# Methodology for Characterization of a Clastic Reservoir Based on Correlations between Electrofacies, NMR and Image Logs. A Case Study from the Gulf of San Jorge Basin

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**Abstract**

This work presents a methodology for characterization of clastic reservoirs. It has been developed with data from the Bajo Barreal formation in the Golf of San Jorge Basin. The methodology is based basically on the definition of Electrofacies and their correlations with conventional open hole logs, resistivity image and NMR logs (T2 distributions and Diffusivity maps); in addition, these data have been associated with information from neighbor wells and 3D seismic.

The electrofacies analysis has allowed us to interpret sedimentary deposits in a continental environment. Furthermore, it yielded information on structural dip of the area and the directions of paleoflows of the reservoirs, which has been found to be in agreement with the seismic interpretation and outcrops observations at the surface.

As a result of this study, a reservoir classification could be established, supported by criteria related to sedimentary genesis, petrophysical characteristics and fluid typing, for which NMR log analysis has added a very significant value.

This methodology for reservoir characterization will find future implementations in the generation of geological models, especially in areas with enough amounts of data at disposal. These areas are of particular interest for purposes of validation and testing the new generated models, towards reducing the uncertainty in the selection of future well locations.

## INTRODUCTION

The The Golfo de San Jorge Basin has a mainly fluvial depositional environment, where the reservoirs are very difficult to characterize, as their petrophysical properties are not easy to correlate against each other; therefore, the generation of a sedimentary model is very important for the reservoir development

This work intends to show how the log data from high technology tools, utilized whether as individual or in combination among themselves, along with information from seismic and outcrops can be integrated into a geological model.

The present study was developed with information from the Bajo Barreal formation, which is part of the Chubut Group (Lesta, 1968), of Cretaceous age (Fig. 1). The production layers are sedimentites from the West side of the basin. This group represents the sedimentary activity of the thermal subsidence age, posterior to the Jurassic rift, the origin of the basin (Figari *et al.*, 1999).

Although many authors believe that the depositional environment of the Bajo Barreal formation is fluvial, many diverse, paleo-environmental models have also been proposed. The range of scenarios can go from ephemeral currents (Hechem 1994) to perennial rivers in a humid temperate climate (Bridge et al., 2000). In general, it is accepted that these so called sedimentites are product of river systems activities in an environment characterized by the permanent contribution of piroclastic material, especially in the basal section of the formation (tuff section). Within the geological succession, the reservoirs are constituted by the numerous body layers placed in the river belts, conforming a multilayered reservoir system, frequently without any lateral connectivity. The thickness average of the sandy bodies is of 3 m, with a lateral extension that varies between 300 and 1500 meters.

The structural configuration of the productive column of the zone responds to the superimposition of the two recognized deformation styles for the western side of the basin: 1. the extensional structures associated with the Jurassic rift, of predominant orientation WNW-ESE, and 2. the compressional train of sub-meridian course, linked to the Andean compression (see Fig.2, from Sanagua et al., 2002).

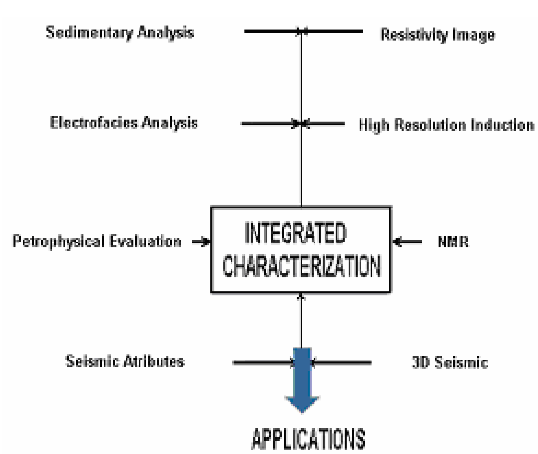
## PROPOSED METHODOLOGY

The proposed reservoir characterization methodology has as main objective the generation of a geological sedimentary model, based on the detailed analysis of log data from high technology open hole logging tools, as High Definition Resolution Induction (HDIL), Resistivity Images (STAR) and MREX for NMR logging, and to integrate the log data with geophysical (seismic) and geological data (outcrops) from the analyzed area.

The resistivity image is obtained from a six-pad logging device recorded with 24 buttons each, covering 60% of the circumference for 8 inches well bore. The image log allowed the detailed sedimentological analysis of the main reservoir layers of the formation. In addition, by means of statistical analysis, the direction of paleoflows can also be determined.

The MREX logging tool is run in the PoroPerm + Oil data acquisition mode (Chen *et al*. 2003). It provides the NMR data to be evaluated with two post processing modules: the Formation Evaluation and Diffusion-T2intrinsic maps, for rock quality and fluid type characterization purposes respectively. The outputs of this evaluation are the total and effective porosities, hydrocarbon types, oil and water saturations, discriminating between bound and movable water, and NMR permeability. By quantifying the heavy oil saturation from the D-T2int maps, it is also possible to correct the permeability for the presence of heavy oil, normally affecting the bound fluid volume (Romero et al, 2007).

**Table 1 schematic methodology for integrated reservoir characterization**




The sedimentary analysis carried out on these log data intents to define different types of reservoirs based on probable common characteristics, which can be associated with the reservoir quality.

**ELECTROFACIES AND GEOLOGICAL INTERPRETATION**

From the nalysis of electrofacies, done following the Serra and Abott criteria (1982), and of internal images structures, interpreted from the image logs, one can infer that the sandy bodies do have a common sedimentary pattern. These characteristics are also very important in the evaluation of the textural variations, of tonality and structures obtained from the analysis of the dips patterns observed on the images. The heterogeneity in the resistivity image allows inferring on important variations of the petrophysical properties of the layers.

**Reservoir Type I**

This reservoir type presents important thickness with probable parallel stratification, separated in sets with increasing arrangement (form of block). The abundance of such sand bodies with these characteristics permits to infer on the presence of amalgamated sequences, formed by smaller bodies that conform the greater sequences. These reservoirs show good petrophysical properties, otherwise deteriorated in reservoirs of different types (Fig. 3).

The thickness of this reservoir type is variable and the contact is generally erosive and occasionally transitional. The occasional presence of contacts of erosive base, suggests events of high flow regime for the backfilling after the erosive events took place. The arrangement is clearly grain descendent in depth. The conditions of deposition are clearly associated with traction processes, suggesting the presence of crossed stratification in trough and parallel. The image shows marked sedimentary characteristics determining regular distribution of the porosity. Transportation of bed loads in traction process.

**Reservoir Type II**

The thickness of this reservoir type is variable; its contact is generally erosive and sometimes transitional. The occasional presence of contacts of erosive base, suggests of high flow regime events for the backfilling after the erosion. The arrangement is clearly grain descendent in depth. The conditions of deposition are associated with traction processes, suggesting the presence of intercrossed stratification in trough and parallel. The image shows marked sedimentary characteristics and hence a regular distribution of the porosity. Transportation of bed loads in traction process (Fig.4).

**Reservoir Type 3**

Presents poor deflection on the SP curve, with sharp peak shape; the resistivity contrast does not result very significant. These reservoirs have a high dispersion of the dip patterns. Transportation as bed loads in traction processes (Fig.5).

**Evaluation of reservoir quality by means of NMR logs**

The deliverables of the post processing regarding rock quality evaluation from the MREX log are:

- MPHS: Total porosity
- MPHE: Effective porosity –
- MBVI: Associated porosity to capillary bound water Implacable Fluids
- MBVM: Associated porosity to mobile Fluids
- Kc: Permeability Index by Timur-Coates (Fig.6).

The parameters utilized to define the quality of the reservoirs are: the NMR-Permeability from Timur-Coates equation and the associated porosity of movable fluids (MBVM), also the amounts of movable and bound fluids, which are very precise indicators of the reservoir quality.

## FLUID TYPING

NMR based fluid typing is based on the evaluation of the reservoir oil (heavy, medium, light) from the 2D-NMR maps. These maps also allow a quantification of the fluids, so that a saturation log for the invaded zone can be generated (Fig.7).

## APPLICATIONS OF THE MODEL

With the interpretations carried out on the resistivity images of this well is possible to infer a probable depositional direction and the possible orientation of the sandy bodies. Due to the presence of variations in sedimentary media in the study area, the directions of paleocorrientes evaluated using a geological sedimentary model, can be considered more reliable for reducing uncertainties related to select future well locations (Fig.8).

## CONCLUSIONS

- The utilization of a similar log suite and the used of the electrofacies methodology for determine the depositional environment can be used for selecting well locations that will allow the consolidation and extrapolation of the model or, eventually, its gradual modification.

-NMR can be used for rock quality determination and fluid typing purposes in this type of formation and electrofacies.

-Examples can be verified in the Cañadon Vasco reservoir, operated by Repsol-YPF in the Golf of San Jorge Basin.

## ACKNOWLEDGEMENTS

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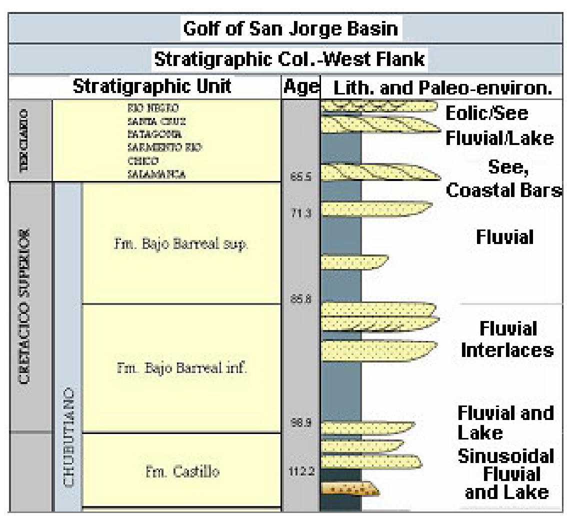


**Figure 1 Stratigraphic column Bajo Barreal formation.**

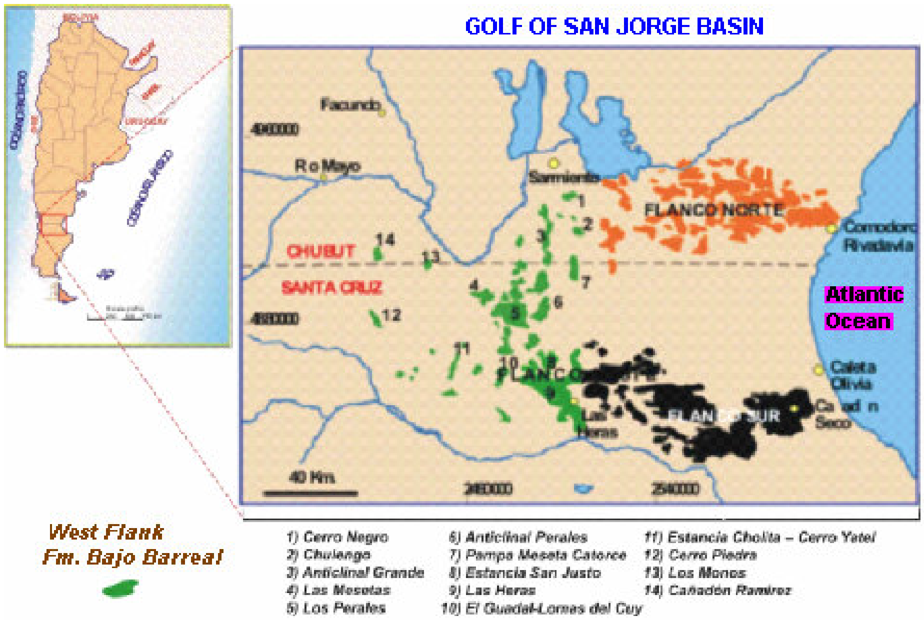


**Figure 2 Geographic location of the Golf of San Jorge Basin and details of the reservoir within the West Flank (from Sanagua et al, 2002).**

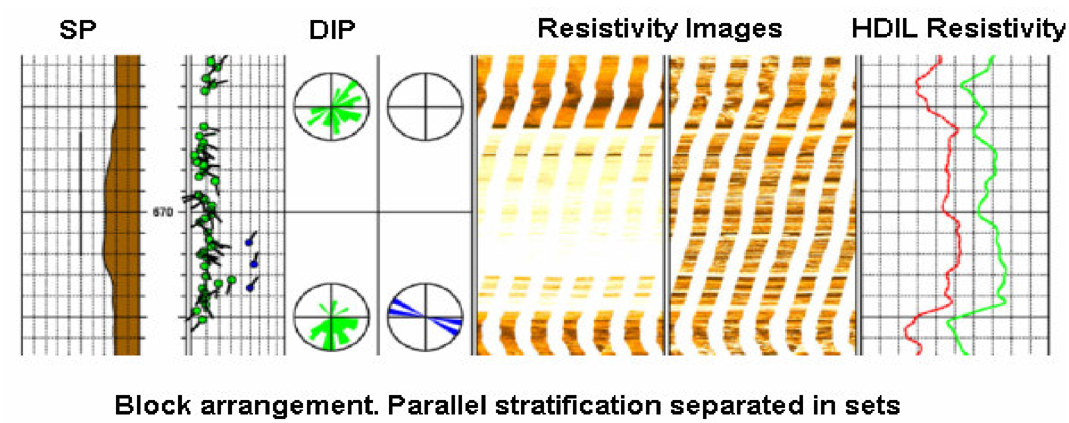


**Figure 3 Log responses for reservoir type I.**

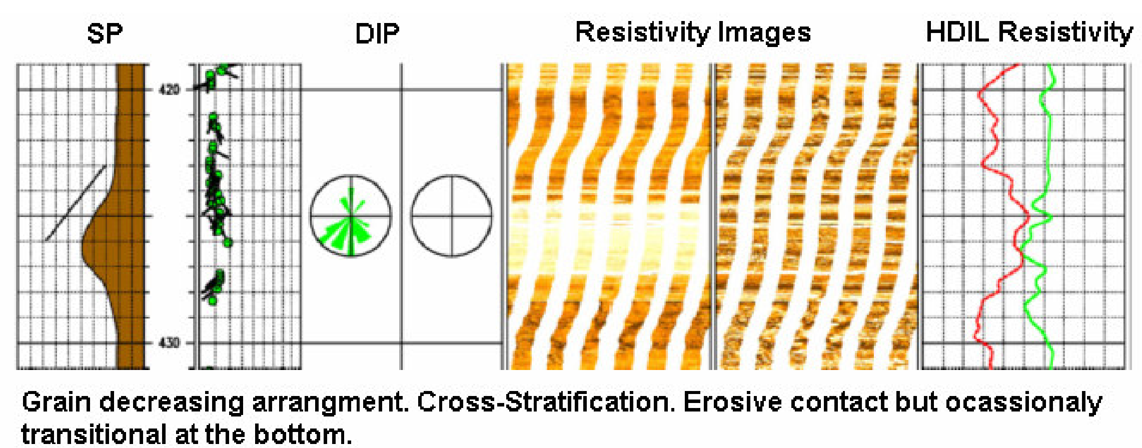


**Figure 4 Log responses for reservoir type II.**

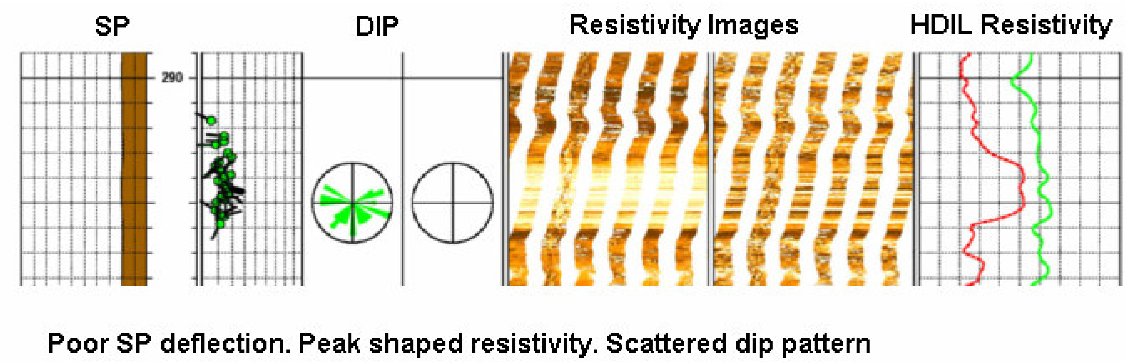


**Figure 5 Log responses for reservoir type III.**

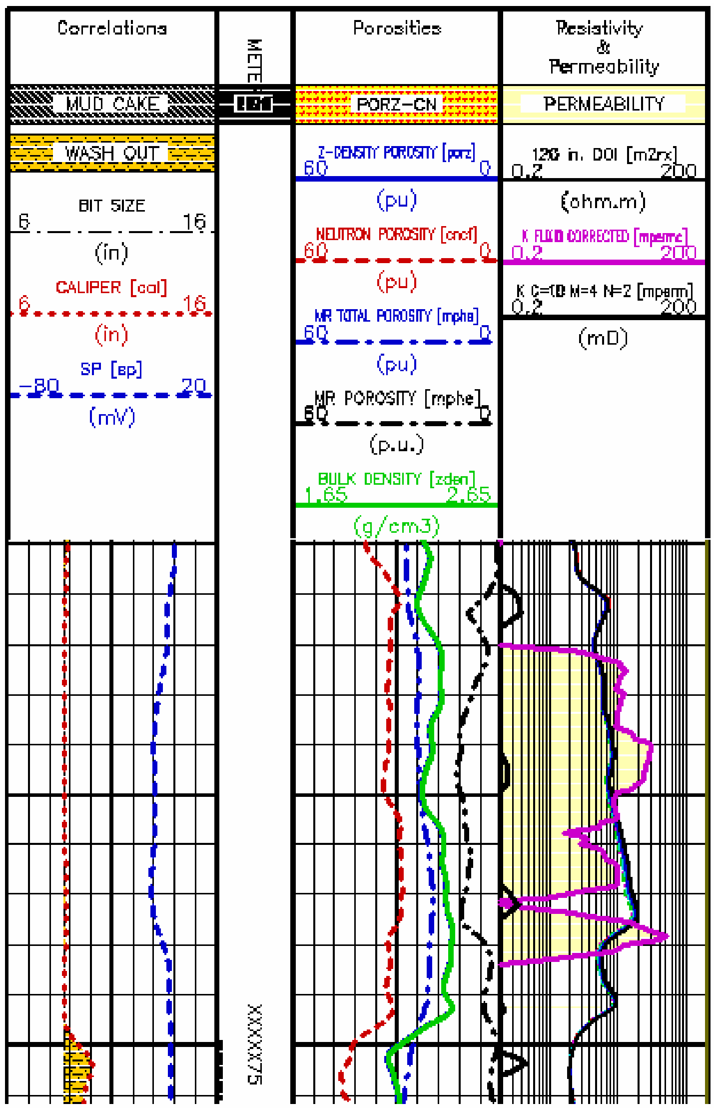


**Figure 6 Log display of conventional and NMR log variables.**

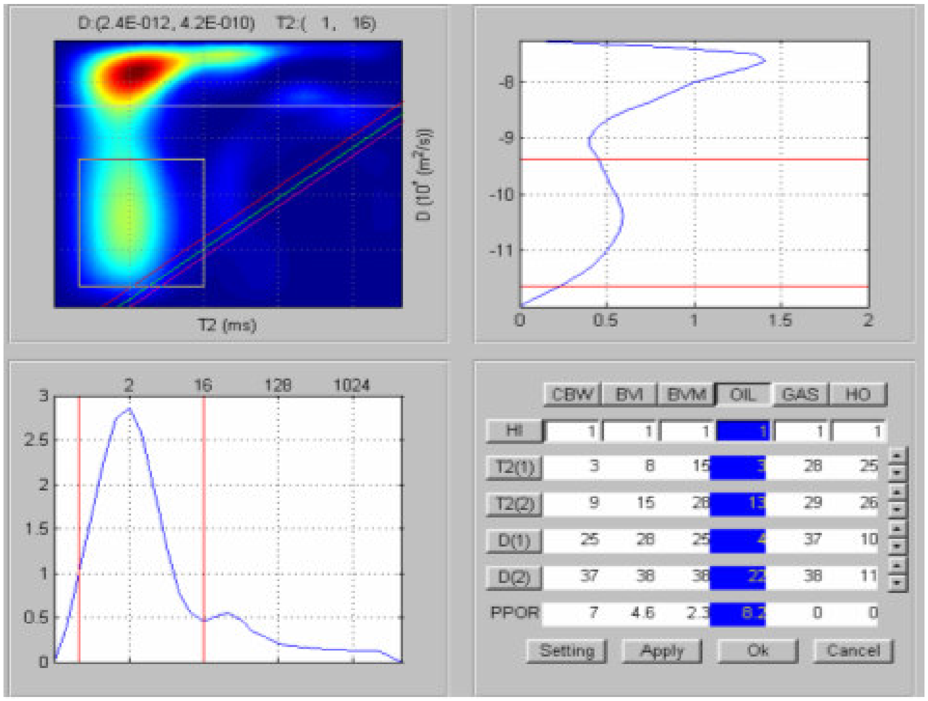


**Figure 7 Diffusivity-T2intrinsic map for fluid typing.**

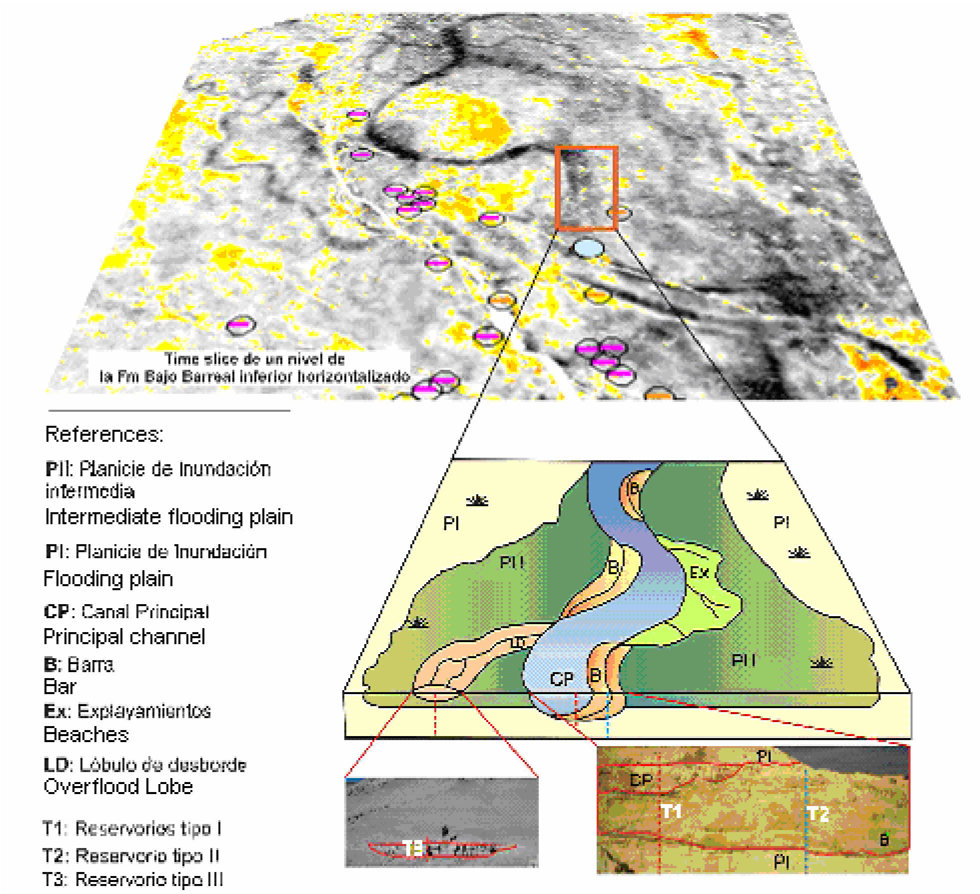


**Figure 8 Conceptual geological model.**