GC Enhancing the Quality of Seismic Impedance Data*

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General Statement

Raw seismic data are almost always found to be contaminated with coherent or incoherent noise. Concerted efforts are directed at elimination of such noise during processing of the seismic data, so that its interpretation can be carried out accurately. These efforts are more relevant for stratigraphic interpretation and where amplitude analysis is the end goal. Usually the coherent noise trains seen on seismic shot records are eliminated early in the processing, and the subsequent processing steps address any residual incoherent noise component that may persist. This strategy works well in most cases.

If acquisition footprint is present in the data, it can be noticed on the vertical and horizontal displays of seismic data. If it is not suppressed, then later any attribute work done on such data only accentuates it further, and masks its meaningful interpretation. Causes and Appearance of Noise in Seismic Data Volumes, Search and Discovery Article #41476 by Chopra and Kurt Marfurt, discusses ways to address the suppression of acquisition footprint from seismic data.

But sometimes the low-frequency linear dipping noise is present in the final processed seismic data, and yet goes unnoticed. When such data are worked upon in terms of generation of seismic attributes, the dipping noise can be seen clearly on both vertical and horizontal displays. Another aspect of which some interpreters are aware is that sometimes seismic attributes, when displayed in colored variable density, may not exhibit certain noise patterns – the dipping noise patterns being one of them. But such dipping noise patterns may be seen clearly when the same data are displayed in variable density gray scale.

Noise on Seismic Attribute Data

The post-stack or pre-stack impedance inversion is a typical common seismic attribute generated from seismic data. Both of these methods have been discussed in Impedance Inversion Transforms Aid Interpretation, Search and Discovery Article #41622, and Prestack Impedance Inversion Aids Interpretation, Search and Discovery Article #41664. We illustrate the above aspect on a segment of an impedance section from west-central Saskatchewan, Canada. It was generated using pre-stack simultaneous impedance inversion and is shown in Figure 1, where Figure 1a shows the section in color and the same data is displayed in gray scale in Figure 1b.

Notice the low-frequency dipping noise patterns indicated with yellow and blue arrows. When we examine the two displays carefully, we notice that the impedance values are affected by the linear noise in terms of their lateral variation. A wormy variation in impedance values is seen in Figure 1a in green and red wherever the noise patterns are present and seen in gray scale in Figure 1b. This low-frequency dipping noise needs to be filtered out of the data in such a way that the amplitudes are not affected.

Filtering Out Noise from Seismic Data

For coherent noise suppression from seismic data, a class of methods exists wherein the input seismic data are transformed from the x-t domain into a different domain using a mathematical transformation. A domain to which the seismic data is commonly transformed is the frequency-wavenumber or the f-k domain by using Fourier transforms. The seismic signal and the coherent noise that appear tangled up in the x-t domain get separated in the f-k domain. The low-frequency dipping coherent noise maps close to the wave number axis, and the seismic signal maps close to the frequency axis. Now the undesired component in the data is muted, and the remaining data transformed back in the x-t domain. The other domains to which seismic data in the x-t domain can be transformed are the tau-p (using Radon transform) and f-x (using Fourier transform) domains. A concern some analysts have in such cases is that some signal can leak through the removed component, especially when the noise and the signal are not well separated in the transformed space, so that the method may not be an amplitude-friendly process after all.

A different workflow illustrated in Figure 2 can be followed in such cases. We begin by first separating the data into the low- and high-frequency components, the former encompassing the frequency range of the dipping noise in the data, which is under discussion in this article. Next, the suppression of the dipping noise is affected by one of the available methods including the f-k filtering described earlier, and subtracted from the input data. Besides the residual dipping noise, this data may contain some residual signal that may have leaked through the filtering process. The higher amplitudes of the dipping noise component are then toned down. The residual component so obtained is added back to filtered low-frequency component and the high-frequency components of the input data. We refer to this workflow as a controlled dip-filtering process.

One could think of running the controlled dip-filtering workflow on the impedance data shown in Figure 1a and Figure 1b. We show the results of such an application in Figure 1c. Notice the overly smoothed appearance of the data, which may not be acceptable to the interpreters, for good reason. Not happy with the result, we go back to the input seismic data, which are the near-, mid- and far-angle stacks generated for performing simultaneous inversion and put them through the controlled dip-filtering workflow shown in Figure 2. The dip-filtered angle stacks are then put through simultaneous inversion. The impedance section equivalent to Figure 1b is shown in gray scale in Figure 1d, where the low-frequency dipping noise is no longer seen. No artifact of the dipping noise is seen on the equivalent section shown in color in Figure 1e. We thus conclude that the quality of the impedance data is much better now.

Conclusion

The low-frequency dipping noise, if present in the input data, needs to be handled with care and in an amplitude-friendly way before impedance inversion, or for that matter before any attribute computation is carried out. When the P- and S-impedance data derived from simultaneous inversion are free from noise artifacts, we ensure that the subsequent elastic parameter attributes are of good quality and thus amenable to more meaningful interpretation.

Acknowledgements

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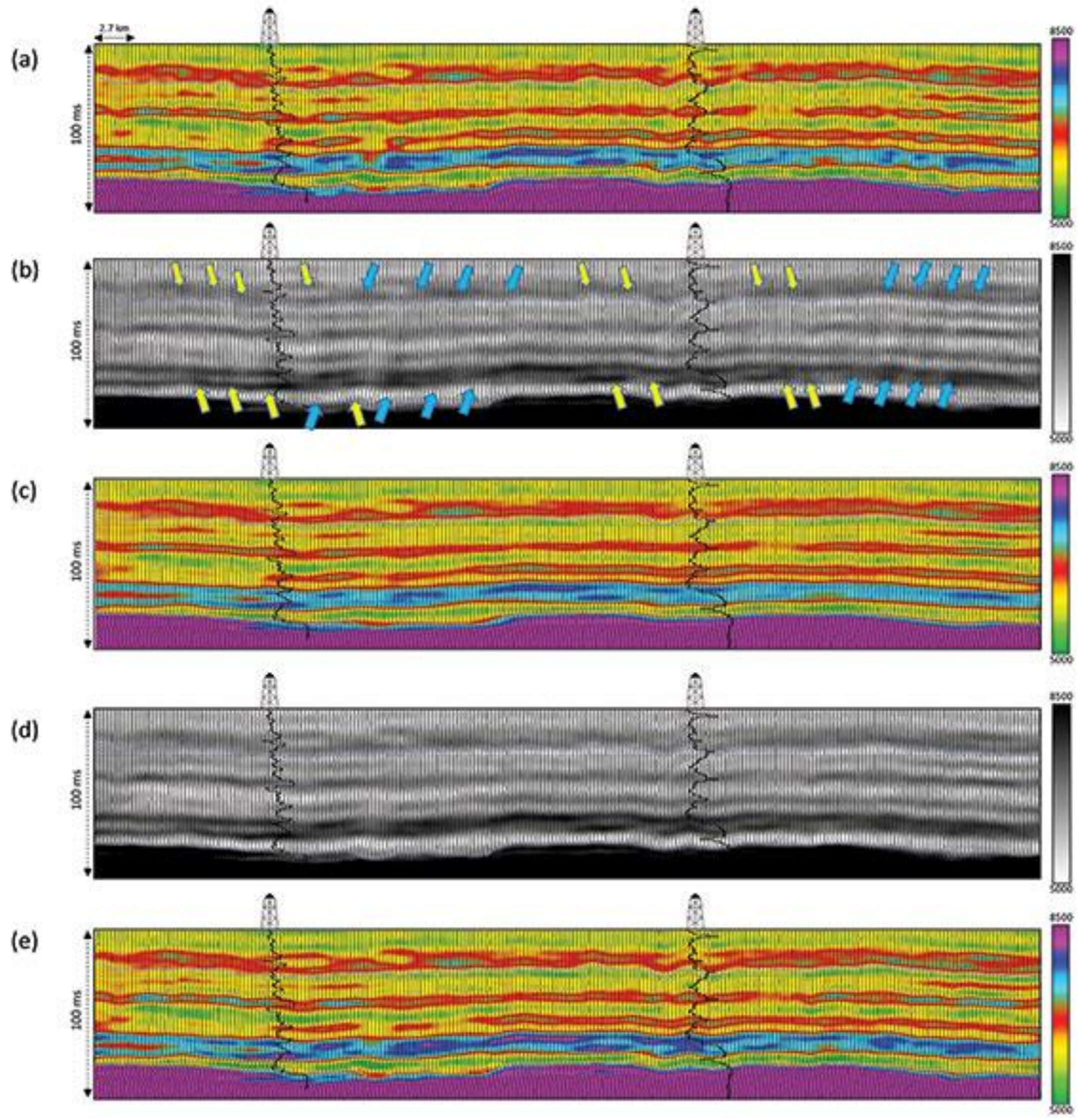

Figure 1. Segment of an (a) inverted impedance section displayed in color; (b) the same section in (a) displayed in gray scale; (c) when the impedance data volume from where the representative section is shown in (a) was dip-filtered (after simultaneous inversion). Notice the lowering of frequency and smoothed events on this section. (d) The equivalent impedance section to data shown in (a) shown in gray scale, but inversion performed on the near-, mid- and far-angle stack data that was put through controlled-dip filtering; and (e) the same impedance section shown in (d) in color. Notice, no low-frequency dipping seen on the gray-scale display shown in (d) and the quality of the impedance section looks much better than the equivalent section shown in (a) or (b).

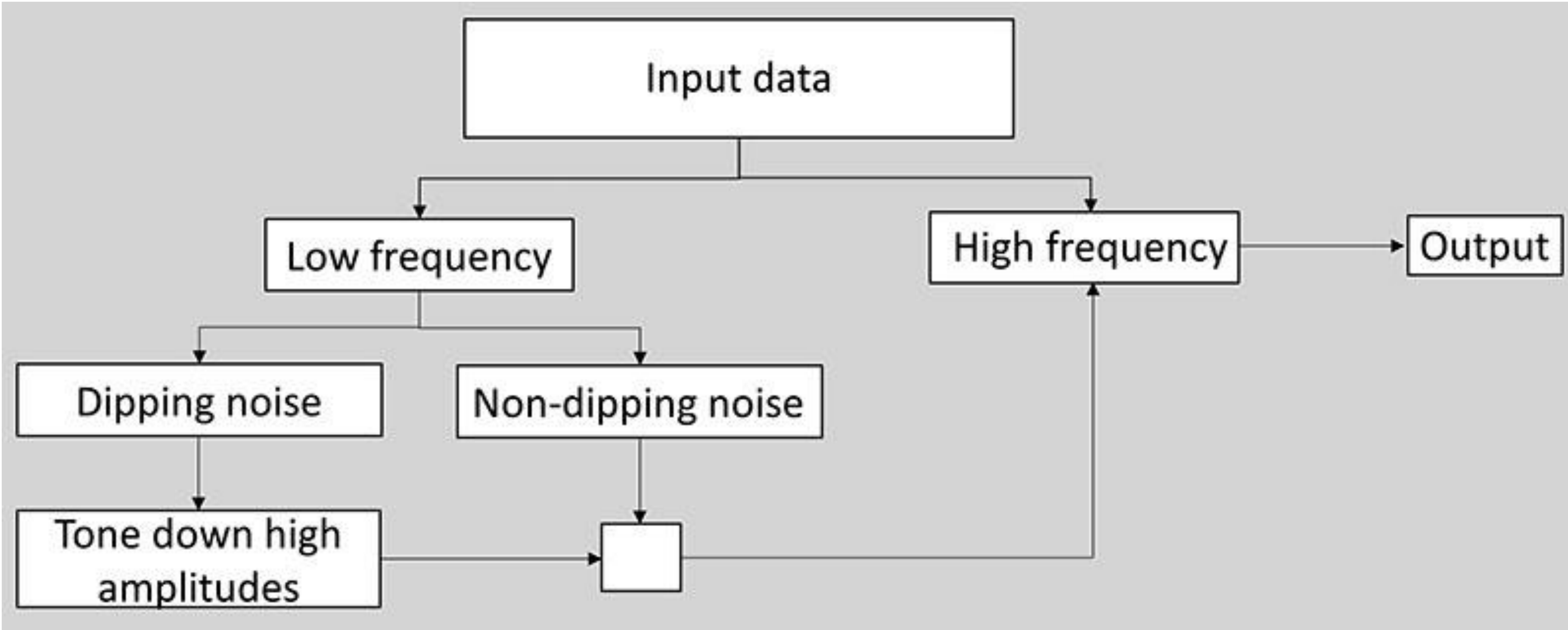

Figure 2. Workflow for controlled dip-filtering that was performed on the near-, mid- and the far-angle stack seismic data, before running simultaneous inversion.