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LOG ANALYSIS OF LAMINATED RESERVOIRS

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ABSTRACT. In some regions of Potiguar Basin offshore Brazil can be found thin laminations that are missed by conventional logging tools with low vertical resolutions.

In this particular well, the conventional logs showed some zones to be so shaly that they would have little or no porosity if investigated using those curves together with standard log interpretation techniques.

INTRODUCTION

The case study well lies on the offshore portion of Potiguar Basin in the Northeast of Brazil. The sands in the zone of interest are a mixture of quartz and orthoclase very pyritic.

Conventional log analysis discarded the zone based on it's high shale content calculated from the crossplot Density-Neutron, Gamma Ray or Spontaneous Potential.

The purpose of this paper is to show that the superior vertical resolution of the CAST (Circumferential Acoustic Tool) combined with the LARA (Laminated Reservoir Analysis) program can greatly enhance reservoir evaluation in sands with laminations.

BASIC CONCEPTS

The vertical resolution of the conventional logging tools as the ones currently run in that area vary from 12 inches for the Gamma Ray, 24 inches for Density - Neutron - Dual Laterolog - High Resolution Induction to 40 inches for the Dual Induction. Those values are too high compared with the thickness of the laminated sands in the zone of interest.

Most logging tools measuring porosity, resistivity, radioactivity etc. can only register average values of sand and shale properties in thinly laminated reservoirs. Using the standard log analysis based on conventional logs will led the analyst to estimate wrong values of porosity and water saturation, this will induce him to eliminate zones which could be hydrocarbon bearing if properly analyzed with the right log interpretation tools.

Only logging tools with very small radii of investigation such as the Dipmeter, Microlog, High Frequency Dielectric and unfiltered Pe have vertical resolutions enought to deliniate thin beds. Another tool with high vertical resolution is the Circunferential Acoustic Scanning Tool. The CAST tool is an ultrasonic device where a transducer located in a rotating head fires an ultrasonic pulse and receives it's echo. Of the reflected signal the tool measures two properties : travel time and amplitude. Travel Time (sometimes called time of flight) is the elapsed time between the transducer's firing and that instant when highest amount of returning energy arrives. The amplitude measurements made by the CAST Tool are associated with the reflected ultrasonic energy from the borehole wall. The reflectivity factor is related with the acoustic impedance of the formation which has a strong dependance with lithology. The tool covers the whole borehole and from this image covering 360 degrees it calculates an Average Amplitude curve which is an linear average of Amplitude in every scan.

A new technique was developed by Naum Ruhovets and described in the papers " A Log Analysis Technique for Evaluating Laminated Reservoir in the Gulf Coast Area " (Ref 1) and " Evaluation of Laminated Complex Carbonate and Sandstone Reservoir from Well Logs" (Ref 2), this program called LARA (Laminated Reservoir Analysis) uses conventional logging suites combined with a high resolution shale indicator to resolve thin laminated reservoirs. The basic assumption is that the shallow devices can be used to isolate thin beds within laminated reservoirs, and to determine shale volume. However, the establisment of properties such as porosity, resistivity and water saturation of the thin beds has to be done using logs with degraded vertical resolution, in conjunction with the high resolution shale indicator. This is possible mainly because the laminated shaly sand reservoir is a binary system (sand and shale), and a change in properties of each of this components within the vertical resolution of most tools is usually very small compared with the drastic differences in properties between two components and consequently changes in the composite properties of the reservoir. Since a sand component property and the logs with degraded vertical resolution usually have similar frequency characteristics, the former can be adequately reconstructed from the logs. Consequently, the high frequency composite log can be derived from the component data and a high frequency shale indicator. In this technique volumes of shale from the crossplot Density-Neutron and from a high resolution shale indicator integrated to the vertical resolution of the Density and Neutron logs are estimated. Then those shale parameters are adjusted to match each other employing an iterative aproach. Using the adjusted parameters the program computes porosity, and shale volume/mode of distribution from the Density/Neutron logs and recompute these results to the high vertical resolution of the shale indicator. Then this information is used to rebuild the conductivity log to the same vertical resolution. Finally water saturation using a Waxman-Smits model when both dispersed and laminated clays are present is calculated. The final result are the Lithology, Porosity and Water Saturation with much higher resolution.

INTERPRETATION

The logs run in this well were GR (Gamma Ray), CDL (Compensated Density), CNS (Compensated Neutron) and DLL (Dual Laterolog) being this the standard suite in this area. (Fig 1)

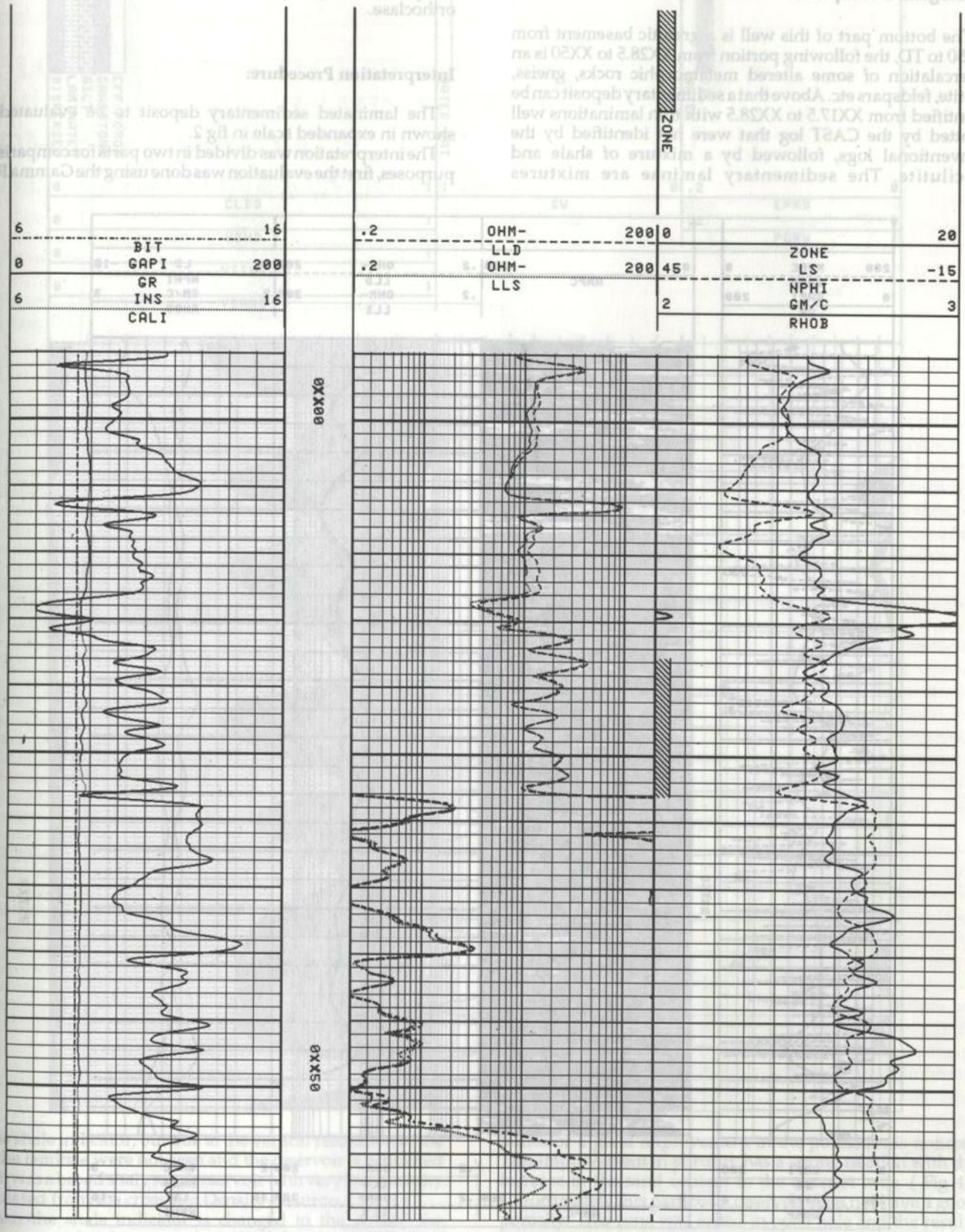


Figure 1: Ruhovets, N. A Log Analysis Technique for Evaluating Laminated Reservoirs in the Gulf Coast Area. 12th CWLS Formation Evaluation Symposium, Paper C, Calgary, Alberta, September 26-28, 1989.

Geological Description

The bottom part of this well is a granitic basement from XX50 to TD, the following portion from XX28.5 to XX50 is an intercalation of some altered metamorphic rocks, gneiss, biotite, feldspars etc. Above that a sedimentary deposit can be identified from XX17.5 to XX28.5 with thin laminations well spotted by the CAST log that were not identified by the conventional logs, followed by a mixture of shale and calcilutite. The sedimentary laminae are mixtures composed mainly of quartz with small amounts of pyrite and orthoclase.

Interpretation Procedure:

The laminated sedimentary deposit to be evaluated is shown in expanded scale in fig 2.

The interpretation was divided in two parts for comparison purposes, first the evaluation was done using the Gamma Ray

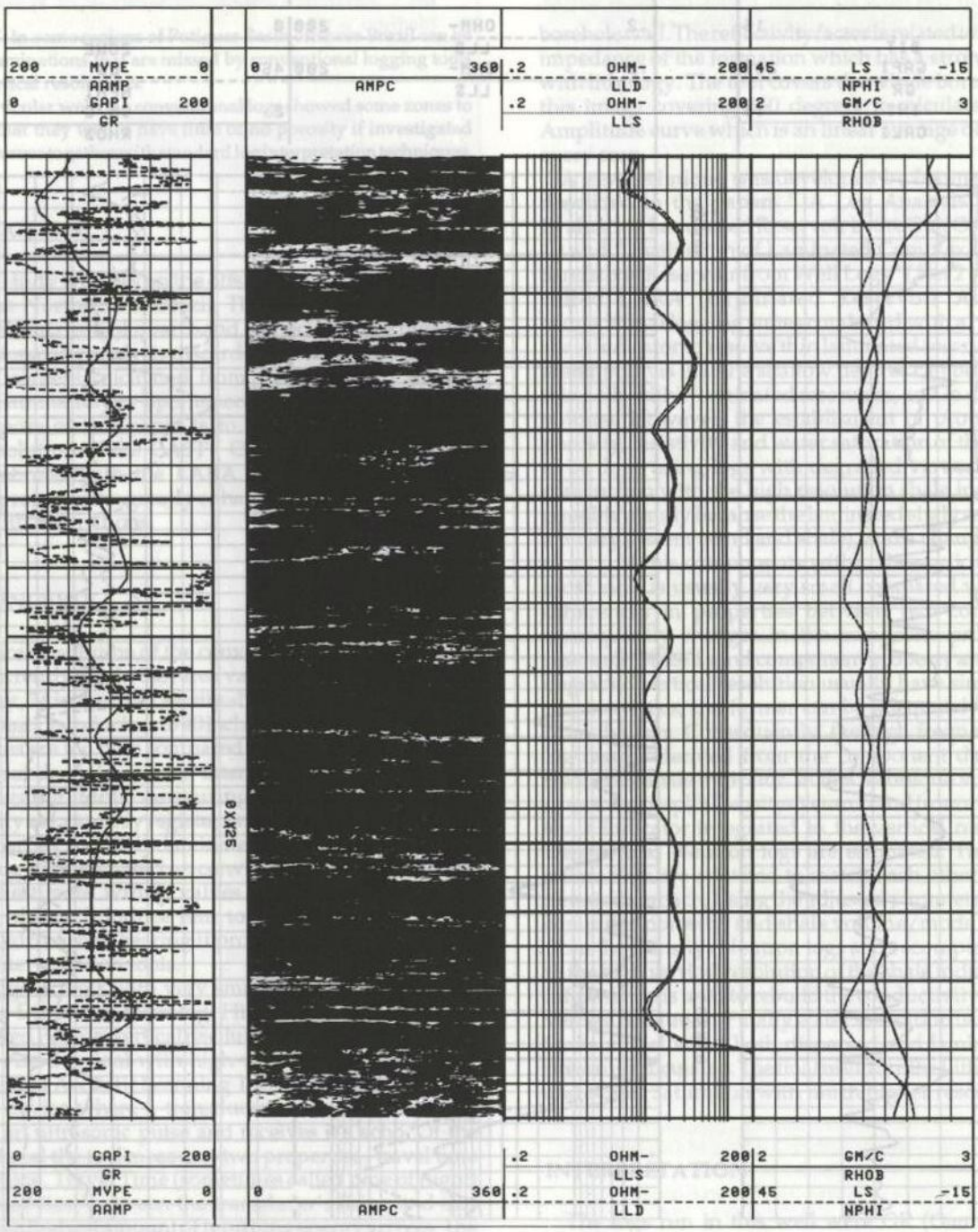
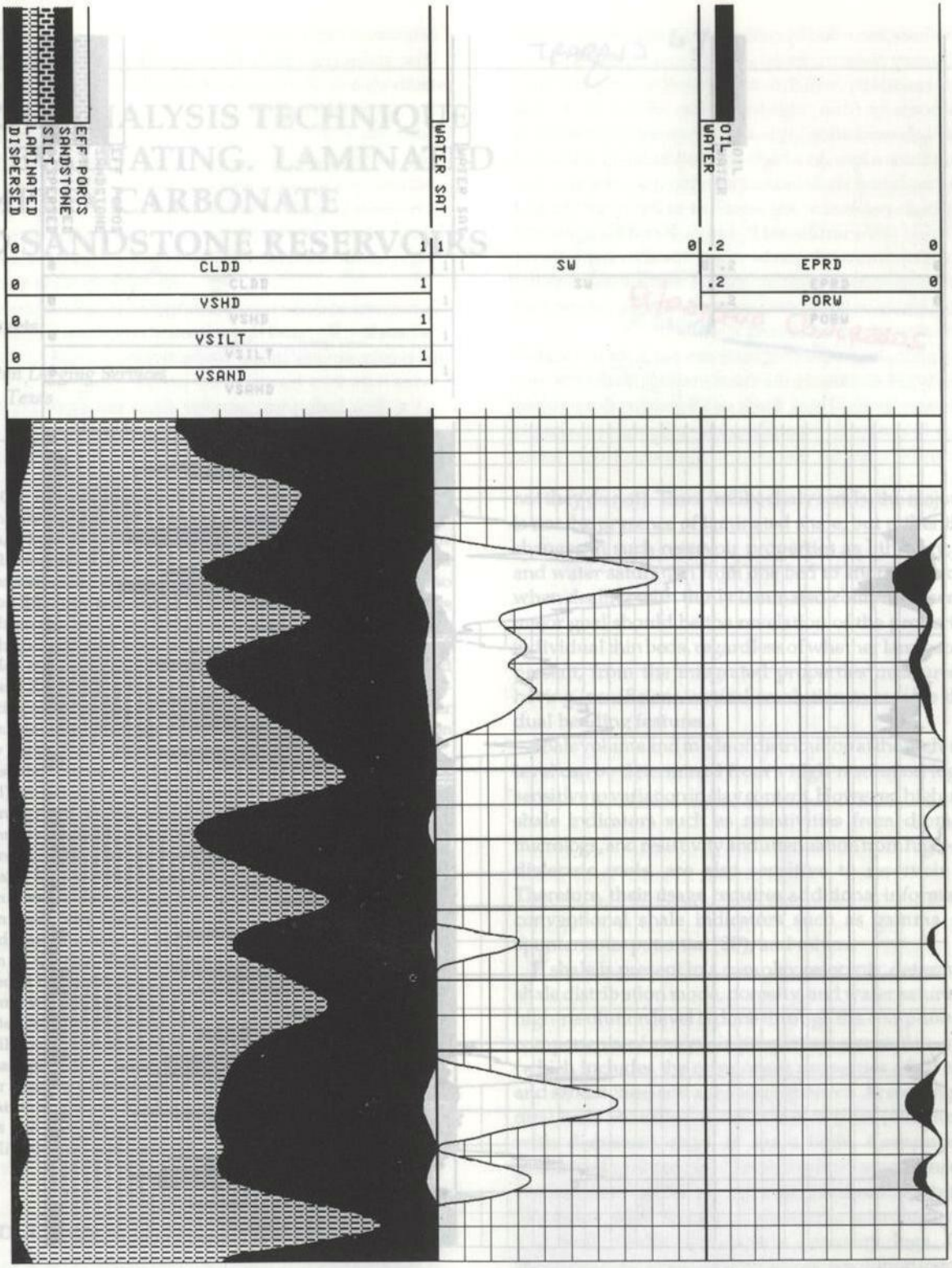
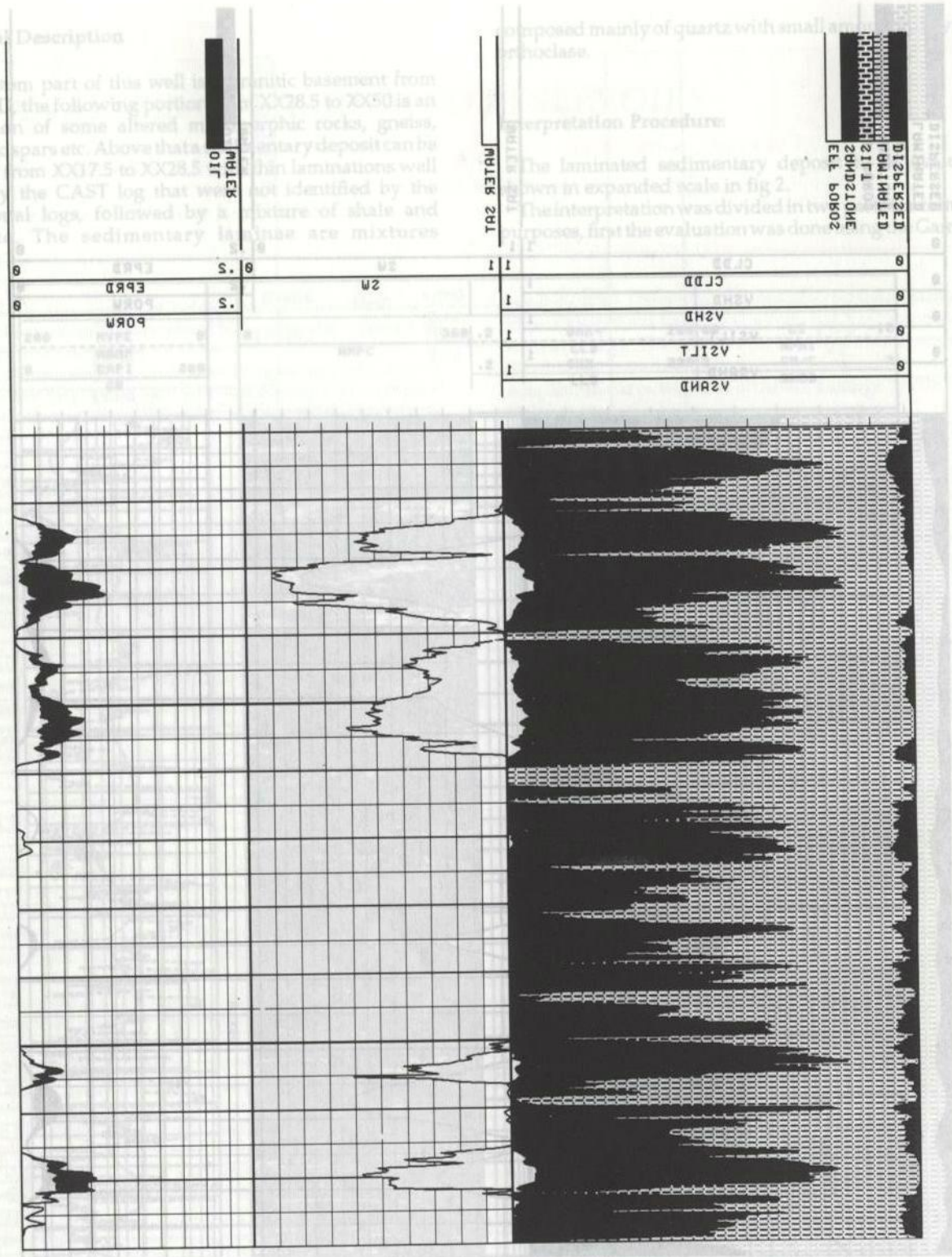


Figure 2: Ruhovets, N. Evaluation of Laminated Complex Carbonate and Sandstone Reservoir from Well Logs 3rd Latin American Petroleum Congress, Paper TT-163, Rio de Janeiro, RJ, October 18-23, 1992.



as the shale indicator, but due to the vertical resolution of the GR the laminae were not seen and the reservoir is estimated as if it was a broad shaly sand reservoir with very low porosity calculated from the crossplot Density-Neutron. (Fig 3)

Then the shale indicator is changed to the AAMP the average amplitude curve furnished by the CAST tool. Reprocessing the LARA using this high resolution shale indicator a good improvement in the porosities is noticed. This improvement in porosity has a strong relation with the increase in the sand content in the cleanest beds. (Fig 4) Unfortunately this particular reservoir does not have a good porosity. This zone was tested in open hole and the results were that it was hydrocarbon bearing but with very low permeability as expected in this range of porosity.



CONCLUSION

In this case study the combination of CAST and LARA undoubtedly helped to more accurately calculate porosity and water saturation. They would have been miscalculated using conventional logs and log interpretation methods as the ones available today.

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