GC Relative Acoustic Impedance Defines Thin Reservoir Horizons*

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General Statement

And now, the rest of the story … You may recall that a novel poststack inversion method was discussed in the May 2008 Geophysical Corner (http://www.searchanddiscovery.net/documents/2008/jw0808chopra/index.html?q=%2Btext%3Achopra); the output from the method described in that article was a reflectivity series that had a resolution superior to that of the input data used to generate the reflectivity response. Some applications of this inversion method were discussed in the 2008 article. Here we illustrate another application of that 2008 reflectivity calculation that aids in quantifying numerous geological features – with the emphasis here being on thin beds.

Many flow units within reservoirs are thin layers that are below seismic resolution, because their thickness is less than one-eighth of the dominant wavelength of the illuminating wavefield, causing the unit to not be resolved seismically. Determining the actual thicknesses of such thin layers is an important task for many geophysicists. We achieve this objective of quantifying thin-bed thickness by a two-step process: First, invert the seismic amplitudes into a reflectivity series using spectral inversion (the topic discussed in the May 2008 article). Second, transform this reflectivity series into relative impedance layers. This step is a trace-by-trace calculation process and can be computed quickly.

Impedance profiles can be represented as either absolute impedances, which have magnitudes equivalent to the magnitudes of log data measured across targeted intervals, or as relative impedances, which have arbitrary amplitudes that show depth-dependent variations equivalent to those exhibited by log data. We emphasize here the option of calculating relative impedances. When interpreting relative impedance profiles, the top and bottom reflection boundaries of a unit are not correlated with well log curves. Instead, the thicknesses of relative impedance layers are correlated with log curve shapes.

Examples

On Figure 1 we illustrate how a 50-meter thick carbonate reef can be distinguished from the base platform carbonate unit that it rests on. As indicated on Figure 1a, the frequency bandwidth of the prestack time-migrated (PSTM) seismic data does not distinguish the reef and the platform carbonate. In contrast, thin-bed reflectivity derived from the PSTM data and then converted into relative impedance data does distinguish between the two units (Figure 1b). The lateral extent of the reef is interpreted as 600 meters. Two wells have penetrated this gas-producing reef, as indicated by the vertical black lines, and verify this interpretation.

Figure 2 shows a vertical section through thin-bed impedance data calculated across a Far East offshore area. This profile follows the trajectory of a horizontal oil producer labeled Well C, which targeted a seven-meter thick sand that was previously encountered in wells A and B. This sand thickness is well below the tuning thickness of the seismic data. The seismic response is further complicated by the presence of coal units, one-meter to two meters thick, both above and below the target sand interval. The horizontal oil producer, Well C, was positioned using the thin-bed impedance data, which showed indications of a higher quality pay sand toward the base of the low-impedance interval that is indicated. The well encountered over 400 meters of good quality pay sand, with high net-to-gross, and stayed inside the seven-meter thick sand interval throughout its entire trajectory.

Our final example shows how relative impedance data helped to distinguish individual sands in a stacked sand sequence. Figure 3 shows sections through:

(a) A prestack depth migrated volume (PSDM), also from a Far East offshore area.
(b) An absolute impedance inversion volume.
(c) A relative impedance inversion data volume.

The log curve is the gamma-ray response that shows an upper dirty sand A, a middle clean sand B and a reservoir in the basal part of sand C. The poor frequency content of the seismic data (Figure 3a) limits the vertical resolution of the stacked sand sequence and gives an erroneous interpretation of the upper reservoir, the B sand. The equivalent acoustic impedance section (Figure 3b) appears to have done a better job of separating the upper sand from the lower reservoirs. Relative acoustic impedances were calculated from the thin-bed reflectivity volume, and the equivalent section shown in Figure 3c shows the separation of the upper dirty sand, the middle clean sand and the reservoir in the basal part of sand C. The stratigraphic boundary corresponding to the basal part of the stacked sands is well defined and allows for a more accurate interpretation.

Conclusion

Relative acoustic impedance calculated from a thin-bed reflectivity series is a useful attribute for extracting thin-bed information from seismic data. We've demonstrated this principle by this column's three examples, which show results that cannot be achieved with seismic amplitudes alone. We recommend that relative impedance be calculated and used for both qualitative and quantitative reservoir characterization.

Acknowledgment

We thank two anonymous companies for permission to publish the examples shown here. The thin-bed reflectivity method mentioned here is commercially referred to as ThinMan™, a trademark owned by FusionGeo, Houston.

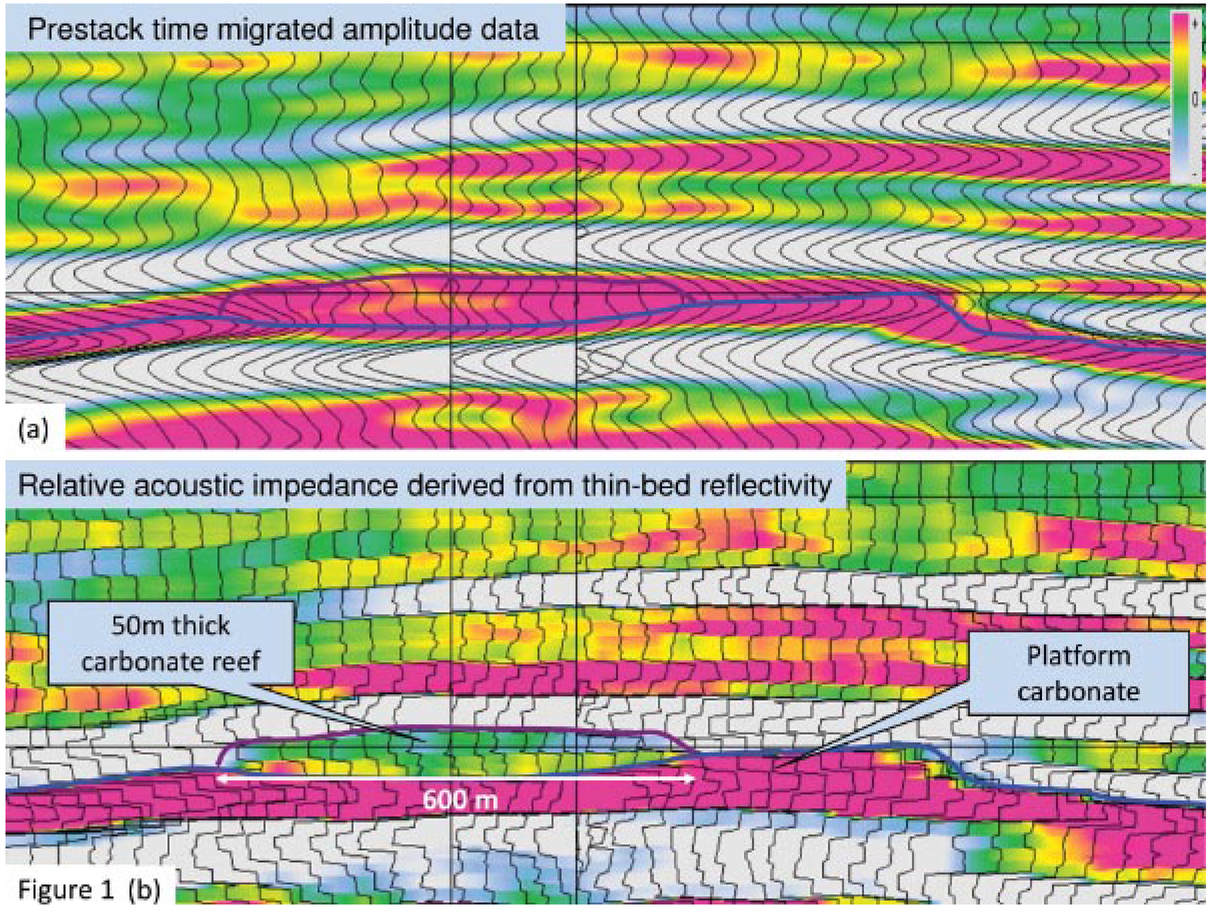

Figure 1. (a) A seismic section from a prestack time migrated data volume showing a weak signature of a gas-producing reef defined by a blue horizon (bottom of reef) and a dark purple horizon (top of reef); (b) the equivalent section shows a relative impedance determined from thin-bed reflectivity. The reef shows up clearly in terms of the green color.

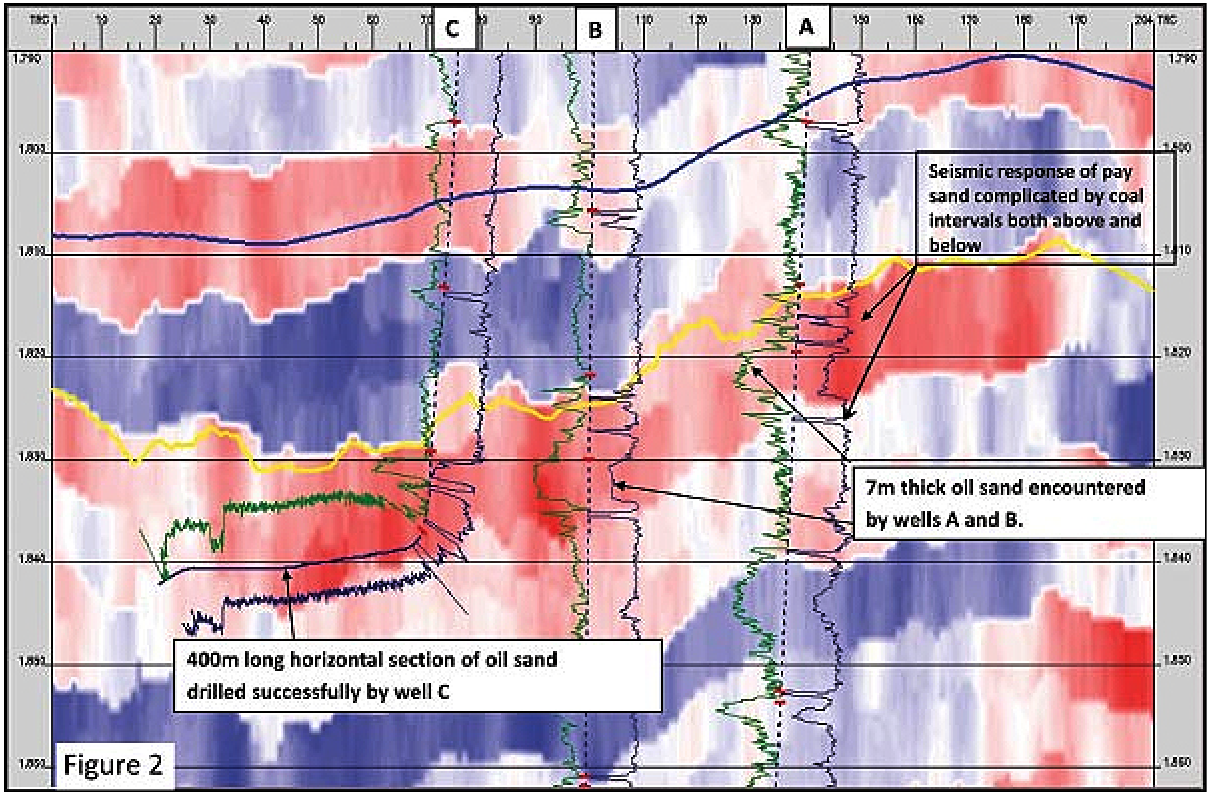

Figure 2. A relative impedance profile calculated from thin-bed reflectivity derived from input seismic data. The log curves are sonic data (right) and gamma-ray measurements (left) at each well. Wells A and B encountered a seven-meter oil sand as indicated, but the seismic signature is complicated because of thin coal units above and below the sand. The relative acoustic impedance exhibits a pale reddish color for the oil sand and allows the sand to be tracked to the left of the profile. Horizontal well C was drilled based on this interpretation, and the horizontal section of this well penetrated approximately 400 meters of productive sand.

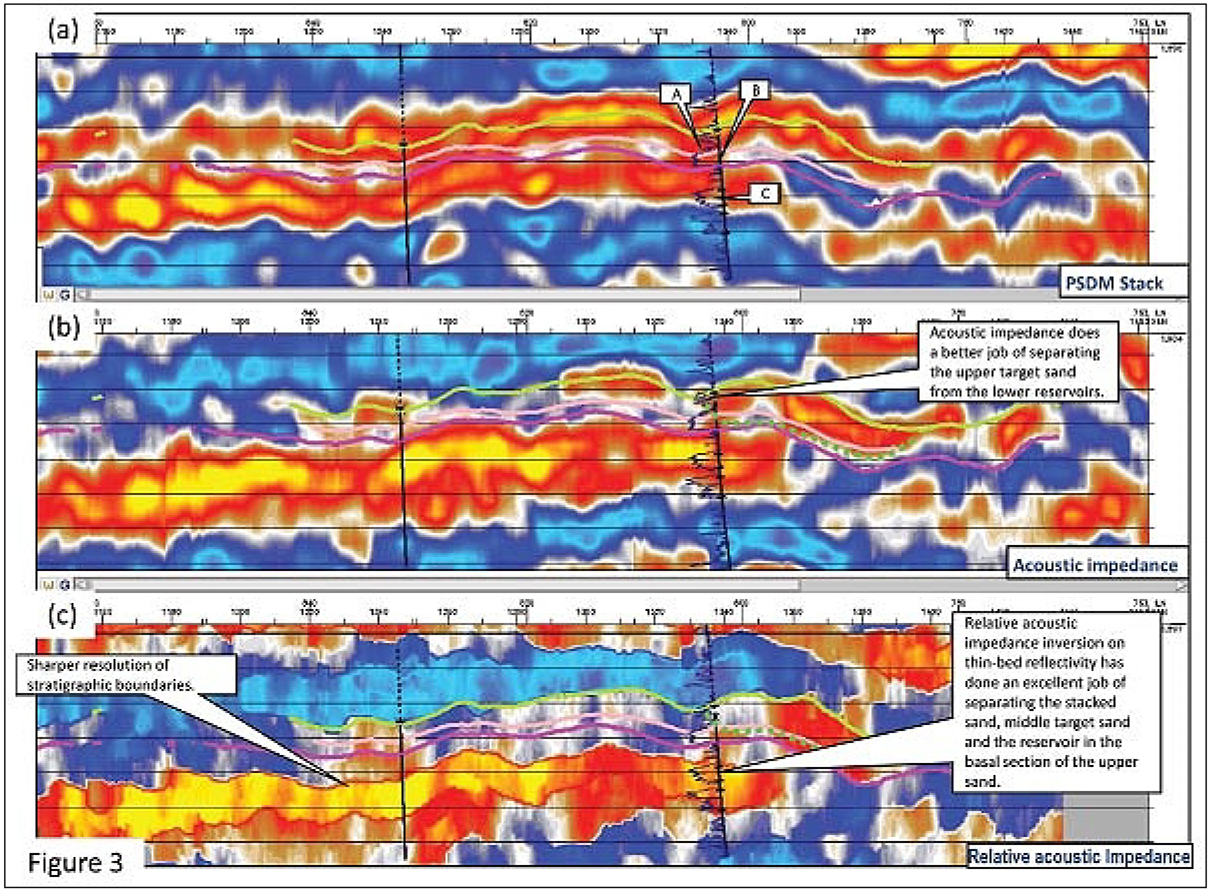

Figure 3. (a) A seismic section of prestack depth migrated data. Reservoir sands A, B and C are indicated on the gamma-ray curve. The poor bandwidth of the seismic data does not show the individual sands. (b) Equivalent section from absolute acoustic impedance. The upper dirty sand is seen with better definition. (c) Relative acoustic impedance calculated from thin-bed reflectivity derived from seismic data. The relative acoustic impedance section has done a better job of separating the stacked sands and reveals the basal part of reservoir sand C.