attained a critical sand content, large-scale linear sand bodies were triggered, which were dynamically analogous to the sand ridges of modern storm-dominated shelves. These features tended to migrate southward across the aggrading shelf surface by means of the accumulation of successive facies packages on their down-current slopes.

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Imaging Beneath Complex Structure: A Case History

Migration is recognized as the essential step in converting seismic data into a representation of the earth's subsurface structure. Ironically, conventional migration often fails where migration is needed most—when the data are recorded over complex structures. Processing field data shot in Central America and synthetic data derived for that section, demonstrates that time migration actually degrades the image of the deep structure that lies below a complicated overburden.

In the Central American example, velocities increase nearly two-fold across an arched and thrust-faulted interface. Wave-front distortion introduced by this feature gives rise to distorted reflections from depth. Even with interval velocity known perfectly, no velocity is proper for time migrating the data here; time migration is the wrong process because it does not honor Snell's law. Depth migration of the stacked data, on the other hand, produces a reasonable image of the deeper section. The depth migration, however, leaves artifacts that could be attributed to problems that are common in structurally complicated areas: (1) departures of the stacked section from the ideal, a zero-offset section, (2) incorrect specification of velocities, and (3) loss of energy transmitted through the complex zone.

For such an inhomogeneous velocity structure, shortcomings in CDP stacking are related directly to highly nonhyperbolic moveout. As with migration velocity, no proper stacking velocity can be developed for these data, even from the known interval-velocity model. Proper treatment of nonzero-offset reflection data could be accomplished by depth migration before stacking. Simple ray-theoretical correction of the complex moveouts, however, can produce a stack that is similar to the desired zero-offset section.

Overall, the choice of velocity model most strongly influences the results of depth migration. Processing the data with a range of plausible velocity models, however, leads to an important conclusion: although the velocities can never be known exactly, depth migration is essential for clarifying structure beneath complex overburden.

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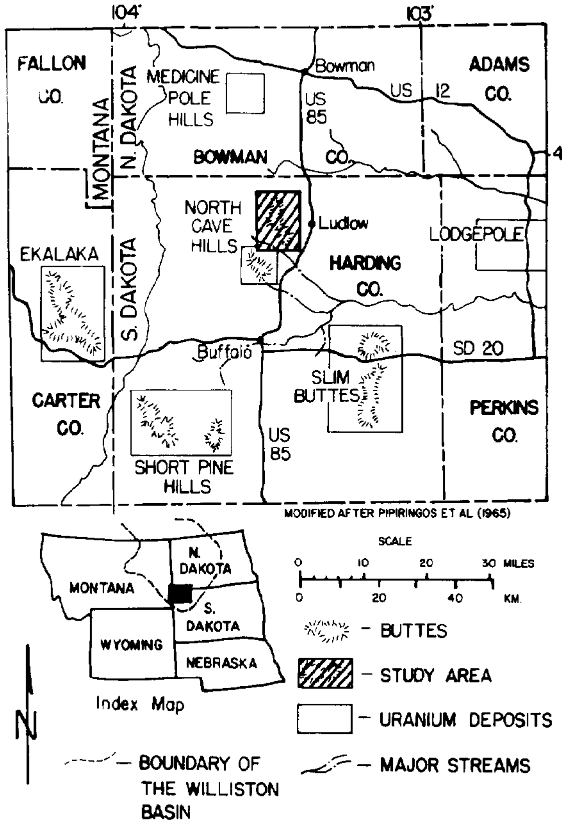
Paleoenvironment of Fort Union Formation, South Dakota

Rocks of Paleocene age are represented in the Cave Hills of northwestern South Dakota by the Ludlow, Cannonball, and Tongue River members of the Fort Union Formation. The Cave Hills are situated within the southern margin of the Williston basin, 80 mi (130 km) north of the Black Hills, South Dakota.

Numerous fine-grained, fining-upward sedimentary sequences comprise the Ludlow Member and are attributed to meandering streams occupying a low-gradient lower alluvial to upper deltaic plain. Major channel sandstones measuring up to 40 ft (12 m) in thickness, crop out and trend markedly to the northeast. Thinner sandstones adjacent to the large channel sandstones vary considerably in geometry and paleocurrent direction and are commonly associated with alternating siltstone, mudstone, claystone, and lignite deposits of levee, overbank, swamp, and possibly lacustrine origin.

The Cannonball Member is 130 ft (40 m) thick in the North Cave Hills and is represented by two fine-grained, coarsening-upward sandstone-mudstone sequences. A distinct vertical succession of sedimentary facies occur within each sequence representing offshore/lower shoreface through upper shoreface/foreshore depositional environments. A north to northeast depositional strike for the Cannonball shoreline is inferred from ripple crest and cross-bed orientations.

Numerous tree stumps in growth position are preserved along the upper surface of the Cannonball Member in the North and South Riley Pass mining districts. These stumps probably represent remnants of a cypress (*Metasequoia*) forest or swamp that stabilized the uppermost sands of the Cannonball shoreline.



The basal part of the Tongue River consists of approximately 40 to 50 ft (12 to 15 m) of lenticular sandstone, siltstone, mudstone, thin-bedded lignite, and kaolinite beds representing thin broad channels, point-bar, levee, overbank, and nearshore swamp depositional environments. Massive fluvial channel sandstones measuring several tens of ft in thickness overlie the fine-grained basal Tongue River lithologies. These channel sandstones represent the continued progradation of continental/fluvial/coastal plain depositional environments eastward over the marine sandstones of the Cannonball Member.

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Petroleum Exploration Contributes to Structural Knowledge of Rocky Mountain Foreland Deformation

The structural configuration and causal interpretation of foreland uplifts in the Rocky Mountain region have gained some clarity through recent petroleum exploration efforts. The most enlightening procedures have continued to be drilling, seismic recording, and surface mapping.

Drilling has confirmed the presence of an overturned limb of Paleozoic rocks beneath many foreland thrusts and a 20° to 30° angle of dip on most fault planes, two characteristics predicted by Berg in 1961 in his fold-thrust theory. Drilling has also revealed that some foreland thrusts do not have an overturned limb of Paleozoic rocks, and instead Precambrian rocks have been thrust directly over Eocene or Cretaceous rocks.

Seismic records have shown a relatively planar fault zone that does not appear to steepen at depth, and, in fact, frequently appears more horizontal, even with velocity corrections to depth. These records have also demonstrated thrust traces at angles ranging from 20° to 35°. Synthetic seismograms made from sonic logs recorded in wells that penetrated Precambrian rocks show zones of intense fracturing in both crystalline and metasedimentary rocks.

Surface mapping and biostratigraphic work on and adjacent to these