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Shallow Geohazard Channel Identification Based On Novel Seismic Interpretation Techniques in South Caspian Sea

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Summary

Shallow channels in the South Caspian Sea are major hazards which need to be identified on seismic data prior to well location positioning and drilling operation. We applied dip-steered-median filtering and automatic gain control to enhance the quality of seismic data during pre-processing. We calculated edge-sensitive attributes such as similarity, semblance and curvature on a migrated poststack channelized seismic volume from the South Caspian Sea. Afterwards, we de-striped the acquisition footprints along the inline direction which interfered with channel edge detection on seismic attributes based on factorial kriging. Moreover, we introduced shearlet edge detection algorithm as a novel edge-sensitive seismic attribute. Besides, we extracted a dense set of horizons (HorizonCube) after manually picking three horizons in the cube. We also investigated the existence of geohazards through geo-time slicing based on flattened seismic cube. Furthermore, we performed RGB blending of spectral decomposition components to visualize thickness variation within the channels. In the last step, the bodies of channels were successfully extracted using Thalweg tracker.

Introduction

Shallow channels in the South Caspian Sea are potential geohazards in E&P drilling operations. To mitigate drilling risks we investigated how conventional 3D seismic data can be used to detect channel systems in the shallow sub-surface. In the study we combined established filters and discontinuity attributes with novel techniques for detecting edges and for extracting 3D bodies. Notably, we introduce a new edge-sensitive seismic attribute based on shearlet transformation. In the next step, we generated a dense set of horizons, known as HorizonCube (de Groot et al., 2010). The HorizonCube method has already been successfully applied in geohazard studies since it aids the visualization and interpretation of seismic attributes and provides co-visualization in structural and stratigraphic domains (Bouanga et al., 2013). Thickness variations within the channels were also investigated using spectral decomposition and RGB blending along an extracted channelized horizon slice. Furthermore, the 3D bodies of channels were extracted using Thalweg tracker (Pelissier et al., 2016) which is a voxel-based auto-tracker.

Geological setting of the study area

We investigated a channelized area within the South Caspian Basin. A shown in Figure 1, the south Caspian Sea, east of Azerbaijan, west of Turkmenistan and northern part of Iran comprise South Caspian Basin (Buryakovsky et al., 2001). The South Caspian Basin has several interesting properties including high rates of sediment accumulation, Sediment thicknesses up to 20 km, low sediment compaction, low geothermal and exceptionally high-pressure gradients (Smith, 2006).

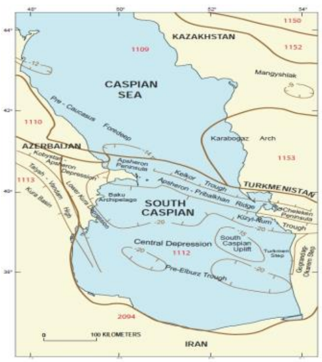

Figure 1. The location map of the South Caspian Basin (Smith, 2006).

Methodology

In this study, the main pre-processing of seismic data included dip-steered median filtering (DSMF), and automatic gain control (AGC). The DSMF replaces the amplitude of the central sample within an analysis window (5 traces) in the direction of the local dip with the median value of the amplitudes of all the samples to attenuate random noise and increase the reflector continuity. Figure 2a displays a time slice at 200 ms containing a turbidite channel system extracted from a poststack seismic volume in the South Caspian Sea. The green arrows show the acquisition footprints in the inline direction. Figure 2b shows the time slice after applying the DSMF, and AGC. The AGC highlighted the amplitude variation within the channel body. Similarity attribute is based on calculating the normalized Euclidean distance between two trace segments (Tingdahl and de Rooij, 2005). To better delineate discontinuities, the similarity is typically computed between trace pairs oriented in different azimuthal directions around the analysis point. The minimum similarity is often taken as the desired similarity attribute. To find the best direction, the similarity is generally computed based on the steering information. The curvature attribute (Roberts, 2001) measures the amount of curvedness of a surface at any position via computing lateral changes in the dip and azimuth in the sense of geometric deformation rather than a change in amplitude. Attribute analysis demonstrate acquisition footprints striping along the inline direction. De-striping algorithm based on factorial kriging can quickly and efficiently remove a striping effect in 2D. The distance between these artifacts in the inline direction measured on the time slice is about 60 m. The results of applying similarity and most negative curvature attributes at time slice 200 ms are depicted in Figure 2(c-d). Yi et al. (2009) proposed the algorithm of shearlet transform edge detection in image processing applications. The edge points of an image **F** can be delineated based on the modulus maxima of the shearlet coefficients (n_1, n_2), which are the local maxima of the energy function **E**, at the finest scale of decomposition j_0:

$$\mathbf{E}(n_1, n_2) = \sum_{\mathbf{k}} |SH_{\mathbf{F}}\,[\,j_0, \mathbf{k}, n_1, n_2]|^2. \qquad (1)$$

Karbalaali et al. (2017) proposed to apply thresholding based on the histogram of the local maxima of the shearlet coefficients for channel edge detection. Figure 3 demonstrates the result of applying the shearlet edge detection algorithm to the channelized time slice at 200 ms

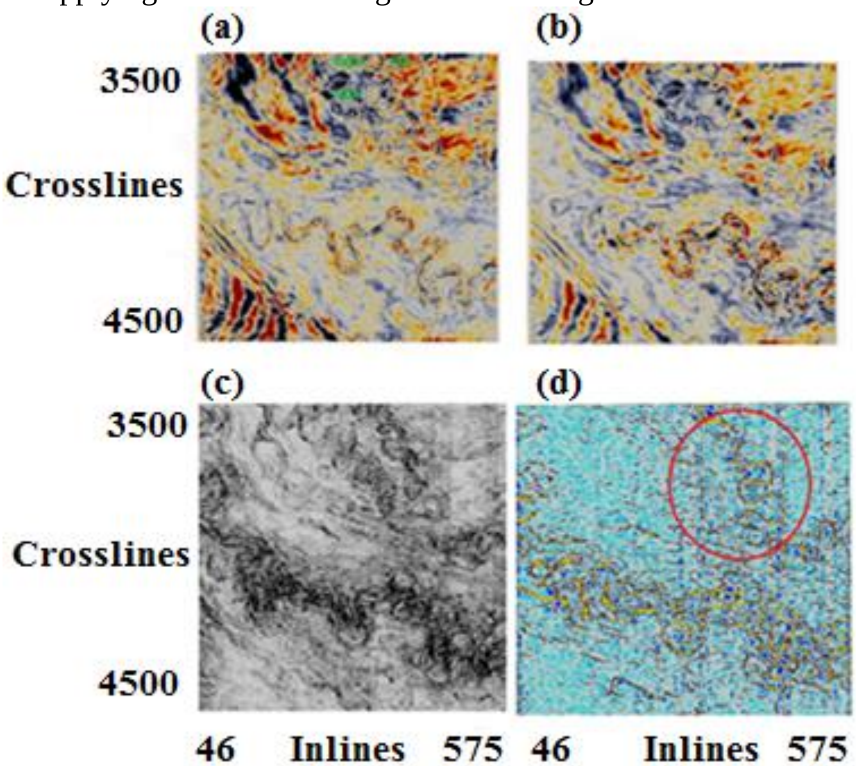

Figure 2. The time slice at 200 ms containing a turbidite channel system (a) Before and (b) After applying DSMF and AGC. (c)-(d) The result of applying similarity, and most-negative curvature to the time slice at b, respectively. The existence of geohazard channels are better obvious using similarity attribute.

Results

We interpreted three main horizons using manual picking and conventional auto-tracking. The dense set of horizons was then accomplished through an inversion algorithm that minimized the error between horizon dips and seismic dips. The advantage of the dip-steered auto-tracking is that dip fields are more continuous than amplitudes and similarities. Besides, the dip field can be smoothed before applying the tracker to reduce the effect of random noise (Qayyum et al., 2012). In the next step, we implemented seismic flattening to view geohazards particularly channels through geo-time slicing. Figure 4 illustrates the interpreted horizons overlaid on the seismic data. Applying spectral decomposition method as well as RGB blending technique along an extracted horizon slice may result in a better delineation of channel morphology and thickness variation inside the channel. Figure 5 displays the RGB color blending of the three spectral components of 20, 40 and 60 Hz along an extracted seismic horizon. Red-to-pink colors indicate thicker parts of the channel while green-to-blue colors correspond to the thinner parts. In the next step, we applied Thalweg tracker (Pelissier et al., 2016) to extract the 3D channel bodies. This voxel-based geo-body tracking method exploits the lateral organization of seismic amplitudes along sedimentation paths which works especially well for channel features. The method begins with an initial seed, represented by a voxel having six faces. The voxels are connected in three dimensions in an iterative manner. The voxel faces are iteratively checked and either the lowest or highest amplitude voxels – lying within the specified amplitude range – are connected. Figure 6 depicts the 3D bodies of one of the hidden channels extracted using Thalweg tracker with 1000 voxels adding a single cell per iteration.

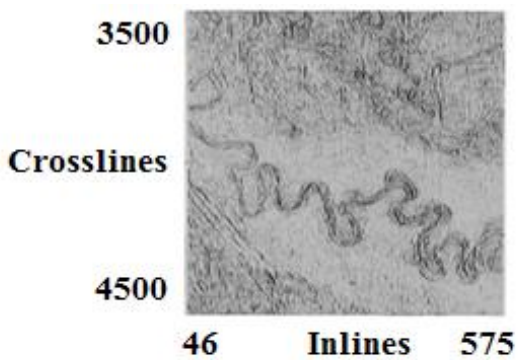

Figure 3. The application of the shearlet transform edge detection algorithm to the channelized time slice of Figure 2a.

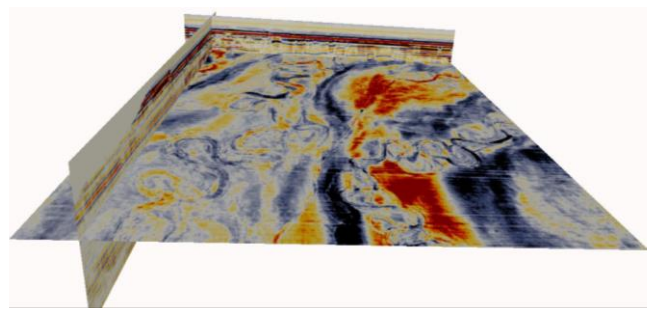

Figure 4. Illustration of geophazard channels through geo-time slicing using flattened seismic cube.

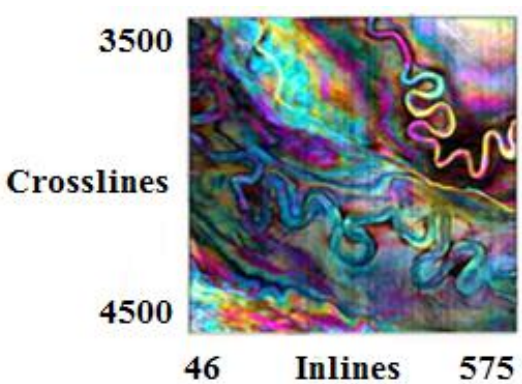

Figure 5. Iso-frequencies of 20, 40 and 60 Hz based on FFT on an extracted horizon slice co-rendered using RGB blending technique.

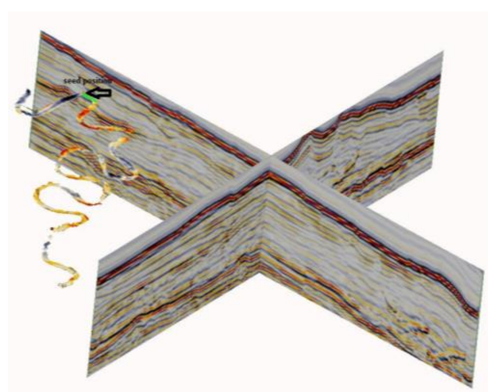

Figure 6. The extracted body of one the hidden channels in the 3D seismic cube based on Thalweg tracker.

Conclusions

We delineated channel boundaries using edge-sensitive attributes like similarity and most negative curvature in the South Caspian Sea where shallow channels cause significant problems in drilling operations. Dip-steered-median filtering and automatic gain control were applied as pre-processing steps to attenuate random noise and amplify seismic amplitudes. In the next step, based on factorial kriging, an iterative process de-striped acquisition footprints along the inline direction. As a new seismic attribute, implementation of the shearlet edge detection algorithm could successfully illuminate edges as well as resolving the acquisition footprint removal issue. We also investigated the existence of geohazards through geo-time slicing based on flattened seismic cube. To remove the effect of non-conforming reflectors, we extracted horizon slices based on three manually picked, and a dense series of dip-steered auto-tracked horizons. The RGB blending of spectral decomposition components extracted along horizon slices were utilized as a means of qualitative thickness estimation. The 3D bodies of meandering channels in the study area were successfully imaged using Thalweg auto- tracker.

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