Vertical Seismic Facies Detection Through Unsupervised 3D Voxel Based Seismic Facies Classification Applied to a Turbidite Field in Campos Basin, Brazil

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Abstract

We propose to use the 3D voxel based unsupervised seismic facies classification to identify vertical facies variations within a turbidite reservoir. The technique was applied to a real data from a deep water field in the Campos basin, Brazil, and the results were compared with other classical facies analysis method, with similar results.

Introduction

Nowadays, automatic seismic facies analysis techniques have been growing as an important interpretation tool for the oil exploration industry. Depending on the reservoir knowledge, the seismic facies analysis could be supervised by a priori geological information, or could be unsupervised, when there are not enough data to guide the analysis. The unsupervised seismic facies analysis is usually applied in the preliminary phase, when the reservoir properties should be estimated almost exclusively with the seismic data. Even when, using supervised facies analysis, the a priori information is usually obtained through well logs data and its associated petrophysics analysis, which is always punctual compared to the large seismic volume density.

Independent of the seismic facies analysis type, the automatic seismic facies analysis is usually performed through the following steps (Johann et al, 2001):

1. Geological oriented spatial and temporal segmentation of seismic traces (input space);
2. Seismic attributes selection (variable space);
3. Choice of the optimal number of classes (facies) and the number of algorithm iterations;
4. Training and classification of the selected attributes using some statistical or neural networks methods (pattern space);
5. Building and interpreting facies map.

The main result of the automatic seismic facies analysis is the facies map, which represents, as a 2D surface, the properties of a volume region around a horizon or between two different surfaces.

Despite the effectiveness of this methodology, it is very sensitive to interpretation errors (Matos et al. 2004), and it does not represents the vertical facies changes.

One innovative way to avoid the interpretation errors is to use time-frequency techniques to locate and to characterize the stratigraphic surfaces, (Matos et al. 2003), (Matos et al. 2004).

This work shows how to identify vertical facies changes through 3D voxel based unsupervised facies classification.

Method

The first step in the proposed method is to define a stratigraphic volume, called strata-cube, which is bounded by two horizons, not necessarily parallel, limiting the analyzed region. This volume is created maintaining the number of samples between the two horizons constant, and each strata-cube sample is called a voxel. If the number of samples will not be constant, the samples should be interpolated between horizons.

In the voxel-based seismic facies classification, each sample, or voxel, is assigned a facies code based on one or multiple attributes unsupervised classifications at each sample (Wen, 2004). Specifically, the Kohonen classification methodology is applied (Kohonen, 1999), (Matos et al., 2003).

The voxel based classification result is also a volume and through 3D visualization it is possible to identify vertical facies variation within the reservoir.

Results

The voxel based classification methodology was applied to a deep water field which has three different stratigraphic units in the same reservoir.

The top and the base of the reservoir is showed in the Figure 1a

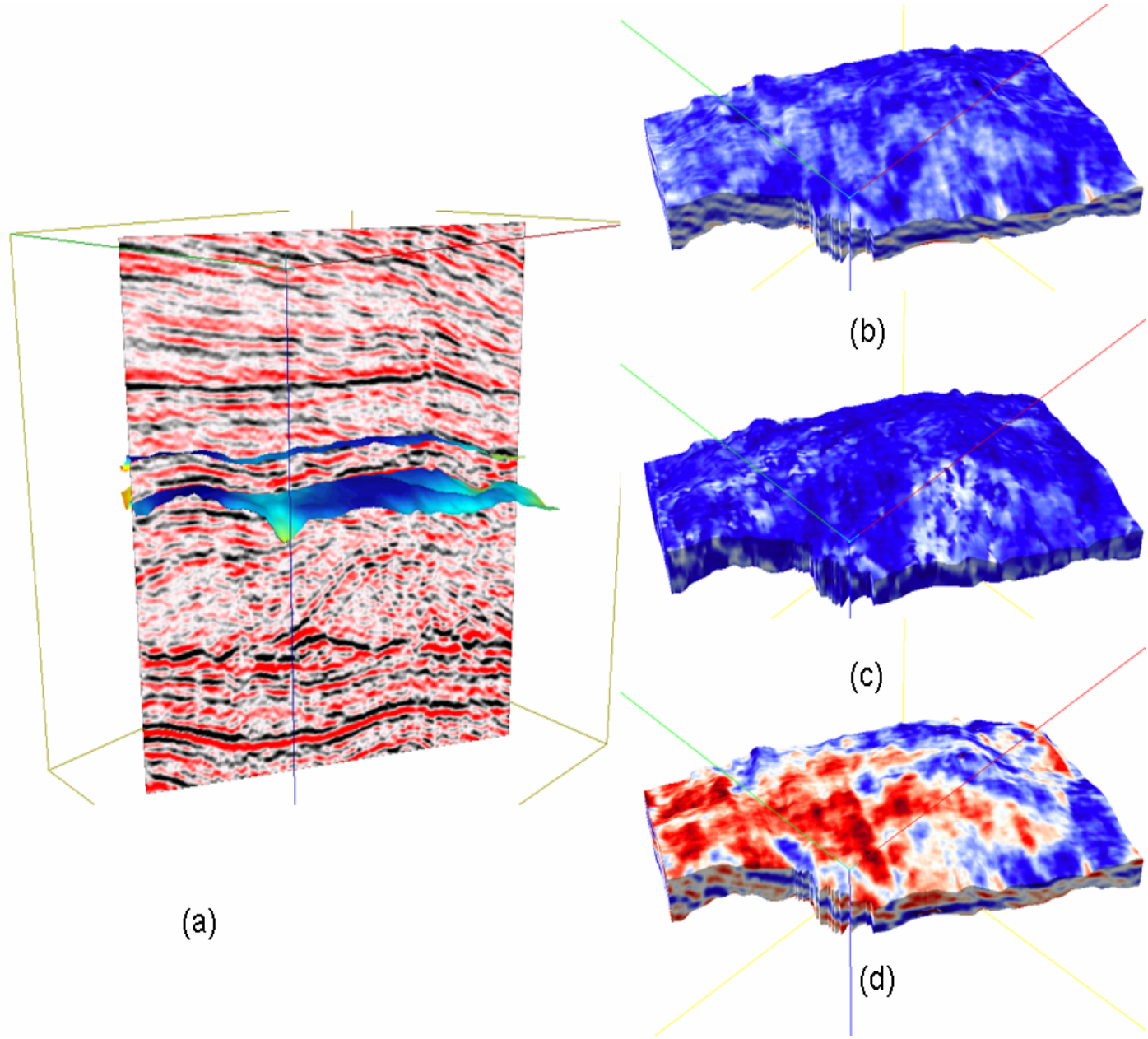

Figure 1: (a) Seismic data line with the top and the base of the reservoir horizons; (b) Instantaneous amplitude strata cube with 24 vertical voxels; (c) Average weighted frequency strata cube; (d) Relative acoustic impedance strata cube.

Three different seismic strata cubes attributes were generated with 24 voxels interpolated between the top and the base of the reservoir:

- The instantaneous amplitude strata cube;
- the average weighted frequency strata cube;
- the relative acoustic impedance strata cube.

The strata cubes attributes are showed in the Figures 1b, 1c and 1d, respectively.

After combining the strata cubes through the Kohonen classification algorithm, the voxel based classification strata cube with 12 facies was obtained. The results are showed in the Figure 2 for different time slices along the strata cube and it is easily verified the vertical seismic facies variation.

The same 3D voxel facies classification procedure with four facies, as suggested by the reservoir litho facies analysis (Johann, 1997), was repeated. The results showed in the Figure 3 are very close to those obtained by the supervised litho facies analysis computed through statistical techniques (Johann, 1997), illustrated in Figure 4. They show the seismic facies maps of the three different stratigraphic units existent within the reservoir.

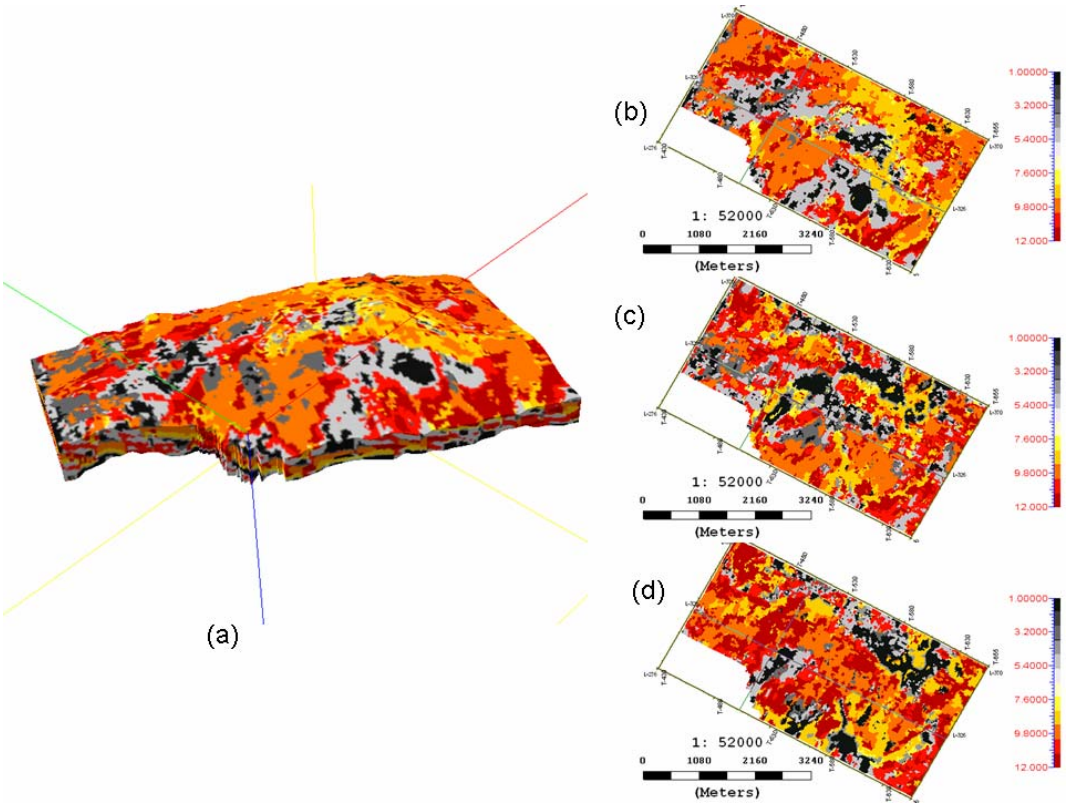

Figure 2: (a) Facies strata cube with 12 facies ; (b), (c) and (d) Facies strata cube slices at different depths.

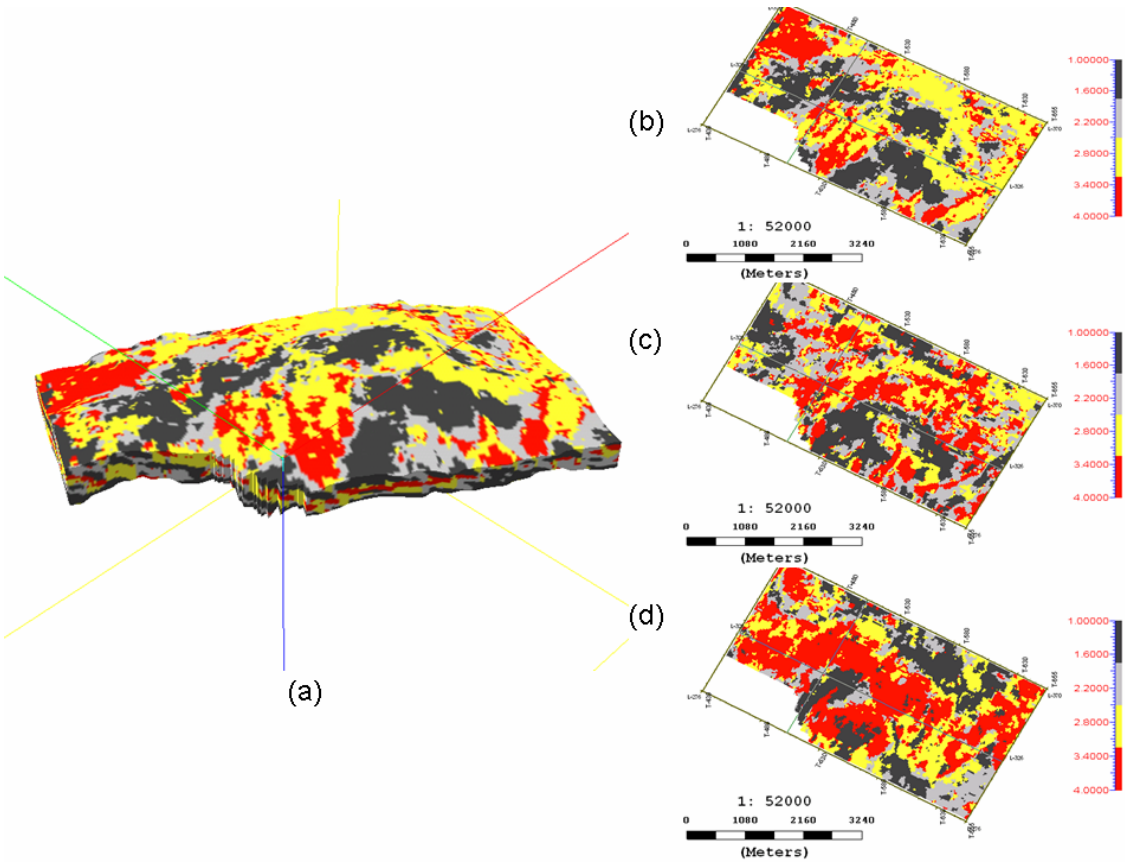

Figura 3: (a) Facies strata cube with 04 facies; (b), (c) and (d) Facies strata cube slices at different depths.

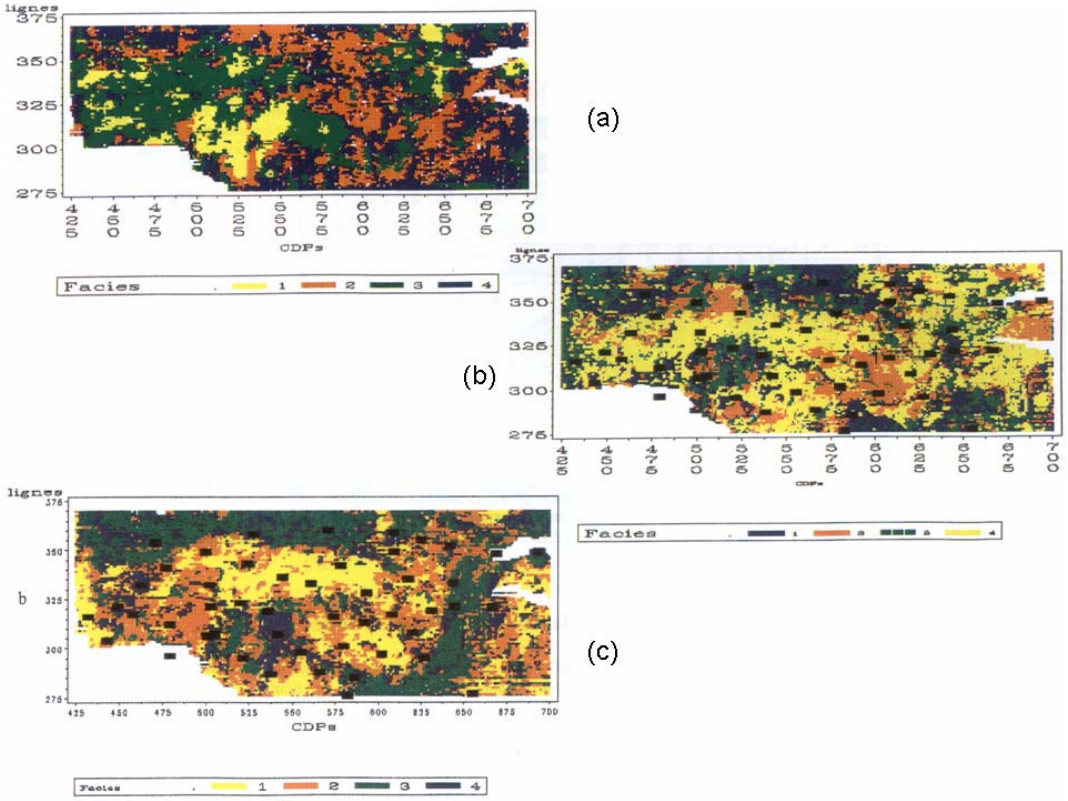

Figure 4: Supervised facies analysis results: (a) Superior stratigraphic unit; (b) Intermediate unit; (c) Basal Unit. The facies maps were extracted from Johann (Johann, 1997).

Conclusions

The results show that 3D voxel unsupervised seismic facies classification could be used as a vertical stratigraphic unit detection and could also be used as a powerful initial unsupervised facies estimator. The facies strata cube could also be used as a horizon interpretation picking help tool to identify the different stratigraphic units within the reservoir.

The strata cube attributes used as input variables to the Kohonen classification algorithm should be selected with parsimony, and a high correlation between the different attributes should be avoided

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