A seismic attributes catalogue for detecting hydrocarbons in the Macuspana Basin, Mexico.

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Summary

Over the last 4 years Petroleos Mexicanos (Pemex) has been combining different techniques in its process of documenting exploration opportunities and defining the limits of mature production fields. The basis for this effort has been a new aggressive strategy for tripling the production output during the current administration. Seismic data, new well drilling results and complete reservoir studies, which utilize new technologies, have been implemented to critically study the Macuspana basin from a different perspective.

Various AVO attributes and an impedance attribute have been calibrated to existing wells and attribute signatures for individual reservoirs have been derived. The correlation between anomalous attributes and producing wells is very high and new prospects are now evaluated according to the attribute responses.

The creation of an attribute catalogue has resulted in a more complete understanding of different reservoirs which, in turn, leads to an increase of the gas discoveries and a significant increase in the success rate for drilling in the Macuspana basin.

Introduction

The Macuspana Basin, which is located in the State of Tabasco, is a mature hydrocarbon-producing basin (fig.1).

During the next three years, Pemex's goal is to triple gas production. This can only be achieved by utilizing high-end technologies. Detailed AVO, inversion to acoustic impedance, elastic inversion and complete reservoir studies have been performed (Fusion 2002, CMG 2002). Existing well control allows for a detailed calibration of the calculated attributes and the well logs. The calibration results are combined in a catalogue to create a valid statistic between certain attribute responses and the presence of hydrocarbons.

Figure 1: Location map of the Macuspana Basin.

The seismic data, which have been input into the different attribute calculations, are processed with amplitude preserving processing sequences.

This paper discusses calibration results of existing wells and the success rate of new wells drilled on the derived statistics.

Method

At least two different AVO sand classes have been observed within the basin. Some reservoirs display a typical class-3 AVO behavior, e.g. a drop in acoustic impedance and an increase in amplitude with offset at the top of the sand. However, gas sands can vary from a class-3 to a class-2 or even a class-1 AVO response. For predicting class-3 reservoirs, conventional AVO attributes were calculated, though this approach is not useful in the presence of class-1 and class-2 sands. Elastic inversion, which is based on the AVO theory, is able to predict these reservoirs and has been used in parts of the basin, namely the Bitzal field. To confirm reservoirs indicated by the two AVO methods, the stacked data was inverted to acoustic impedance.

The seismic data were processed with a preserved amplitude processing sequence. This sequence included an offset varying amplitude balancing, noise attenuation, pre-

stack Kirchhof time migration, a detailed velocity analysis and zero phasing. The resulting CDP gathers were used for the AVO analysis and the elastic inversion. The stack of the preserved amplitude processed CDPs was inverted to acoustic impedance. This method helped eliminating errors at the calibration stage which were caused by incorrect seismic amplitudes.

The quality of the final seismic gathers was questionable at the near offsets. To compensate for this, the incidence angle range for the AVO attribute calculation did not include these traces (figure 2).

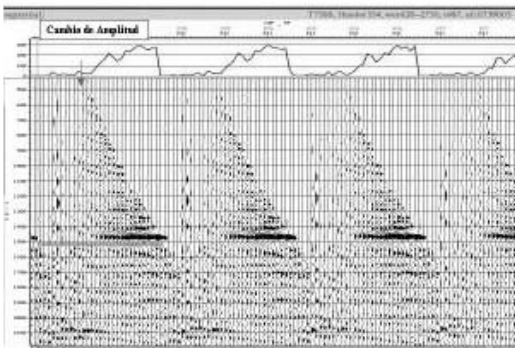

Figure 2: Seismic CDP gathers after preserved amplitude processing. These zero phased gathers were the input for the attribute calculation. Please note the amplitude problems at the near offsets.

Zero phasing of the seismic data is an essential part of every attribute study. Only attributes derived from zero phased data can be directly calibrated to well log data.

The well logs were edited and smoothed in order to allow for a more accurate calibration. At most well locations a very good tie between the attribute response and the reservoir response from the logs was achieved. This resulted in an attribute signature for producing versus non-producing wells, which was then used to find new drilling locations.

Examples

The Cobo field is a mature gas field in the Macuspana Basin. The top of gas-saturated sands normally displays a class-3 AVO response. It has been assumed, therefore, that a conventional AVO study, which generates product stack and fluid factor attributes, should predict new drilling locations. Figure 3 displays a composite line of the product stack attribute through various well locations. Positive anomalies are colored red and according to theory should indicate the presence of gas sands. A very good agreement between positive anomalies and gas sands can be observed on all seven well locations. For example, the wells Cobo-7 and Cobo-4 do not intersect hydrocarbon-bearing reservoirs and no positive product stack anomaly is present at these locations.

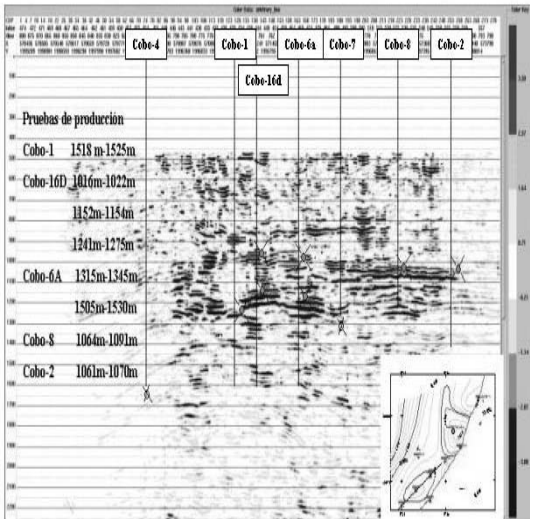

Figure 3: Composite line of the product stack attribute at different existing well locations. Red color indicates positive AVO anomaly and the presence of gas sands.

After a successful relationship between positive product stack anomalies and producing reservoirs was established, the AVO attributes were employed to design new drilling locations. Detailed geological studies, which result in confirmation of the presence of reservoir conditions at anomalous locations, helped earmark such areas for future drilling locations.

Other producing fields in the basin display different geological settings and different AVO responses. Over some of the reservoirs the reflectivity is very weak, which represents an additional difficulty. This is caused by a low acoustic impedance contrast at the top of the gas sands. To complicate things further, synthetic modeling showed that at the top of these sands, the near offsets display a positive

reflectivity which changes phase at the far offsets and results in a typical class-2 AVO response. Conventional AVO does not resolve these gas sands, so elastic impedance attributes were calculated. For example, the elastic attribute Poisson's ratio calculated from a pre-stack inversion does not differentiate between class-3 and class-2 AVO responses. In theory it only reacts to the drop of Poisson's ratio at the presence of gas and therefore can be used in all AVO class scenarios.

Well	Field	Attribute response	Reservoir
Akot-1	Vernet	Yes	Testing not finished
Jose Colomo-1001	Colomo	No	Mechanical failure
Vernet-601	Vernet	Yes	Producer
Bibiloni-1	Colomo	No	Not tested
Lotatal-1a	Vernet	Yes	Producer
Tak-1	Vernet	No	Not producing
Chunel-1	Vernet	Yes	Producer
Mohina-1	Morales	No data	Not producing
Shishito-1	Fortuna Nacional	Yes	Producer
Akaito-1	Fortuna Nacional	Yes	Being tested
Chilapilla Oeste	Chilapilla	No	Mechanical failure

Table 1: Summary of drilled wells, attribute responses and reservoirs characters.

Location	Basin	Attribute response	reservoir
Chilapilla somero	Chilapilla	Yes	Prospect
Yukin-1	Fortuna Nacional	Yes	Prospect
Akot somero	Vernet	Yes	Prospect

Table 2: Summary of new drilling locations and attribute response.

Table 1 shows a summary of existing wells, attribute responses and different reservoirs. The AVO and impedance attributes seem to characterize the individual reservoirs quite well and are now being used to establish new drilling locations within the Macuspana Basin as seen in Table 2.

Conclusions

The Macuspana Basin in Mexico exhibits varying geological settings and seismic responses in the presence of gas. Conventional seismic attributes do not provide a good method for predicting hydrocarbons, so a number of AVO and impedance attributes were generated. A detailed calibration study with attributes and existing wells shows a very good correlation between attribute anomalies and the presence of hydrocarbons.

Proposed prospects are re-ranked by taking the AVO and impedance attributes into account. Wells drilled since the completion of the study show a high success rate and the method is being used for all future drilling. The production rate of the whole basin has been increased dramatically by deriving specific attribute signatures for individual reservoir settings. Carefully preparing the seismic data and combining seismic attributes and well log responses achieves this.

A geological interpretation and understanding of the structure is necessary for detecting hydrocarbons but is not sufficient in most cases. Seismic derived attributes, which are designed for individual, different reservoirs, add much needed information for reducing the risk and increasing the production output.

Reference

Fusion 2002, Cobo Area Reservoir Characterization Project Cobo, Bitzal, and Guiro Fuilds, Pemex report.

CMG 2002, various attribute and reservoir studies, Pemex reports.