mineralogic, paleontologic, petrophysical, and geochemical techniques. Extractable heavy hydrocarbon and organic carbon contents were used as standards to which the other techniques were compared. It was found that lithic characteristics, particularly sedimentary structures and thin-section properties, correlate quite well with the standards. Test-tube pyrolysis, followed by careful measurement of the amount of fluorescence produced by the condensed liquids, was the most useful method developed.

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ELONGATE CONCRETIONS AS PALEOCHANNEL INDICATORS, TONGUE RIVER FORMATION, NORTH DAKOTA

Two types of sand bodies occur in the nonmarine Tongue River Formation (Paleocene) of western North Dakota, linear and tabular. The tabular sand bodies have sharply scoured bases, become finer upward, and the vertical sequence of sedimentary structures shows a decrease in the flow regime upward. These bodies are overlain by gray lignitic silts and clays, and they are interpreted as high-sinuosity stream deposits.

Linear sand bodies are the most common type in the Tongue River Formation. They are usually straight and have deeply channeled bases and flat tops. Vertical changes in grain size show no consistent pattern, but the upper parts become finer upward in many places. Sedimentary structures are about 60 % planar (omikron) cross-stratification, 25% horizontal or low-angle planar laminae (plane bed) with parting lineation, and 15 % small-scale ripple cross-stratification. Paleocurrent indicators parallel the axes of these bodies, which are interpreted as low-sinuosity stream deposits.

Elongate concretions, up to about 15 ft wide and hundreds of feet long, occur only in the linear bodies. They consist of calcite-cemented sandstone, and they usually occur at or near the tops of the bodies. They help to protect the bodies from erosion so that in places the bodies exist as exhumed paleochannel systems that form an inverted topography. The axes of the concretions parallel both paleocurrent indicators and the axes of the sand bodies. The concretions are clearly visible on air photos and can easily be used to map paleochannel patterns either on the air photos or in the field.

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SILURIAN CARBONATE RECYCLING: EXPLANATION FOR ANOMALOUS SUB-DEVONIAN UNCONFORMITY IN WILLISTON BASIN

Conventional electric-log correlations of the lower Paleozoic sequence in southern Saskatchewan express the sub-Devonian boundary as a major unconformity which has traditionally been interpreted as an erosion surface involving the removal of large volumes of Interlake carbonate rock between Late Silurian and Middle Devonian times. The amount of sediment removal invoked by this concept seems anomalous for the Williston basin, in terms of the short timespan involved.

Based on facies analysis, an evolutionary model is presented involving marginal upwarp and erosion throughout the span of Interlake deposition, augmented by sediment recycling in the latter part of Interlake times. Marginal attenuation of Interlake units is coupled with the passage of normal marine to supratidal carbonate facies on a gradient which predicates the emergence of a broad surrounding hinterland at least by mid-Interlake time. This area emerged gradually and a corresponding regression of Interlake seas exposed increasingly greater surface areas of lithified carbonate sediment to subaerial processes. Chemical and mechanical erosion of this terrain caused a natural recycling of carbonate material toward the marine basin, both as clastic and dissolved particles. These were redeposited as part of a broad coastal plain complex which prograded into the shrinking marine area and eventually covered all of southern Saskatchewan. Hence, long before Interlake sedimentation had ceased, erosion had strongly beveled preexisting sediments around the Williston Basin margin, developing the unconformity which separates Silurian from younger rocks in this basin. Much of the sediment removed by this erosion was recycled during Late Interlake time and post-Silurian erosion caused only slight modification of the terrain.

Exploration of the Interlake Group for petroleum should be based on an understanding of the evolutionary changes accompanying Interlake sedimentation. Because the most favorable porosity occurs in dolomitized marine carbonates, exploration efforts should be directed toward southeastern Saskatchewan, where marine deposition prevailed over the longest period of time and accordingly potential reservoirs should be thickest.

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LOW- AND HIGH-SINUOSITY STREAM DEPOSITS OF SENTINEL BUTTE FORMATION (PALEOCENE), MACKENZIE COUNTY, NORTH DAKOTA

Low-sinuosity stream-channel sands in the study area are 8–20 m thick and up to 400 m wide. They are lens-shaped, with flat tops and concave-upward, deeply channeled bases. Paleocurrent directions are subparallel to sand-body axes. Epsilon cross-strata are rare, but numerous other types are common. The sands are fine- to very fine-grained and moderately sorted. Cross-stratification and grain size changes suggest one or more episodes of upward decrease in flow regime.

High-sinuosity stream-channel sands may also reach 20 m in thickness but may be a kilometer or more in width. They are tabular bodies with scoured bases. Paleocurrent directions are parallel to sand body axes. Cross-strata types are less varied than in low-sinuosity stream sands but epsilon cross-strata are more common. The high-sinuosity sands are generally coarser grained and better sorted than the low-sinuosity deposits, and grain-size changes along with cross-stratification changes show an upward decrease in flow regime.

Alternate thin beds of tan and rust-colored sands, silts, and clays in wedge-shaped bodies overlie the high-sinuosity sand, but occur adjacent to and slightly above the low-sinuosity sands. These characteristics, plus low organic content, numerous thick concretionary layers and abundant climbing ripples suggest that these are natural levee deposits.

The natural levee deposits grade laterally and vertically to the disturbed and dark-colored clays of the flood basin. These laterally extensive deposits commonly become fine upward and become organic, and are overlain by beds of lignite.

Thin, very fine-grained sands occur in either the natural levee or flood-basin deposits of the low-sinuosity streams. They have channeled bases, pinch out laterally, and show highly variable current directions. They are probably crevasse-splay deposits.

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LAMINATED ("VARVITIC") CARBONATES AND ANHYDRITES FROM ORDOVICIAN AND DEVONIAN OF SASKATCHEWAN

Bituminous-laminated (or "varvitic") carbonates, which grade upward into laminated anhydrites, are of particular interest to the petroleum geologist, because the carbonates may act as source, carrier, and reservoir rocks whereas the overlying anhydrites form impermeable caprocks. Commonly, such sediments exceed 10 ft in thickness and are traceable over thousands of square miles, but have been interpreted as of upper intertidal (algal mat) and supratidal (sabkha) origin.

Carbonate-anhydrite laminites occur as a basin facies of the Middle Devonian Winnipegosis Formation in Saskatchewan and are located on the basin floor between large carbonate banks. The laminites grade downward into a thin (1–10 ft) unit of black, highly bituminous, laminated mudstone containing a pelagic fauna. Near carbonate banks this mudstone thickens and includes carbonate beds interpreted as turbidites or mud-