Rock Properties Estimation in the Vivian Sand in Northern Peru

POS 2.16

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SUMMARY

The Capahuari Sur Oil field is located in the North-central part of the Maranon Basin. This basin extends from Southern Columbia through Eastern Ecuador and Northern Peru. 80% of the discovered Oil reserves have been found in the Upper Cretaceous Vivian Formation. The Vivian Formation consists of fluviodeltaic sandstones with thicknesses varying from 40 to 200 feet (Del Solar 1982). A 3D seismic survey was collected over the oil field in 1976. The objectives of this study are to determine the lateral extension of the oil field and the spatial distribution of both the water saturation and porosity of the Vivian Sand. The foregoing objectives were accomplished with the use of a recursive seismic inversion technique, flattened horizontal sections along the producing sand, and by cross-plotting the seismic and well log data. The results obtained from the cross-plotting of the seismic and well log data consist of maps showing the porosity and water saturation distribution along the Vivian Sand. Porosity values vary from 5 to 14% and water saturation has an average value of 7% in the oil bearing zone.

INTRODUCTION

The 3D seismic data were collected using a modified "SEISQUARE" method. It consisted of 14 contiguous rectangles covering a total sub-surface area of 13.125 square miles, as shown in figure 1. With this particular shooting geometry, the center of the rectangles are highly affected by the stacking velocity field, this is, it could introduce spurious time anomalies with the reflection events still having the same stacking response. The solution to this problem was given by maintaining the Interval Velocity between the strong reflection events relatively constant.

In order to obtain reliable results from the seismic inversion process, the seismic traces needed to be properly conditioned. This means that the residual wavelet convolved with the reflectivity function must be zero phase. The calibration of the seismic traces was done through the use of crossequalization filters between the seismic and synthetic traces derived from three wells in the oil field.

PROCEDURE AND INTERPRETATION

The flowchart shown in figure 2, outlines the procedure taken in this study to calculate the water saturation and porosity distribution in the producing sand.

Although the structural shape of the Capahuari Sur field has been well known for a number of years, it is necessary to delineate the structure for this reprocessed data volume in order to "flatten" the inverted traces. The two seismic horizons at which the data volume was flattened, are the base of the Vivian sand and a limestone inside the Chonta Formation. The reason for the flattening to the limestone inside the Chonta Formation, was because the time structure map of the Vivian sand shows a jitter caused by poor data quality, namely two fold traces, and it does not represent the true structure of the formation. Within the Capahuari Sur field the interval between the base Vivian sand and the top of the limestone is almost constant. Consequently it is also valid to flatten at the top of the limestone and take time slices at Vivian sand level. The horizon picking and flattening was done in an interactive interpretation workstation. It was found that there exist a small velocity difference along the Vivian sand, 450 ft/sec, in the zones where it is water saturated and oil saturated. The interactive interpretation workstation was particularly helpful in displaying the flattened data volume, because the small velocity difference contrast can be enhanced by choosing contrasting colors. By using this velocity contrast criteria enhanced by colors, from a set of time slices of the flattened data volumes, one can estimate the areal extent of the hydrocarbon bearing zone by simply contouring the color change. Figure 3 is a map showing the areal extent of the oil bearing zone from the flattened velocity data volumes.

After the seismic inversion and flattening process is completed, there is a uniform grid of velocity values across the entire survev area.

In order to crossplot velocity and well log data, there must be a similar grid of well log parameters to match the velocity grid. There were 24 well logs used in this study and its distribution is also shown in figure 3. To obtain the log parameters grid it was needed to input more control points by manually contouring the formation water resistivity "Rw", and the formation resistivity "Rt". The missing points were estimated by means of gradient determinations based on least squares best plane fitting through the input points and their closest neighbors.

The crossplot approach in formation evaluation, is probably the simplest and most effective method for estimating the water saturation in any given formation (Picket and Towle, 1976). The concept is based on the recognition of common variables in the response equations of two log measurements, and by elimation of these common variables, a third measurement or parameter can be obtained. In this study, velocity, formation resistivity and the calculated formation water resistivity are the known variables. Hence by using Archie's (1942) and Geertsma's (1956) equations:

$$Rt = P \exp(-m) * Rw * I \quad \text{(Archie)}$$

$$Dt = Dtm + K * P \quad \text{(Geertsma)}$$

where:
- P = Porosity
- m = Cementation factor
- Rw = Formation water resistivity
- I = Water saturation indes = Sw exp(-n)
- n = Saturation exponent
- Dt = Transit time
- Dtm = Rock matrix transit time
- k = Fluid transit time

and by substituting P and taking the logarithm base 10, we have:

$$\log Rt = \log Rw + \log I + \log K - m \log(Dt-Dtm)$$

By making a log-log plot of Rt and (Dt-Dtm), all the points with equal water saturation, constant m and Rw, will lie along a straight line. All the points to the right of the 100% line will have an Sw less than 100%, see figure 4.

Porosity values can be calculated in several different ways, the approach taken in this study is by direct application of Geerthma's equation and for comparison purposes it was also calculated using Archie's formula for the formation factor "F".

$$F = Ro / Rw = P \exp(-m).$$

CONCLUSIONS

In this study a methodology to obtain reservoir rock parameters has been presented This methodology consolidates borehole measurements with a three dimensional seismic survey to provide water saturation and porosity estimates in the reservoir rock by using a crossplot technique. Although these were the only parameters calculated, the technique can be extended to estimate other reservoir rock characteristics.

The seismic velocity and well log resistivity crossplots, provided results that are shown in figures 6 and 7 and summarized below:

The water saturation values obtained for the Vivian sandstone, vary from 7 to 100%. The 50% water saturation contour which is taken as the upper limit for production purposes, agrees reasonably well with the velocity contour map derived form the interpretation of the flattened velocity volumes by themselves. The porosity values derived by direct application of Archie's formula vary from 5 to 14%. When using Geertma's equation for porosity it varies from 5 to 22%. This discrepancy is to be expected form the two different types of measurements.

In spite of the apparent agreement between known oil production and seismic attributes (velocity, amplitude), the authors wish to caution the reader that because of the slight change in rock properties caused by oil vs water, there might be alternative explanations for the correlations.

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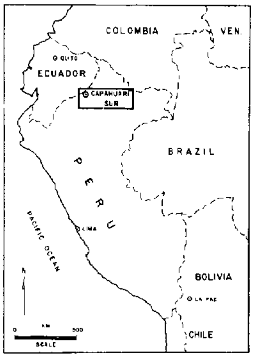

FIG. 1. Political map.

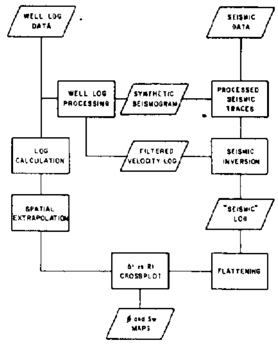

FIG. 2. Data flow chart.

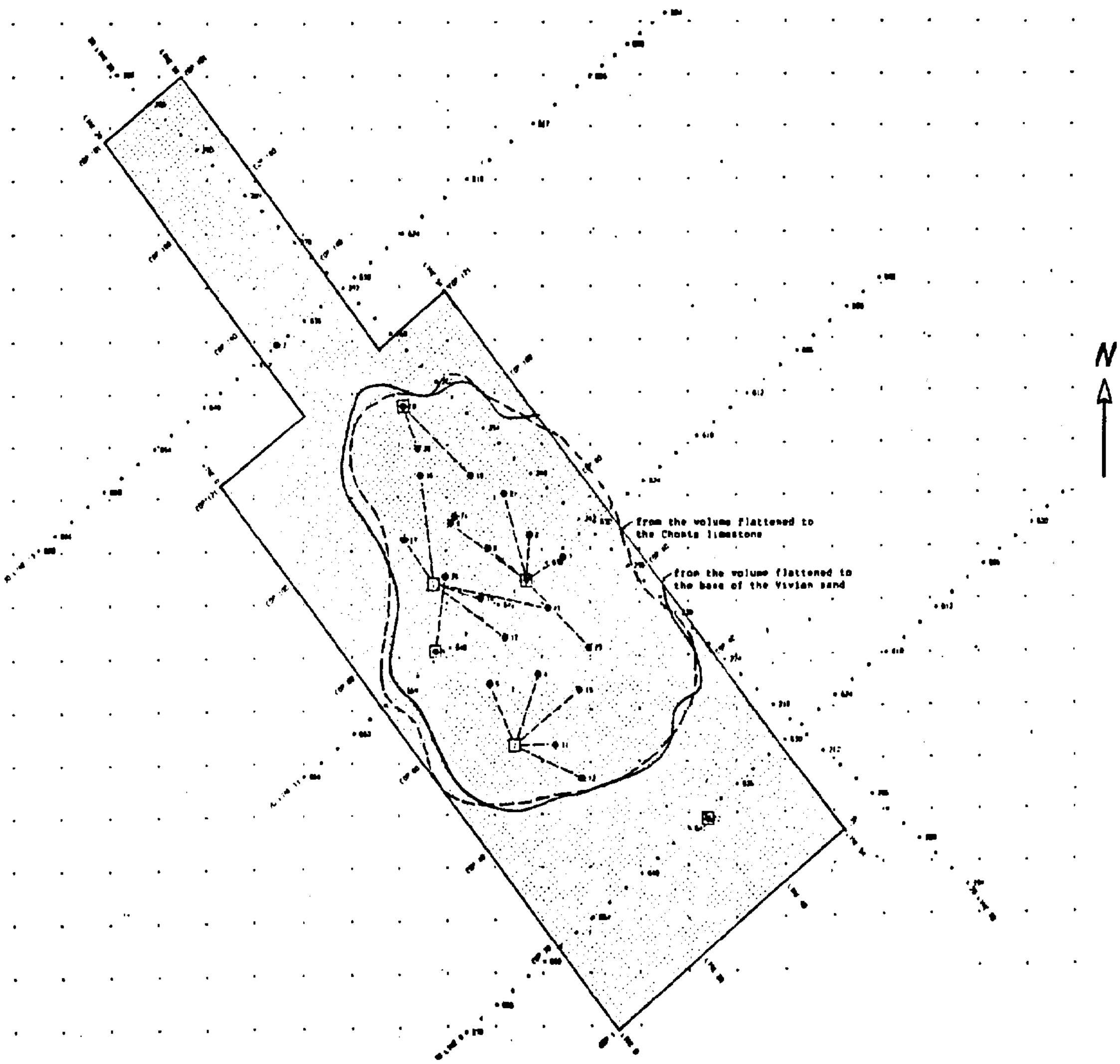

FIG. 3. Hydrocarbon areal extent.

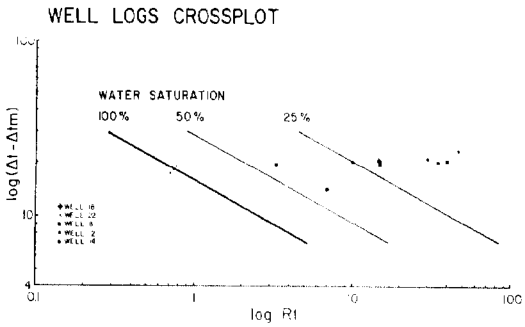

FIG. 4. Well log data crossplot.

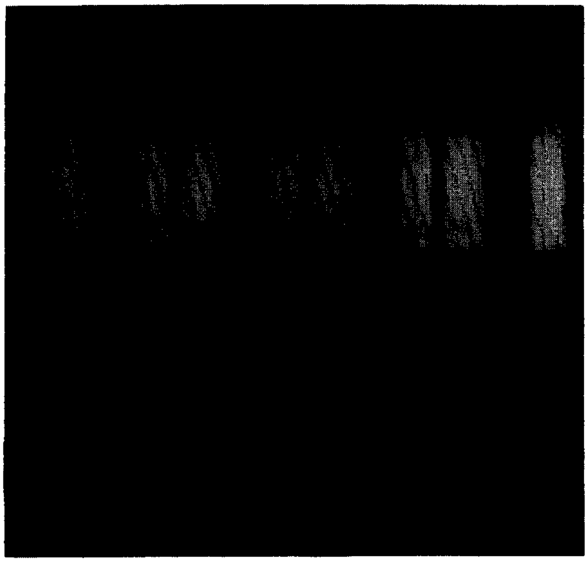

FIG. 5. Final crossplot results 1.

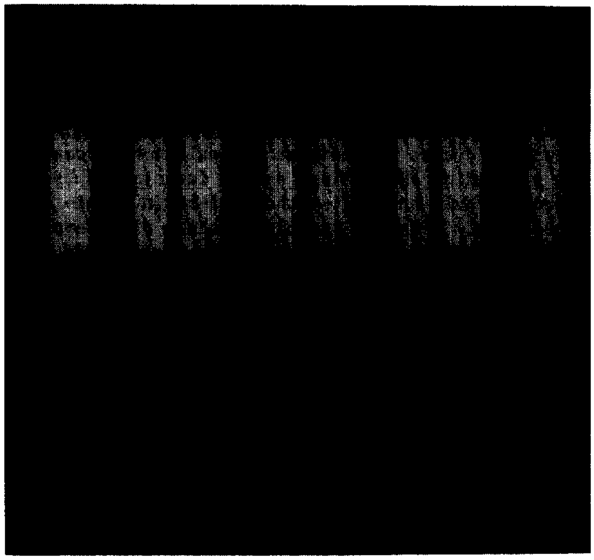

FIG. 6. Final crossplot results 2.