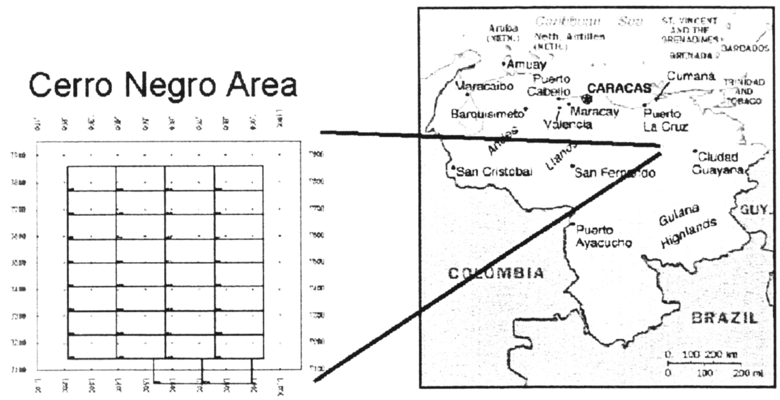

Figure 1: Location Map

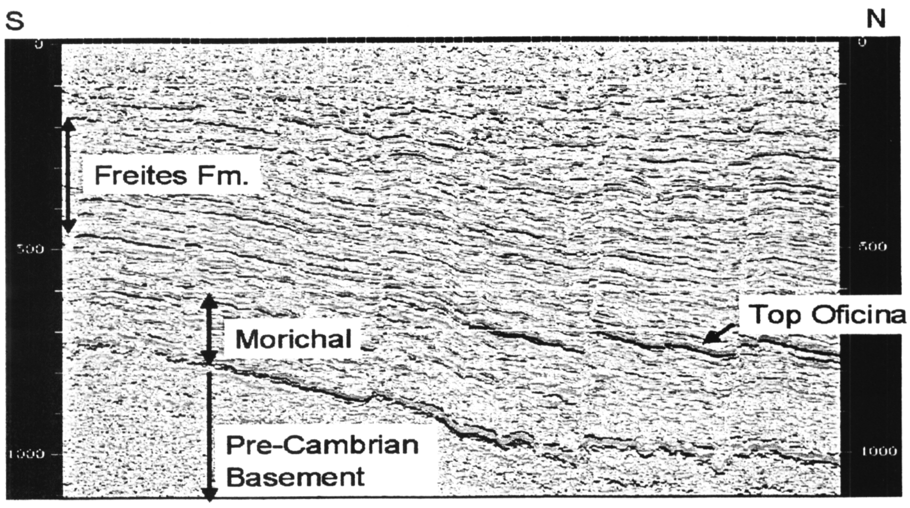

Figure 2: South-North Seismic Section

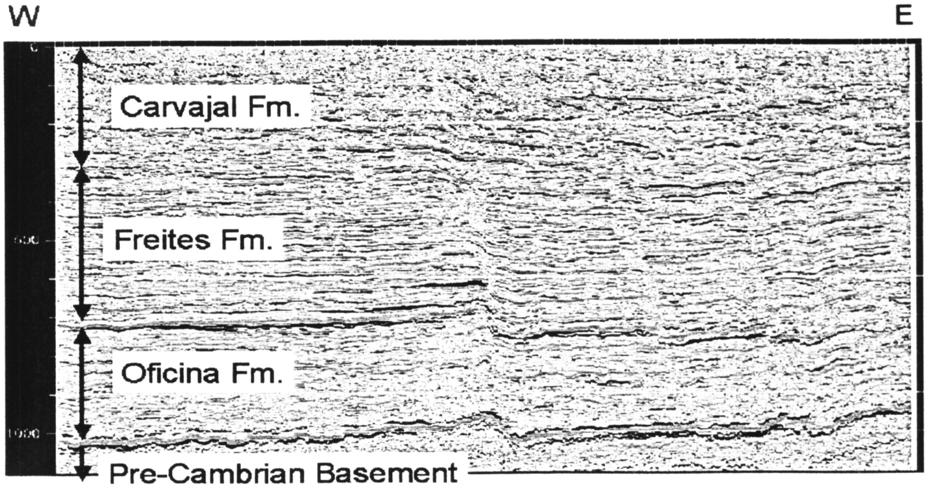

Figure 3: West-East Seismic Section

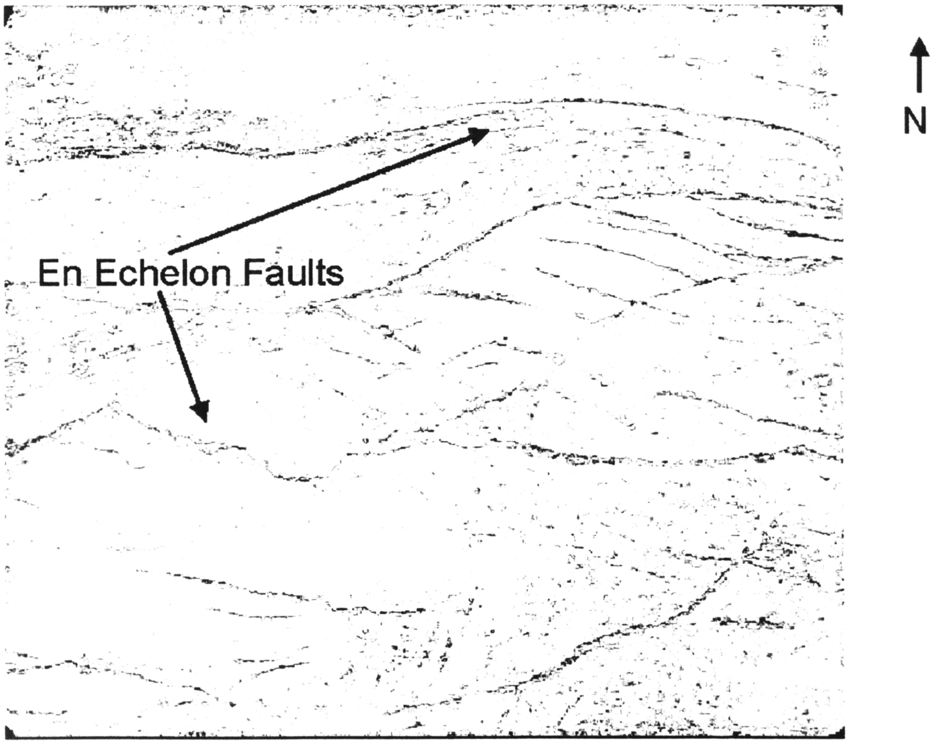

Figure 4: Basement Continuity

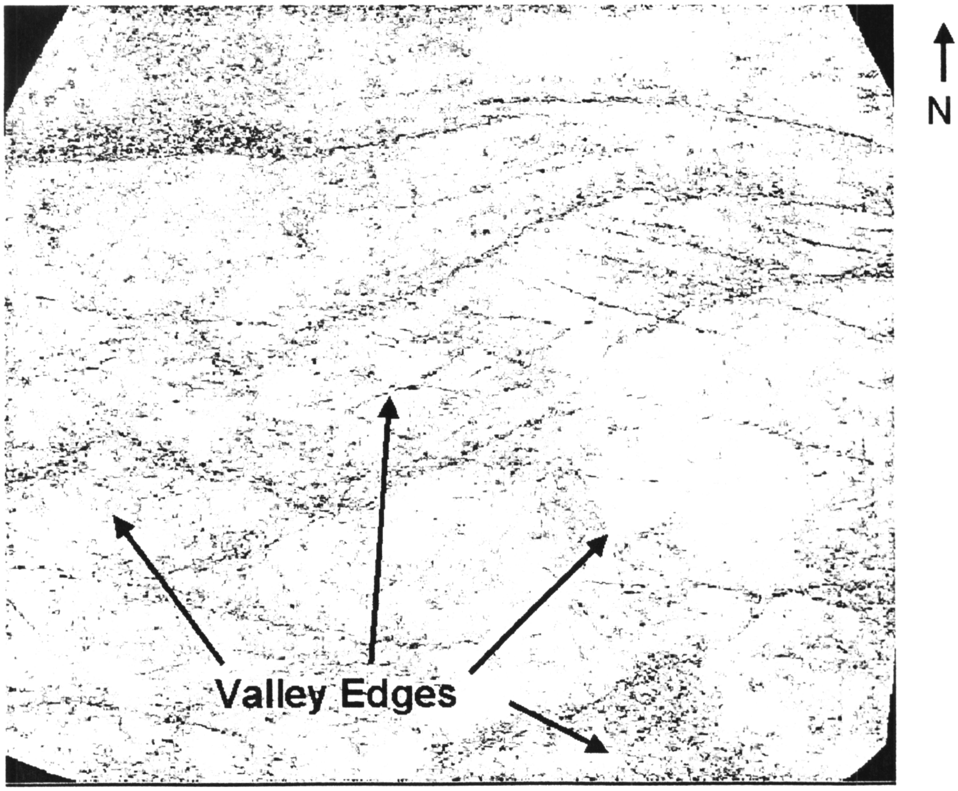

Figure 5: Intra-Upper Morichal Continuity