3D seismic visualization of shelf-margin to slope channels using curvature attributes

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Summary

Fluvio-deltaic systems have long been an exploration target, but in the shelf of the Gulf of Mexico, preceded the introduction of high-quality 3D seismic and modern 3D geometric attributes. Given the abundance of seismic data, well control, and basin understanding of the depositional history, the Gulf of Mexico provides an excellent natural laboratory to calibrate interpretational tools and workflows that can be applied to other less well-understood basins. To this end we compute a full suite of attributes over modern survey acquired over a salt-controlled minibasin in the Gulf of Mexico to better illuminate channel systems. We found the most-curvature and the valley-shape attributes were particularly effective in delineating continuous channels extending to the edge of the shelf. Other attributes including amplitude, coherence and amplitude gradients indicate the presence of gas-charge, pockmarks, and debris flows. Most-positive curvature best delineates the shelf edge. Together these attributes allow us to interpret subtle channel features in the appropriate structural and depositional framework.

Introduction

Seismic curvature can be interpreted as the reciprocal of the radius of a circle that is tangent to the given curve at a point (Roberts, 2001). Most-positive and most-negative curvature attributes have been demonstrated to be very helpful in fracture prediction, distribution and orientation (Blumentritt, 2006), carbonate collapse chimneys (Sullivan et al., 2006), and channel delineation (Chopra and Marfurt, 2007). In this paper we demonstrate the value of the curvature attributes in delineating subtle channel features in the shelf-edge to slope environment.

Method

The study data correspond to a high-resolution 3D seismic survey located along the shelf edge of the Gulf of Mexico that was acquired to image deeper objectives. The upper 600 ms of the seismic show the presence of acquisition footprint that needed to be removed due to the sensitivity of the seismic attributes to noisy data. Several filters (mean-, median-, and principal-component –structure-oriented smoothing) were tested in order to suppress this noise. After applying the best possible filter to the seismic, we computed 3D seismic attribute volumes including coherence, amplitude gradients and curvature to provide alternative images of the stratigraphic features of interest.

Time slicing of the seismic through the volumetric seismic attributes revealed the presence of channels that developed at the slope of the basin around 300 (ms), Pleistocene age.

Seismic geometric attributes applied to slope channels

The different geometric attributes extracted from the picked horizons demonstrated the presence of channels connecting the edge of the shelf to the slope in a salt-controlled minibasin. Dip-oriented profiles of the seismic (Figure 1) show clinoform geometries interpreted as a shelf-margin deltaic system prograding from the shelf to the slope. The strike oriented profile shows the undulations produced by the slope channels in the minibasin (Figure 2). The time – structure map (Figure 3) shows a bowl-shape minibasin that has a general direction of deposition from NW to SE.

Attribute extraction such as coherence (Figure 4a and 5a) and amplitude gradients (Figures 4b, 4c, 5b, and 5c) along the interpreted horizons indicate the presence of a system of slope channels that converge into two main channels at the axis of the minibasin that then continue to the base of the slope. The minibasin was lately affected by later faulting at the base of the basin.

Seismic curvature attributes (Figures 4d-f, and 5d-f) illuminated a continuous channel system extending to the edge of the shelf. Curvature also reveals the presence of more slope channels coming from the east side of the minibasin feeding the main axis channels. The better visualization of this channel system on curvature attributes is directly related to differential compaction of the channels versus the surrounding facies in the slope of the minibasin. Thus in this case the most-negative curvature delineates the channel axis meanwhile the most-positive curvature defines the overbank deposits.
Roberts (2001) introduced the shape index to the seismic community. AlDossary and Marfurt (2006) the shape index can be used to generate individual bowl, ridge, saddle, valley and planar shape volumes. The valley-shape attribute (Figures 4f and 5f) is particularly effective in delineating the thalwegs of the channel system. Since these slope channels do not produce levee deposits we interpret them to be bypass channels that transport the sediment to the base of the slope.

Conclusions

Computed curvature attributes, provide the seismic interpreters supplementary information about the geological features that are useful in 3D seismic visualization.

The presence of the shelf to slope channels is an important factor to predict deposition of deep-water systems at the base of the slope.

Most negative, most-positive and valley-shape curvature attributes were particularly effective in delineating subtle channel features that are connected to the shelf-edge that were not detected by other geometric attributes.

Acknowledgements

We wish to thank PGS that provided the 3D seismic.

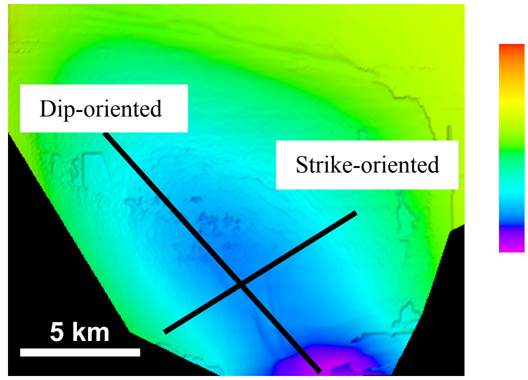

Figure 3. Time-structure map of horizon B shwing the dip-oriented profile in Figure 1 and strike-oriented profile in Figure 2.

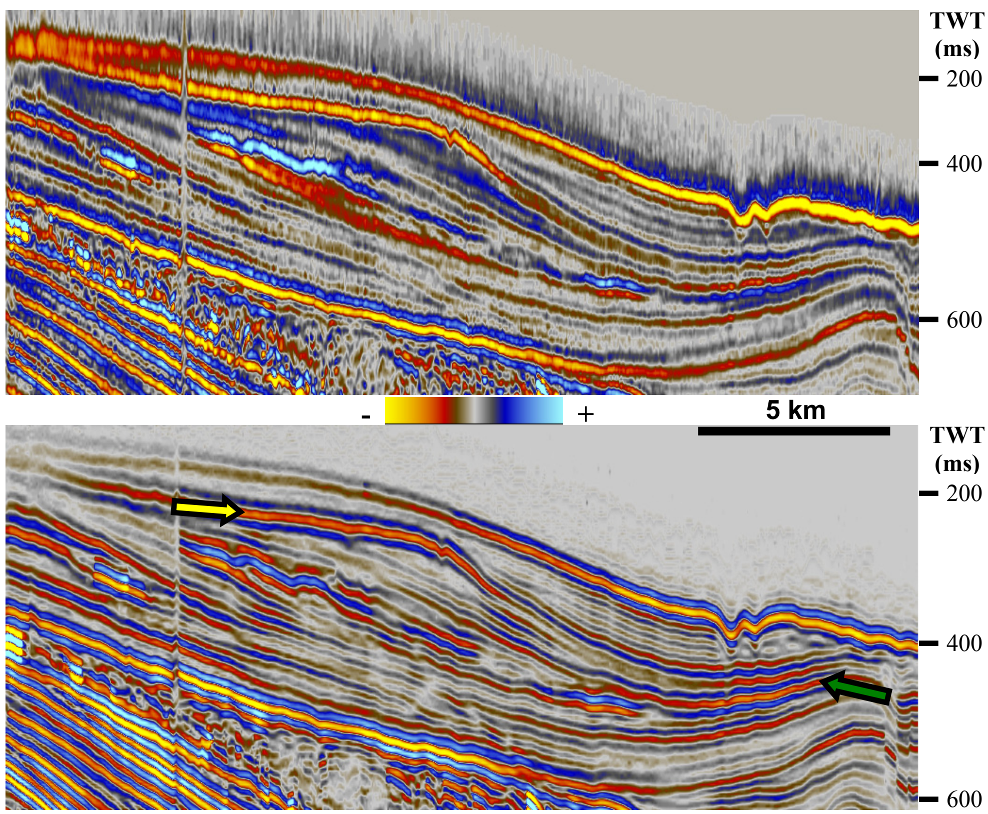

Figure 1: NW-SE dip-oriented profile of the sesimic data. (a) Original data before filtering. (b) Filtered data showing the progarding clinoforms. Green and yellow arrows indicate horizons A and B, both which arre throughs.

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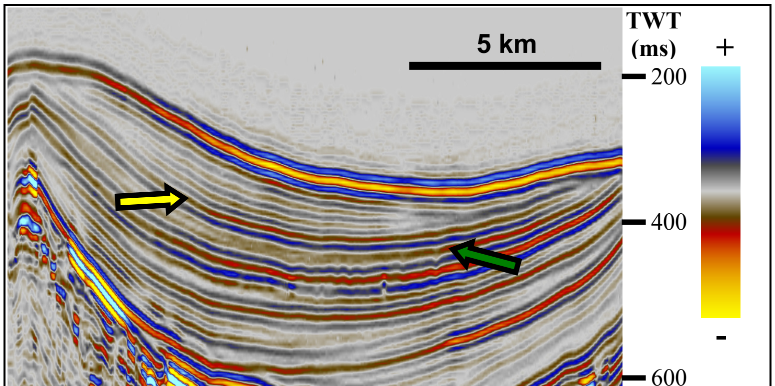

Figure 2. Strike-oriented profile showing undulations produced by slope channels running along the two horizons. (Green and yellow arrows indicate horizons A and B.)

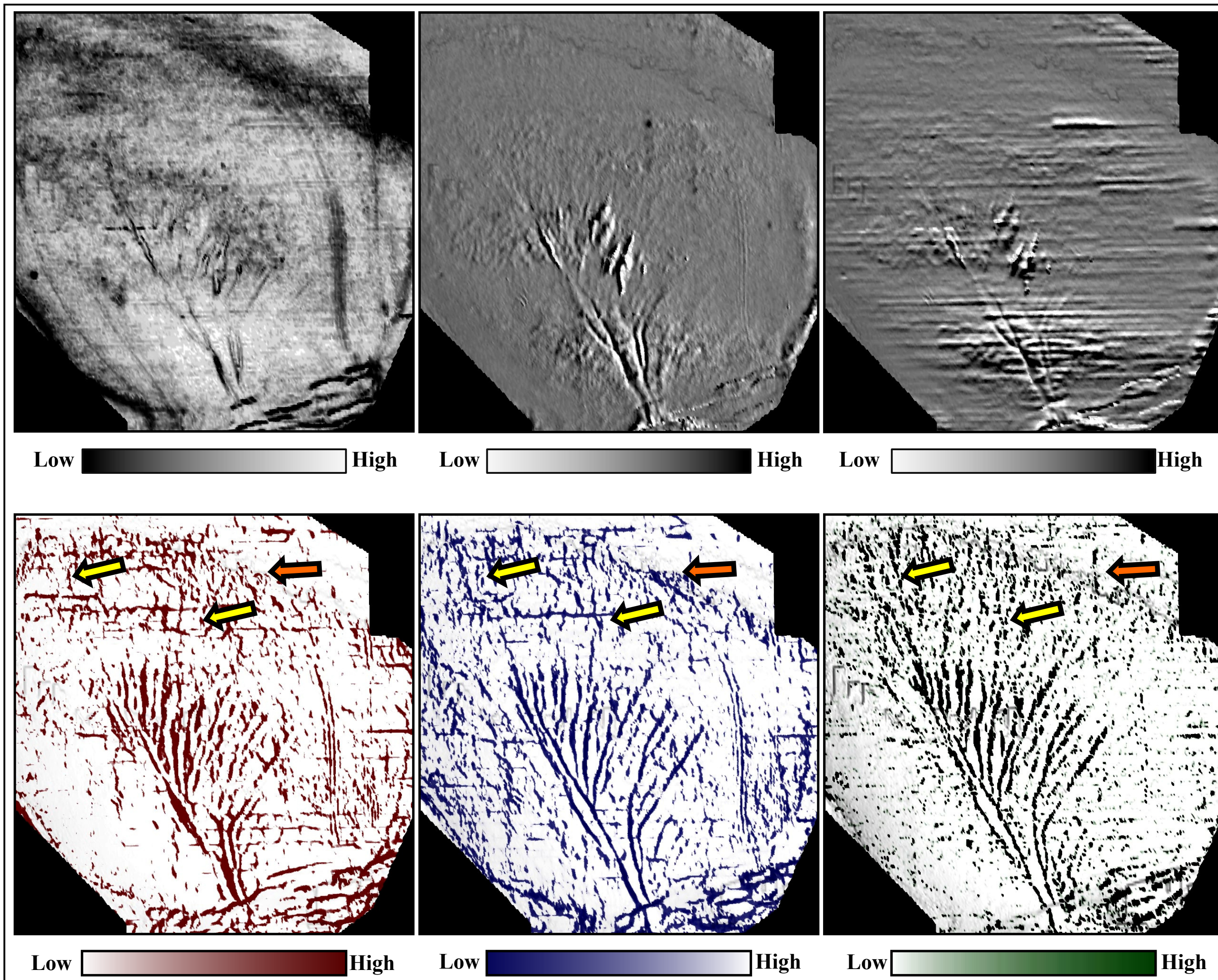

Figure 4. Slices along horizon A through: (a) Coherence, (b) N-S amplitude gradient, (c) E-W amplitude gradient, (d) Most-positive curvature, (e) Most-negative, and (f) Valley-shape attribute vlumes. The curvature helps to fully visualize the channel system (Yellow arrows). Orange arrow show the shelf edge

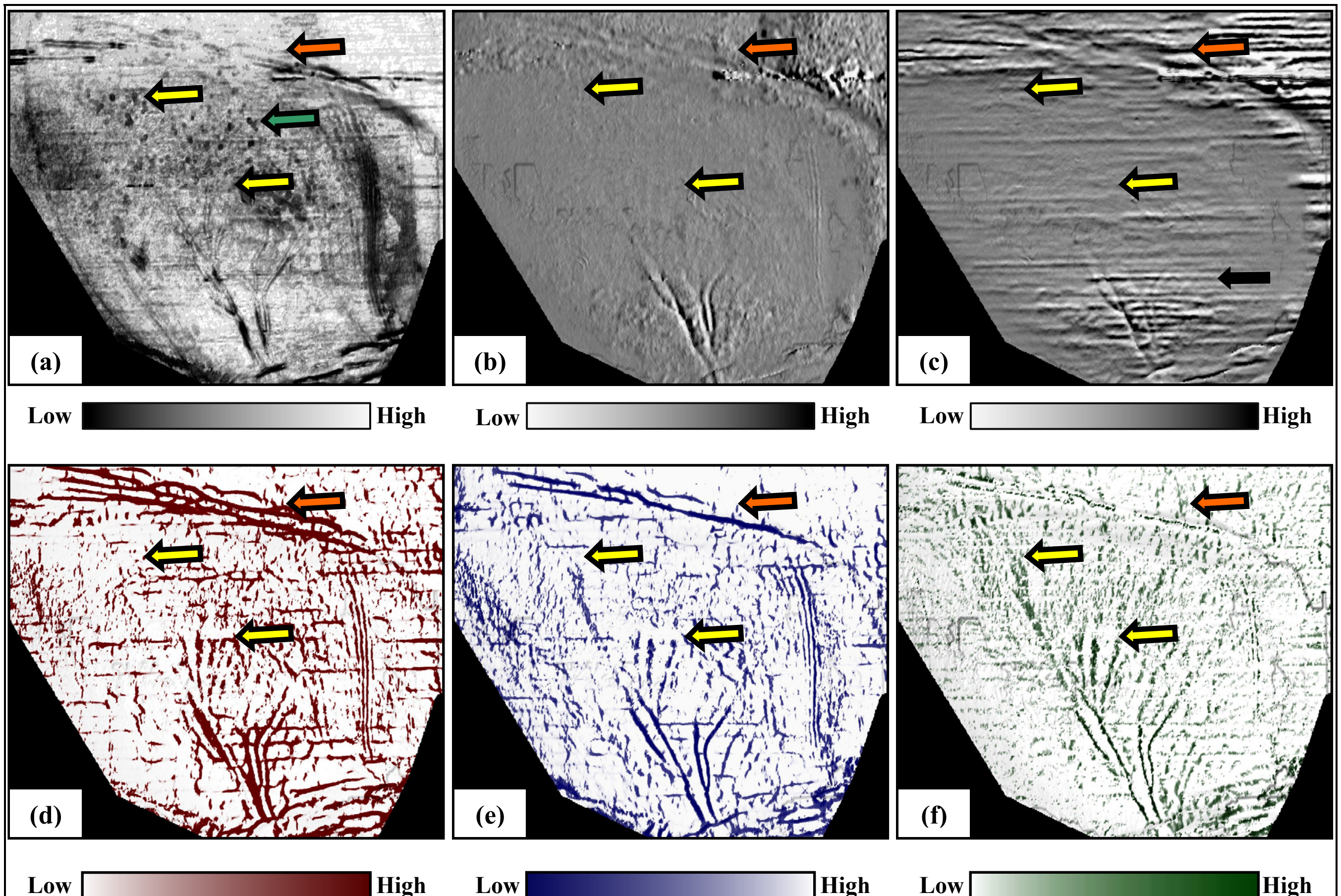

Figure 5. Slices along horizon A through (a) Coherence, (b) N-S amplitude gradient, (c) E-W amplitude gradient, (d) Most-positive curvature, (e) Most-negative curvature, and (f) Valley-shape attribute volumes. Black dots (green arrow) observed on (a) are interpreted as gas pockmarks that are associated with to differential compaction an zones of weakness along the channel edges. Acquisition footprint (black arrow) is clearly notice on (d). The curvature attributes, delineate a continous chnnel system exteding to the edge of the shelf (orange arrow), and delineate a suite of feedere channels (yellow arrows).