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Inversion benefits from untrackable horizon picking

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Introduction

The impedance contrast in the subsurface rock layers give rise to reflections on seismic records, and are referred to as horizons. The processed seismic data exhibit such horizons as a record of the subsurface reflectivity. Once the seismic data are correlated with well log data, the seismic interpreters can identify the horizons of interest with confidence.

An identified horizon may represent the top of a reservoir, or the reservoir may be located between two horizons. The next task for the interpreter is to track these horizons on 2D seismic lines or on 3D seismic volumes as time surfaces. This task of horizon picking usually begins as a manual exercise, and depending on whether the horizon being picked is a strong or a weak marker, it could be a quick or a long drawn out process (Chopra and Marfurt, 2014).

Horizons may have a consistently high amplitude displaying high lateral continuity, or may have a weak discontinuous amplitude exhibiting little continuity. These characteristics of horizons depend on the depositional environment for the subsurface intervals from where they originate, the lateral changes in the overburden, whether they represent a lithologic interface or a sequential stratigraphic boundary, as well as the signal-to-noise ratio of the seismic data.

Autotracking of horizons is an available option in interpretation software packages, and while prominent horizons may be zapped in no time, for horizons with weaker and variable lateral amplitudes, seed horizons at every 20 inlines and 20 crosslines are usually inserted before using autotracking. The autotracking algorithms are designed to work by detecting the high amplitude peak or trough, or by correlating the wavelets from adjacent traces. Once the seed lines provide the initial controls, the algorithm follows through in the data in the inline and crossline directions to autopick the complete surface. Voxel tracking has also been added in the autopicking procedures in some commercial packages.

These days, commercial software packages (PaleoScan from Eliis, and Horizon Cube from OpendTect) are available that perform high density horizon picking on seismic data. In the event of unavailability of such software packages, other similar techniques can be used for conveniently tracking horizons that are otherwise difficult to pick. Computing the second-derivative of seismic data shifts its frequency spectrum towards higher frequencies, and thus can define some reflections better, making them amenable for tracking. A better alternative for horizon tracking is to make use of voice components (Chopra and Marfurt, 2016). While using the continuous wavelet transform method for spectral decomposition of seismic data, if the mother wavelets are crosscorrelated with the seismic data, the spectral voice components are generated. These voice components are equivalent to the narrow bandpass filtered

versions of the input seismic data, and contain more information that can subsequently be processed and interpreted. If we examine the individual voice components of the input seismic data, we note that a horizon tracked on them may not all fall on the horizon tracked on the input. However, if we pick a horizon on that voice component which is closer to the peak frequency of the input seismic data, the horizon overlaps the one tracked on input data.

Data examples

We demonstrate the application of voice components for picking horizons that otherwise are difficult to pick on the input seismic data.

In Figure 1a we show a segment of a seismic section for a 3D seismic data volume from Oklahoma, US. It shows a diverging set of stratigraphic reflections from right to left. H-1 is the limestone marker and so prominent. H-2 is the top of the Woodford shale, and is another strong marker. However, between these two main markers are several horizons that are difficult to track.

When impedance inversion is performed on seismic data over the broad zone of interest, horizons are usually used to constrain intervals in the input low-frequency models. For simplistic layer-cake geology, a horizon above and another below the reservoir could suffice, and an acceptable impedance volume may be obtained. But for areas where subsurface lithologies were developed in the form of stratigraphic intervals, it is important to constrain the low-frequency models using appropriate seismic sequence horizons. When such low-frequency models are used in the impedance inversion of seismic data, the stratigraphic patterns are much better defined on impedance data, and thus contribute to more accurate interpretation.

We illustrate such an example below where it could be challenging to pick horizons between two bounding prominent markers, yet the intermediate horizons need to be defined for preserving stratigraphic definitions in the interval of interest.

In Figure 1b we show the equivalent 50 Hz spectral voice component to the seismic section shown in Figure 1a. Notice, the different reflections appear as nice and continuous, and we attempt to track horizons 3 to 5, between the main markers 1 and 2. These horizons may not present themselves as ideal candidates for autotracking, depending on the signal-to-noise ratio of the input seismic data, but prove useful for picking of say with 50 inlines and 50 crosslines as seed lines. Also, when these picked horizons are overlaid on the original seismic data (Figure 1c), they look quite reasonable.

In Figure 2 we show the impedance sections equivalent to the sections shown in Figure 1, but for the impedance inversion section shown in Figure 2a, markers H-1 and H-2 only were used for constraining the low-frequency impedance model. The impedance section shown in Figure 2b is drawn from the impedance inversion that used a low-frequency model that utilized horizon H-4 in addition to the two markers H-1 and H-2. Horizons H-3 and H-5 were too close to the main markers and so were left out. Notice that the impedance section in Figure 2b exhibits more well-defined strata as indicated with the pink arrows as well as the black dashed ellipses.

Conclusions

In conclusion, we emphasize the importance of constraining the low-frequency models properly so as to better define the subsurface stratigraphic geometries in our areas and intervals of interest. Such geometrical patterns may not be amenable to horizon tracking on the input seismic data. Tools such as spectral voice components can be used for this purpose, and one or more horizons may be tracked on these data and brought into the impedance inversion. The inversion stands to benefit from doing so as we have illustrated.

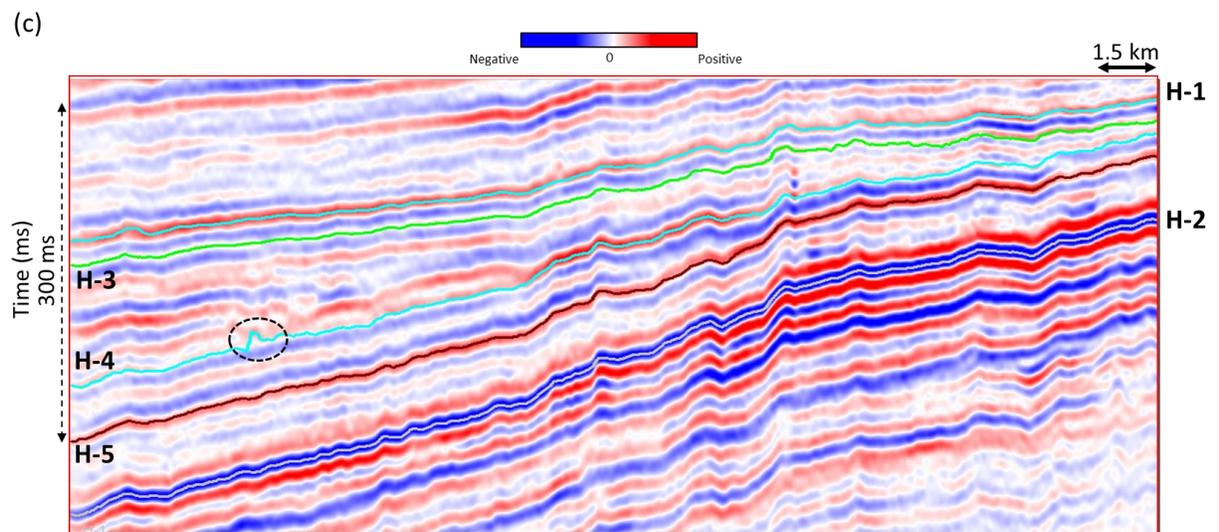
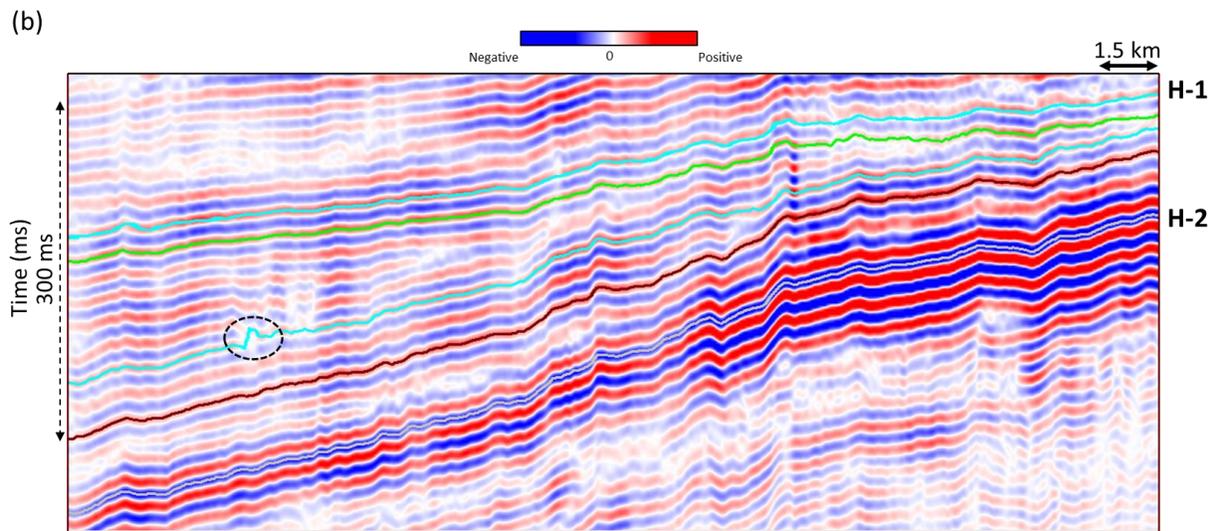
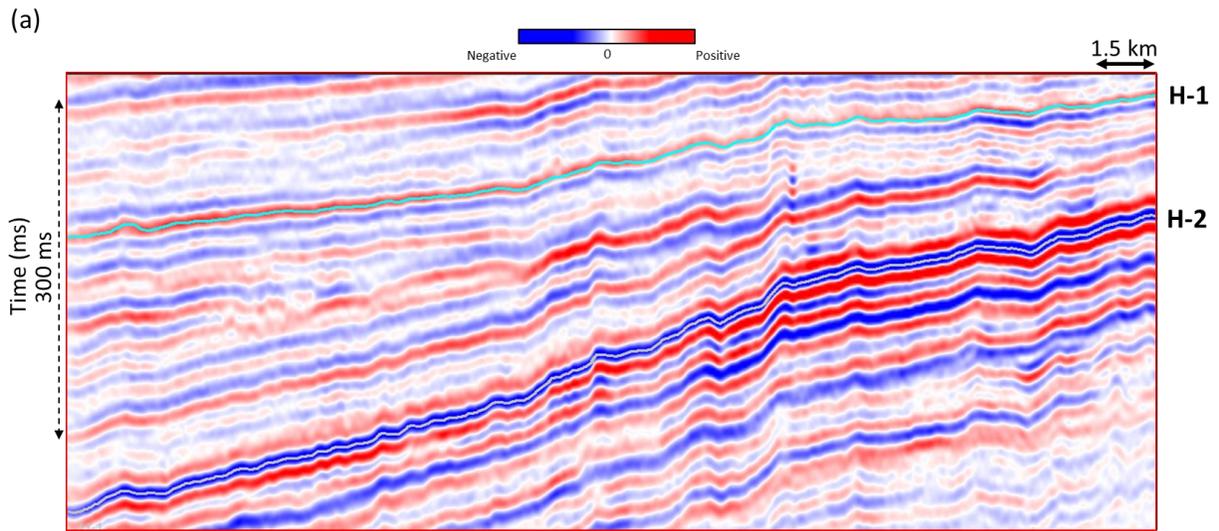


Figure 1: (a) Segment of a seismic section from a 3D seismic volume from Oklahoma, US showing a divergence of reflection events from right to left. Horizons H-1 and H2 are the trackable markers that can be easily autotracked on the data, and the horizons in-between these two markers are difficult to track, even if attempted manually. (b) Equivalent section from the 50 Hz voice component derived from the input seismic data. The intermediate horizons H3, H-4 and H-5 can now be tracked conveniently, though not autotracked in one go. (c) the same section as shown in (a) with the overlay of intermediate horizons. Notice these tracked horizons do not look out of place. Should some unresolved events as shown in the black dashed circle be present in the data, these will need to be smoothed out before generating stratal slices or for running the impedance inversion. (Data courtesy: TGS, Houston)

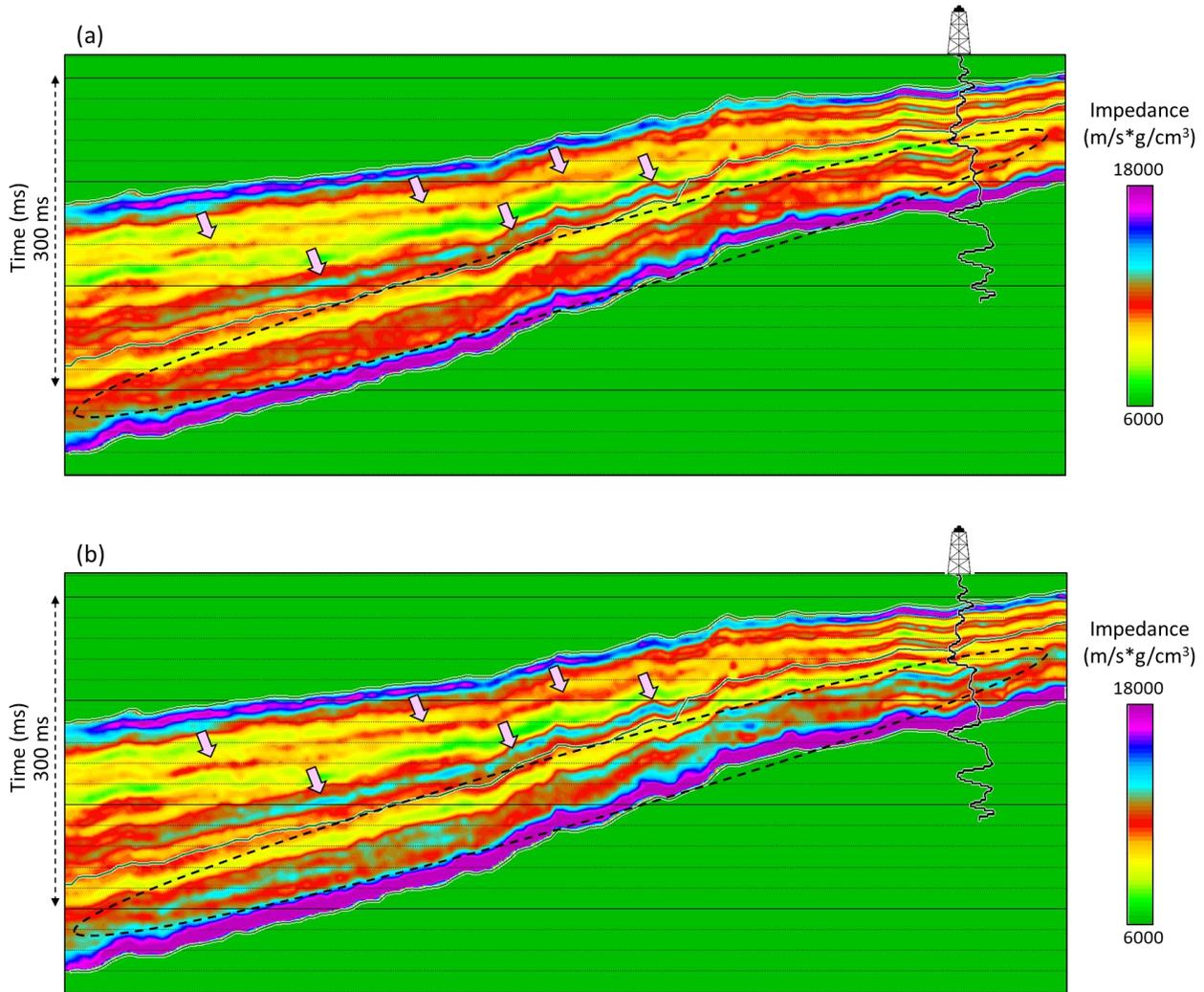


Figure 2: Equivalent impedance sections for the data shown in Figure 1. The impedance inversion was generated for a window bigger than the one shown here to avoid edge effects. (a) the impedance section when only H-1 and H-2 markers were used for constraining the low-frequency impedance model derived from well log data. The log overlay to the right is the impedance log filtered to the seismic bandwidth. (b) Equivalent impedance section but now constraining the low-frequency impedance model by including horizon H-4 in addition to markers H-1 and H-2. Notice the overall impedance section shows better-defined stratal layers as marked with pink arrows and also included in the black dashed highlighting ellipses. (Data courtesy: TGS, Houston)

References

Chopra, S. and K. J. Marfurt, 2014, Autotracking your way to success, AAPG Explorer, 52-53.

Chopra, S. and K. J. Marfurt, 2016, Spectral decomposition and spectral balancing of seismic data, The Leading Edge, 26, 936-939.