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Wireline Logs Restoration Through Self–Adjustable PSF.

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Abstract

The lack of a good vertical resolution of deep investigation wireline tools is the main cause of difficulties in the log interpretation, mainly in the cases where the layers reservoirs have thickness less than the vertical resolution of the tool. The combined measurement of shallow and deep resistivities, for instant, enable the parameters determination like R_t(true resistivity), R_{xo} (resistivity of invaded zone) and d_i (diameter of invasion). But in complex reservoirs we have difficulty in obtaining a confident reading of R_t due the low vertical resolution of deep reading tools. In this work, we present a methodology that outlines this problem, using image processing techniques, which allow to incorporate information from high-resolution log into the low-resolution log. This information is generated by the shallow investigation tool, whose measurements do not relate directly with the reservoir parameters. The final result is an improvement in the vertical resolution of logs got from deep investigation tools.

INTRODUCTION

The task of restoration or improving the logs vertical resolution is a classical problem in borehole geophysics. The poor vertical resolution has plagued log analysts for years, mainly in cases where the actual reservoir layers are thinner than the logs vertical resolution. This problem arises from the following doubt: to avoid the influence of invasion and borehole vicinity problems, a log measurement as far away from the wellbore as possible is desired. In practice, however, deep readings require source-detector spacing about the same distance as the desired investigation depth of measurement. This in turn implies that the vertical resolution will also be of the same magnitude as the source-detector spacing and, therefore, an accurate deep reading in a thinly bedded reservoir is impossible. In order to outcome this dilemma, a lot of computational methodologies has been proposed. Frequency domain methods have been used, but the problem of blind frequency on induction log (Barber, 1988) is an obstacle for this approach, because of inversion problems. In an other point of view, was presented a methodology that combine logs of different vertical resolutions, known as Laminated Sand Analysis (Allen, 1984). And finely, was presented high vertical resolution tools, like EPT(electromagnetic propagation tools), BHT (borehole televiewer), dipmeter and FMS (formation microscaner), that have been used to characterize layering and structure of strata penetrated by wellbore. These tools, however, are only rarely used for classical formation evaluation because their measurement are not directly related to petrophysical properties of rocks(maybe with exception of EPT, whose measurement is sensitive to the amount of water).

METHODOLOGY

The geologic approach for associating the information of two different vertical resolutions logs, bases sufficiently on the choice of a layer with a good thickness, denominated here by control interval, that guarantee a correct measurement of the physical property made by the tool of low resolution, and a perfect definition of its base and top interfaces by the high-resolution tool. The best example is a shale bed, where there is not invasion influences and the actual reading of two wireline tools are very close.

The first step is about the automatic choice of the control interval, which is accomplished in two stages. The first one is about the matching of the vertical resolution of the high-resolution log to the low-resolution log. In this stage, a filter is applied to the high-resolution log (**A**), in the frequency domain, in order to matching its total spectral energy to the total spectral energy of the low-resolution log (**B**), that is:

$$\mathbf{A_F = A.F_R} \, ,$$

where $\mathbf{A_F}$ is the adjusted high resolution log and $\mathbf{F_R}$ is the applied filter. Can be shown that vertical resolution of a log depends fundamentally of the spectral energy of actual log based on Parseval Theorem:

$$\int_{-\infty}^{+\infty} |\, a(z)\, |^2 \, dz = \int_{-\infty}^{+\infty} |\, A(w)\, |^2 \, w$$

Since the logs are perfectly adjusted in depth and the vertical resolution of a log is still related with its total spectral

energy, $\mathbf{A_F}$ should have the same vertical resolution of the low-resolution log **B**.
The second stage consists of obtaining an interval of better correlation among the logs $\mathbf{A_F}$ and **B**, now in the space domain, that is, $\mathbf{a_f}$ and **b**. Starting from the choice of an appropriate window, it continues to the calculation of the correlation coefficient among intervals of the logs **b** and $\mathbf{a_f}$. It will be taken then as a control interval, the one which presents the largest correlation coefficient.
The second step consists of the adaptation of a classic technique of images processing as: Determination a Posteriori of the Point Spread Function (PSF). The PSF could be interpreted as degrading function and is important in the processes of images restoration (Rosenfeld & Kak, 1982). It is assumed that inside the control interval, the log of high vertical resolution represents the real distribution of the physical property of the formation. On the other hand, the low-resolution log represents a degradation of the real distribution, due to application of a PSF (**g**) in the form:

$$\mathbf{b} = \mathbf{a} * \mathbf{g},$$

where (*) represents the convolution operation in the space domain. The main task is get the coefficients of a filter **h**, which inside the control interval makes the mapping of the log **b** into log **a**, that is to say, the filter **h** operates in inverse way of PSF. In frequence domain we have,

$$H = \frac{A_i}{B_i}$$

Where $\mathbf{A_i}$ and $\mathbf{B_i}$ are sub-intervals of low and high resolution logs in the control interval. Once obtained the inverse filter in the control interval, it is applied to whole low-resolution log.

RESULTS

It is shown in the Figure 1 a synthetic example of application that methodology, where the dotted curve is the low-resolution log. We can note that the solid curve (recovered low-resolution log) approaches to the dashdot curve (real distribution of physical property). This is clearly an effect of inverse filter applied, which introduced information from the high-resolution log. In the Figure 2 , we show an actual example, from a borehole at Amazon Basin, where the dashed line is the Deep Induction Log and solid line represents the recovered Deep Induction Log. Is easy to see the effects of this methodology.

CONCLUSIONS

The recovering in vertical resolution observed in the two examples is an evidence of the information incorporated from the high resolution logs. The energy matching process based on the Parseval´s theorem and correlation analysis build a self and automatic choice of a control interval and consequently a better consistent PSF, that enables the restoration process.

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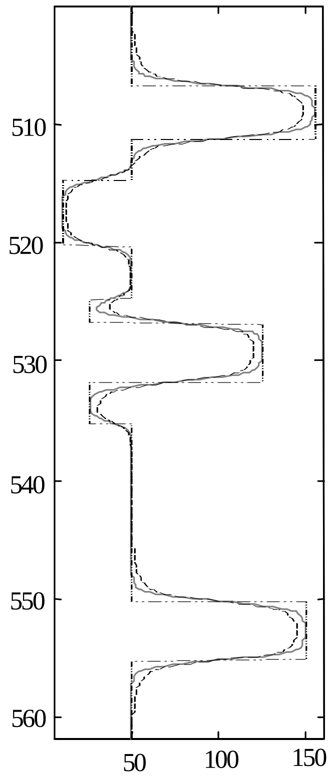

Figure 1: The dashdot line is the real distribution of physical property into formation. The dotted line is the low resolution log and the solid is the recovered low-resolution log by the Self-Adjustable PSF process.

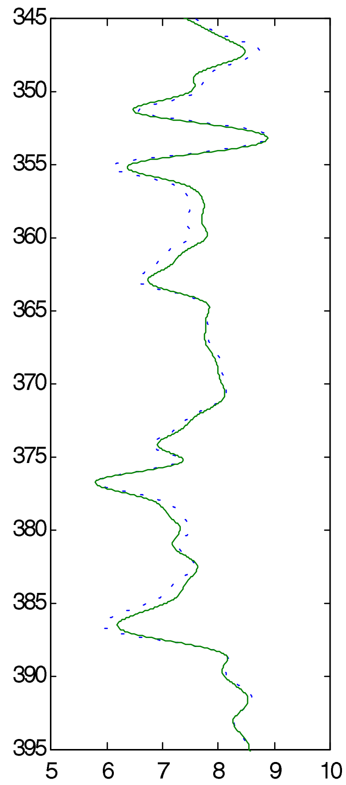

Figure 2: The dashed line is the Deep Induction Log and solid line represents the recovered Deep Induction Log recovered by the Self-Adjustable PSF process.