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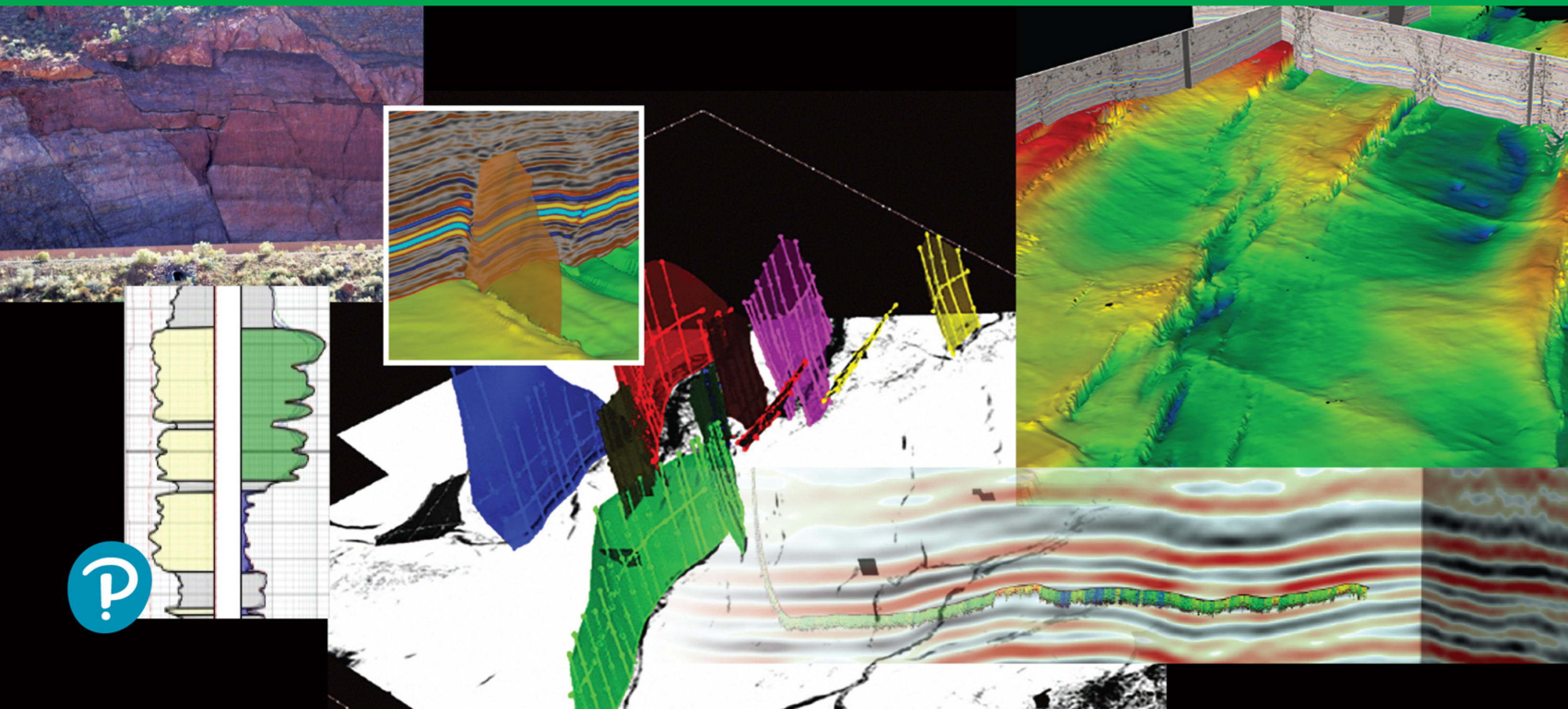
Applied Three-Dimensional Subsurface Geological Mapping with *Structural Methods*

Third Edition

Co-authored by J. Brenneke *and* D. Metzner



APPLIED THREE-DIMENSIONAL SUBSURFACE GEOLOGICAL MAPPING

WITH STRUCTURAL METHODS

Third Edition

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Richard E. Bischke

With James Brenneke and David C. Metzner

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Correlation Cross Sections

During the log correlation phase of subsurface interpretation, the geologist can build cross-section displays, optimized for log correlation, that contain several dozen wells each. Figure 6-46 shows an eight-well correlation cross section through Pliocene sediments. Correlation sections can be set up to show any track of a series of electric logs. By limiting the view to just one track, several dozen closely spaced logs can be viewed on a computer screen at one time, and log picks can be rapidly correlated from the type well across these specialized cross-section panels. The track chosen for Figure 6-46 is the SP/GR track. Note the missing sections, due to faults, displayed in Wells No. 2, 3, 5, and 7 in the stratigraphically datumed cross section. Picking and "gapping" faults during the correlation phase of a study greatly facilitates sorting out the stratigraphy in complexly faulted regions (see section Computer-Based Log Correlation in Chapter 4). Deviated wells need to be corrected to a true vertical depth display utilizing the directional survey.

Stratigraphic Cross Sections

Stratigraphic cross sections are designed to reconstruct original depositional geometries prior to structural deformation. Computer-based cross-section software facilitates the construction of stratigraphic cross sections in a number of ways. The ability to quickly select any correlation and rehang the section on the selected datum allows the geologist to reconstruct, with the click of a button, depositional geometries for successive correlations. To properly reconstruct accurate stratigraphic geometries, wells can be spaced proportional to map distance (or projected to a line of section). For wells with deviated wellbores, the program used should be able to adjust the

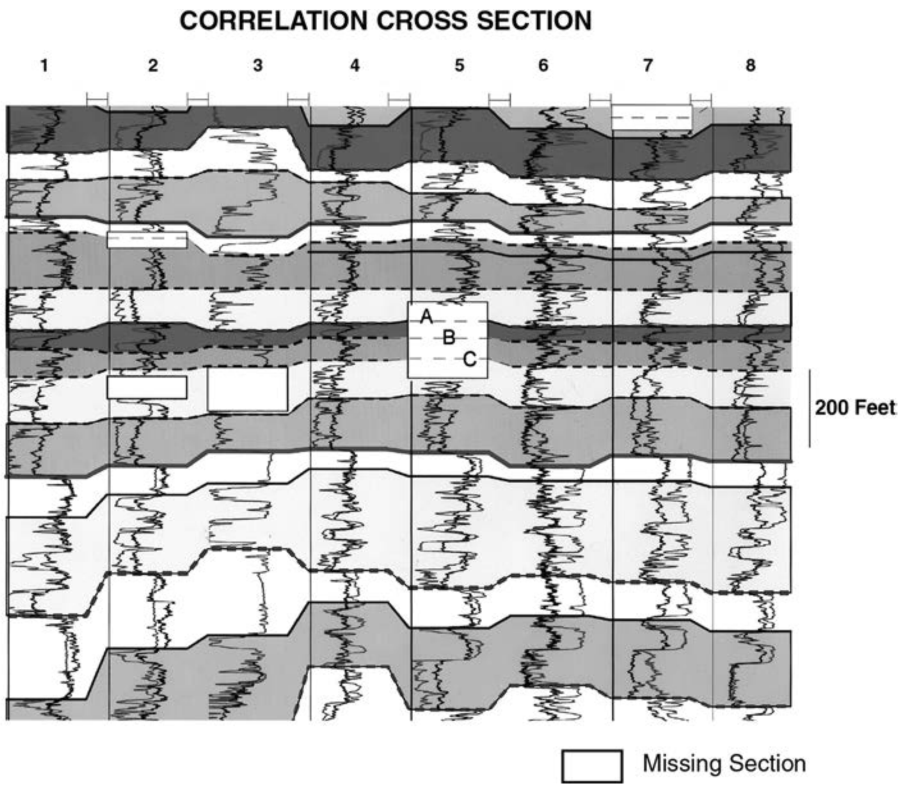
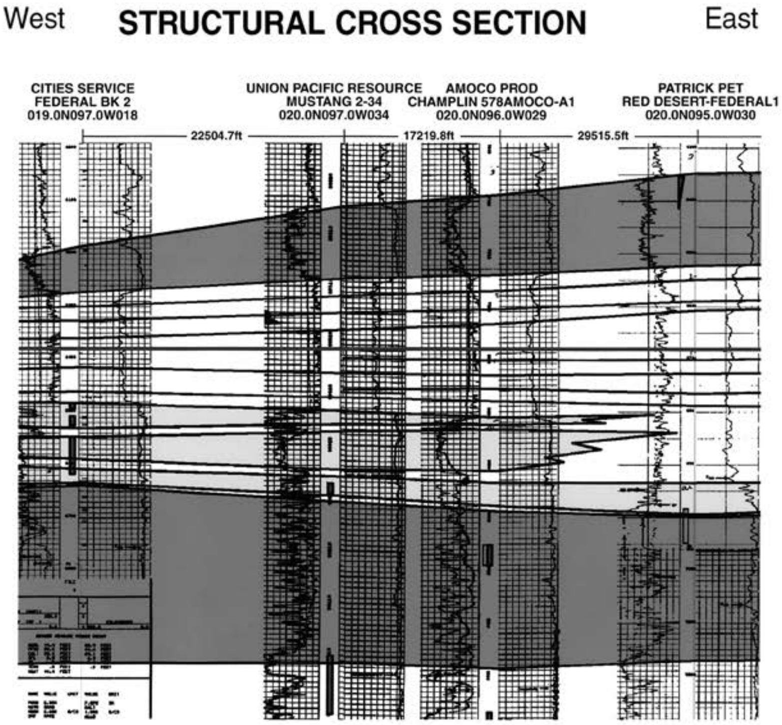
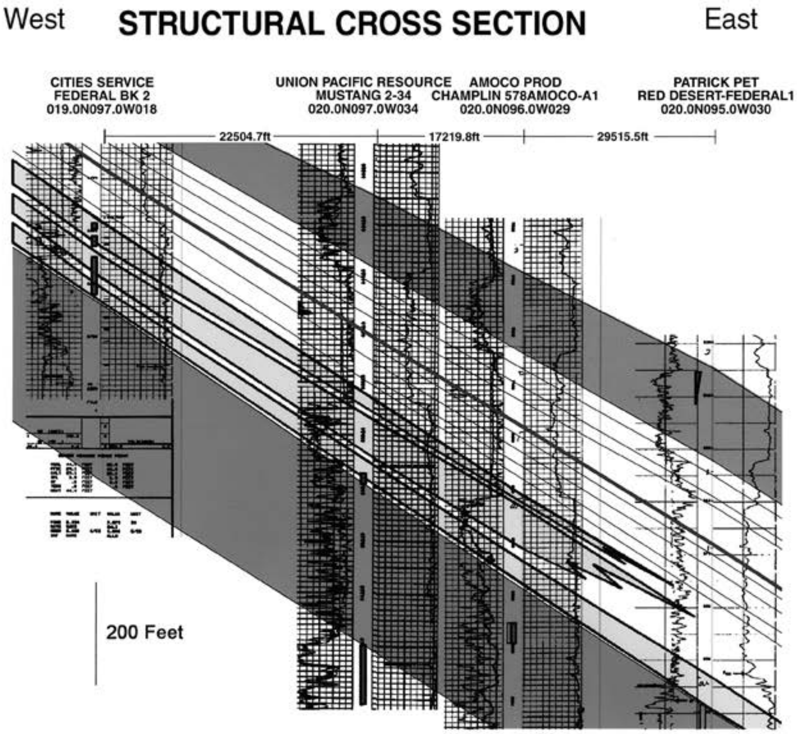


Figure 6-46 Eight-well, closely spaced correlation cross section set up to show the SP/GR track of a series of electric logs. The orientation of the section is constantly changing as all wells in the field study were included for correlation purposes. The missing section due to faulting is restored using a fault-gapping tool. Wells numbered 1 through 8 at the top of the section are all Mesa Petroleum-operated wells. (Published by permission of W. C. Ross and A2D Technologies.)



(a)



(b)

Figure 6-47 Stratigraphic (a) and structural (b) cross sections of Almond Formation and Lewis Formation stratigraphic relationships in the Green River Basin of Wyoming. Wells are spaced proportional to map distance. Facies changes and sandstone pinchouts, interpreted in the inter-well space in stratigraphic mode (a), are automatically repositioned properly in structural mode (b), and tops picked in the time-stratigraphic gap are used to determine and draw the position of onlap and erosional truncation terminations above and below the sequence boundary, respectively. (Published by permission of W. C. Ross and A2D Technologies.)

spacing of the wells to be proportional to map distance using the latitude and longitude positions along the chosen datum. Cross-section software should support the picking and termination of correlations, facies boundaries, and unconformities in the space between wells (Figs. 6-47 and 6-48). As wells are reordered or the section re-datumed from stratigraphic to structural views, the inter-well interpretation shifts appropriately (Fig. 6-47a and b).

Missing Section in Stratigraphic Cross Sections

Building stratigraphic cross sections can be enhanced by restoring those portions of the cross section that are missing due to erosion, nondeposition, or faulting. Unconformity/fault tools allow geologists to split or gap logs proportionally to reflect the amount of section lost due to erosion or faulting. An example of restoring a missing section due to channel erosion is illustrated in Figure 6-48a, where a siliciclastic package of marine shales and shelf sandstones is truncated by an incised valley system. Figure 6-48b shows the same system where the logs have been split, or gapped, at an unconformity (sequence) boundary. The gap space represents missing time due to erosion (in the valley) and nondeposition (in the interfluves). Correlations from the marine shale interfluve are extended into the missing section gap and represent an estimate of stratigraphic geometry prior to erosion. The ability to pick tops within these gaps allows geologists to hang cross sections on tops that have been cut out by erosion. Tops picked within the channel feature are extended into the interfluve space. When the gaps are closed, the software automatically determines the appropriate onlap and truncation geometries in the inter-well space, above and below the unconformity surface, respectively (Fig. 6-48a).

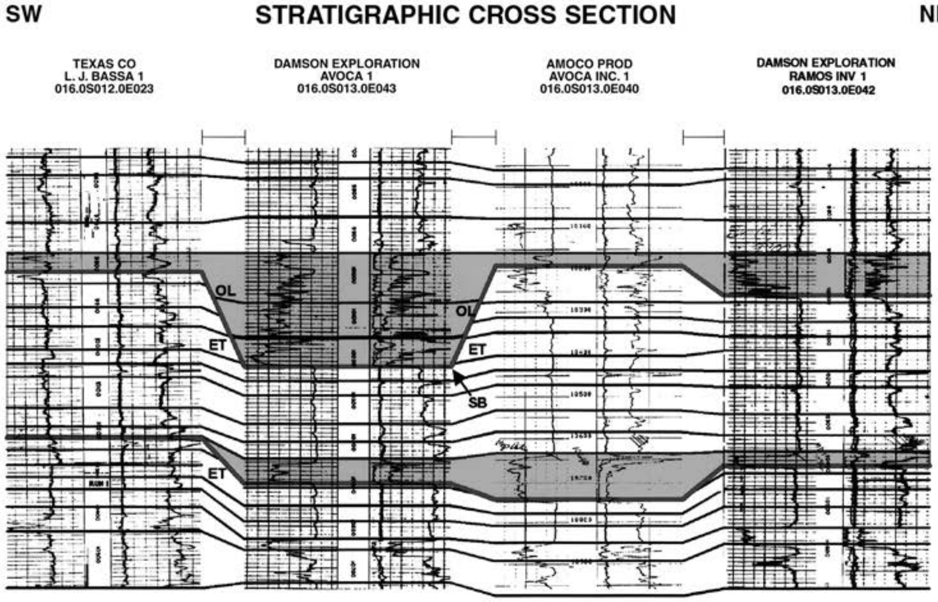
Structural Cross Sections

Structural cross sections are built by geologists as a complement to structure maps. Creating structural cross sections using a computer is simply a matter of selecting a structural datum and a well spacing proportional to map distance or projected to a line of section. These sections can be produced on-the-fly to check the validity of an evolving interpretation.

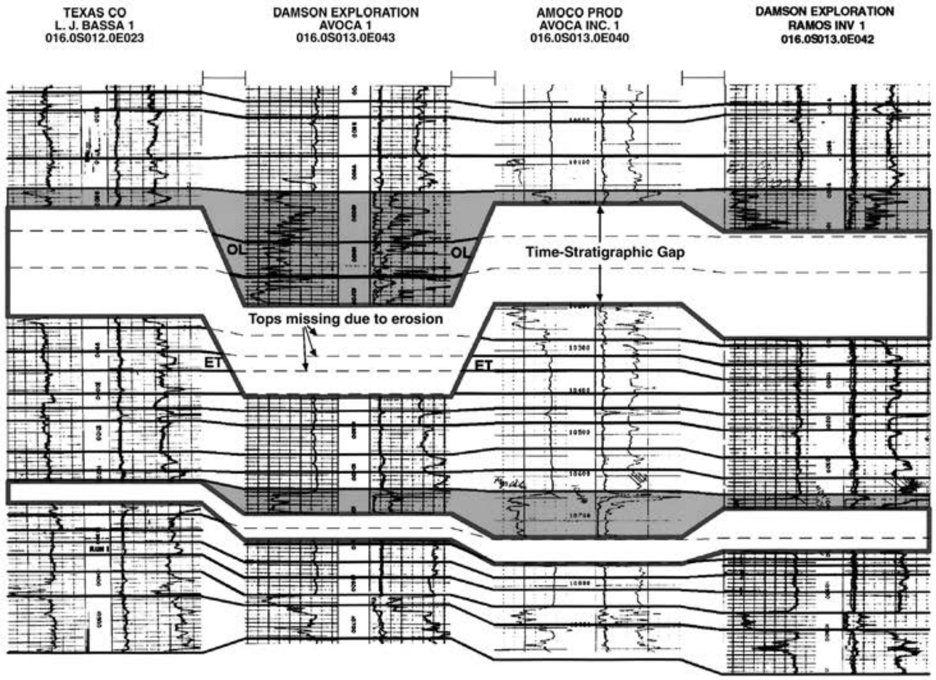
To include fault interpretations in a structural interpretation, the geologist first picks faults using an arbitrary, generic fault-naming scheme (Fig. 6-49). In this phase of interpretation, fault picks and missing section estimates can be interactively interpreted in "fault gap mode" by splitting the log and dragging down the fault gaps with a mouse-controlled fault tool (Fig. 4-33c and d in Computer-Based Log Correlation in Chapter 4). Once the generic fault locations in the wells are in place, the geologist can correlate or assign them with the same fault name (Fig. 6-50). These correlated faults each possess a missing section or vertical separation value interpreted by the geologist when the fault was first picked and after the gap was "pulled down" in gap mode. When the faults are correlated, these vertical separation values are interpolated from well to well to create an overall vertical separation fault function along the length of the fault. When the geologist instructs the software to create a structural cross section, the fault gaps are automatically closed and correlations intersecting the fault are automatically offset utilizing the vertical separation value at the fault-correlation intersection point (Fig. 6-51). The appropriate offset is determined using logic described in Chapter 4.

In addition to being a significant time-saver in the construction of structural cross sections, the automated offsetting of correlations provides a powerful constraint on the attitude of beds in the inter-well area, including beds cut out by the fault (see offsets of correlations A, B, and C, which are missing at cross section Well No. 3 in Fig. 6-51).

The ability to interactively interpret fault location (depth) in a well and the amount of missing section (vertical separation), and then to pick markers within these missing-section gaps, provides the geologist with a powerful set of tools for subsurface interpretations in regions dominated by normal faults. Figure 6-52a and b show stratigraphic (with missing-section gaps) and structural versions of a cross section from the Wilcox of South Texas (Edwards 2001). The large faults have



(a)



(b)

Figure 6-48 Stratigraphic cross sections of shallow marine and incised valley-fill sediments. (a) Shallow marine shelf facies are shown truncated by an incised-valley system. The base of the incised-valley system is a sequence boundary (SB). Erosional truncation (ET) of shelf strata below the sequence boundary and onlap (OL) of channel-fill strata above the unconformity are automatically positioned using the timeline geometries shown in (b). (b) The logs have been pulled apart, or "gapped," at the sequence boundary to represent a missing section due to erosion and/or nondeposition. The intersection of the sequence boundary and tops picked in the time-stratigraphic gap are used to determine and draw the position of onlap and erosional truncation terminations above and below the sequence boundary, respectively. (Published by permission of W. C. Ross and A2D Technologies; and AAPG©1990, reprinted by permission of the AAPG whose permission is required for further use.)

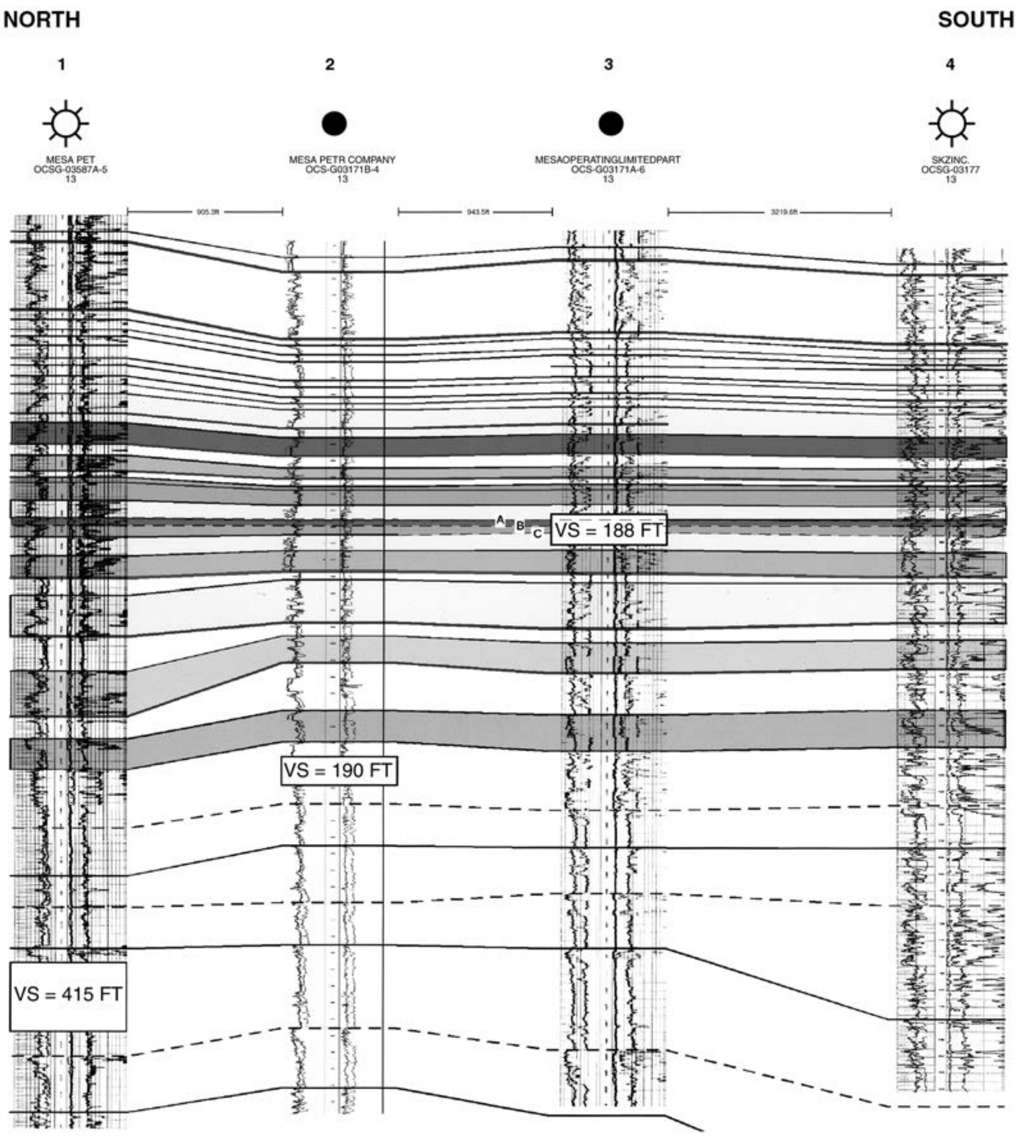


Figure 6-49 Stratigraphic cross section of Pliocene sediments. The missing section fault gaps show the results of fault identification through detailed correlation and vertical separation (VS) analysis. Estimates of a missing section (VS), due to faulting, have been performed at three locations and are shown within each missing section fault gap. Fault names are generic. As a result, no fault correlation is required at this stage of fault interpretation. Correlations A, B, and C are picked within the missing fault gap on the Mesa Petroleum OCS-G 03587 A-6 well. (Published by permission of W. C. Ross and A2D Technologies.)

cut out hundreds of feet of section. Tops cut out by the faults have been picked within the missing-section gaps across the entire cross section. Missing-section stratigraphic cross sections are useful for removing structure and providing an undistorted view of the correlation framework (Fig. 6-52b).

One challenge with constructing cross sections on a computer is controlling the projection of wells into the section. Most if not all software systems project wells into a section using the normal-to-section projection method. As discussed earlier in this chapter, this projection method is not the preferred method in many cases. Some software systems allow the interpreter to manually project wells using alternative projection systems such as plunge projection, structural strike projection, fault-strike projection, and so on. Using these alternative projections, which are

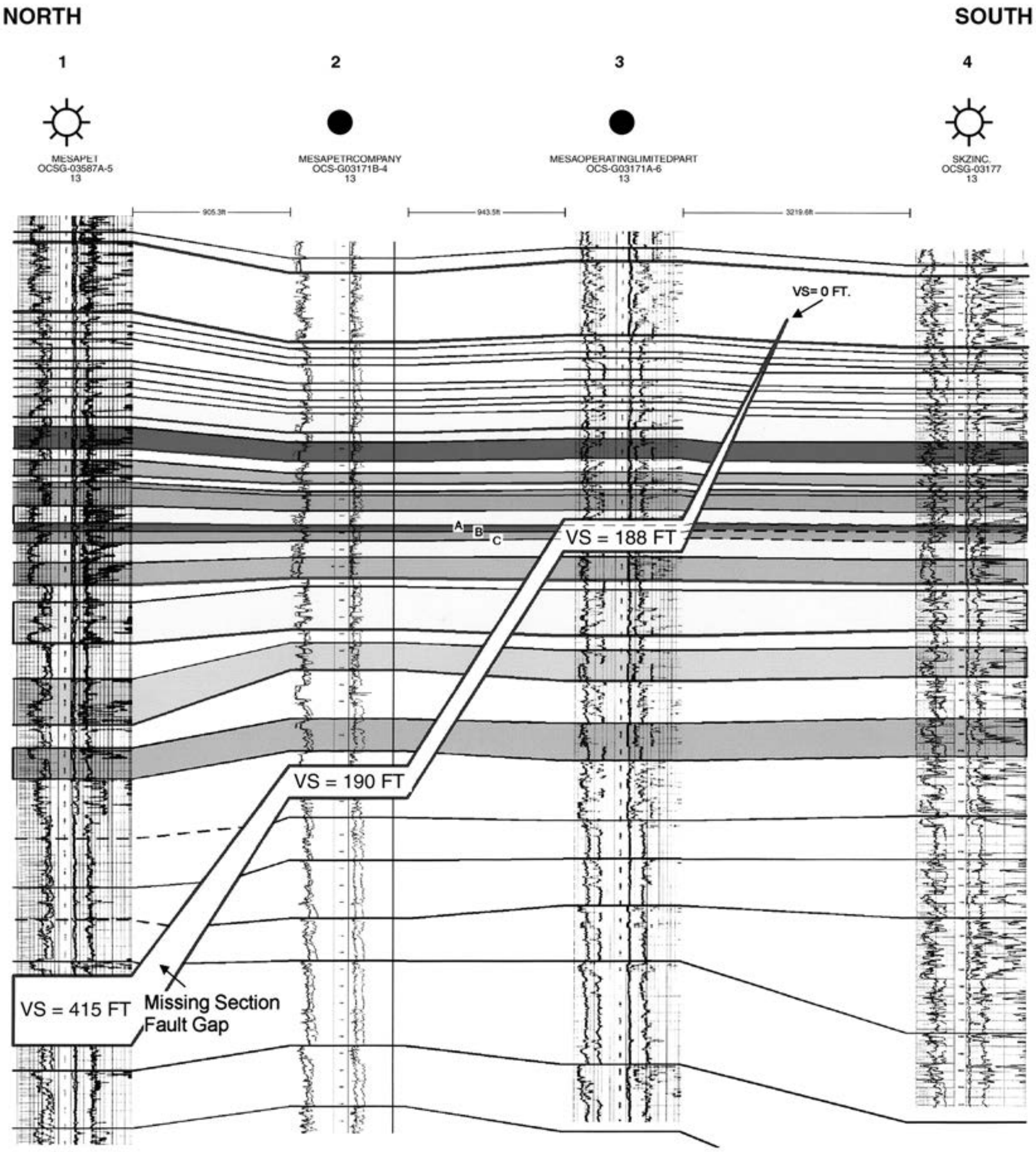


Figure 6-50 Stratigraphic cross section from Figure 6-49 showing fault geometry after geologist assigns a specific fault name to each generically named fault. (Published by permission of W. C. Ross and A2D Technologies.)

preferred in many instances, requires a geologist to manually control how wells are projected, assuming that the software package being used allows this manual control, as the software does not know the plunge or strike of a structure. Having to project wells by hand obviates some, but not all, of the advantages of constructing cross sections on the computer.

FAULT-SEAL ANALYSIS

The evaluation of potential hydrocarbon seal along a fault surface can be critical to exploration and development prospects and to reservoir evaluation. Some aspects of this analysis that are typically considered are (1) juxtaposition of rock units, which we can classify as a structural or geometric aspect; (2) lithologic characteristics of the fault zone such as shale smear, fault