

^{GC}Stratal Slicing Makes Seismic Imaging of Depositional Systems Easier

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General Statement

Many people today view land surfaces from commercial airplanes or on satellite images and are amazed by the geomorphic forms of river channels, deltas, barrier islands, dune fields, and other features. These views show us modern stratal-time surfaces of exposed landforms.

Three-D seismic technology has now made it possible to image similar, but much older, geomorphic features and stratal surfaces preserved in the rock record. Historically, interpreters have analyzed vertical sections of 3-D seismic volumes line by line and found field-scale (50 meters or thicker) geologic and depositional features. Sometimes, reservoir-scale (three-10 meters thick) features can be detected in these vertical sections, but many of these small-scale targets cannot be resolved and interpreted because of data bandwidth limitations.

For example, in the vertical view in Figure 1a the seismic facies around the dash line are interpreted to be fluvial deposits, based on the presence of discontinuous, patchy events and frequent lateral changes in amplitudes. Wells drilled through the interval support this interpretation.

However, correlating individual channel-fill sand bodies and marginal facies (levee, crevasse splay, etc.) on adjacent vertical views is difficult because these facies elements are thin (three-10 meters) and the seismic resolution barely resolves the tops and bases of the thickest units. In this particular section view, it is not possible to decide what depositional elements are represented by the circled features.

Time, Horizontal, and Stratal Slices

One strategy to map depositional systems with high resolution is to change the emphasis of seismic interpretation from vertical sections to horizontal sections. For a perfectly migrated 3-D seismic data set, horizontal resolution is the same as vertical resolution. Outcrop and subsurface studies show depositional bodies have horizontal dimensions

greater than their vertical dimensions. As a result, small depositional bodies often can be resolved in plan view even if they can only be detected in vertical view.

As a demonstration of this principle, a stratal slice made by the method described in this article and then passed through the dash line in Figure 1a shows high-quality images of fluvial channels, crevasse splays, floodplain, and a mud plug (Figure 1b). Although most of these depositional elements are less than 10 meters thick -- and thus below vertical seismic resolution -- they are well resolved in the horizontal dimension.

To implement horizontal-view seismic interpretation, we must pick geologic-time surfaces (or stratal surfaces) from 3-D seismic volumes so that seismic attribute maps across these fixed-geologic-time surfaces can be analyzed in terms of depositional systems. Time slices and horizon slices are the horizontal-section views most commonly used by seismic interpreters (Figures 2a-b). Time slices are extracted from a data volume at a constant image-time coordinate. A horizon slice is constructed by extracting a seismic attribute parallel to a picked time-varying horizon.

For either horizontal view to be an accurate representation of a stratal surface, one must assume the formation being sliced is flat-lying when time slicing is used (Figure 2a), or that the formation has a sheet-like geometry (Figure 2b) when horizon slicing is used.

Many depositional sequences, however, are characterized by thickness changes (Figure 2c), which cause horizon-slice and time-slice surfaces to sample seismic events that are associated with strata of different geologic ages. A different surface extraction method must be used to ensure an extracted surface follows a fixed-geologic-time surface.

One such method is “stratal slicing” (Figure 2c), or proportional slicing, which divides the variable-thickness vertical interval between two seismic reference events (Figure 2) into a fixed number of uniformly spaced subintervals. If the number of subintervals is 10 and the time thickness between the reference surfaces at points A and B (Figure 2) is 27 ms and 58 ms, respectively, then the thickness of each subinterval at coordinate A is 2.7 ms, and at point B each subinterval is 5.8 ms thick. The interface between each pair of subintervals (the dash lines in Figure 2) approximates a stratal surface.

In principle, no major angular unconformities (truncations) or other discordant reflections should occur between the reference events.

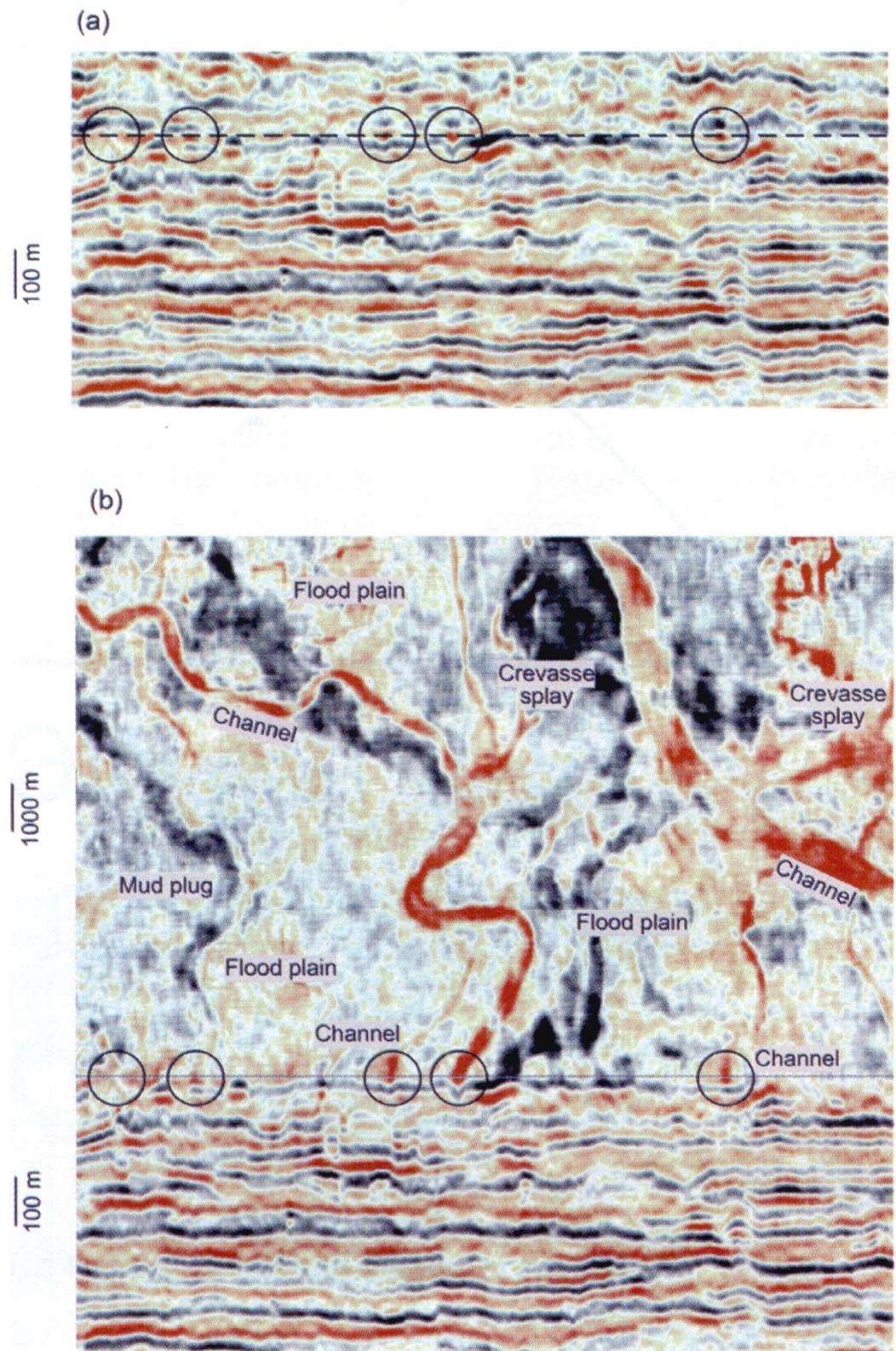


Figure 1. (a) Vertical section view of a fluvial environment (dash line and circled features); (b) Stratal slice showing small depositional features are better seen in horizontal view than in vertical view.

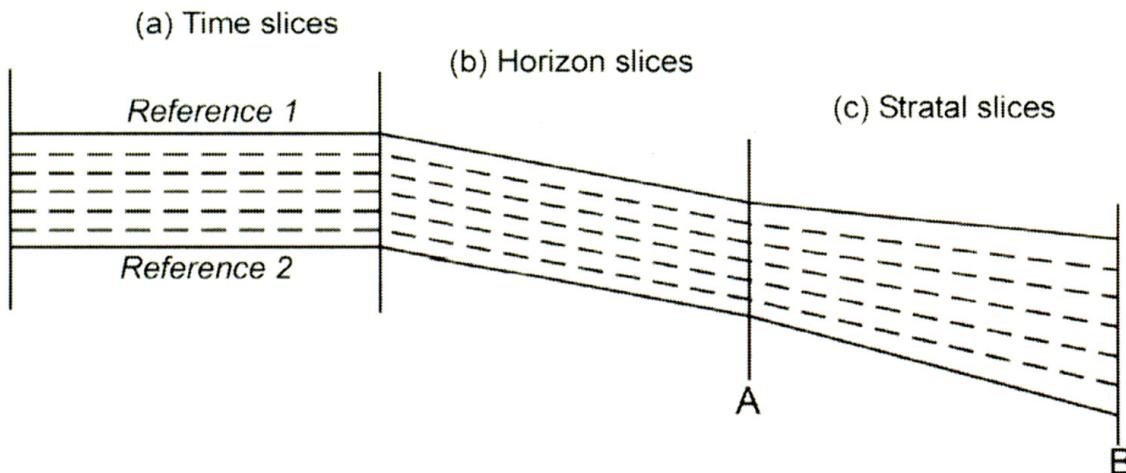


Figure 2. Distinctions among time slices, horizon slices, and stratal slices: A time slice (a) follows a constant image-time coordinate; a horizon slice (b) parallels a reference reflection event; stratal slices (c) divide a time-varying interval thickness into uniform geologic time increments.

Example of Stratal Slicing

Stratal slices provide a stratigraphic resolution that cannot be achieved using vertical sections alone. The data in Figure 3 show a Gulf Coast Pliocene sequence having a dominant frequency of 30 Hz and a vertical resolution of 10 m.

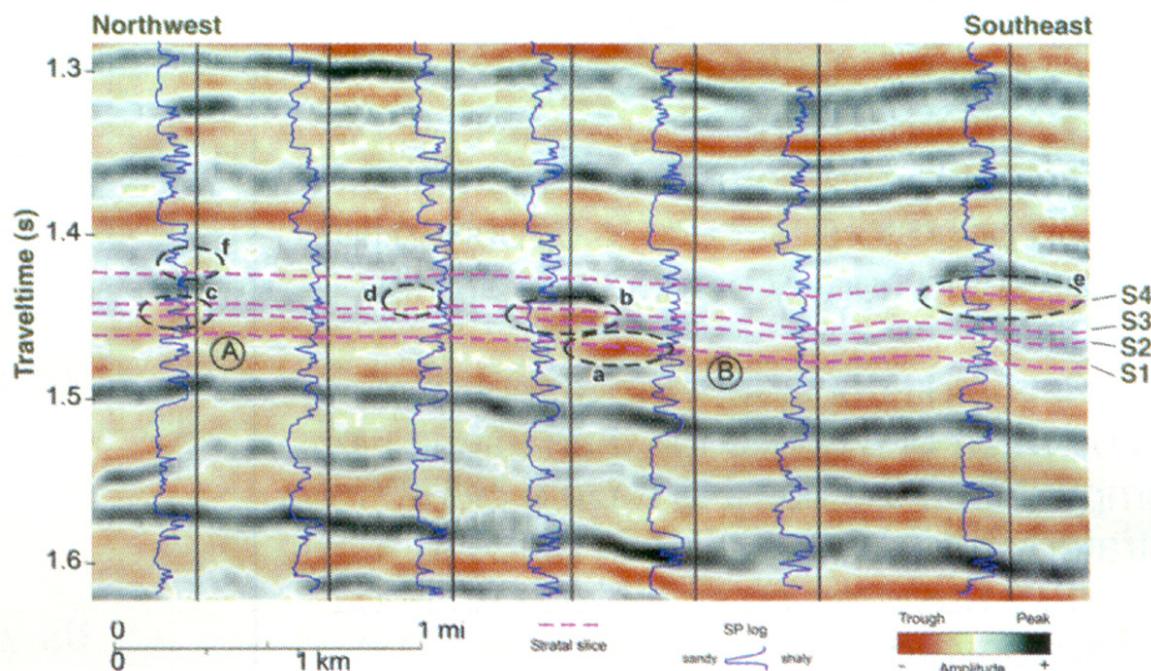


Figure 3. A Pliocene interval from the Gulf of Mexico. Dash horizons S1 through S4 are stratal slices. Time intervals between stratal-slice pairs vary in thickness across seismic image space, as seen by comparing the interval between S1 and S2 at points A and B. Circled features are sandstone units.

Four stratal slices were taken inside a 30-ms (36-m) interval (Figure 3, S1 through S4). Interpretation of wireline well logs (SP) across the interval shows the sandstones are fluvial in nature. Some of the sandstone units (e.g., a, b and e in Figure 3) are thick (20 to 25 meters) and create amplitude anomalies. Others are thin (10 meters or less) and subtle (c, d and f in Figure 3).

In map view, the four stratal slices image four episodes of fluvial deposition (Figure 4, S1 through S4). The fluvial systems on stratal slices S1, S2, and S4 are fully resolved without interference from overlying or underlying units.

Stratal slice S3 shows a narrow (35 to 70 meters, or 1 to 2 traces wide), well-developed meandering feature interpreted to be a small coastal plain channel (Figure 4, arrows). Wireline logs indicate this channel-fill sandstone is about four meters thick. Image S3 is only six ms (seven meters) above slice S2 and is contaminated by some interference from the S2 fluvial system.

Even so, identification of the meandering channel across stratal surface S3 is unambiguous. The image resolution achieved in this case is much smaller than vertical resolution and probably represents the limit of resolution expected from stratal-slice analysis for this data set.

Appendix

The software used to make stratal slices, including necessary reconditioning of seismic data and various attribute applications, was developed by a joint effort of academia and industry, and is available at www.austingeo.com.

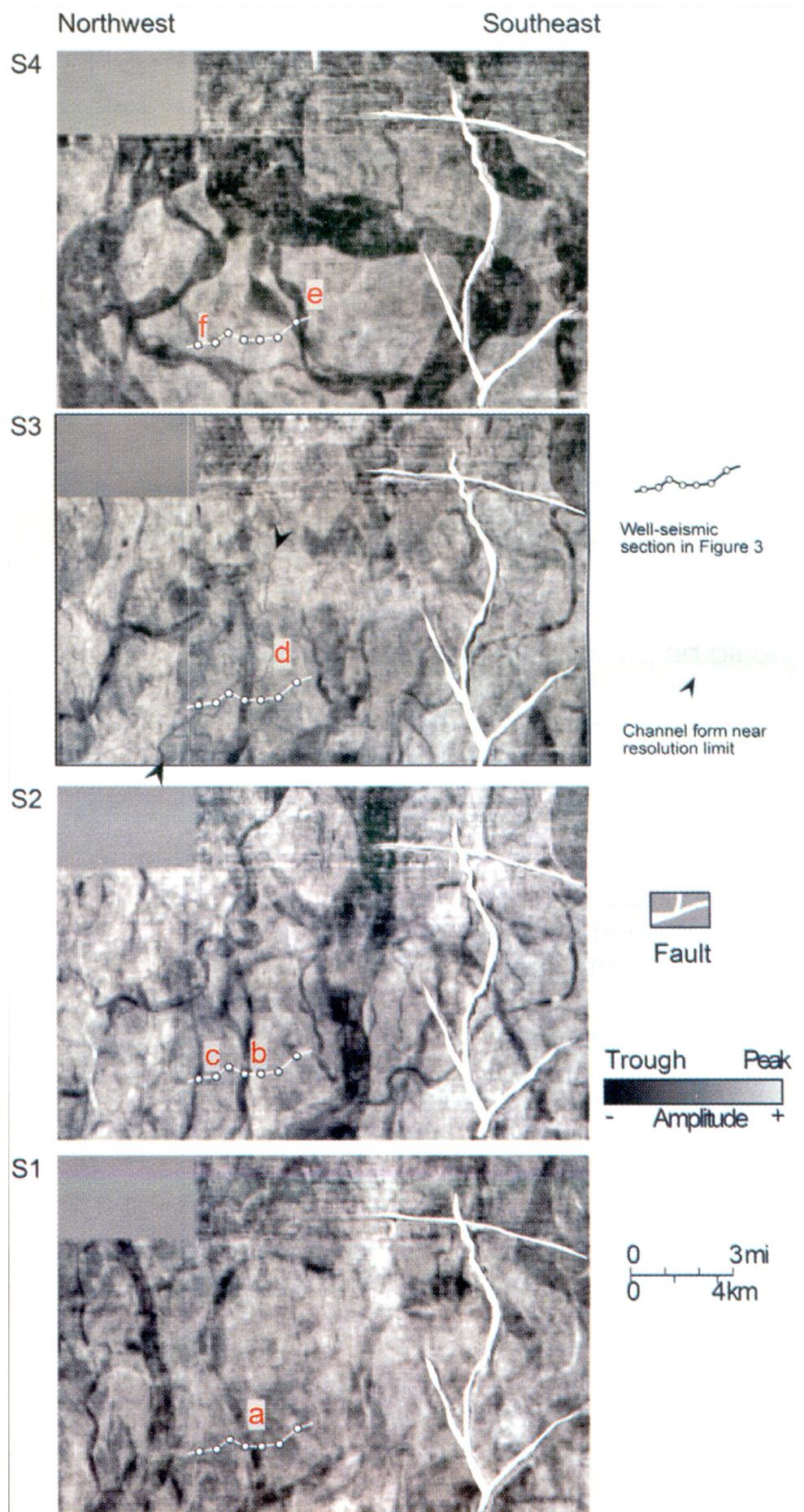


Figure 4. Large-area map views of geology across the stratal surfaces defined in Figure 3. The position of the vertical section in Figure 3 is identified on each surface.