GC Differential Compaction: 3-D Attributes Can Help*

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General Statement

Differential compaction has been used by seismic interpreters to map features of exploration interest such as carbonate build-ups, fans and fluvial channels. However, the 3-D mapping of compaction can take considerable time – and so many times it is not pursued.

But 3-D seismic attributes such as coherence and curvature can be used to map compaction features. This month we illustrate the more common differential compaction expressions over paleo channels and carbonate reefs using examples from the Western Canadian Sedimentary Basin.

Examples

Seismic attributes such as coherence and curvature are routinely used for mapping structural features such as faults, folds and flexures:

- The coherence attribute, which is a measure of similarity of seismic traces, has been used for mapping discontinuities that arise at channel edges, or boundaries, of reefs.

- Similarly, curvature is a measure of bending of seismic reflections and has been used to map faults and folds. Calibrated with borehole image log data, curvature can be used to predict fractures. As differential compaction causes the deformation of overlying, previously flat surfaces, such surfaces can be used to map underlying features of interest.

As the name implies, "differential" compaction is a topological change due to lateral changes in the loss of rock volume as it lithifies. Channels that are filled with shale and are separated by sandier interfluves will appear as structural lows. Channels that are filled with sand cut through a shale matrix may appear as structural highs. Channels incised in older, previously compacted rock, will usually appear as lows regardless of their fill.

In Figure 1 we show a chair display for a strat-cube constructed from the coherence attribute volume and a vertical slice through seismic amplitude perpendicular to the thalweg of the channel. The seismic signature of the incised channel is seen at the positions of the colored arrows, the incision being deeper at the location of the yellow arrow, less deep at the location of the orange arrow and lesser at the green arrow. The disposition of the channel is clearly indicated on the coherence stratslice.

In Figure 2 we show a chair display with seismic amplitude as the vertical section, and for the horizontal section we have overlaid the most-positive (red) and the most-negative curvature (blue) attributes using transparency.

Notice the edges of the channel are seen in red and the axis of the channel is defined in blue. Segments of a deeper channel also are seen in the display and these have been marked with light blue arrows.

In general, it is easier to reduce pore space – and therefore compact shales – than sand. If the channel is filled with sand, it will appear to have a positive relief feature seen over the length of the channel and slight negative relief feature at the edges of the channel. The coherence attribute picks up the edges of such a channel – however, the most-positive curvature attribute shows the central mound over the channel (Figure 3a) and the most-negative curvature defines the edges of the channel as shown with the help of yellow arrows in Figure 3b. Such patterns serve as a lithologic indicator.

Carbonates are stronger and more difficult to compact than sands and shales. While living, the carbonate mound was structurally higher than the surrounding sediments. Once it died it was covered by flat overlying, typically softer, more easily compacted sediments.

Differential compaction between the reef carbonate facies and the off-reef facies results in an image whereby the overlying sediments appear to drape across the carbonate buildup. The extent of the drape would depend on the variation in the compaction of the reefal and the off-reef material as well as the thickness of the overlying sediments. In Figure 4a we show a chair display with the horizon slice from coherence and correlated with the vertical seismic section. Notice the prominent reef feature on the coherence and the drape of the seismic reflections over it – the most-positive curvature (Figure 4b) defines the mound and corresponds to the edges of the reef clearly.

Conclusion

Thus, a clear understanding of the effects of differential compaction can facilitate the rapid interpretation of otherwise subtle, and perhaps otherwise overlooked geological features of interest.

Acknowledgment

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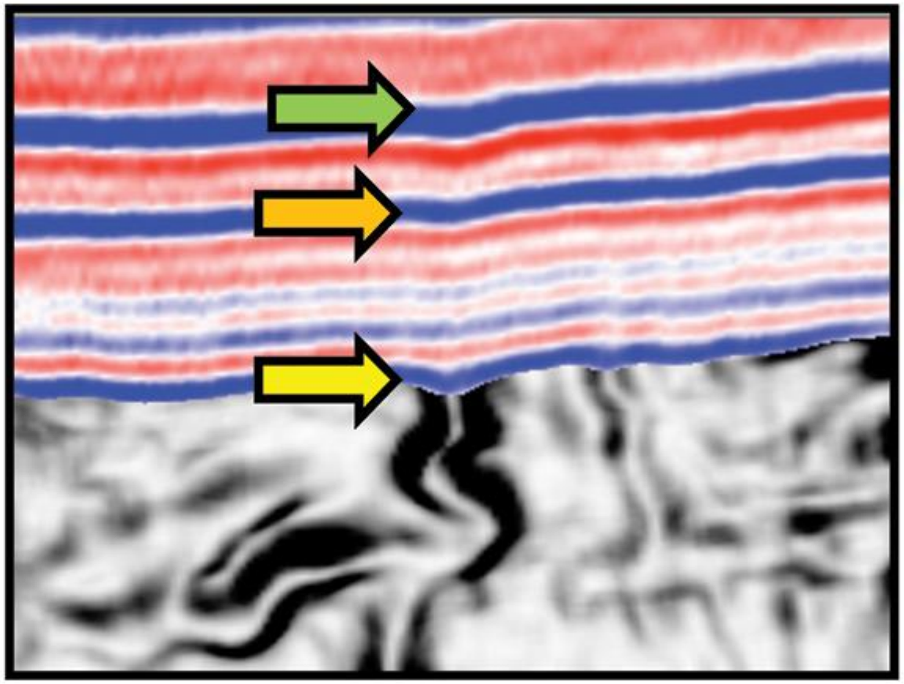

Figure 1. Chair display showing an incised channel on a coherence stratal slice and its seismic amplitude signature. We interpret the sag over the channel to indicate that it contains more shale than the surrounding matrix.

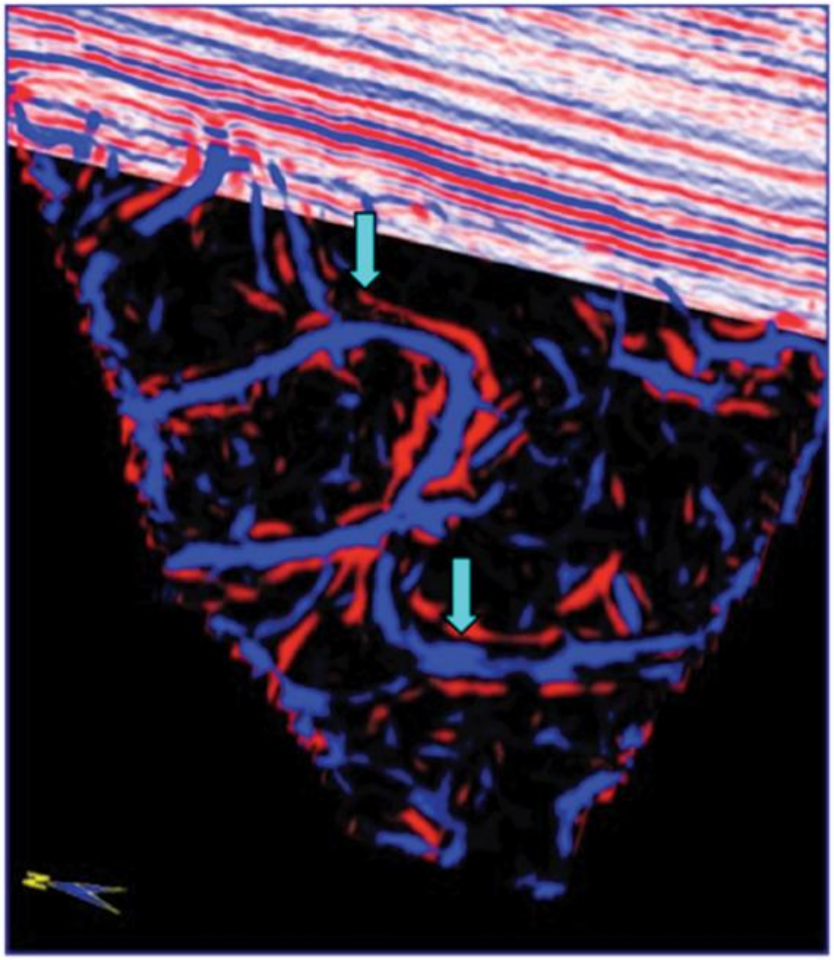

Figure 2. A chair display of the same volume shown in Figure 1 showing a vertical slice through seismic amplitude and a thin strat cube through co-rendered most-positive and most-negative curvature volumes where moderate curvature values are rendered transparent. Sediments within the channel have undergone more compaction and give rise to a strong negative curvature anomaly along its axis (in blue). Levees and channel edges appear as ridges and give rise to strong positive curvature anomalies (in red).

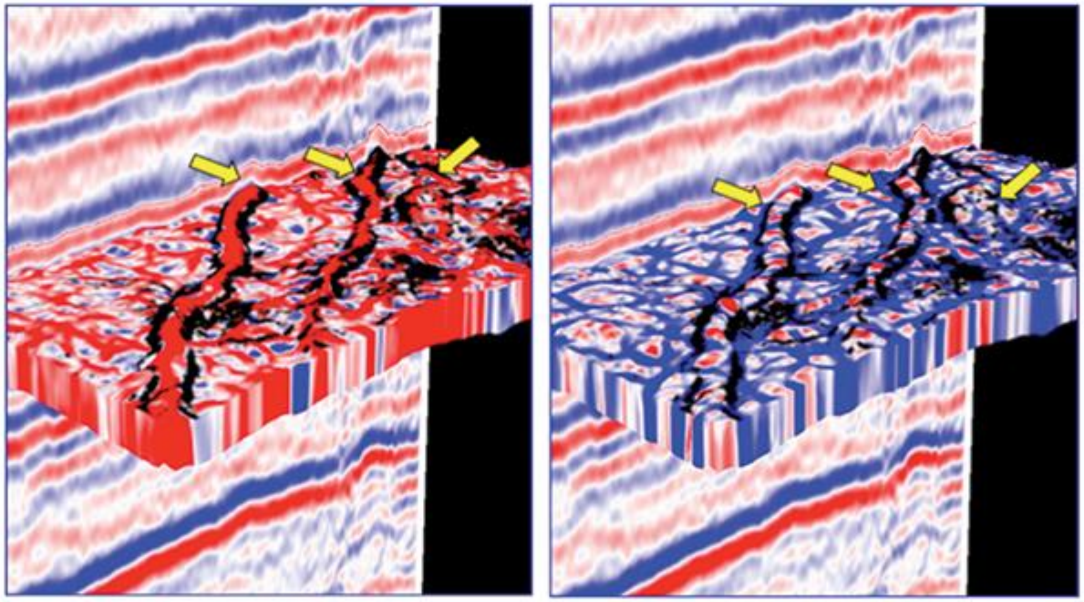

Figure 3. A chair display showing a vertical slice through seismic amplitude and (a) a strat cube from the most-positive curvature attribute co-rendered with coherence, and (b) a strat cube from the most-negative curvature attribute co-rendered with coherence. Notice in this case we see the edges of the channel very nicely on the negative curvature.

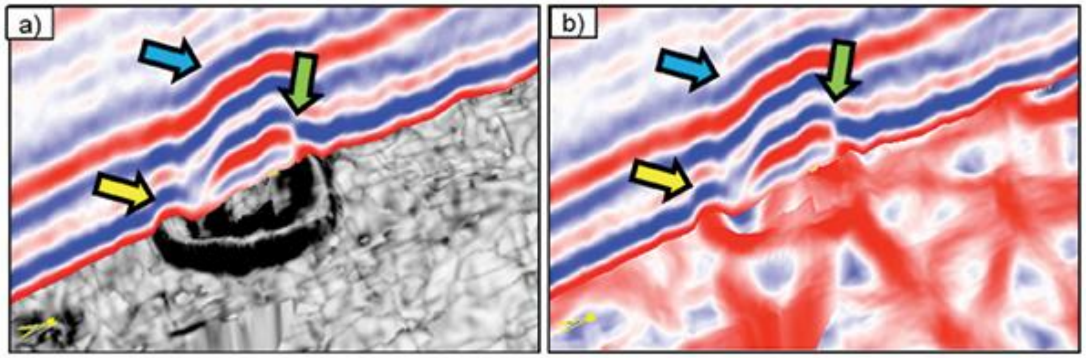

Figure 4. Chair display of seismic amplitude and stratal slices through (a) coherence and (b) most-positive curvature showing differential compaction over a carbonate reef. Yellow arrow indicates the rim or atoll. Strong compaction often gives rise to discontinuities (green arrow). Note compaction drape well above the structure (blue arrow).