Stratigraphic Interpretation

Recognition of Characteristic Shape

Where a vertical seismic section intersects a stratigraphic feature the interpreter can normally find a small amplitude or character anomaly. The expression of a sand-filled channel or bar, for example, is therefore normally so subtle that it takes a considerable amount of interpretive skill to detect it. In contrast, a horizontal section reveals the spatial extent of an anomaly. The interpreter can thus observe characteristic shape and relate what he sees to geologic experience. A shape or pattern which is unrelated to structure may prove to be interpretable as a depositional, erosional, lithologic or other feature of significance. Klein (1985) and Broussard (1975), among others, have provided depositional models on which the interpreter can base his recognition of depositional features. The study of horizontal sections and horizon slices can provide a bird's-eye view of ancient stratigraphy, analogous to the view of modern stratigraphy obtained out of an airplane window.

Figure 4-1 shows five adjacent vertical seismic sections from a small 3-D survey in the Williston basin of North Dakota. Note that the reflections indicate largely flat-lying beds. At 1.8 seconds there is a very slight draping of reflections which is only just discernible. Figure 4-2 shows two single-polarity horizontal sections superimposed on each other. The data from both levels reveal the same almost circular shape. This is the outline of a carbonate buildup measuring approximately one kilometer in diameter.

Figures 4-3 and 4-4 are horizontal sections from a 3-D survey recorded in the Gippsland basin offshore southeastern Australia (Sanders and Steel, 1982). Many small circular features are strikingly evident. These appear as small depressions on the vertical sections which attract little attention. It is the characteristic circular shape when viewed horizontally that attracts the interpreter's eye. The circular features measure 200 to 500 m in diameter and are interpreted as sinkholes in a Miocene karst topography. The beds in which these features exist are dipping from upper left to lower right (east) in Figures 4-3 and 4-4. The width of the reflection is a function of seismic frequency and structural dip (see Chapter 3). The visibility of the sinkholes in the presence of this structure is because their diameters are each less than the reflection width.

Figure 4-5 shows a bifurcating channel close to a Gulf of Mexico salt dome. The salt dome's semi-circular expression results from the intersection of the horizontal section at 416 ms with the dipping structural reflections adjacent to the dome. Away from the salt dome the beds are close to flat-lying, so the horizontal section is sliced along the bedding plane. As a result, the channel is almost completely visible. In fact, the bedding is not exactly flat and some parts of the channel are more clearly seen on the adjacent section at 412 ms. Simple addition of these two horizontal sections improved the continuity of the channel (Figure 4-6). Adding together of horizontal sections is a useful approach to the enhancement of stratigraphic features if, *but only if*, the structural

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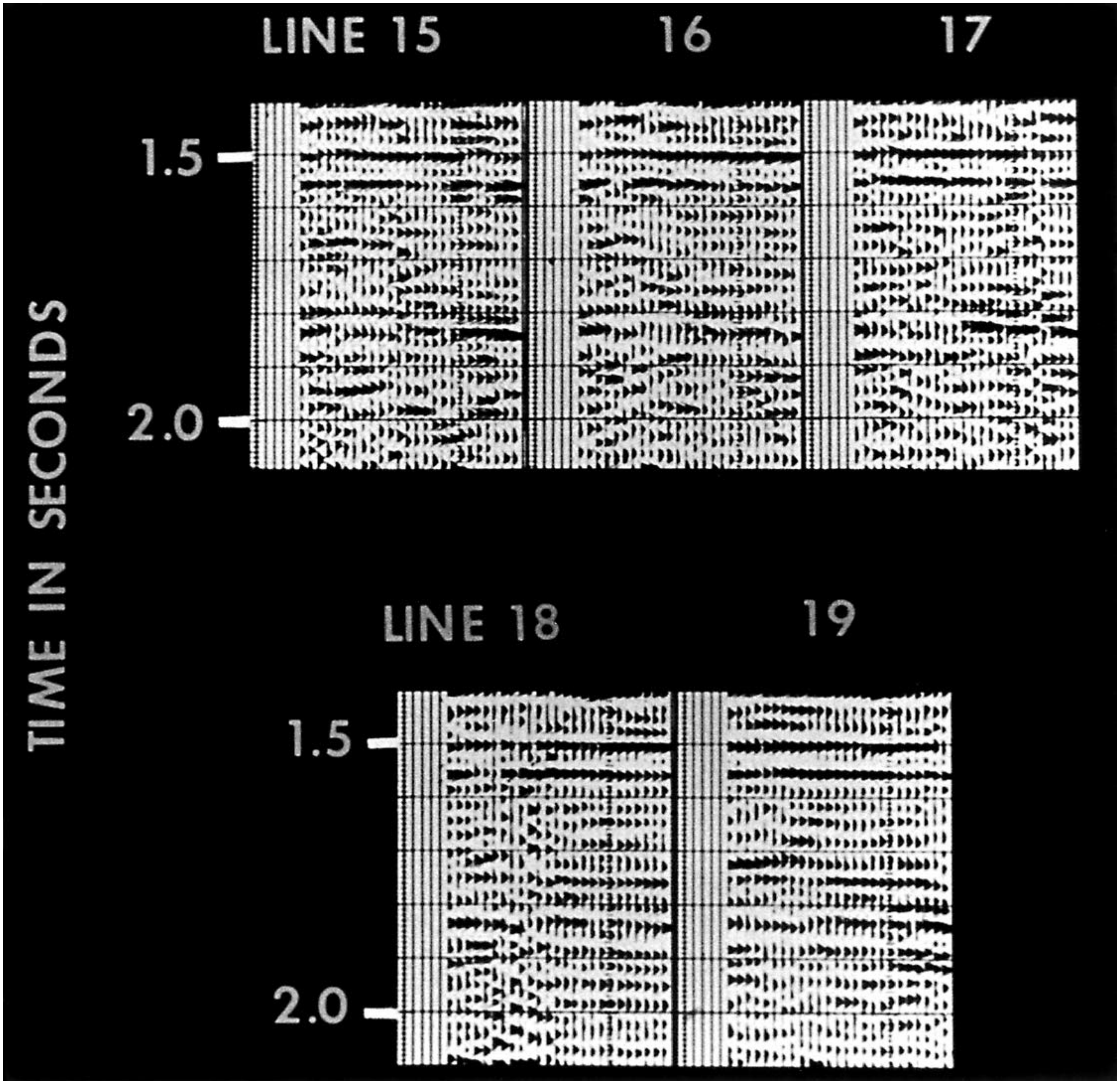

Fig. 4-1. Five adjacent vertical sections from 3-D survey in the Williston basin of North Dakota. (Courtesy Geophysical Service Inc.)

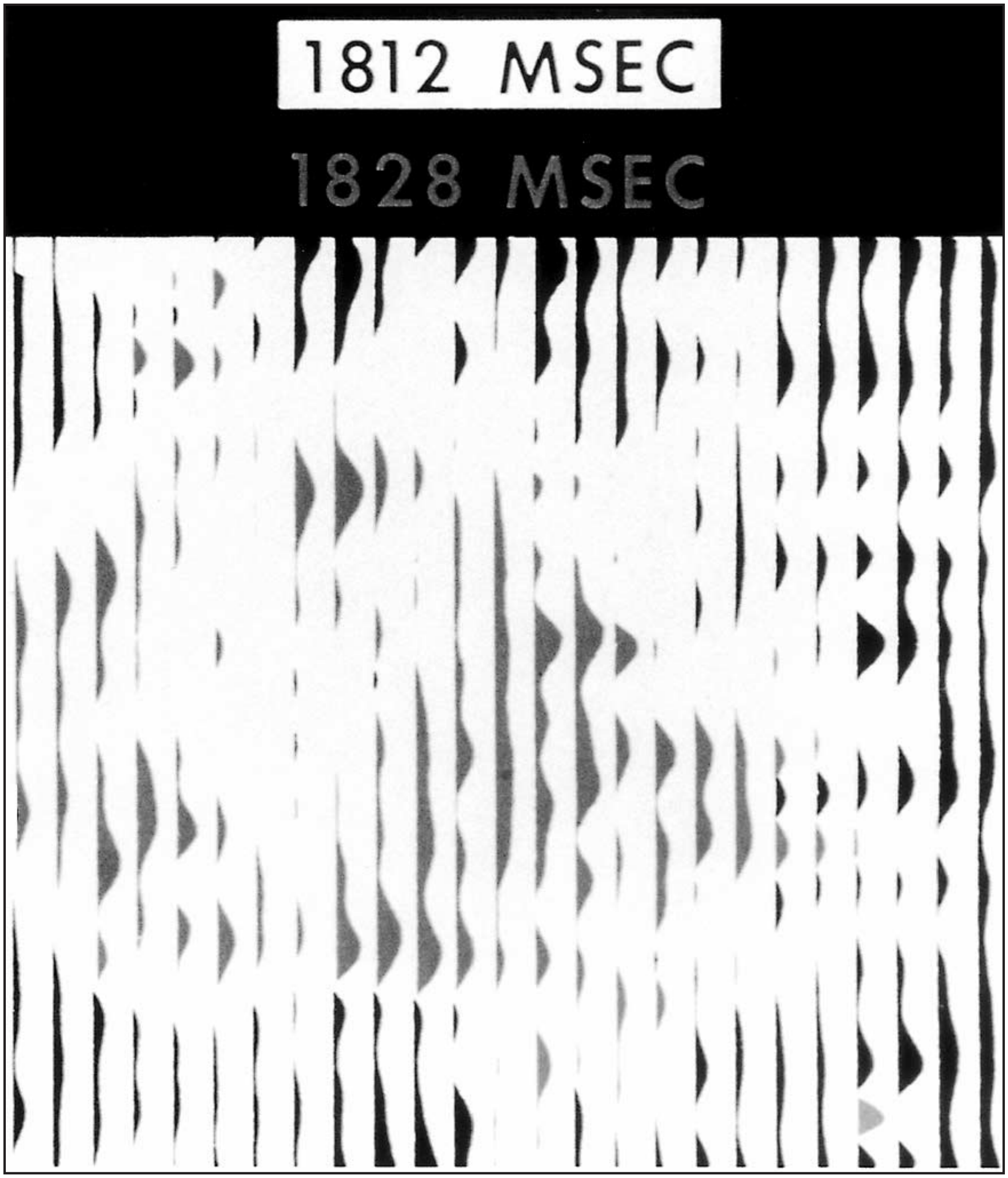

Fig. 4-2. Horizontal sections from 1812 and 1828 ms from North Dakota, each showing positive amplitudes only. The approximately circular outline between the black and the gray indicates the shape of a carbonate buildup. (Courtesy Geophysical Service Inc.)

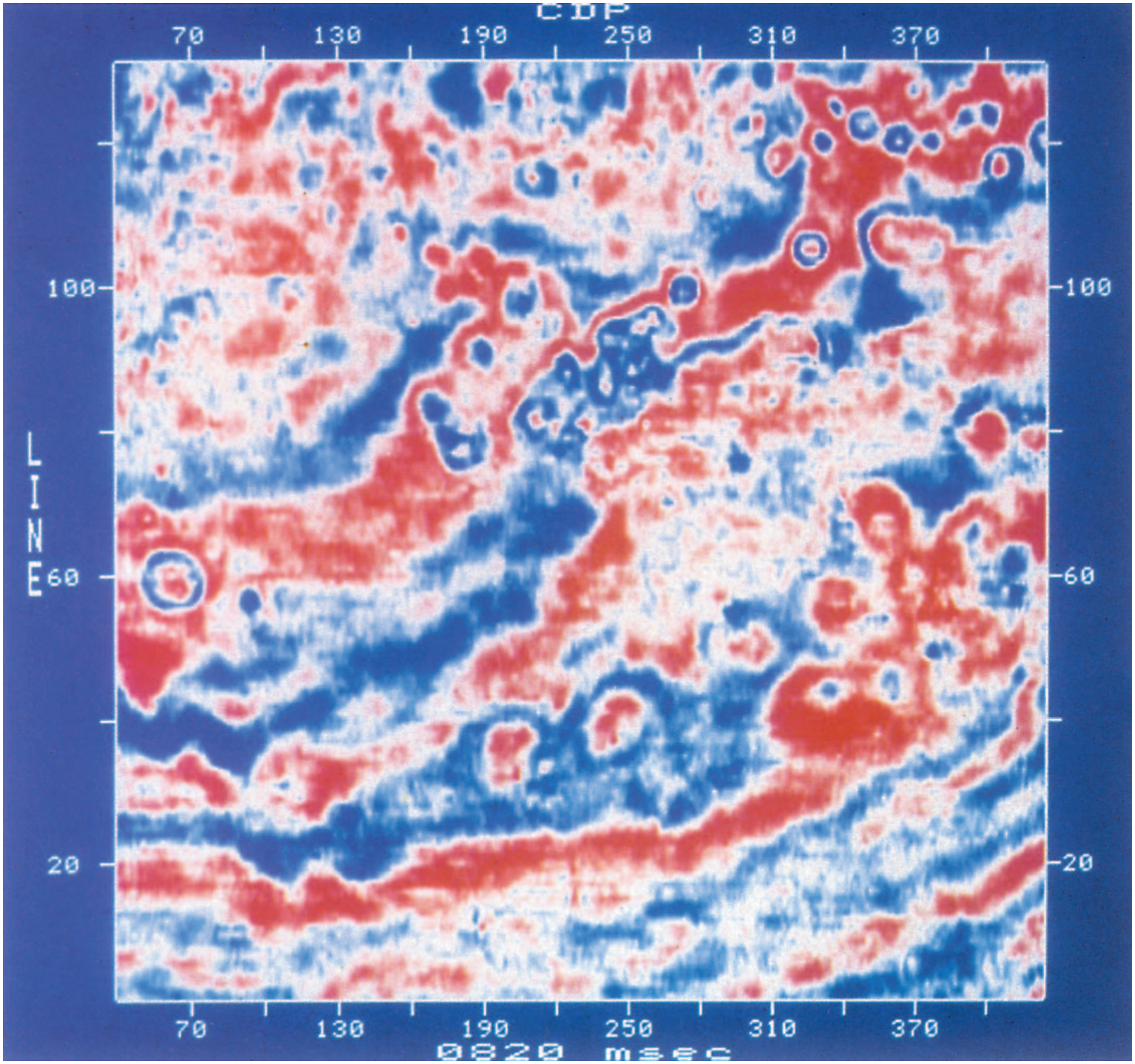

Fig. 4-3. Horizontal section at 820 ms from 3-D survey over Mackerel field in offshore Gippsland basin, southeastern Australia. Circular objects are interpreted as sinkholes in karst topography. (Courtesy Esso Australia Ltd.)

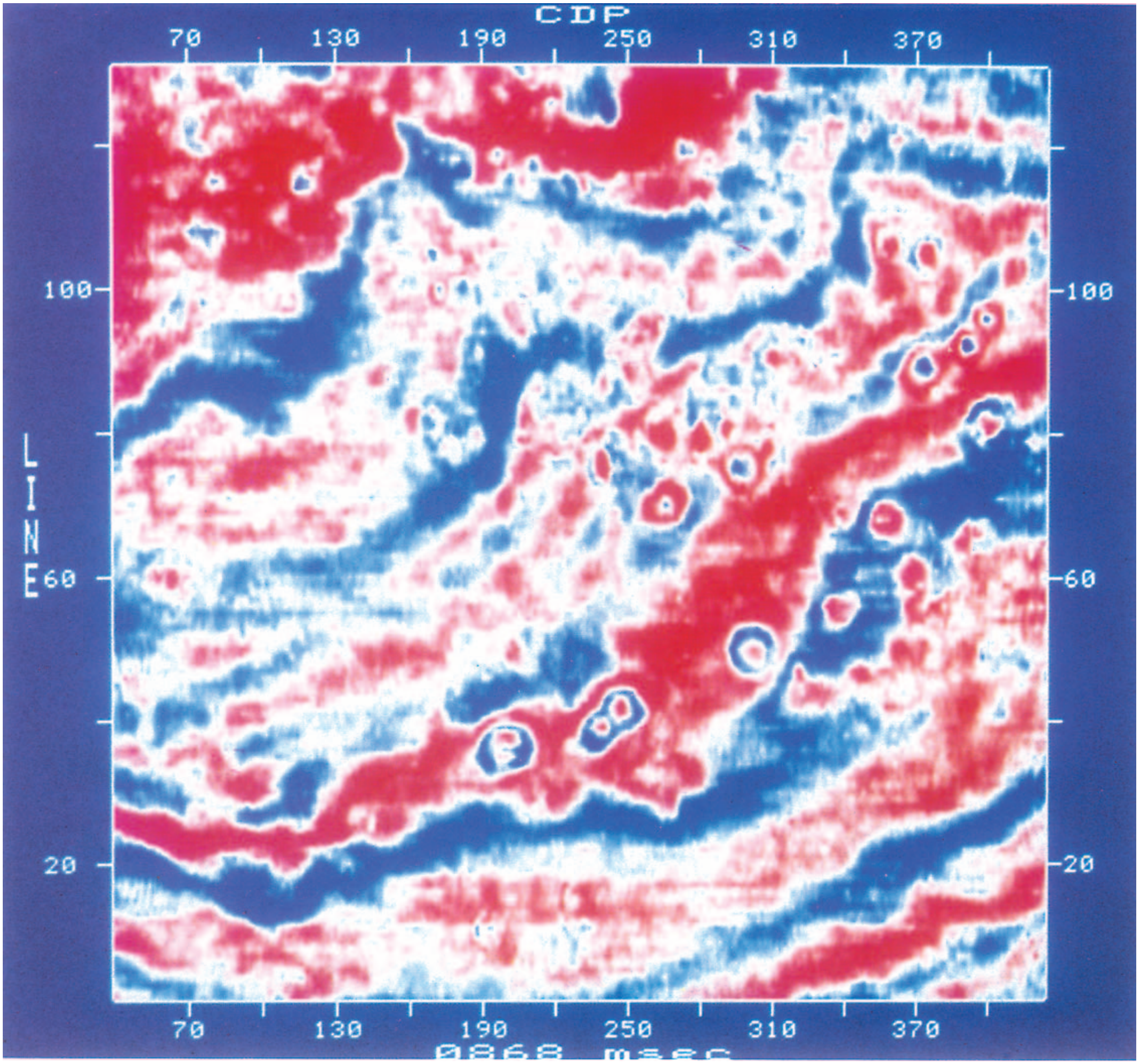

Fig. 4-4. Horizontal section at 868 ms from 3-D survey over Mackerel field in offshore Gippsland basin, southeastern Australia. Circular objects are interpreted as sinkholes in karst topography. (Courtesy Esso Australia Ltd.)

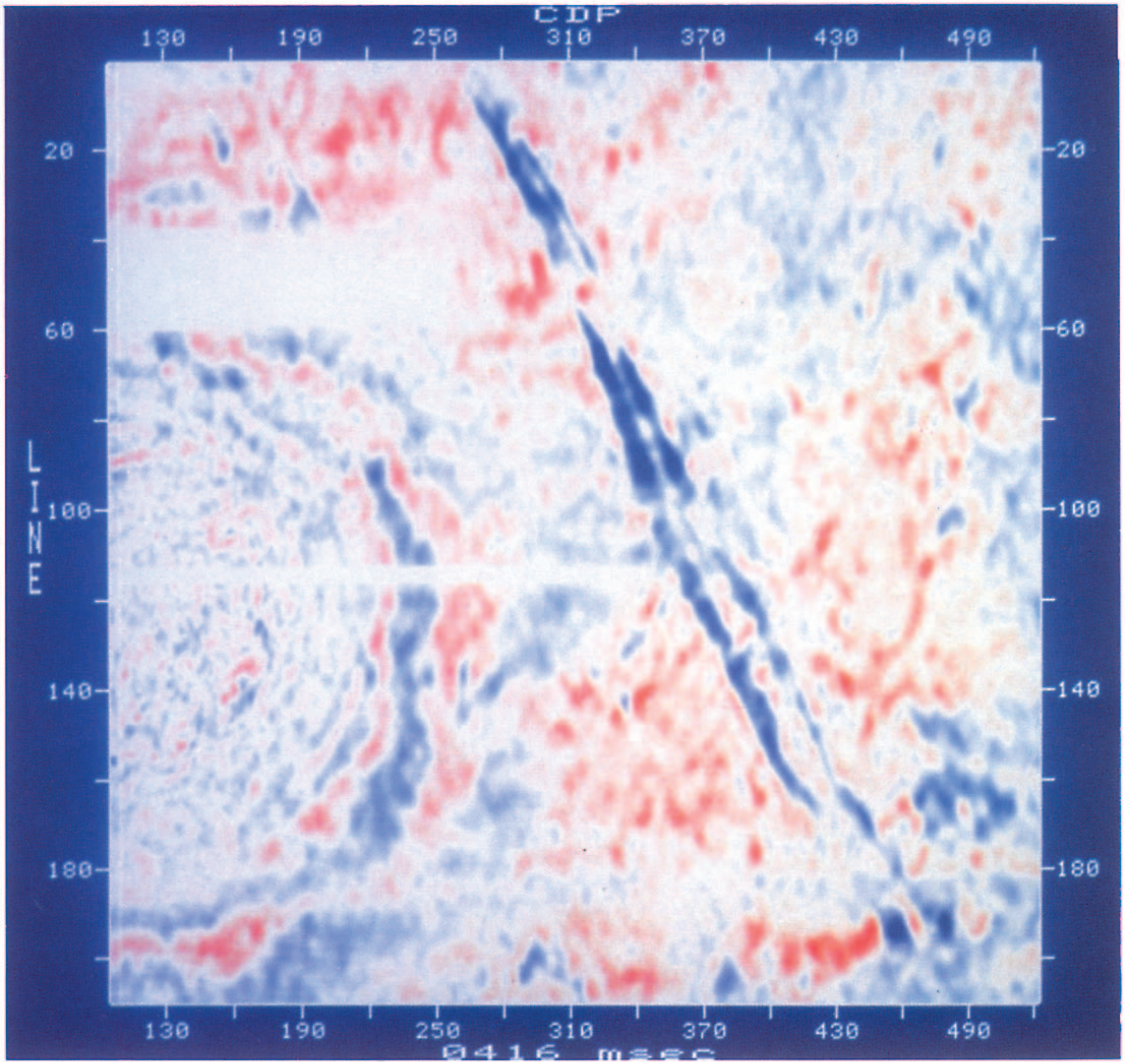

Fig. 4-5. Horizontal section at 416 ms from 3-D survey in the Gulf of Mexico. The bifurcating channel is seen close to the edge of a salt dome. (Courtesy Chevron U.S.A. Inc.)

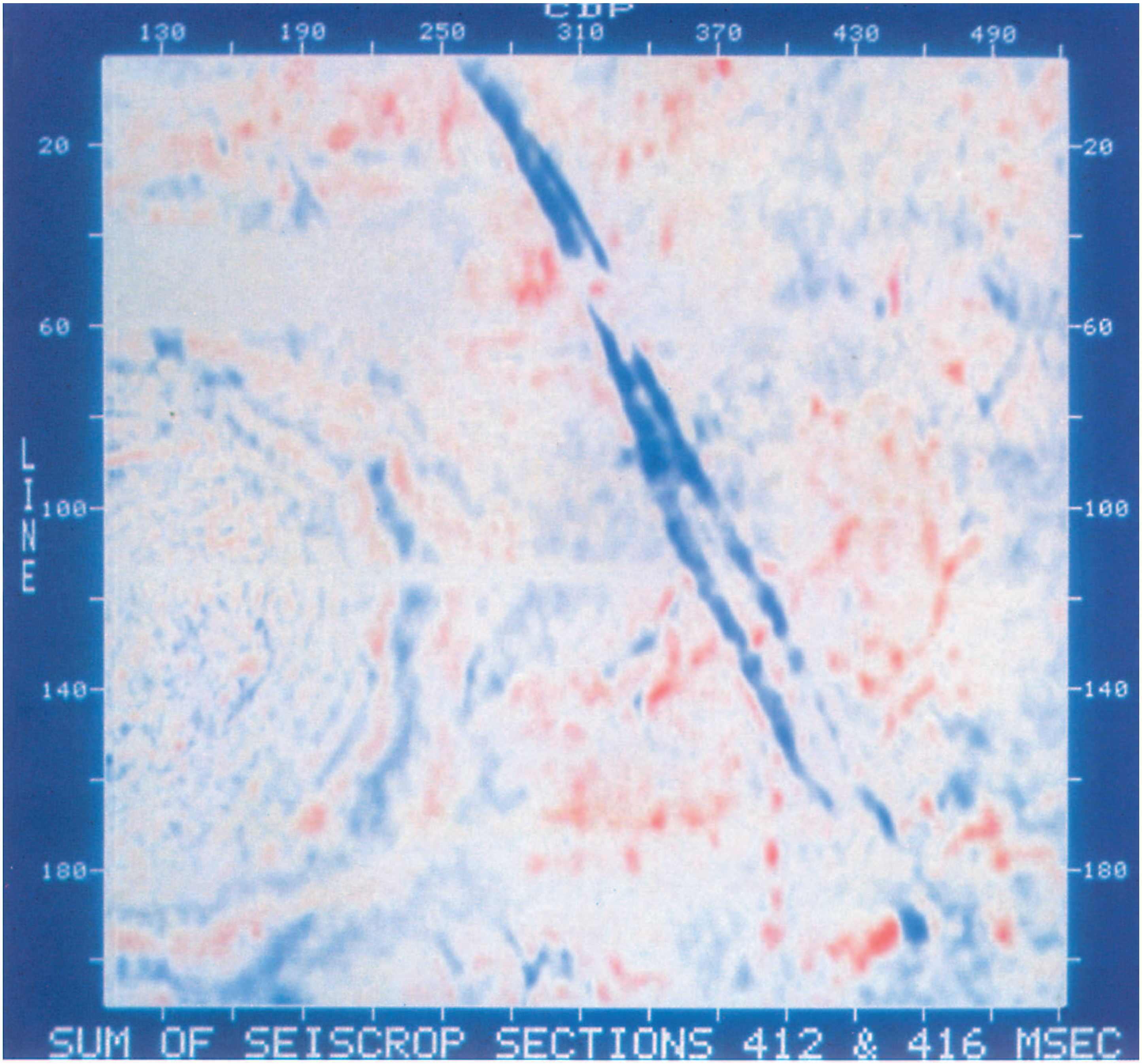

Fig. 4-6. Sum of horizontal sections at 412 and 416 ms from same survey as Figure 4-5 showing enhancement of the channel. (Courtesy Chevron U.S.A. Inc.)

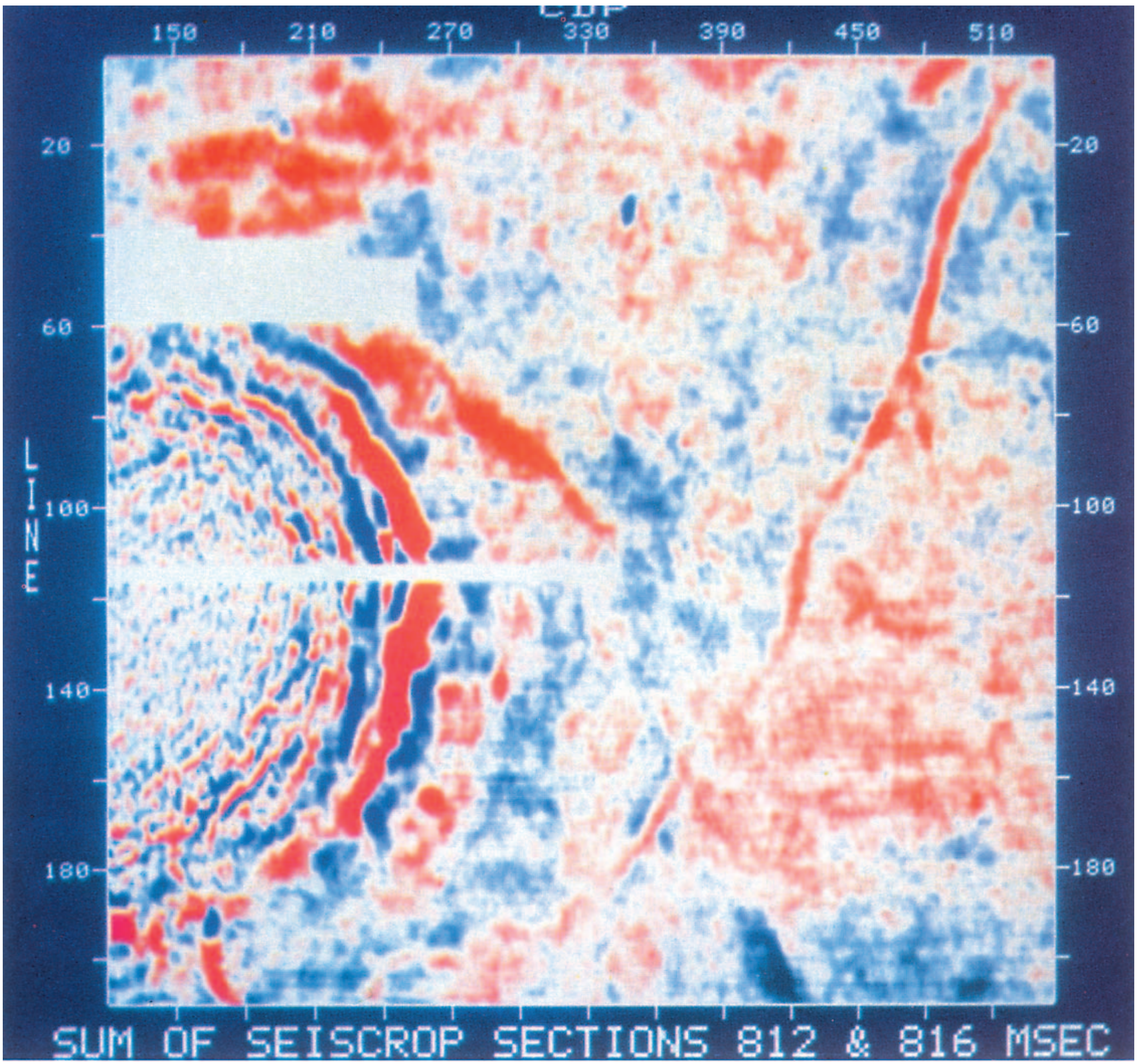

Fig. 4-7. Sum of horizontal sections at 812 and 816 ms from same survey as Figure 4-5 showing a branching channel. (Courtesy Chevron U.S.A. Inc.)

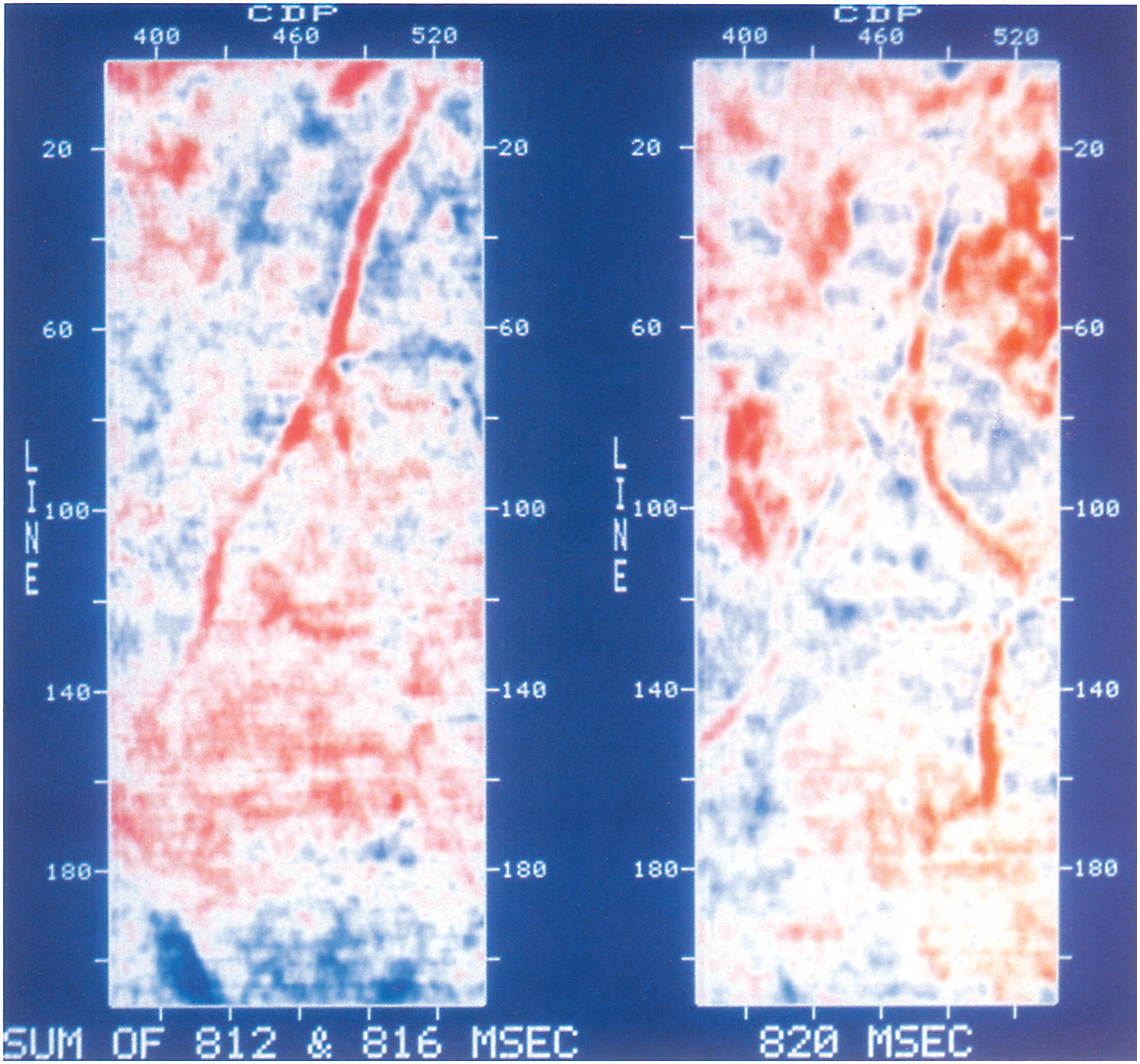

Fig. 4-8. Composite display of horizontal sections at 812 and 816 ms showing western branch of channel and at 820 ms showing eastern branch. (Courtesy Chevron U.S.A. Inc.)

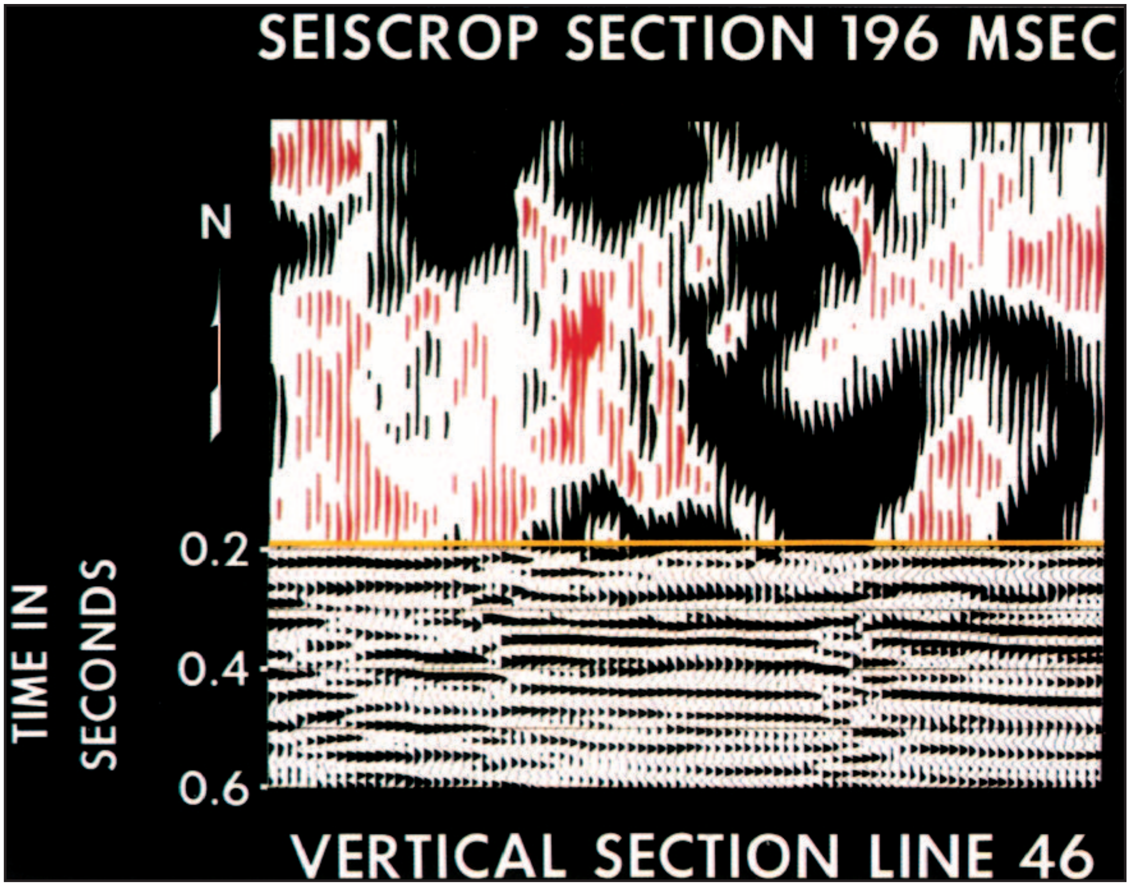

Fig. 4-9. Composite display of vertical and horizontal sections from Gulf of Thailand showing spatial continuity of vertical section event segments. (Courtesy Texas Pacific Oil Company Inc.)

variation across the feature is less than half a period of the appropriate seismic signal.

Figure 4-7 shows another channel deeper in the same data volume. Enhancement again resulted from adding together the horizontal sections from 812 and 816 ms. The channel branches at Line 70, CDP 470, but the eastern branch is not visible. Figure 4-8 shows just the portion of the survey area covering the channel system and includes the horizontal section at 820 ms. Here the eastern branch is clearly visible showing that it is structurally slightly deeper than the western branch. This indicates that the depositional surface containing this channel dips away from the salt dome, which dip was presumably induced by the movement of the salt. Thus, in order to view the entire channel system, several horizontal sections covering the structural range of this depositional surface are required.

Figures 4-9 through 4-16 show examples of depositional features observed on horizontal sections through flat-lying beds in the Gulf of Thailand. The vertical section in Figure 4-9 shows that the beds are flat-lying and that around 200 ms there are some abrupt character changes. The attached horizontal section shows that these reflection segments have spatial continuity. Figure 4-10, covering the whole prospect area, makes it clear that the continuity is part of a meandering channel system. Anyone who has flown over the Mississippi River will immediately relate Figure 4-10 to observations made from the airplane window.

In the Gulf of Thailand there is a regional unconformity in the mid-Miocene and above that unconformity the beds in this prospect area are largely flat-lying. Therefore, many horizontal sections above 900 ms directly reveal depositional features because the sections are parallel to bedding planes. Figure 4-11 is a schematic composite of the features observed. The interpretation of these in sequence indicated a delta prograding across the survey area from southwest to northeast during the mid-Miocene to Pleistocene.

Examples of the depositional features observed are presented in Figures 4-12

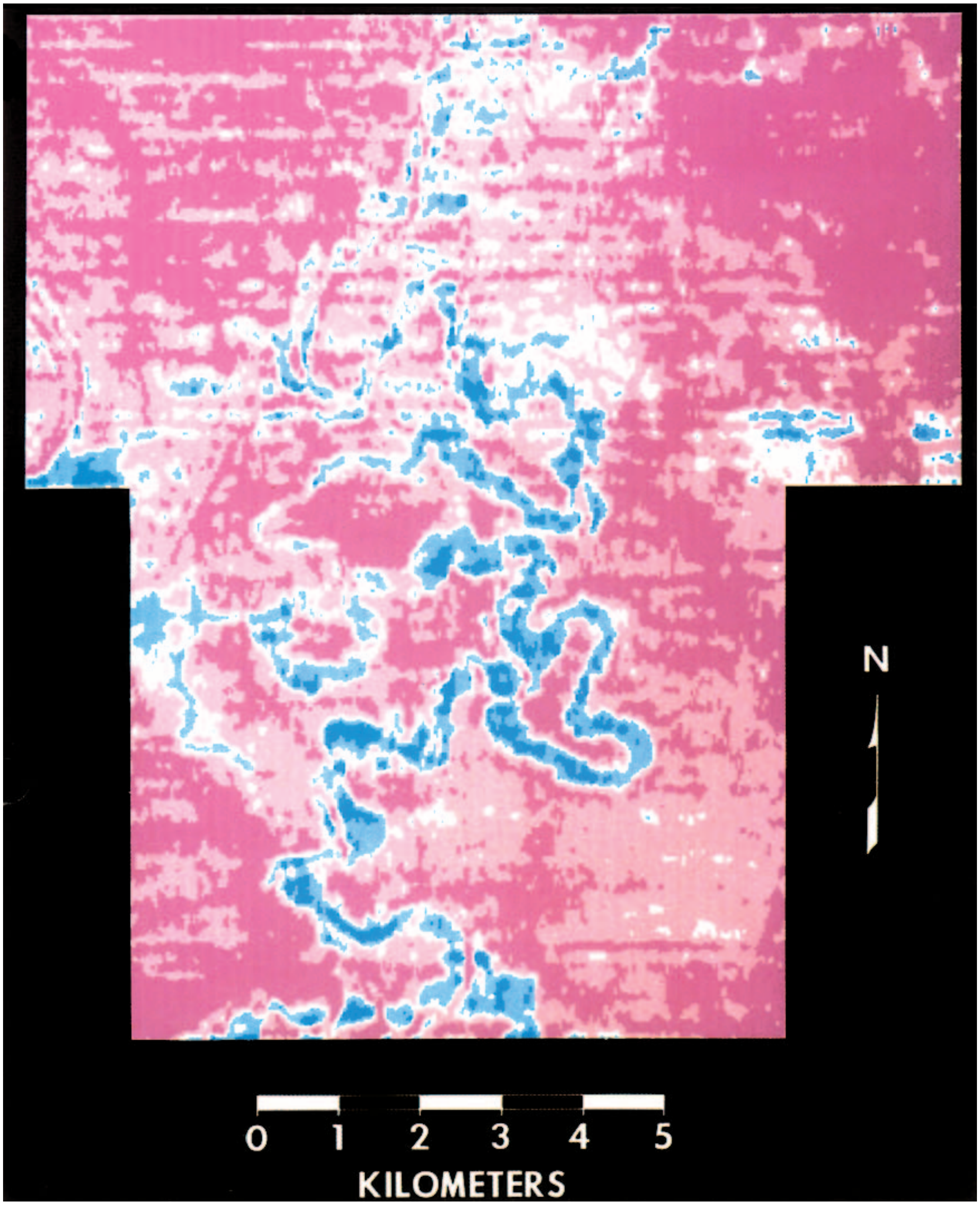

Fig. 4-10. Horizontal section at 196 ms from Gulf of Thailand showing meandering stream channel. (Courtesy Texas Pacific Oil Company Inc.)

through 4-16. Figure 4-12 shows in the upper center a delta front channel. Figure 4-13 shows a large offshore bar trending northwest-southeast, transverse to the direction of delta progradation. Figure 4-14 shows two smaller bars, center and lower left, with the same orientation. Figure 4-15 shows, in the upper right, a reworked bar; toward the bottom are straight linear features suggestive of distributary channels. Figure 4-16 shows many twisting channels, some of them very narrow.

Figure 4-17 shows part of the Mahakam delta in Indonesia. At this time (about 18,000 years ago) deposition was clearly occurring in this part of the delta. Patterns are very similar to those visible in the present Mahakam delta (Figure 4-18). However, in another part of the ancient delta (Figure 4-19) erosion was occurring as evidenced by the dendritic patterns of canyons.

Figure 4-20 shows a shallow horizontal section from a part of the Gulf of Thailand

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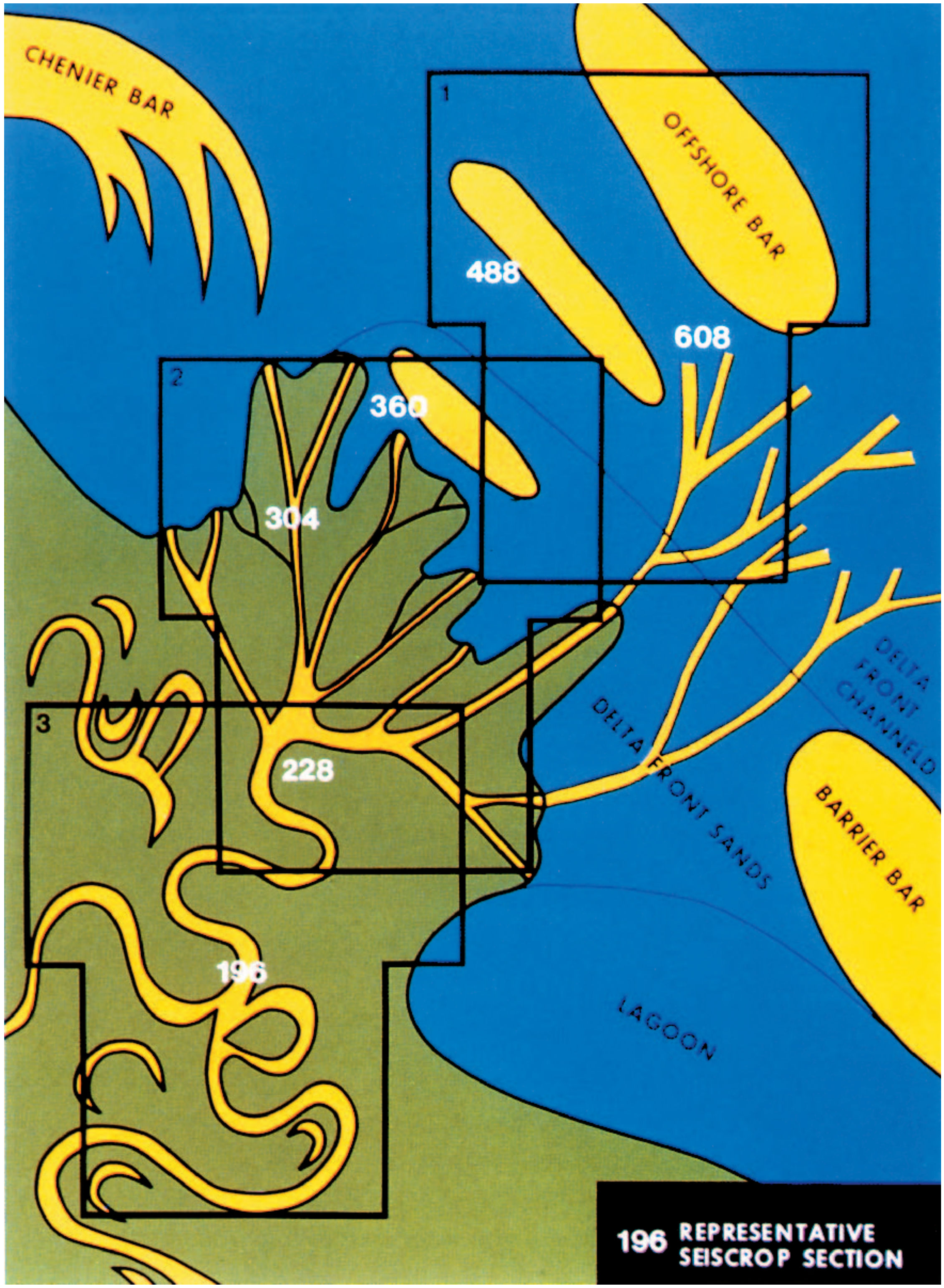
Fig. 4-11. Schematic diagram of delta prograding across the Gulf of Thailand 3-D survey area between mid-Miocene and Pleistocene.



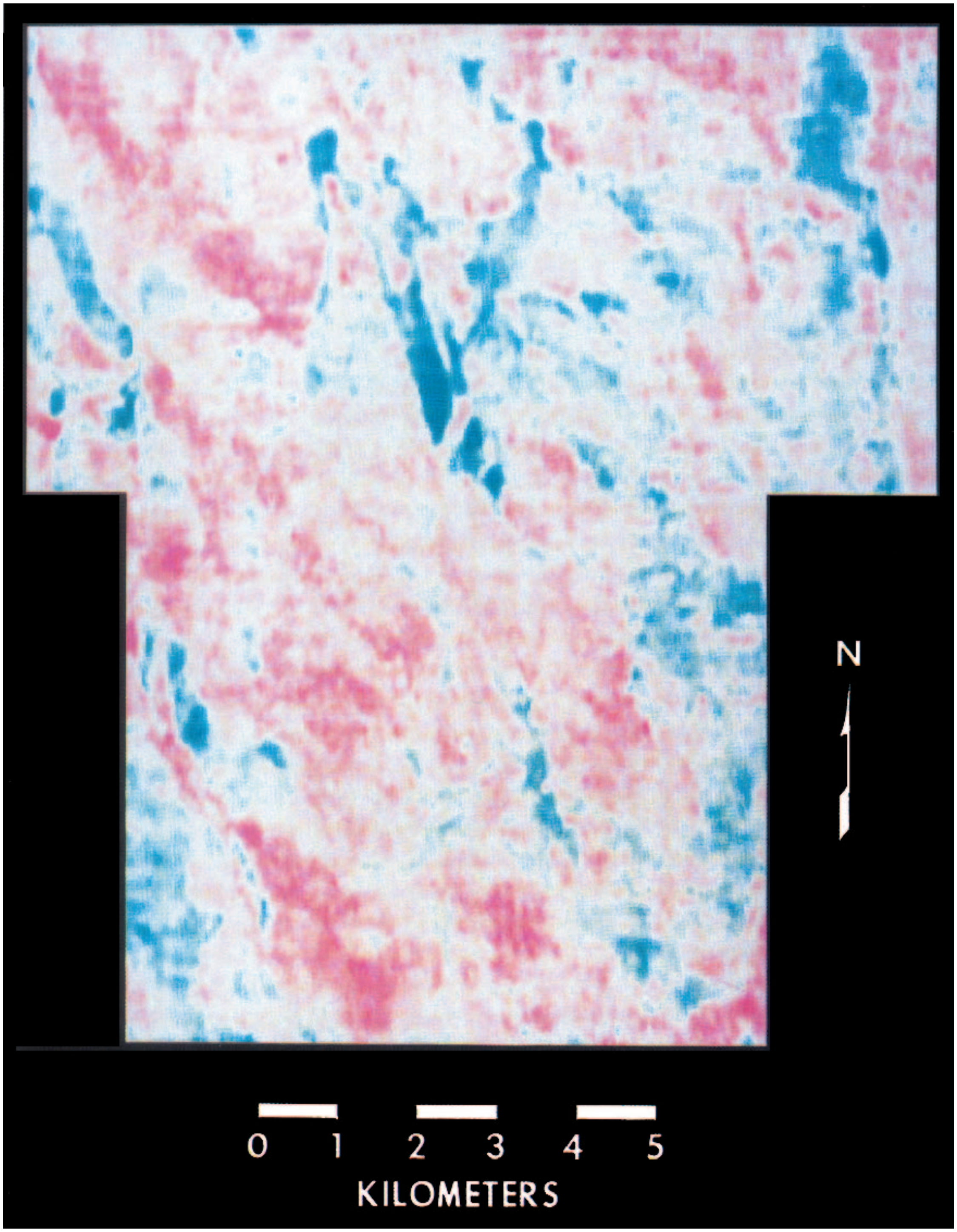
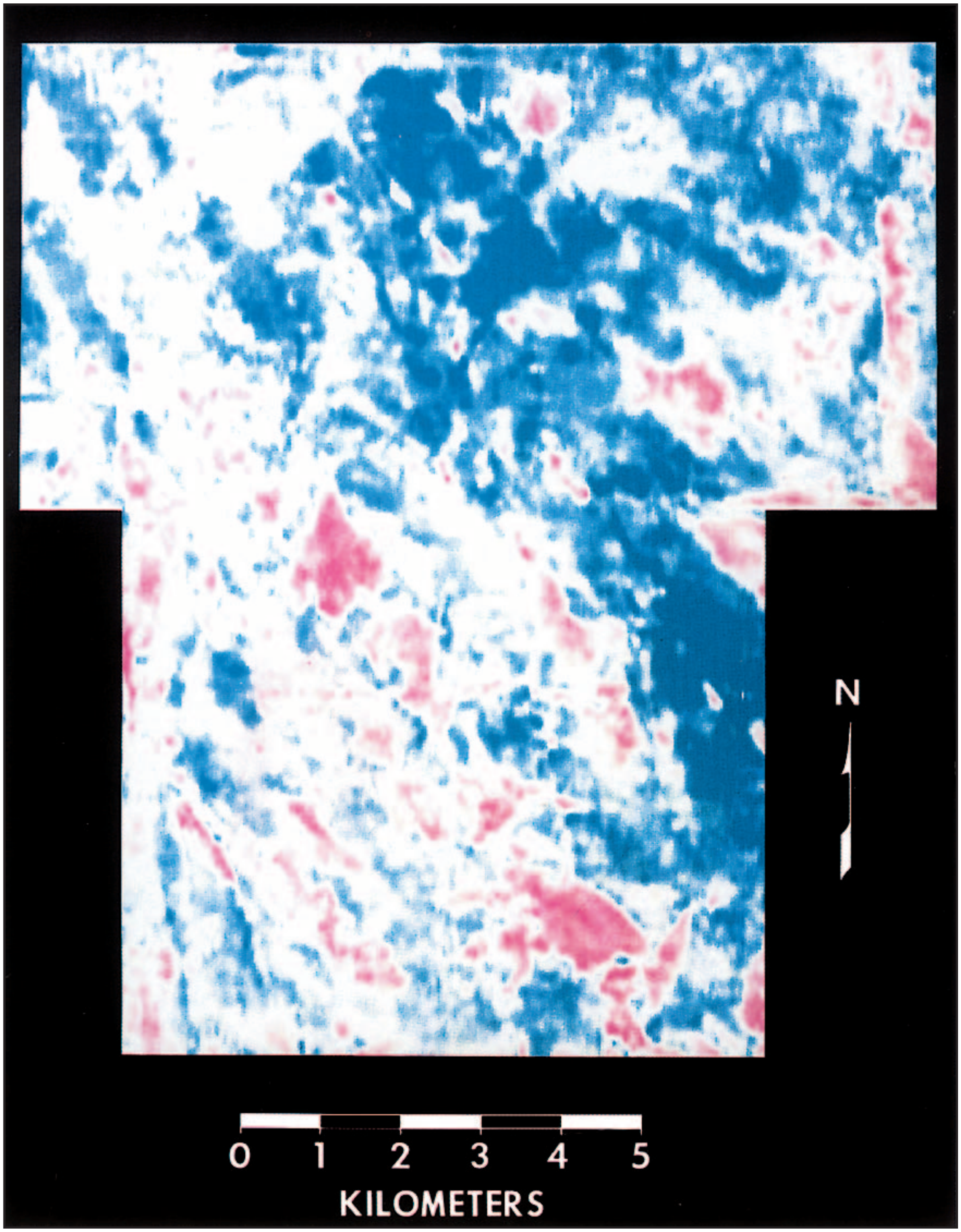


Fig. 4-12. Horizontal section at 608 ms from Gulf of Thailand showing delta front channel. (Courtesy Texas Pacific Oil Company Inc.)

Fig. 4-13. Horizontal section at 488 ms from Gulf of Thailand showing large offshore sand bar. (Courtesy Texas Pacific Oil Company Inc.)



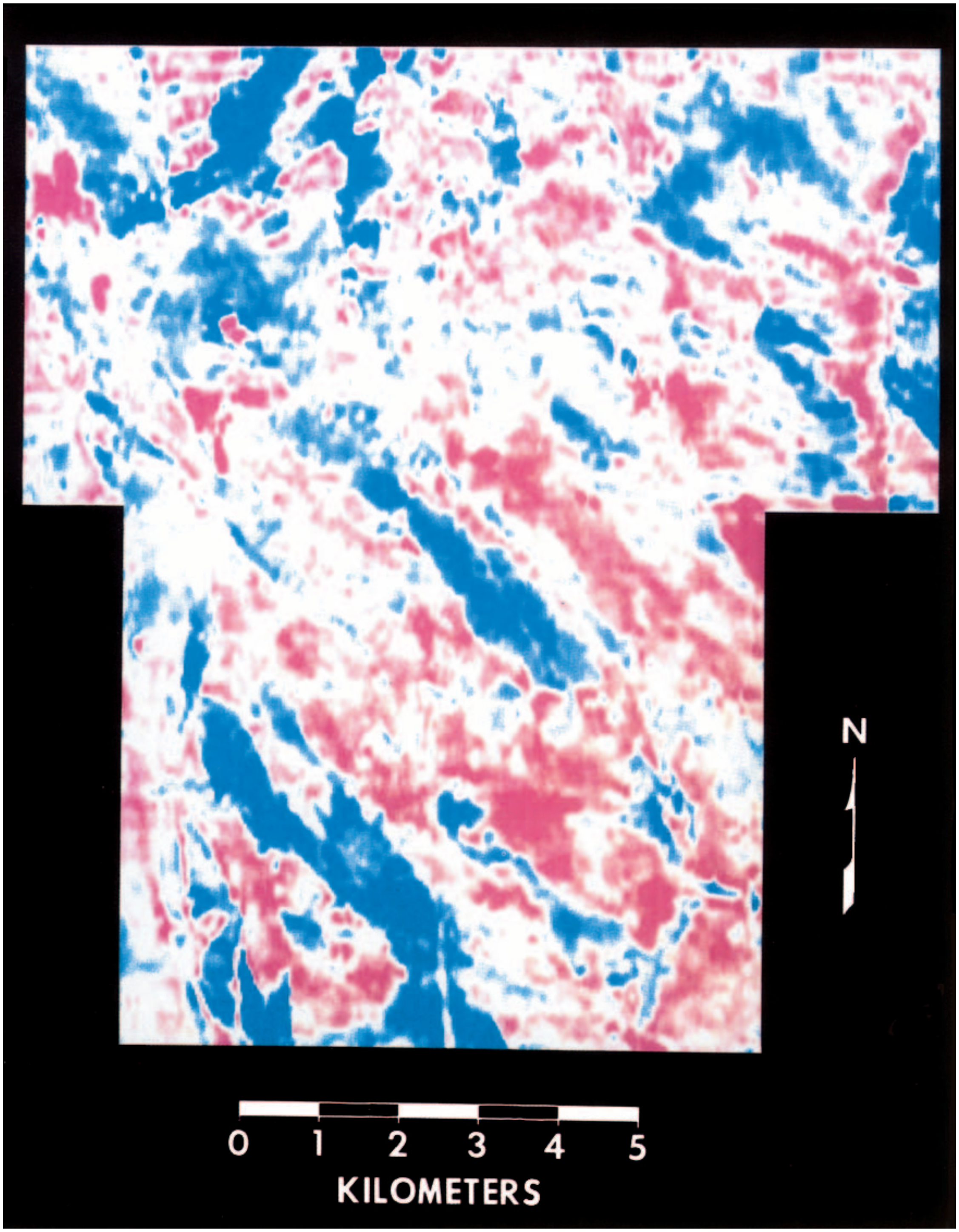


Fig. 4-14. Horizontal section at 360 ms from Gulf of Thailand showing small sand bars. (Courtesy Texas Pacific Oil Company Inc.)

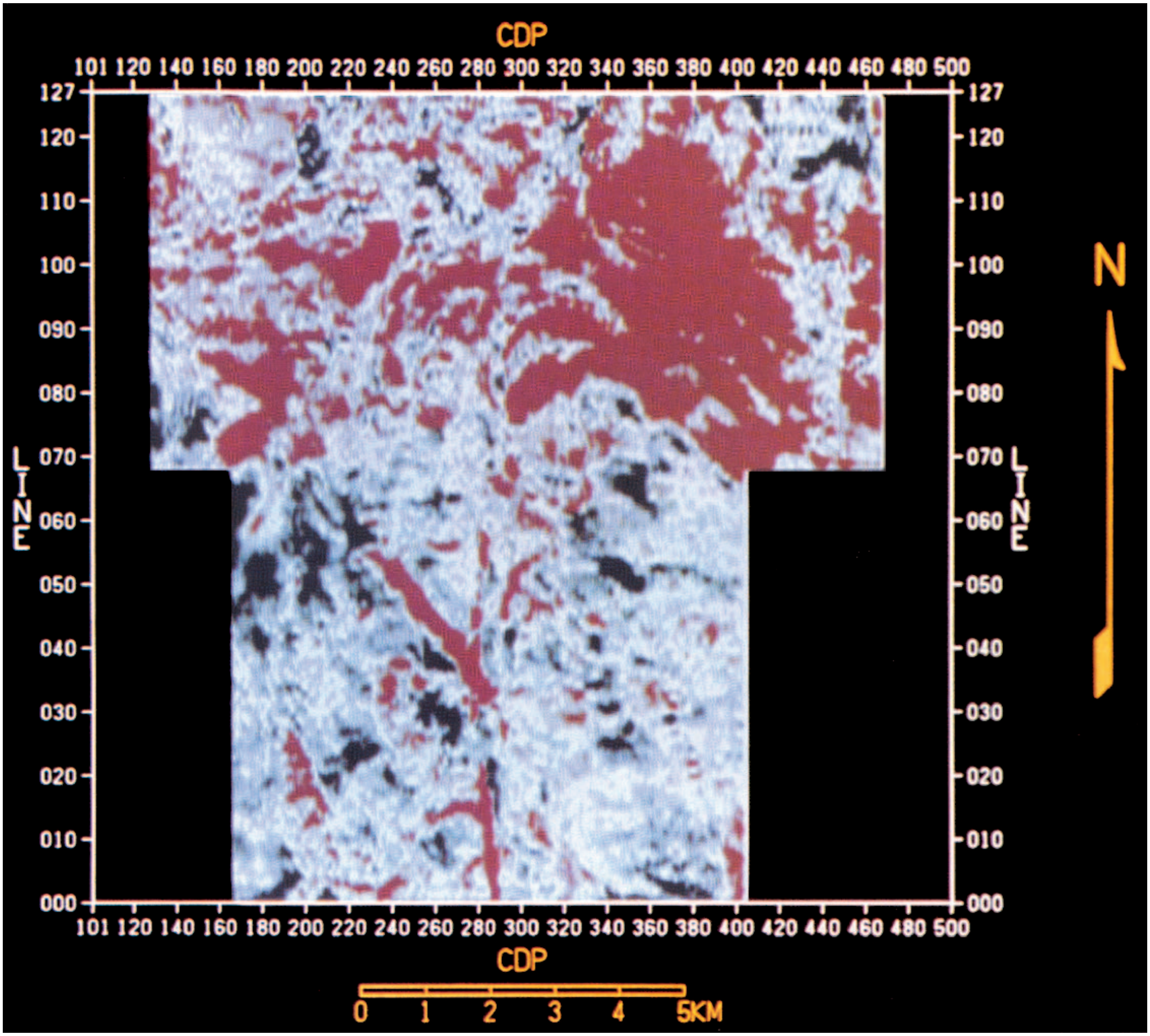


Fig. 4-15. Horizontal section at 304 ms from Gulf of Thailand showing a reworked bar and distributary channels. (Courtesy Texas Pacific Oil Company Inc.)

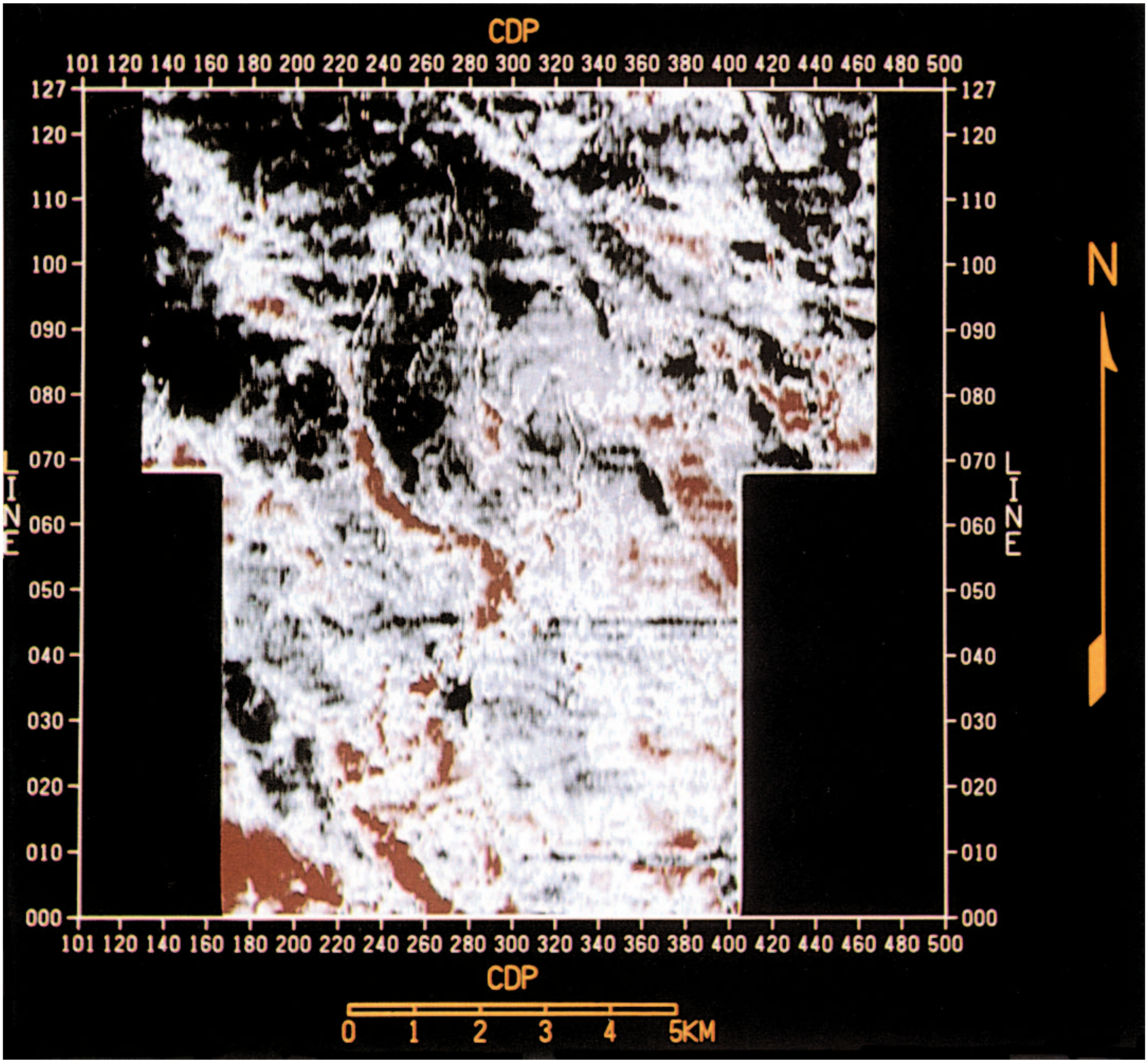


Fig. 4-16. Horizontal section at 228 ms from Gulf of Thailand showing several channels, large and small. (Courtesy Texas Pacific Oil Company Inc.)

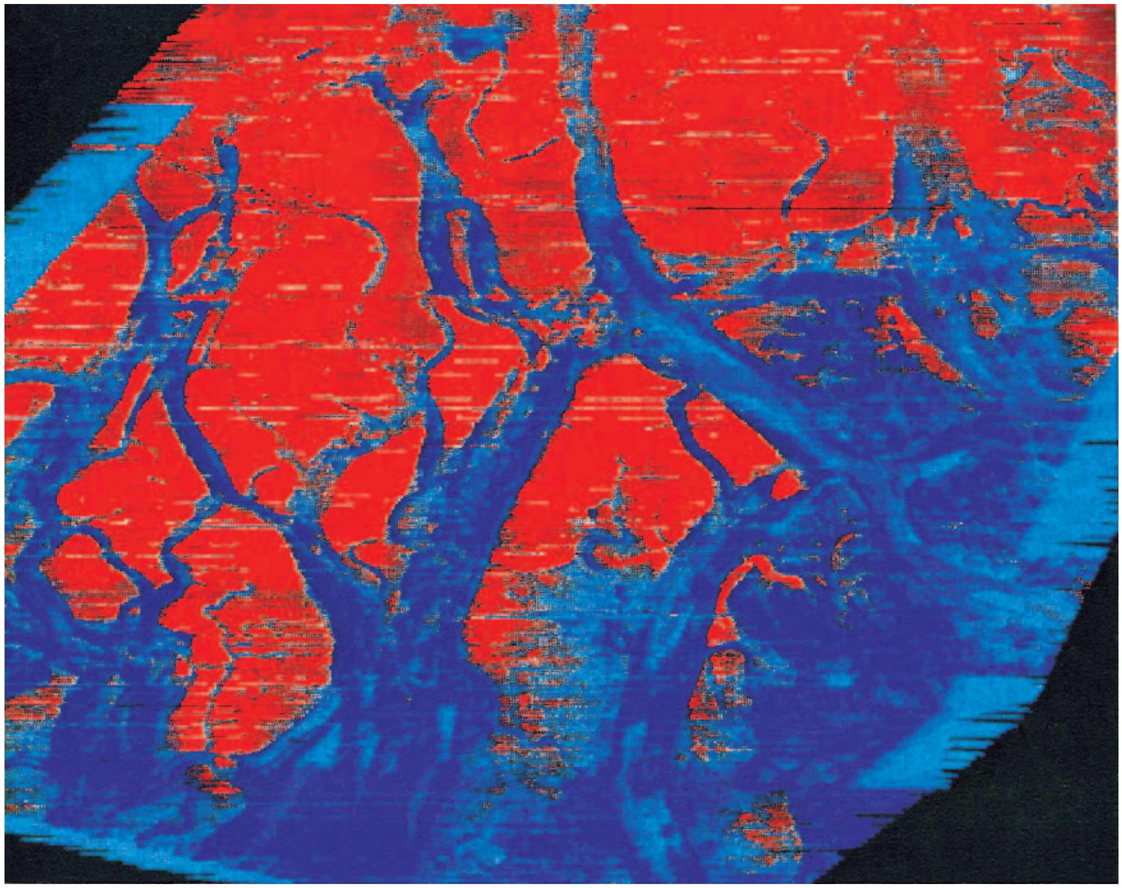


Fig. 4-17. Horizontal section at 100 ms from Peciko 3-D survey recorded in the Mahakam delta offshore Kalimantan, Indonesia. The deltaic features seen here are about 18,000 years old. (Courtesy Total Indonesie.)

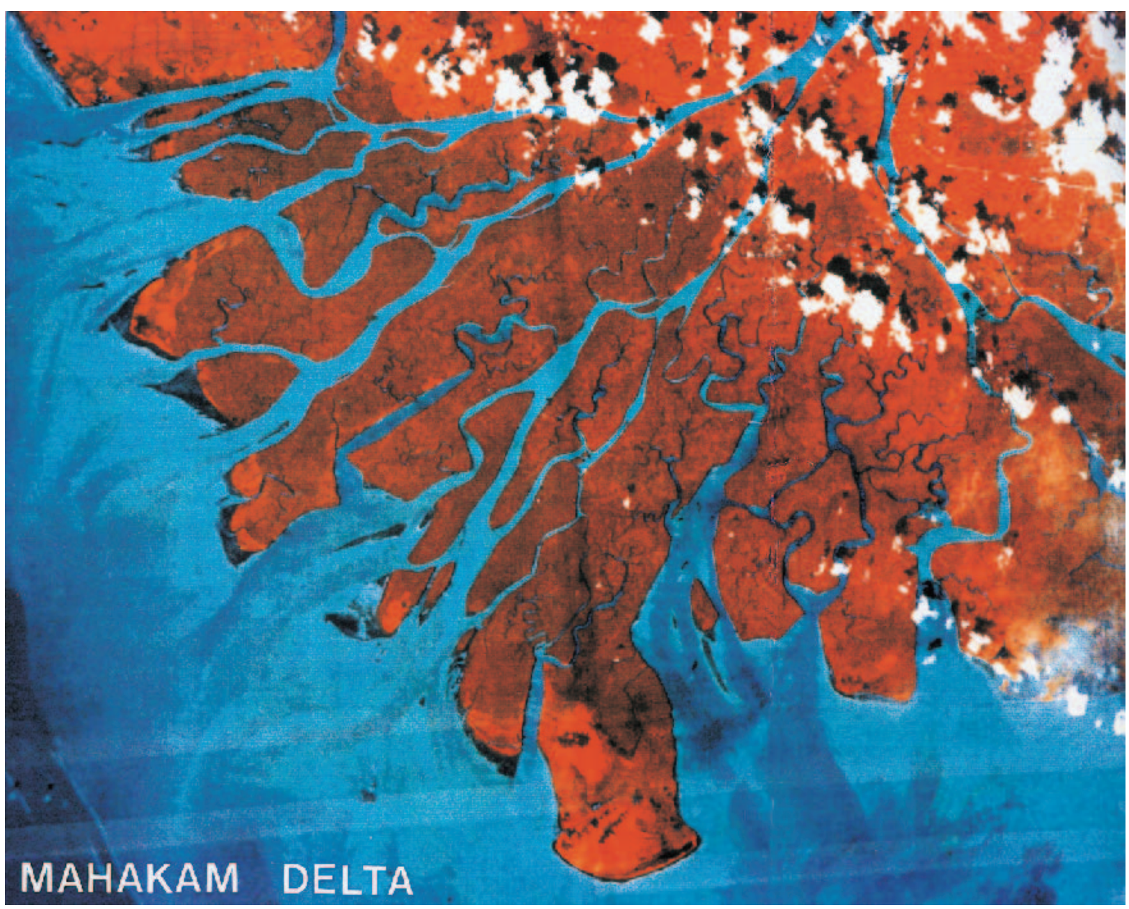


Fig. 4-18. Satellite photograph of part of present Mahakam delta for comparison with Figure 4-17. (Courtesy Total Indonesie.)

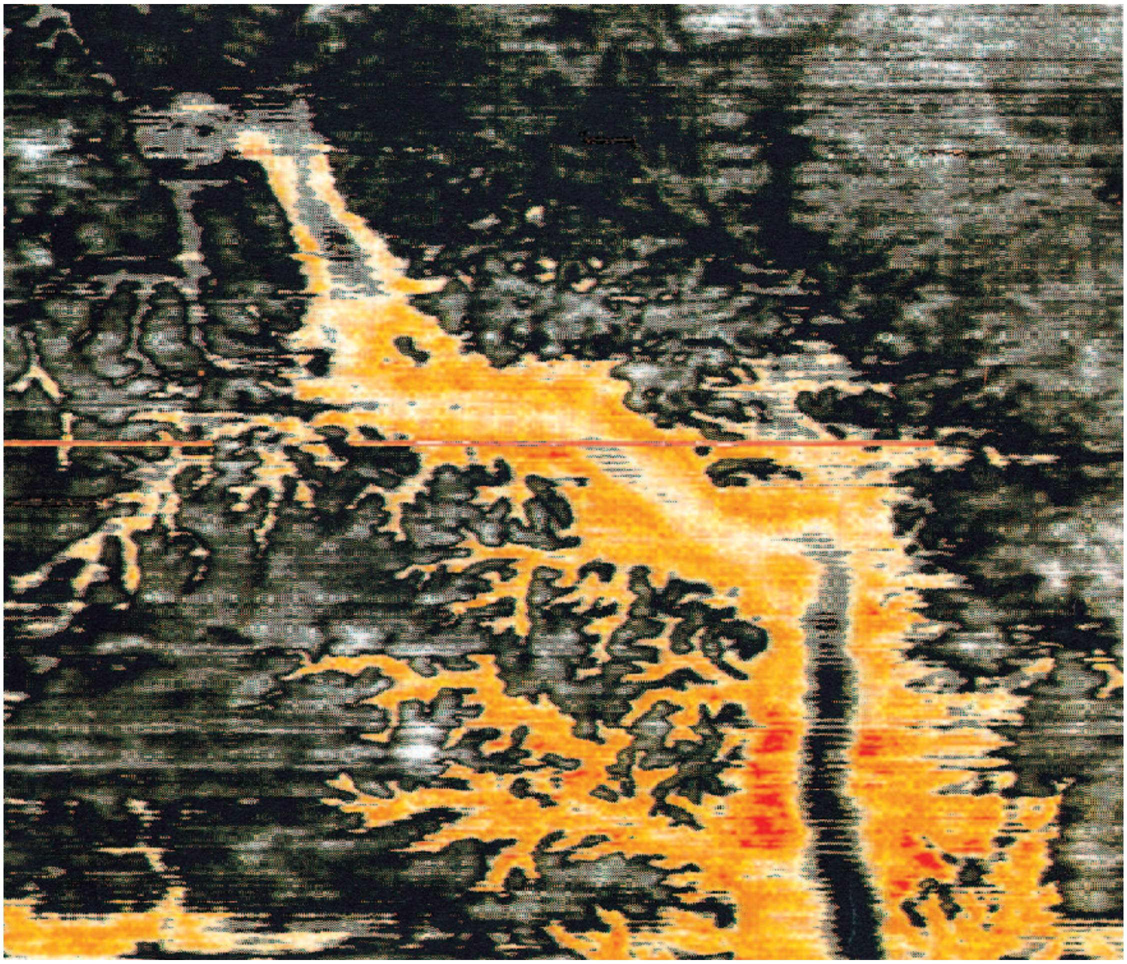


Fig. 4-19. Horizontal section at 104 ms from Nubi 3-D survey recorded in the Mahakam delta offshore Kalimantan, Indonesia. Note the dendritic patterns of incised canyons. (Courtesy Total Indonesie.)

different from that discussed above; it covers a much larger area than other sections in this chapter, which is evidenced by the collage of eight panels. There is a plethora of depositional features clearly visible. In the lowermost and uppermost parts of the figure, channels cross each other. This is evidence that a horizontal section observes a slab of the subsurface of finite thickness (around a quarter of a wavelength) during the deposition of which, in this area, conditions changed significantly. On the right center of Figure 4-20 a meandering channel is visible. Where this channel turns into the center of the figure, it passes point bars inside the meander loops and crevasse splays outside them.

Figure 4-21 is a horizontal section from the Gulf of Mexico showing another clearly visible channel. The channel is fairly difficult to observe on the companion vertical section of Figure 4-22. This demonstrates again the unique value of the strike perspective in recognizing characteristic stratigraphic patterns.

Figure 4-23 shows the interpretation of several Miocene deltaic fans. They are visible on one horizontal section because the structural dip is very gentle. Figure 4-24 shows one deltaic fan from deeper within the same area. The single gray scale used for display of these two examples was beneficial for the overall fan morphology because much of the stratigraphic patterns were in low amplitudes (refer to the discussion of color schemes in Chapter 2).

Reconstituting a Depositional Surface

In general, stratigraphic features, after being deposited on a flat-lying surface, will be bent and broken by later tectonic movements. Stratigraphy and structure then become confused and the interpretive task comes in separating them. The structure must be interpreted before stratigraphy can be appreciated.