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Thalweg Tracker: A Voxel-Based Auto-Tracker to Map Channels and Associated Margins

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Abstract

In this paper we introduce a Thalweg tracker as a new tool for tracking channels and associated margins. A Thalweg tracker is a voxel-based auto-tracking algorithm in which geobodies are allowed to grow in a user-controlled way. Unlike conventional voxel-based methods controlled primarily by amplitude thresholds, the growth can be adjusted to preferentially follow channel features and then build out the associated margins. In this paper we explain how the algorithm exploits the amplitude organization of channel features about 3D local maxima and minima and we show examples from three different basins.

Introduction

Since the introduction of seismic interpretation workstations in the 1980's, many methods have evolved for auto-tracking seismic events. Sheffield et al. (2003) provide a summary of methods used to track individual horizons or geobodies. An overview of global methods used to track dense sets of horizons is given by Hoyes and Cheret (2011). An overview of state-of-the-art seismic stratigraphic interpretation methods is given by Qayyum et al. (2015). The progression of these methods shows that more and more stratigraphic detail can be extracted from the seismic images.

In this paper we present a refinement of the voxel-based method and apply this to the tracking of channels and associated margins. The conventional voxel-based auto-tracking process attaches cells to a geobody based on an amplitude range. The geobody is iteratively constructed by progressively coating its outer shell (hull) with a layer of voxels. In our method, we control the evolution of the geobody by first scanning the values of all voxels lying on the hull. In this way we can select a narrow range of available voxels to track a channel's Thalweg. In addition, by progressively widening the acceptable ranges we can subsequently track channel margins, amalgamated sands, sheet sands and flooding surfaces.

Methodology

Concept: Both local and global horizon tracking methods take advantage of the fact that refection events on a seismic trace are represented by local minima and maxima. Impedance data also has local minima and maxima along a seismic trace. In our voxel-based geobody tracking method we take advantage of the fact that laterally, along a seismic amplitude event or impedance layer, the data are also highly organized around local amplitude or impedance minima and maxima. This is especially true for channel features; the axis of a channel is usually associated with a local minimum or maximum in stratal slices.

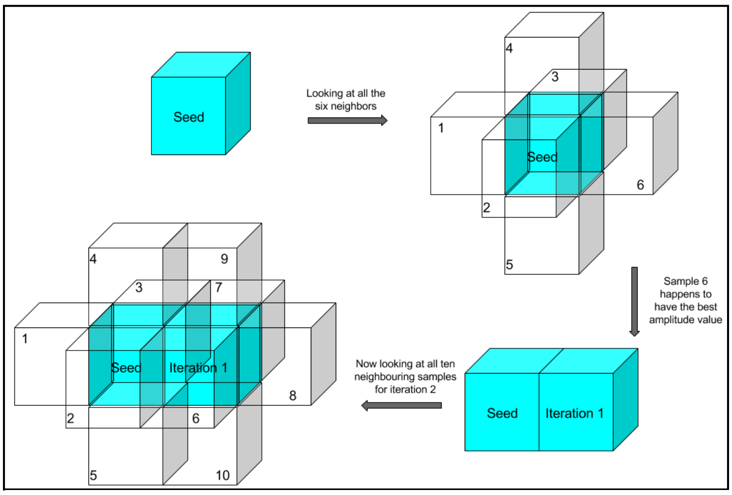

Figure 1 *Concept of weighted tracking.*

In conventional volume based tracking, all voxels within a specified amplitude range are given an equal weight. This means that within the seismic volume, or within a pre-defined region, all cells lying on the geobody hull can be attached to the geobody on any given iteration, subject only to the connectivity constraints. This is a trace-to-trace method. In our proposed, multi-trace method, we preferentially attach a subset of all eligible voxels. The subset consists of the voxels with the lowest or highest values, respectively. Consequently, our tracking process follows a preferred direction that is close to the lateral distribution of minima/maxima.

To define the subset of voxels that might be attached, we can consider the set of all voxels lying on the geobody hull, and then select a percentage or number of voxels with the lowest/highest values. Figure 1 illustrates the tracking process for the case where the subset of voxels to be attached is limited to a single voxel. This is especially well suited to tracking the Thalweg of a channel system. 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. This process continues until neighbouring voxels are not in range or the specified number of voxels has been attached. Our method is designed to grow a geobody that is vertically contiguous, in other words, along a seismic trace, all voxels between the top and base of the geobody fall within the specified amplitude range. To ensure this outcome, *upper and lower* boundaries (as a ceiling and a floor) are dynamically computed for each trace. They reflect the first values encountered vertically beyond the thresholds. This minimizes multi-layer tracking and abrupt jumps.

Tracking control: The primary control is on the number of voxels to be attached for each iteration. In a typical workflow the interpreter first sets one voxel per iteration to track the system of Thalwegs or spines from a given seed point. In general, this defines the lateral local minima or maxima. The interpreter can then isolate a selected feature by adjusting the number of tracked voxels and possibly refining the seed point location. The local feature can then be extended by adding more cells per iteration. The example in Figure 2a shows the minimum amplitude horizon from a geobody tracked with 5000 voxels adding a single cell per iteration. The colour coding is the tracking order. Isolating the feature on the left by tracking 1800 voxels is shown in Figure 2b. The geobody extended by tracking on a much broader front is shown in Figure 2c.

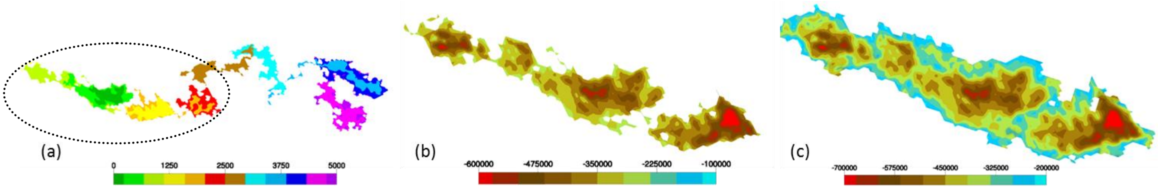

Figure 2 *(a) Tracking order for a channel system, 5000 voxels, one voxel per iteration; (b) minimum amplitude surface for geobody reduced to 1800 voxels; (c) minimum amplitude surface for geobody extended by a further 5000 voxels using 1000 voxels per iteration.*

Thalweg & Margin Tracking: As mentioned above, the concept was originally developed to identify a Thalweg and its margins for a given channel system. In practice, both features of channels are tracked sequentially. First, the Thalweg of a channel is tracked by connecting the best matching voxels per iteration. Next the results are extended to the margins by relaxing the threshold in a percentage or in fractions such that more voxels are connected per iteration (Figure 3).

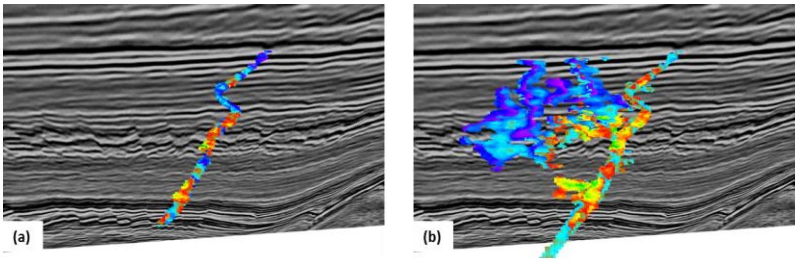

Figure 3 *An example illustration to show a narrow deep-water channel that is being tracked through Thalweg-margin tracking concepts. When only the Thalweg is tracked the result (a) is restricted to the areas of the channel base. Thalweg is extended to its margins (b) through a simultaneous processing. The latter shows slopes, banks and overbank facies.*

Attributes: For each tracked sample the iteration number (the order of tracking), amplitude, thickness (between the ceiling and the floor) and other attributes are computed and stored for subsequent analysis. The tracking order is a useful interpretation aid. This attribute contains information about the depositional geometry that is less apparent using amplitudes alone. Because cells are preferentially attached according to their amplitudes, the tracking order is akin to relative amplitude. A comparison of the horizon amplitude and tracking order is shown in Figure 4. The tracking order provides a clearer image of the internal geometry and evolution of the meandering channel system.

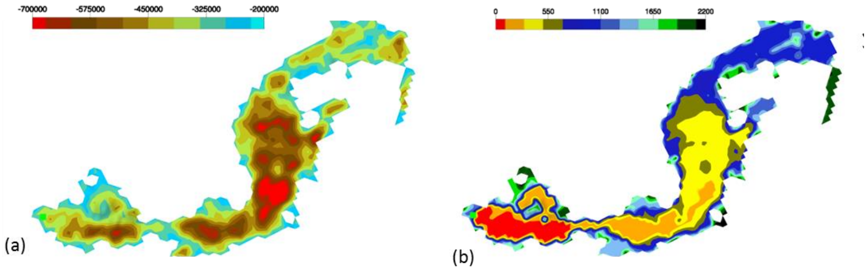

Figure 4 *Comparison of the attributes along a meandering channel system extracted through Thalweg tracker: (a) horizon amplitude and (b) tracking order. The latter map clearly helps in classifying intra-channel facies.*

Multiple seeds: For laterally extensive features, instead of using multiple seeds to track a single geobody, overlapping geobodies can be tracked separately from single seeds, after which the bodies can be merged. This process is illustrated in Figure 5.

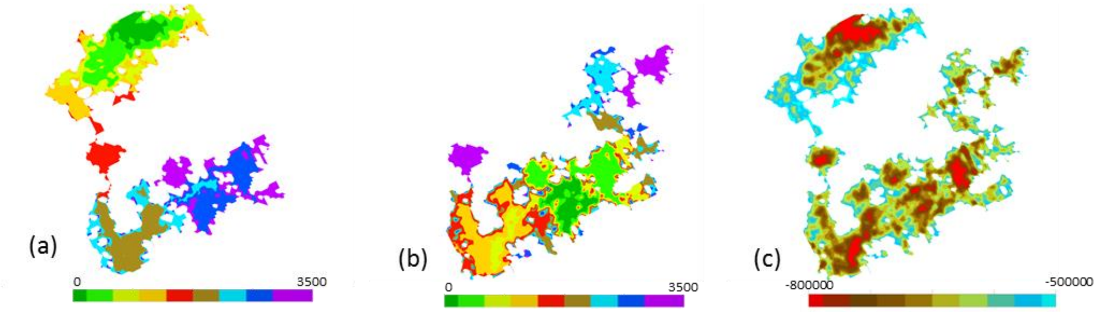

Figure 5 *Multiple seeds are used to track overlapping geobodies defining the same facies. In (a) an initial horizon patch with a tracking order attribute map is presented. The same channel system is defined by another seed to produce an intermediate horizon patch (b) partially overlapping the previous patch (a). Both maps are then merged into a single horizon with a minimum amplitude attribute (c).*

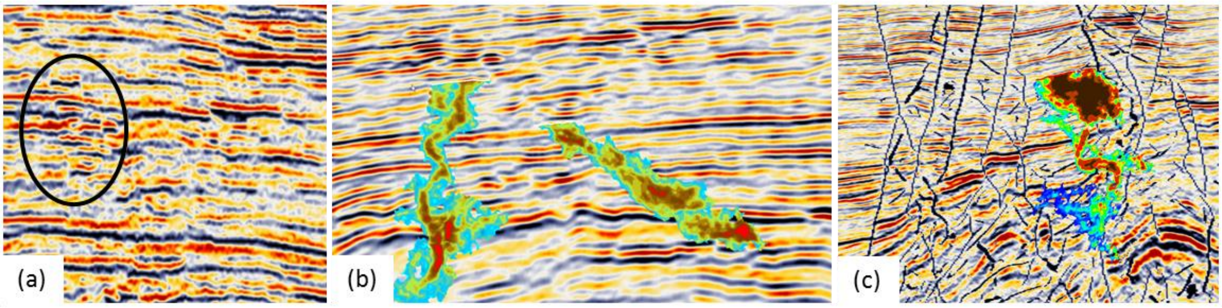

Figure 6 *Examples of a fluvial channel deposits, Bohai Bay, China: (a) A seismic cross-section showing a typical fairway; (b) Couple of channel systems extracted from a single seeded Thalweg tracker; (c) A channel complex based on a composite volume (seismic amplitudes and fault likelihood).*

Examples

Stacked Channel System, Zhao Dong field, Bohai Bay

In the Zhao Dong Oil Field (Bohai Bay, China), the Neogene reservoirs consist of sand-rich fluvial channel systems. Examples of meandering channels are identified using the proposed method (Figure 6). In faulted areas, we use a composite volume derived from a thinned fault likelihood attribute (Hale, 2013) and the seismic amplitude to constrain the tracking. For example, for tracking minimum amplitudes, we assign high positive values to large values of fault likelihood.

Porcupine Basin, Ireland

The basin contains abundant incised valleys lying above tilted Jurassic blocks (Quintero, 2013). The 3D geomorphology of the incised valleys is extracted using the proposed method (Figure 7). The mapping is accomplished by locally picking a specific segment of the incised valley. Eventually several horizon patches were produced and subsequently merged in a facies map of the feature (see also Figure 5). The mapped feature corresponds well with regional geological information.

Conclusions

The Thalweg tracker presented in this paper is an effective tool for tracking channels and associated margins. In this paper we showed results from three different basins: North Sea, Bohai Bai and Porcupine. Based on the way the algorithm works we believe that the tool has wider applicability. The tracker exploits the inherent amplitude organization of sedimentary bodies and has potential as general-purpose seismic facies tracker. However, more research is required to understand which depositional facies can be mapped using the proposed method.

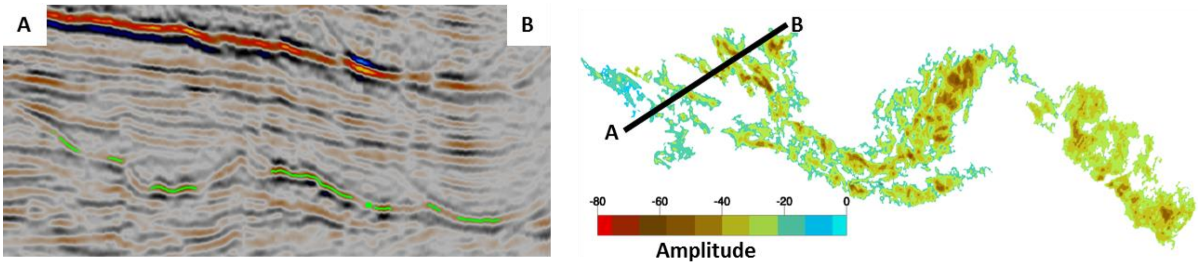

Figure 7 *An example from Porcupine Basin to identify incised valleys through Thalweg tracker.*

Acknowledgements

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