GC Conditioning Prestack Seismic Data in the Offset-Azimuth Domain*

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Search and Discovery Article #42462 (2019)
Posted October 14, 2019

*Adapted from the Geophysical Corner column, prepared by the authors, in AAPG Explorer, October, 2019. Editor of Geophysical Corner is Satinder Chopra (schopra@arcis.com). Managing Editor of AAPG Explorer is Brian Ervin. AAPG © 2019. DOI:10.1306/42462Sharma2019

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General Statement

These days acoustic and elastic impedance are commonly derived from 3-D seismic data, which help us compute porosity and reservoir fluid estimates. Somewhat less commonly, vertical fracture density and fracture orientation in the reservoir rocks are derived from seismic data, enhancing our ability for optimum placement of horizontal wells and optimal recovery. To achieve the latter objective, good quality seismic data are required, which might be acquired not only with such objectives in mind, but also to yield data with good signal-to-noise ratio. The processing sequence adopted for the seismic data employs all the usual steps, including 5-D interpolation used for regularization of the offset and azimuth sampling within common mid-point, or CMP, gathers. Thereafter, the common procedure is to azimuthally sector the gathers (six sectors of 30 degrees each), and put them through the azimuthal amplitude variation with offset, or AVO, analysis procedure to determine the fracture density and orientation.

We do not intend to describe that application here. Rather, we focus on preparing that same data for traditional AVO analysis or prestack simultaneous impedance inversion, which in many cases is the end goal these days.

The azimuthally-sectored data are vertically stacked, such that the prestack migrated gathers are obtained. These are then put through a series of steps for signal-to-noise enhancement, comprising bandpass filtering, generating supergathers, applying random noise attenuation and trim statics, etc. as shown in Figure 1. All this is done in the offset domain, wherein the traditional processing of seismic data is carried out. We believe traces that exhibit azimuthal velocity variations when stacked deteriorate the quality of the far stack, which is where the fluid information resides.

An Alternative Method

We propose in this article that the above sequence for conditioning of data is not optimal. Instead of stacking the azimuthally-sectored normal moveout, or NMO, corrected traces at every CMP, we suggest generating supergathers using adjacent CMPs and organizing those supergather traces in a snail gather for every CMP. In Figure 2a we show such a snail gather plot where there are six subtraces (one for each 30-degree azimuth sector) and offsets increasing from left to right. At shorter offset traces, no azimuthal velocity variation is seen, and reflection events are seen aligned horizontally. As we get to the larger offsets, we begin to see the azimuthal velocity variations in the form of undulations, as indicated with yellow arrows. Before the individual azimuth traces are stacked within every CMP trace, the azimuthal variation should be removed so that the traces are aligned for an enhanced-quality stack. It may be mentioned here that in the azimuthal AVO analysis such azimuthal variation is quantified into attributes such as fracture intensity and orientation. But for preparation of presatck seismic data for traditional AVO analysis or impedance inversion, the azimuthal variation does not need to be quantified. One of the methods for aligning the azimuthal variation on individual azimuth traces is to pick some horizons at appropriate intervals on the stacked data, and then overlay them on the CMP gathers. Using a cross-correlation procedure within individual intervals, the reflection events are aligned. We show the application of this procedure in Figure 2b. On comparing with Figure 2a, one can see the alignment the events have gone through. Now if the individual azimuthal traces are stacked for every CMP, the resulting gather traces appear flatter after conditioning and alignment. In Figure 3a and Figure 3b, we show such a comparison.

Conclusion

We take this exercise forward and generate the far-angle (27 to 34 degrees) stacks for both the before and after conditioning of data in the offset/azimuth domain. In Figure 4a and Figure 4b we show a comparison of segments from these datasets. The highlighted areas in orange and magenta outlines represent the zones of interest. The reflection events between the block arrows in pink, yellow and green seem strengthened after the proposed conditioning. Such conditioned data, when taken into the impedance inversion and derivation of elastic properties, exhibit enhanced quality and better characterization of reservoir properties.

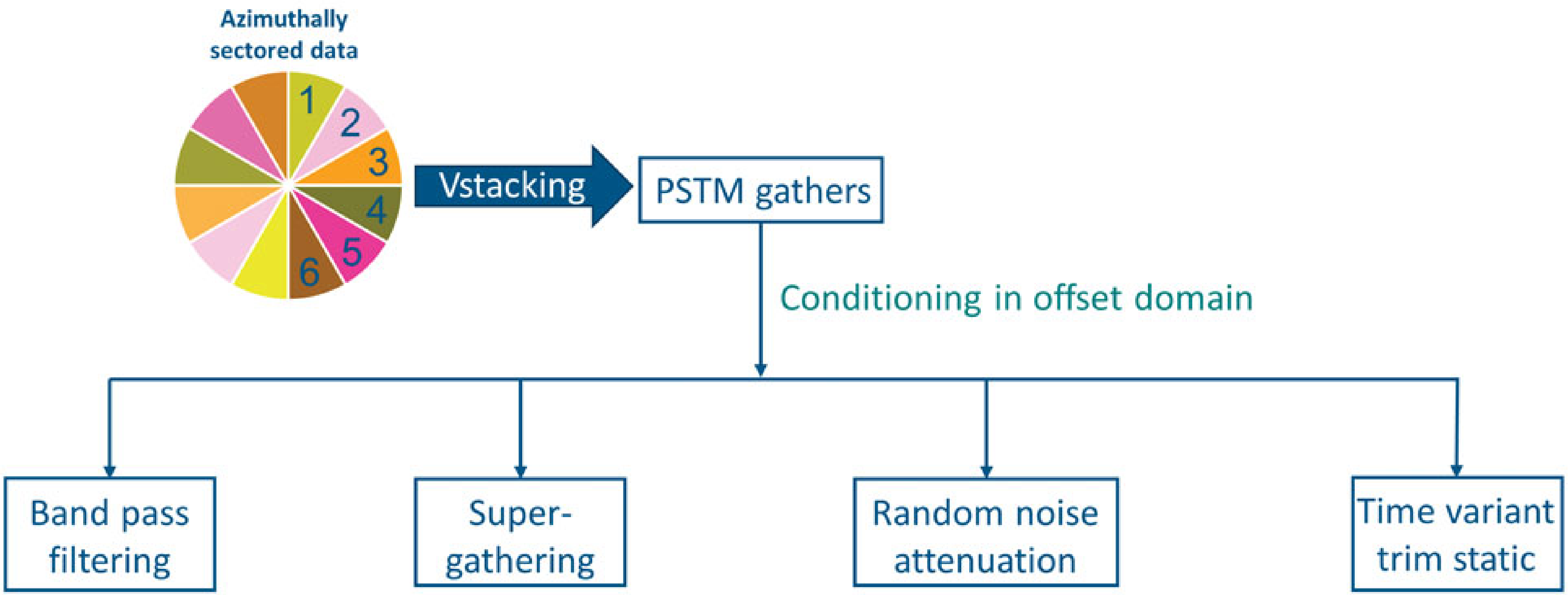

Figure 1. Flowchart for conditioning azimuthally-sectored seismic data for ASVO analysis or simultaneous impedance inversion. The azimuthal amplitude variations in the data if stacked as such can deteriorate the quality of the stacked data.

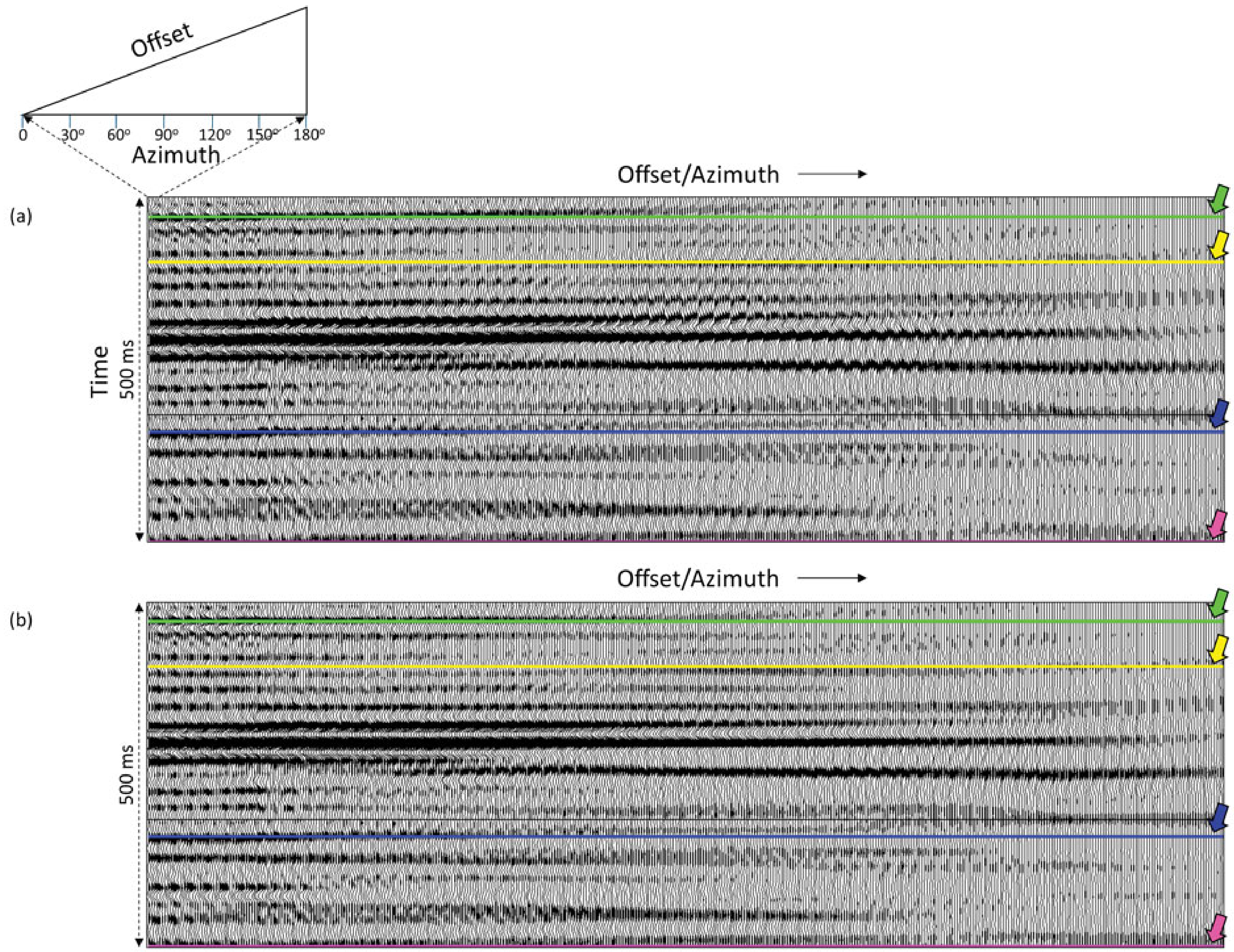

Figure 2. (a) A snail supergather, where each offset trace also has six 30-degree azimuthally-sectored traces as shown on the top left. The azimuthal variations are seen more pronounced from the mid-to-far offsets. (b) The same gather as shown in (a), after aligning the azimuthal variations using a cross-correlation technique within an interval defined by consecutive horizons picked on stacked seismic data. (Data courtesy: TGS, Canada)

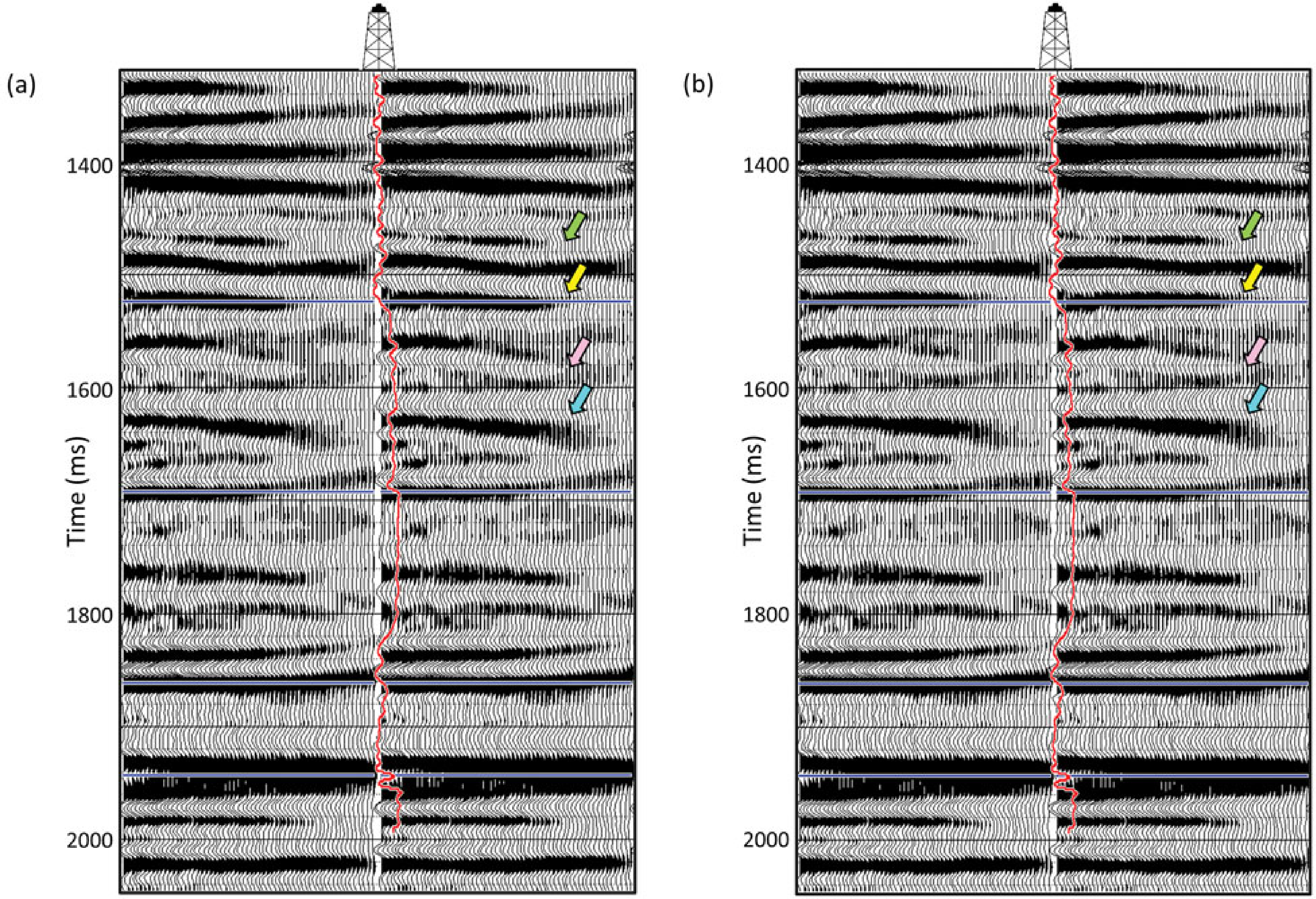

Figure 3. (a) Two representative gathers after traditional conditioning in the offset domain, (b) the same pair of gathers after proposed conditioning in the offset-azimuth domain. Notice the reflection events appear flatter in the latter than the former. (Data courtesy: TGS, Canada)

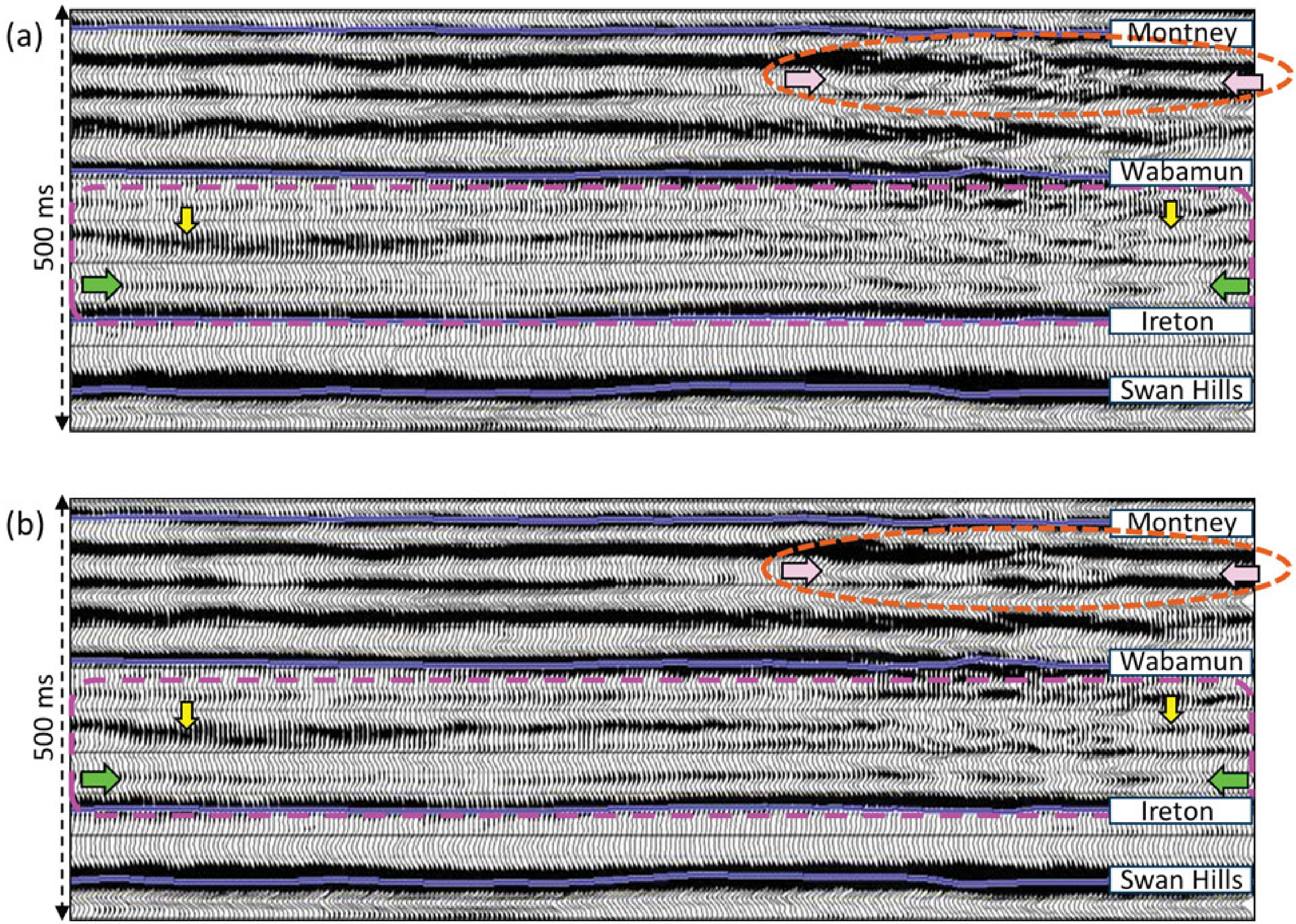

Figure 4. Segments of far-angle stacked seismic sections (a) before, and (b) after offset/azimuth domain conditioning. The highlighted areas in orange and magenta outlines represent the zones of interest. The reflection events between the block arrows in pink, yellow and green seem strengthened after the proposed conditioning. Such enhanced definition of reflection events contributes to better characterization of the reservoir properties. (Data courtesy: TGS, Canada)