# 3-D Seismic Stratal-Surface Concepts Applied to the Interpretation of a Fluvial Channel System Deposited in a High-Accommodation Environment

Bob A. Hardage and Randy L. Remington

Bureau of Economic Geology, The University of Texas at Austin,
University Station, Box X, Austin, Texas, USA 78713-8924

**Abstract**

A fundamental thesis of seismic stratigraphy is that seismic reflections follow impedance contrasts that coincide with stratal surfaces, which are surfaces where depositional processes occur at a fixed moment in geologic time. This stratal-surface concept is used herein to image a narrow (width ~300 ft), thin, fluvial channel system that is embedded within a seismic reflection peak. The peak reflects from a large (about 2- × 2-mi) area of nonchannel facies that dominate its waveshape.

The targeted channel facies are confined to an interval that vertically spans less than 30 ft. According to principles of seismic stratigraphy, four conformable seismic stratal surfaces that pass through the interior of this channel sequence were constructed across the 3-D seismic-data volume. The channel images portrayed on these seismic horizons, which were spaced at vertical increments of 2 ms, illustrate the principle that seismic attributes viewed on seismic stratal surfaces provide valuable images of facies distributions within thin-bed sequences and help seismic interpreters segregate channel facies from nonchannel facies. A comparison is made between channel images on seismic stratal surfaces that are conformable to two different reference surfaces, one reference surface being positioned below the targeted fluvial system and the second reference surface being above the thin-bed channels. This comparison supports the premise that seismic interpreters should extrapolate stratal surfaces both upward and downward across a thin-bed target to optimize the image of that target.

## INTRODUCTION

The term *accommodation space* refers to that volume of a depositional basin that lies below base level—a surface above which erosion occurs and below which deposition occurs. A *high-accommodation depositional environment* is a basin setting in which the space available for sediment to accumulate, whether because of basin subsidence or sea-level rise, always balances or exceeds the volume of sediment input. High-accommodation sediments, which are rarely subjected to erosion, therefore, tend to be excellent records of depositional processes and environments because once sediment layers are deposited in such an environment, they tend to be altered and modified only by normal compaction and diagenetic processes. Recent- to Miocene-age rocks of the Gulf of Mexico are excellent examples of high-accommodation depositional environments. 3-D seismic-data examples illustrated here come from this very basin setting, the 3-D survey area being located only a short distance northwest of Corpus Christi, Texas.

A *stratal surface* is a depositional bedding plane, that is, a depositional surface that defines a fixed geologic time. Any siliciclastic sediment deposited in a high-accommodation environment contains numerous vertically stacked stratal surfaces. A fundamental thesis of seismic stratigraphy is that a seismic reflection event follows the impedance contrast associated with a stratal surface, that is, a surface that represents a fixed point in geologic time (Mitchum and others, 1977; Vail and Mitchum, 1977). Because lithology varies across the area spanned by a large depositional surface, the implication is that an areally pervasive seismic reflection event does not necessarily mark an impedance contrast boundary between two fixed rock types as the reflection traverses a prospect area. The application of this fundamental concept about the genetic origin of seismic reflections to seismic interpretation is referred to as *stratal-surface seismic interpretation*. Tipper (1993) illustrated and discussed situations in which a thin-bed seismic reflection can be either chronostratigraphic or diachronous, depending on (1) the vertical spacings between beds, (2) the lateral discontinuity between diachronous beds, and (3) bed thickness. The conclusion that a thin-bed seismic reflection is chronostratigraphic or diachronous thus needs to be reached with caution because the answer depends on the local stratigraphy, the seismic bandwidth, and the horizontal and vertical resolution of the seismic data.

If two seismic reflection events, A and B, are separated by an appreciable seismic-time interval (say a few hundred milliseconds) yet are conformable to each other, then the uniform seismic-time thickness between these two seismic stratal surfaces represents a constant and fixed period of geologic time throughout the seismic image space spanned by reflectors A and B. An implication of seismic stratigraphy that can be invoked in such an instance is that any seismic surface intermediate to A and B, which is also conformable to A and B, is also a stratal surface. The purpose of this study is to illustrate the validity of this stratal-surface seismic-interpretation concept when the principle is applied to the interpretation of a complex channel system.

The channel system used to illustrate the stratal-surface concept of seismic interpretation is a shallow Miocene fluvial system at a depth of approximately 2,200 ft. The 3-D seismic acquisition geometry constructed across the prospect was designed to produce 55- × 55-ft stacking bins and a stacking fold of 12 at this target depth. The signal-to-noise character of these rather low-fold 3-D data is quite good, and the stratal-surface seismic-interpretation approach described herein produces excellent images of the channel complex.

## SURFACE VIEW OF TARGETED FLUVIAL SYSTEM

A display of seismic reflection-amplitude strength across the targeted stratal surface is shown in Figure 1. This image corresponds to the geologic time during which the targeted Miocene fluvial system was active, and the meander patterns revealed in the lower-right and upper-right quadrants of the image define the geometric shapes and spatial positions of the channel complexes that are to be analyzed. Crossline profiles 174, 200, and 222 (Figure 1) are key vertical slices through the 3-D seismic volume that can be used to illustrate the principles of stratal-surface interpretation.

The east-west-trending ripplelike pattern in the south half of the image is not caused by a depositional process. Rather it is the result of the seismic analysis horizon cutting through low-amplitude, zero-crossing regions of the reflection waveforms in a way that causes the reflection amplitude to shift systematically from a small positive value to a small negative value. The ripple effect can be altered by simple adjustment of the four-tone color bar used to display the data.

## VERTICAL VIEWS OF CHANNEL AND NONCHANNEL SEISMIC FACIES

**Crossline 174.** Crossline 174 crosses two separate Miocene channel systems, a narrow feature spanning inline coordinates 240 to 245 and a wider feature between inline coordinates 64 to 80 (Figure 1). Because the stacking bins created by this 3-D recording geometry measure 55 × 55 ft, these coordinate ranges mean that the smaller channel system is about 300 ft wide and the larger channel complex is about 900 ft wide at the point where crossline 174 crosses each feature. That part of crossline 174 that images the narrow channel is displayed in Figure 2.

Only 200 ms of data centered about the targeted channel system is displayed in this figure, as will be the case for crossline 222 that follows. These wiggle-trace displays are shown in a highly magnified format to allow subtle variations in reflection waveshape to be seen easily. Every second trace is plotted to avoid trace overlap so that individual reflection waveshapes can be inspected independently. Because of this trace decimation, the data appear to have a trace spacing of 110 ft, whereas the actual trace spacing in the 3-D data volume was 55 ft. The wiggle-trace data are shown with a high display gain to ensure that low-amplitude features can be seen; some high-amplitude troughs are consequently clipped.

A good-quality reflection peak, the "reference surface," is labeled in each display. This particular reflection peak satisfies the fundamental criteria required of a reference stratal surface used to study thin-bed sequences such as this fluvial channel system, namely:

(1) the event extends over the total 3-D image space and has a high signal-to-noise character,

(2) the event is reasonably close to the targeted thin-bed sequences (within 100 ms in this example), and

(3) the event is conformable to the targeted thin-bed sequence.

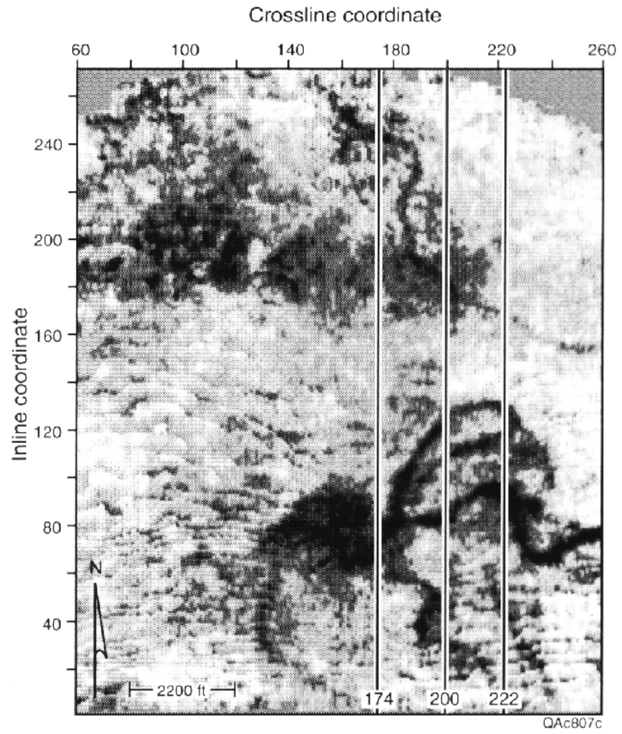


Figure 1. 3-D seismic image of the targeted thin-bed Miocene fluvial channel systems. This image is a display of reflection amplitudes on a stratal surface 26 ms below, and conformable to, reference surface 2 defined in Figure 4.

Criterion 3 is the most important requirement for any seismic stratal surface that is to be used as a reference surface—one from which constant-depositional-time surfaces are to be made that span targeted thin-bed sequences.

Because the surface labeled "reference surface" follows the apex of an areally continuous reflection peak, the basic premise of seismic stratigraphy is that this reference surface follows an impedance contrast that coincides with a stratal surface.

Each vertical seismic section is shown with four conformable surfaces, A, B, C, and D, added to the profiles. These four surfaces are, respectively, 92, 90, 88, and 86 ms above—and conformable to—the reference surface. Visual inspection of the reflection events above and below surfaces A, B, C, and D shows that all of these reflection peaks and/or troughs in this 200-ms vertical data window are reasonably conformable to the reference-surface event. Surfaces A, B, C, and D can thus be assumed to be stratal surfaces, or constant-depositional-time surfaces, because they are conformable to a known stratal surface (the reference surface) and are embedded in a seismic window in which all reflection events are approximately conformable to the selected reference surface.

The circled feature in Figure 2 identifies the location where stratal surfaces A, B, C, and D intersect obvious variations in reflection waveform. These waveshape changes are the critical seismic attributes that distinguish channel facies from nonchannel facies, as can be verified by comparing the inline coordinates spanned by the circled feature with the inline coordinates where crossline 174 intersects the northern channel feature in Figure 1.

**Crossline 222.** Crossline 222 extends across two point-bar segments of the southern fluvial channel system (Figure 1). Part of the profile that is centered on these two fluvial features is displayed in Figure 3 to show the position of the reference surface when that seismic surface is extended to crossline 222. Following the previous format used for crossline 174, the data display (Figure 3) shows the positions of stratal surfaces A, B, C, and D that are conformable to, and 92, 90, 88, and 86 ms above, respectively, this reference surface. The two highlighted data windows in this display emphasize the variations in reflection waveform that occur when the profile crosses the two point-bar complexes. The inline coordinates on which these circular data windows are centered correspond to the coordinate positions of the point-bar meanders in Figure 1.

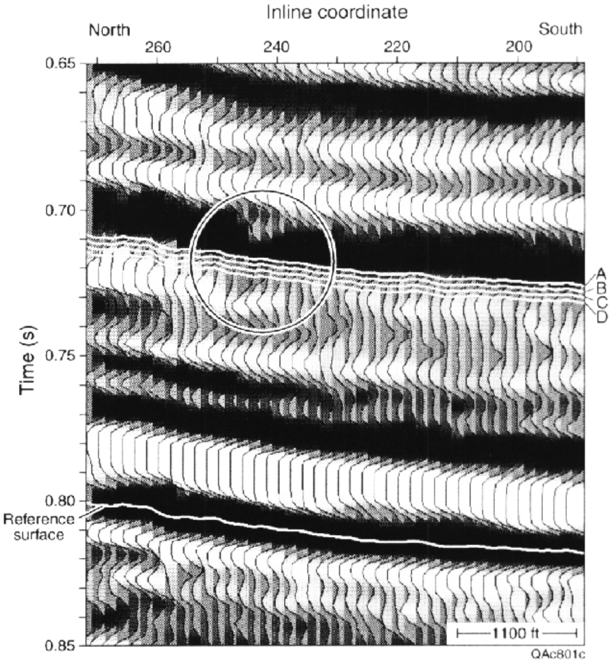


Figure 2. Data window from crossline 174 showing stratal surfaces that traverse the northern, smaller channel system. Surfaces A, B, C, and D are reasonable approximations of surfaces of constant depositional time because (1) they are conformable to the reference surface that follows a seismic stratal surface and (2) they are embedded in a 200-ms data window in which all seismic reflection events are approximately conformable. The highlighted data window encircles the subtle changes in reflection waveform that identify the seismic channel facies. The inline coordinates at the center of this circular data window correspond to the position of the channel image in Figure 1.

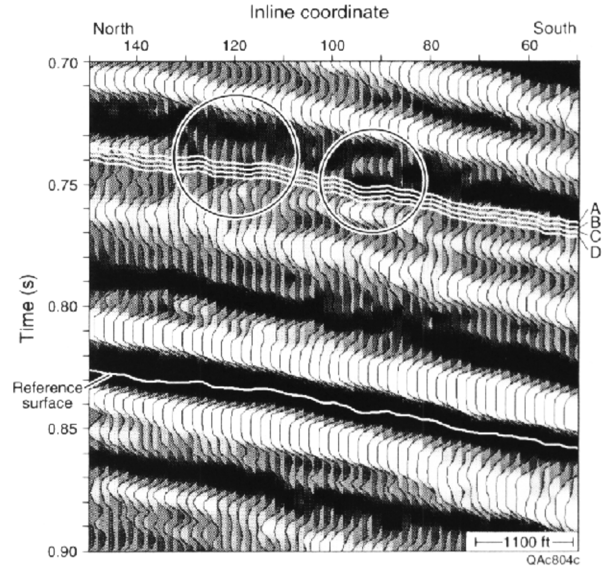


Figure 3. Data from crossline 222 showing stratal surfaces that traverse point-bar facies. Surfaces A, B, C, and D are reasonable approximations of surfaces of constant depositional time, as explained in the caption of Figure 2. The inline coordinates at the centers of these circular windows correspond to the position of point bars in Figure 1.

## COMBINING UPWARD AND DOWNWARD EXTRAPOLATIONS OF SEISMIC STRATAL SURFACES TO IMPROVE THIN-BED INTERPRETATION

In challenging thin-bed interpretations such as the fluvial channel system considered here, it is important to define two seismic reference surfaces that bracket the thin-bed system that is to be interpreted, one reference surface being below the interpretation target and the second reference surface being above the target. By creating conformable reference stratal surfaces above and below a thin-bed system, conformable seismic stratal surfaces can be extrapolated from two directions to sweep across a thin-bed target. One set of seismic stratal surfaces is commonly a better approximation of constant-depositional-time surfaces within the targeted thin-bed sequence than the other set is and produces more accurate images of facies patterns within the thin-bed unit.

To illustrate the advantage of this opposite-direction convergence of seismic stratal surfaces onto a thin-bed target, a second reference surface was interpreted above (and, in this case, closer to) the targeted fluvial system. Specifically this second stratal reference surface followed the apex of the reflection troughs immediately above the thin-bed channels (Figure 4). The fluvial system is about 24 to 30 ms below this second reference surface.

The reflection-amplitude response across the channel systems observed on a stratal surface 26 ms below and conformable to this overlying reference surface is displayed in Figure 1. The improved channel image in this case occurs because stratal surfaces that are conformable to the overlying seismic stratal surface are better approximations of constant-depositional-time surfaces for this channel system than are stratal surfaces that are conformable to the deeper reference surface. This result illustrates that upward and downward extrapolations of conformable stratal surfaces across a thin-bed target are a recommended interpretation procedure, especially in those instances when valid stratal reference surfaces can be interpreted both above and below the targeted thin-bed sequence.

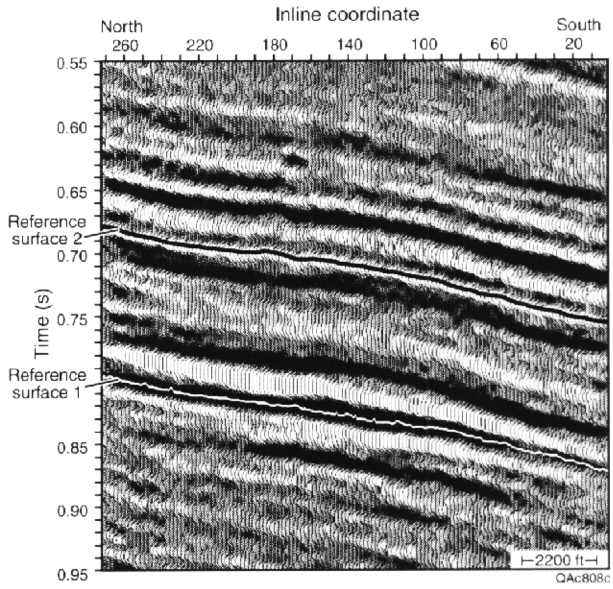


Figure 4. Location of reference-surface 2 on crossline 200. Reference-surface 1 is the horizon labeled "reference surface" in the displays of crosslines 174 and 222 in Figures 2 and 3. Reference-surface 2 is an alternate seismic stratal surface positioned above the thin-bed target. The positions of the thin-bed channels on this profile are defined by the coordination in Figure 1.

## CONCLUSIONS

The interpretation of thin-bed reservoirs in 3-D seismic data volumes can be achieved by (1) interpreting a reference surface that is conformable to the areal geometry of the thin-bed sequence and (2) creating seismic stratal surfaces conformable to this reference surface that pass through the thin-bed target. If the seismic stratal surfaces constructed according to this logic are satisfactory approximations of constant-depositional-time surfaces that existed during the deposition of the thin-bed sequence, then seismic attributes across these stratal surfaces can be valuable indicators of facies distributions within the sequence. Evidence that this stratal-surface approach to 3-D seismic thin-bed analysis is a robust interpretation technique is provided by the fluvial channel images described here. A previous publication supports the same conclusion (Hardage and others, 1994).

Thin-bed interpretation can be further strengthened by extrapolating seismic stratal surfaces and stratal-bounded windows onto a thin-bed target from opposite directions, that is, from both below and above the thin bed. The logic in this dual-direction extrapolation is that one of the seismic reference surfaces is generally more conformable to the thin-bed sequence than is the other reference surface, and this improved conformability leads to improved attribute imaging of facies distributions within the thin bed.

## REFERENCES


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