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Carbonate Reservoir Characterization Using 3-D Seismic Attributes And AVO: Example From Campos Basin, Brazil

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ABSTRACT

The Congro Field is located in Campos Basin, Brazil, approximately 90 Km away from the coast in a water depth ranging from 200m to 600m. The main reservoir is composed of fine-grained low permeability Albian limestones with good hydrocarbon reserves. The vertical wells drilled in this field were considered non-economic due to the low hydrocarbon productivity of the carbonate reservoirs. An area of the field was tested by a horizontal well in 1996 and presented high productivity. Then, it was conducted a detailed revaluation study involving multidisciplinary efforts (geophysics, geology and reservoir engineering) to obtain a better understanding of the reservoir characteristics and to improve the economicity of the field. The present work shows the results of the geophysical and geological reservoir interpretation using Congro 3D seismic data.

INTRODUCTION

Congro Field corresponds to a very large anticlinal structure associated to a rollover feature with an area around 100 Km^2. The main limestone reservoir occurs at a depth around 3,000m and has considerable hydrocarbon reserves. The Albian reservoirs are composed of fine-grained limestones that show good porosity (up to 28%) but low permeability values (usually less than 1mD). Earlier studies considered these reservoirs non-economic due to the low hydrocarbon productivity in vertical wells.

Lately, Petrobras has been using new drilling technologies, as horizontal and multilateral wells, to revaluate the reservoir productivity. The first horizontal well drilled in Congro Field in 1996, resulted in high productivity. Then, it was decided to conduct an advanced and integrated reservoir reinterpretation (1997/98) that involved multidisciplinary efforts, geophysics, geology and reservoir engineering, to improve the Congro economicity.

RESERVOIR INTERPRETATION

The initial step of the work was a careful data reprocessing of the Congro 3D volume, which lead to an excellent quality in terms of multiple attenuation, velocity data and preservation of relative amplitudes. After the seismic reprocessing, a detailed reinterpretation was performed. A better definition of the carbonate reservoir was achieved with the 3D seismic data, allowing a subdivision into four stratigraphic levels (R1, R2, R3 and R4). In acoustic terms they are vertically isolated, separated by tight limestones (non-reservoirs) but laterally they are linked (Figure 01).

These porous carbonates interbedded with very tight rocks show negative seismic reflection coefficients at the corresponding top, resulting in seismic amplitudes maps that are helpful to indicate the better porous zones. A detailed analysis of the seismic attributes of the Congro 3-D seismic data (amplitude, interval velocity and coherency) was made. The amplitude and interval velocities maps were used as a 3-D data tool to estimate porosity variation along the reservoirs. This integrated analysis resulted in the identification and mapping of seismic features, distributed along approximately NE-SW parallel trends. These features correspond to more negative seismic amplitude values and lower seismic interval velocities than the surrounding rocks (Figure 02). Keeping in mind that the original depositional environment largely controls the carbonate reservoirs distribution, these seismic features may reveal sedimentological features that correspond to the sites where the best quality reservoir rocks were deposited.

In 1998 a position structurally higher than in horizontal well (well D) was chosen to drill the first multilateral well in Congro Field. This well revealed the presence of carbonate reservoirs with gas and condensate (well B, Figure 02). After this result, a detailed study of amplitude variation with offset (AVO) were conducted. The AVO product map (intercept versus gradient) gave more accurate information about seismic amplitude of the interpreted depositional trends. Comparatively, the AVO map presents higher amplitude values to the well B position than the area tested by the well D. Additionally, the offset-dependent modeling for the carbonate reservoir in well B indicated that the absolute reflection coefficient increase slightly with the angle of incidence (offset) in the presence of gas, as opposed to the case of the oil-filled reservoir, that presented a slight decrease. These results indicate that the amplitude anomalies in the AVO product map probably represent the conjugated effect of porosity and, mainly, the presence of gas in the carbonate reservoirs of the Congro Field.

CONCLUSIONS

The integrated multidisciplinary efforts (geophysics, geology and reservoir engineering) improved the understanding of the carbonate reservoir characteristics and supported decisions about the economic viability of the Congro Field.

A careful 3D data reprocessing was a very important step for the detailed reinterpretation of the carbonate reservoirs.

Detailed analysis of the seismic attributes of the carbonate reservoirs (amplitude, interval velocity and seismic coherency) resulted in the identification of seismic features that correspond to sedimentological features, according to the depositional environment.

The AVO product map and the offset-dependent analysis of synthetic data showed that amplitude variations represent the conjugated effect of porosity and fluid type.

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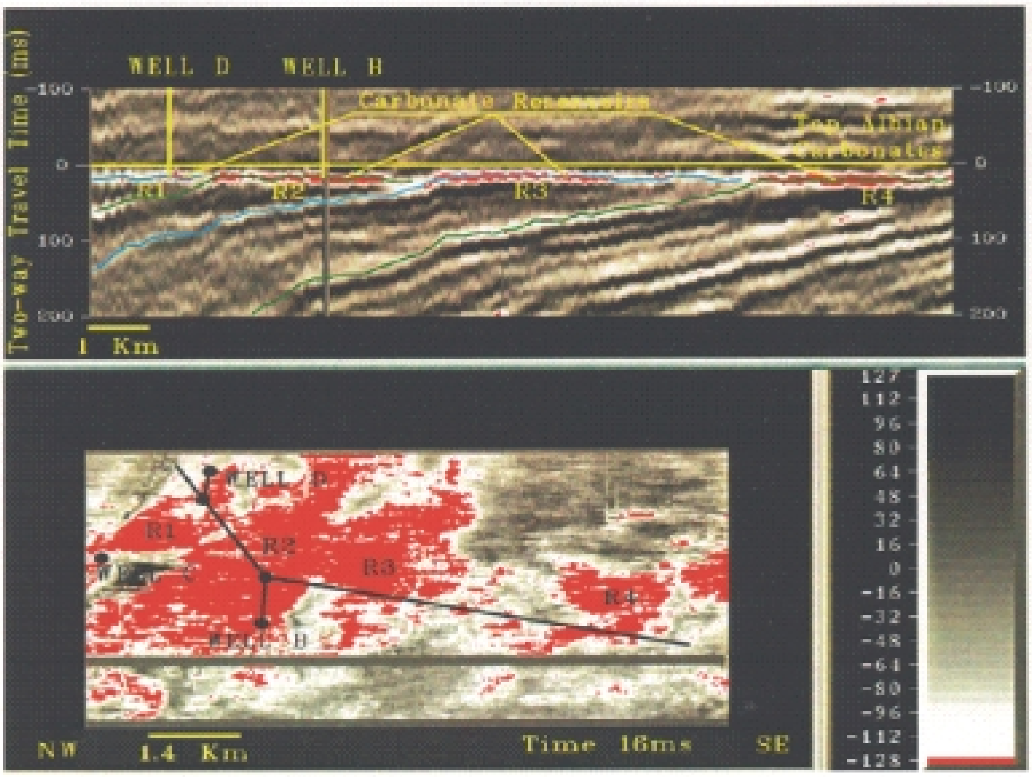

Figure 01: Flattened seismic profile showing the four interpreted carbonate reservoirs (more negative amplitude values) and time slice at 16ms below of datum. Line indicates location of seismic profile.

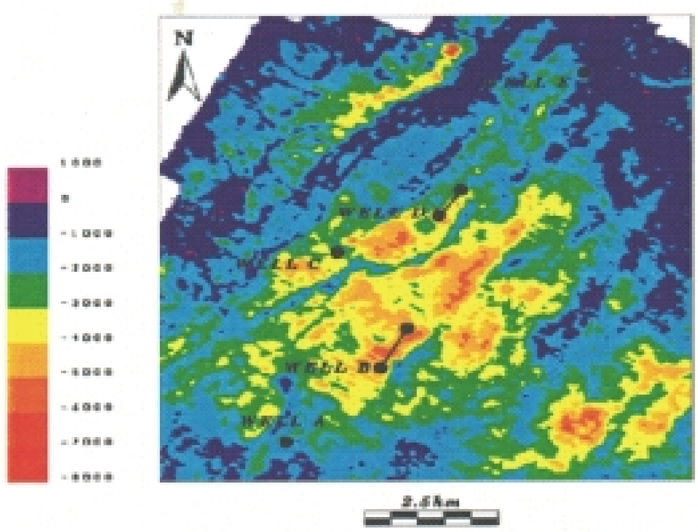

Figure 02: Seismic amplitude map of the carbonate reservoirs.