When Thin Is In – Relative Acoustic Impedance Helps

Satinder Chopra*
Arcis Corporation, Calgary
schopra@arcis.com

John P. Castagna
University of Houston, Houston
and

Yong Xu
Arcis Corporation, Calgary

Summary

Spectral inversion produces sparse reflectivity estimates that resolve thin layers below the tuning thickness. The process differs from other inversions in that it is driven by geological rather than mathematical assumptions, and is based on aspects of the local frequency spectrum obtained using spectral decomposition of various types. The resolution of thin-bed reflectivity inversion is far superior to the input data and so makes it very suitable for characterization of thin reservoirs. Relative acoustic impedance run on thin-bed reflectivity is a useful attribute for extracting meaningful interpretation from seismic data. We demonstrate this by three different examples and also show the advantages that accrue therefrom which is not possible when interpretation is done only on seismic amplitudes.

Introduction

Many significant reservoirs or important flow units within reservoirs are in the form of thin layers, that fall below seismic resolution (i.e. one-eighth of a wavelength and cannot be resolved seismically). However, determination of thicknesses of such layers where the top and base of such layers are not seen distinctly is an important goal for many geophysicists. This can be attempted by first extracting the reflectivity series from the given seismic data and then transforming the reflectivity series into layer thicknesses. While these transformations are referred to as ‘inversion’, the latter application in particular that we discuss here is termed as ‘relative acoustic impedance inversion’, to distinguish it from the usual absolute impedance inversion. The difference lies in the fact that ‘absolute impedance inversion’ refers to the transformation of seismic amplitudes into absolute impedance values which can be compared to impedance values obtained from well logs. Also these impedance profiles/volumes exhibit the basic impedance structure that we expect and see on such data, i.e. impedance values increase with time/depth. During the impedance inversion, this ‘background’ impedance structure is added to the impedance transformation of amplitudes.

Relative acoustic impedance inversion only refers to the impedance transformation of seismic amplitudes where the basic impedance structure is not added. In the present application we demonstrate that its application on thin-bed reflectivity is very useful.

So, the process involves the following two steps:

1. Invert the seismic amplitudes into reflectivity using spectral inversion.

2. Transform the reflectivity series into relative impedance layers. This step is a trace-by-trace process and is relatively fast.

There is one significant difference when we interpret impedance profiles. Instead of correlating the tops and bottoms of formation reflection boundaries with well log curves, relative acoustic impedance allows us to interpret reflection isochron units as individual formation thicknesses which can be clearly correlated with log curves. Even though the impedance values are not absolute, relative inversion is a useful attribute, which we illustrate with the following three examples.

Other workers (Cooke et al (1999); Rahmani et al (2006); Brown et al (2008)) have also demonstrated convincing application of relative acoustic impedance for characterizing thin reservoirs.

Example 1

In Figure 1 we illustrate the usefulness of thin-bed reflectivity application in the identification of a 50 m thick carbonate reef which could not be distinguished from the base platform carbonate. As indicated in Figure 1(a), the limited frequency bandwidth of the prestack time migrated (PSTM) seismic data does not distinguish the two. Thin-bed reflectivity was derived from the PSTM data and put through relative acoustic impedance and the equivalent impedance section is shown in Figure 1(b). Notice the clarity with which the reef is seen, sitting on top of the base carbonate platform. Its areal extent as interpreted here is 600 m across and the two wells penetrating this gas-producing reef are indicated with the vertical black solid lines.

The presentation will show a section through the thin-bed impedance data from the Far East offshore area, taken along the trajectory of a horizontal oil producer, Well C. This well targeted a ~7m thick sand which was previously encountered in Wells A and B. The sand thickness is well below the tuning thickness of the full-stack seismic. The seismic response is further complicated by the presence of 1-2m thick coal intervals both above and below the target sand interval. The horizontal oil producer, Well C, was targeted using the thin-bed impedance data, which showed indications of higher quality pay sand toward the base of the low impedance interval shown. The well encountered over 400m of good quality pay sand, with high net-to-gross, and was able to stay inside the 7m thick target sand interval throughout.

The third example in the presentation will show how the relative impedance helped in distinguishing the individual sands in a stacked sand sequence. Segments of sections through (a) the prestack depth migrated volume (PSDM) also from the Far East offshore area, (b) acoustic impedance inversion volume, and (c) relative acoustic impedance inversion data volume. The overlaid log curve is gamma ray and it shows an upper dirty sand A, the middle clean target sand, B and the reservoir in the basal part of the upper sand C. However, the poor frequency content of the seismic data limits the vertical resolution of the stacked sand sequence and gives an erroneous interpretation of the upper reservoir. The equivalent acoustic impedance section appears to have done a better job of separating the upper target sand from the lower reservoirs. Relative acoustic impedance was run on the thin-bed reflectivity volume and the equivalent section will show how an excellent job has been done in separating the upper dirty sand, the middle clean sand and the reservoir in the basal part of the upper sand B. The stratigraphic boundary corresponding to the basal part of the stacked sands is defined well for drawing an accurate interpretation.

Conclusions

Relative acoustic impedance run on thin-bed reflectivity series is a useful attribute for extracting meaningful interpretation from seismic data. This has been demonstrated by three different examples and this analysis would not be possible with seismic amplitudes alone. It is recommended that this useful seismic attribute be made use of for not only qualitiative but quantitiative seismic reservoir characterization as well.

Acknowledgements

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.

References

Cooke.D., A. Sena, G. O'Donnell, T. Muryanto and V. Ball, 1999, What is the best seismic attribute for quantitative seismic reservoir characterization, 18, no. 1, p1588-1591.

Rahmani, A., A. Belmokhtar, A. Murineddu, J. Khazanehdari, J. English, H. Roumane, B. Godfrey, 2006, The art of seismic inversion – an example from Erg Chouiref, Algeria, 25, no. 1, p264-268.

Brown, L.T., J. Schlaf, and J. Scorer, 2008, Thin-bed reservoir characterization using relative acoustic impedance data, Joanne Field, U. K., 70th EAGE Conference & Exhibition, Rome.

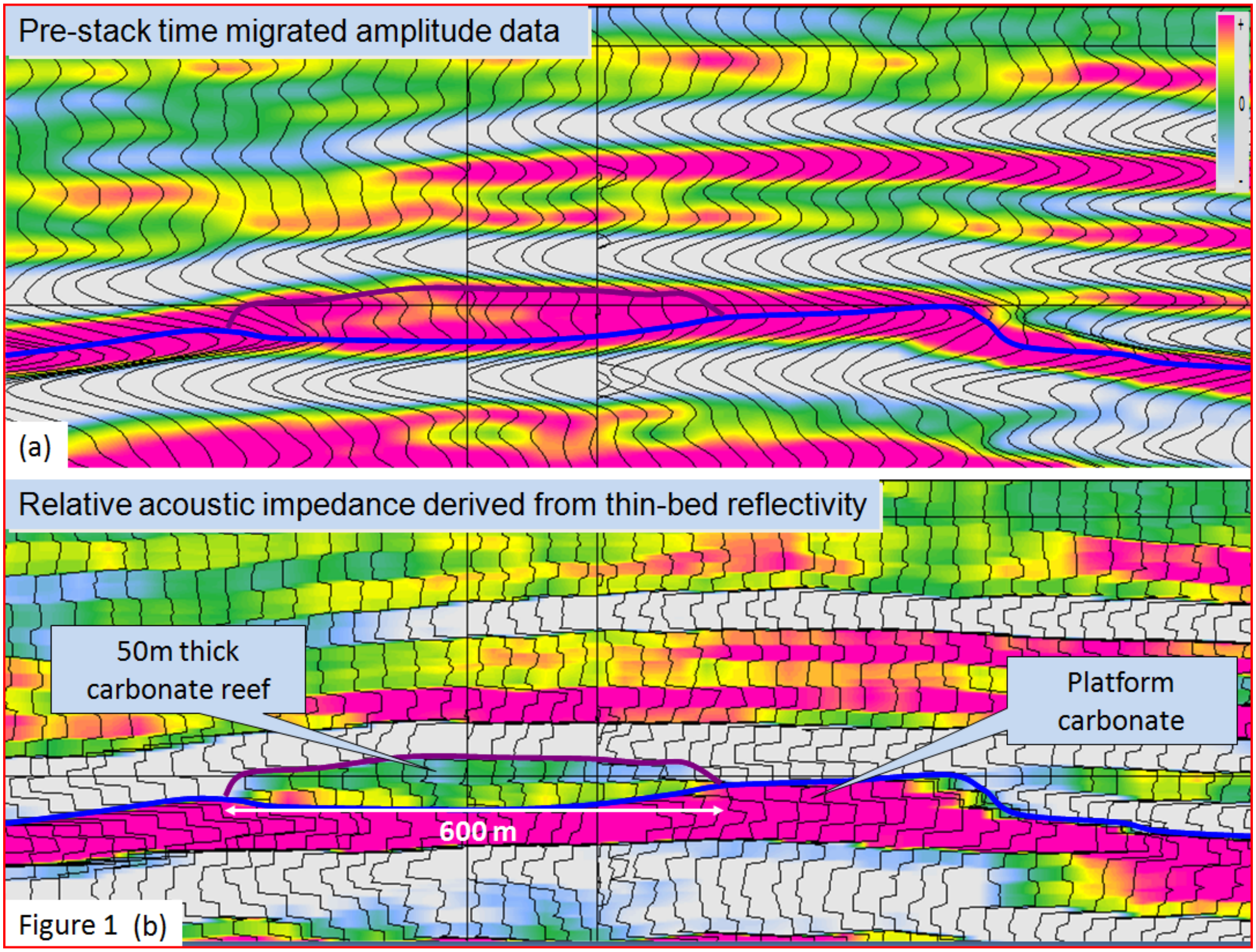

Figure 1. (a) A segment of a seismic section from the pre-stack time migrated data volume shows a weak signature of a gas-producing reef as shown with the blue horizon and the dark purple line over it, (b) the equivalent section from relative impedance run on the thin-bed reflectivity derived from the input seismic data and whose representative section is shown in (a). Notice the signature of the reef shows up clearly in terms of the green colour. *(Data courtesy of Arcis Corporation, Calgary).*