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A 3-D stratigraphic inversion in the Sacramento Basin, California

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Abstract

A gas play was established in marginal marine sandstones of the Upper Cretaceous Winters Formation in Solano Co. CA during 1992. The discontinuous sands are stratigraphically trapped along the west-dipping basin paleoshelf. The entire reservoir and seal interval has minor thickness changes, initially suggesting relatively uniform subparallel correlations within the major stratigraphic packages. However, production results suggested that complex correlations and pinchouts are present. A 1995 3-D seismic dataset suggested subtle amplitude variations within the reservoir interval, confined to a one half-cycle seismic trough. In order to better image the play, a 3-D stratigraphic inversion was carried out for the upper cretaceous sandstones. The inversion improved the correlations between reservoir and seal intervals.

INTRODUCTION

The aim of a seismic acquisition in a production area is to interpolate seismic properties between existing wells. Due to the difference in scale between the wells logs and the seismic data, the interpolation can be seen as an inversion process. The inversion is meant to increase the spatial and vertical resolution of the seismic dataset. Depending on the problem at hand one can invert for the structure (pre stack depth migration), for a given seismic attribute (such as impedance), or for physical parameters that are relevant to the properties of the reservoir itself. This paper describes the utilization of a proprietary 3-D inversion package (TDROV) for the seismic impedance on a particular dataset.
The inversion illustrated in this paper is characterized, as any inverse process, by several features: the input dataset, the initial model, the mathematical algorithm, the inversion QC and the output format. These features are analyzed in the first part. The second part describes the results obtained for the Winters formation on the 3-D Solano 92 survey. Details on the seismic acquisition and results of a subsequent AVO study have been described by Nickerson and Cambois (1998).

THE TDROV INVERSION

The input data. The inverted dataset is usually a noise free zero-phase stacked volume. It is assumed that coherent noise, (especially multiple reflections) has been removed and that the pre-processing has been performed in preserved amplitude mode (or at least that the relative amplitude of the events is preserved).
Although the inversion can be performed without any well information, reliable density and acoustic logs are a methodological requirement. The constructed impedance logs constrain the inversion process and provide a QC of the inversion results.
In addition, it is assumed that the seismic wavelet representative for the area concerned by the inversion is available. That wavelet is produced either prior to inversion by matching the seismic data with the acoustic well data, by statistical methods if no wells are available, or by a combination of both.
The initial model. The information provided by the input data defines the inversion domain and the process constraints. The macromodel is made of the main interpreted geological horizons. A micromodel is then derived, by subdividing each macroformation into layers. The thickness of each layer is in general a function of the wavelet, the minimal thickness of a layer being about a quarter of the width of the wavelet. The impedance logs at the wells contribute to the initial model in the form of a soft constraint. An impedance corridor is defined from the wells (see Figure 1) and the inversion process is constrained to provide output impedance values that are located inside the defined corridor.
The inversion algorithm. The inversion process is a true 3-D volume process, in the sense it does not work trace by trace. The process consists in minimizing the misfit between the data and the synthetic traces constructed by introducing impedance values at each node of the 3-D grid. The inevrsion is subject to local constraints on smoothness and continuity and soft constraints at the wells. Because inverting for both thickness and seismic impedance values is a strong non-linear process, care has to be taken to avoid the process finding some local minimum of the cost function, that can be located far away from the global minimum. In this respect, the Monte Carlo algorithm has been chosen, that generates randomly impedance models (Metropolis algorithm implemented within a simulated annealing schedule).
The inversion process modifies the initial micromodel. For instance, two adjacent layers can be merged because the impedances found are the same, pinchouts can appear, or a layer can disappear because its impedance equals zero.

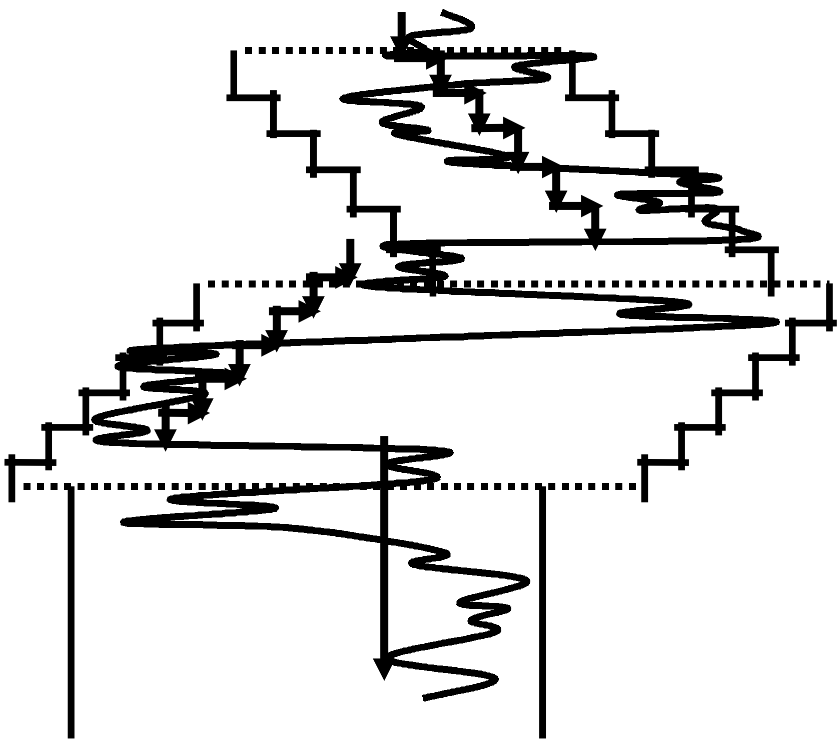

Figure 1. The impedance log at a well and the corridor for the inversion. The arrowed line in the middle shows the initial model at the well.

Output and QC. The output of TDROV inversion is of two types: (i) an impedance volume, and (ii) impedance layers that can be transferred to any commercial mapping package. The quality control of the impedance volume is particularly important. In this respect, it is worthwhile to think again of the inversion as of an interpolation of impedance logs between wells. An obvious interpolation strategy would constrain the process to obtaining the same impedances at the wells as those actually measured. However, such a strategy would ignore whether the actual logs are reliable or not. Moreover, it would not address the quality control issue. Because the actual log values are not used, the control of the output volume is obvious. If the actual logs and the computed logs at the wells are comparable, the inversion is assumed acceptable throughout the volume. It is precisely this quality control that characterizes TDROV among the other inversion packages commercially available.

THE INVERSION RESULTS FOR THE WINTERS FORMATION

The inversion of the seismic data seismic data, and the resulting 3-D impedance volume, indicated at least three inclined 6-10 ms. thick layers of similar impedance's at the reservoir interval, within a stratigraphic interval of relatively uniform thickness. Comparison of the impedance layers with the well logs improved internal correlations within the reservoir

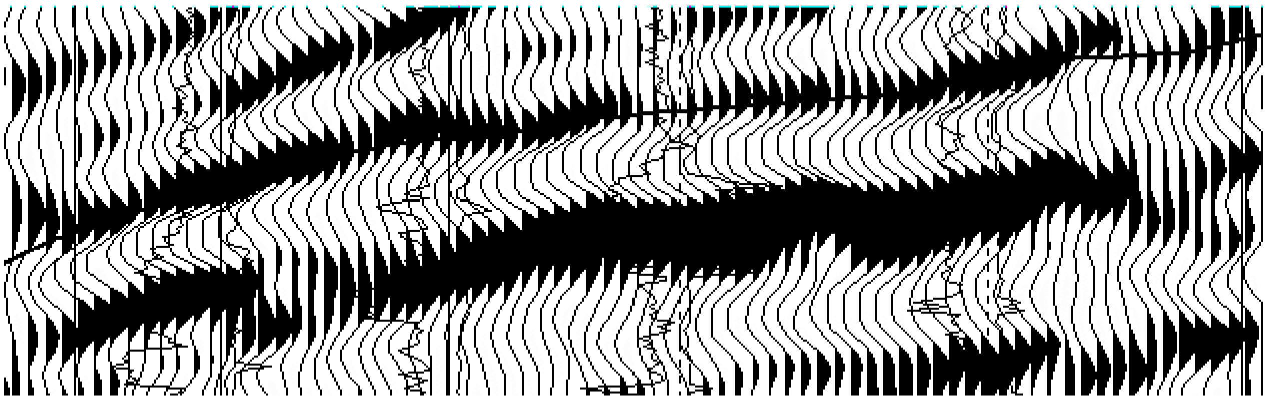

Figure 2. The seismic section at the target horizon. The gas pay is located between the peak of the strong event in the section and the through preceding it.

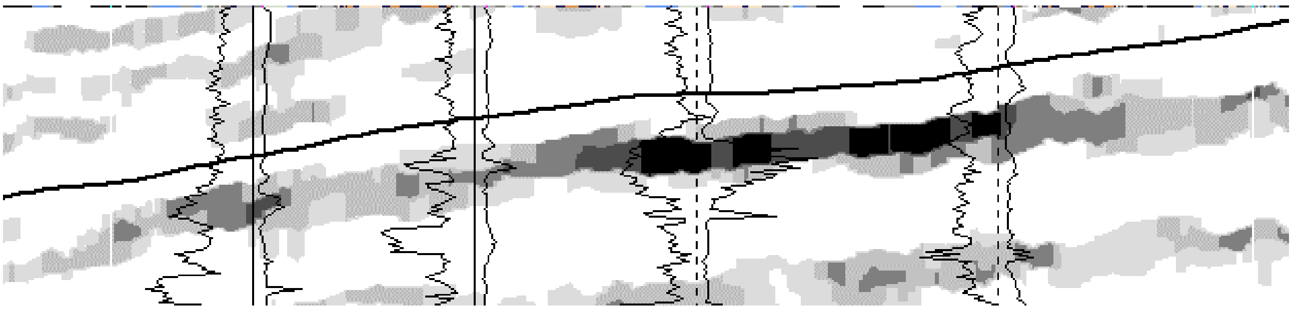

Figure 3. The impedance values on a line that intercepts four wells. At each well, the log on the left is a gamma ray log and on the right is the resistivity one. The producing wells are the three wells on the left, with the third, then the first as best producers. The well on the right, where the producing formation is updip, is dry.

sandstone interval and the relatively characterless shaly seal units immediately above (see Figure 3). This interpretation is consistent with the interpreted environment of deposition, but more detailed than either the seismic or well log interpretation alone allows. Comparing with the seismic data (Figure 2), the increase in resolution is obvious.

CONCLUSIONS

The layered approach to the 3-D inversion for the seismic impedance is able to generate a volume that can be directly correlatted to well data for better prediction of the lithology. The particular strength of this approach is that existing seismic and well log data are used, but combined in a new way, that enables a reliable quality control of the inversion output. In the case history presented in this paper the comparison of the impedance layers with the well logs improved the description of the reservoir.

REFERENCES

Nickerson, R.,L., and Cambois, G., 1998, AVO attribute analysis on marginal 3-D land data improved target selection in the Sacramento Basin, The Leading Edge, vol 17, p 1672-1677.