Structural, stratigraphic, and geomorphic analyses have been performed to locate geologic anomalies. Image analysis provides a better understanding of the regional stress-strain relations for tectonic correlation.

Digital Landsat (satellite) data were processed to produce a variety of images (i.e., edge-enhanced, high pass filter, false color, and ratio). Some of the images were geometrically corrected with map controls and nonlinear deconvolution resampling techniques (coverage 13,000 mi^2; 33,670 km^2). This helped facilitate more detailed mapping, interpretation, and data integration. These specially processed images have been used to map surface geology, lineament systems, and tectonic anomalies in relation to subsurface geologic and geophysical data.

Project areas are defined in terms of tectonic genesis, structural trends, and hydrocarbon potential. Numerous exploration targets and several modes of hydrocarbon entrapment were identified by geologists at the TCU Center for Remote Sensing and Energy Research. This information is being used by various companies for planning their seismic programs in these frontier drilling areas.

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Manetoe Facies—Gas-Bearing Late Diagenetic Dolomite of Northwest Territories, Canada

The white coarsely crystalline space-filling and replacement, late-diagenetic Mississippi Valley-type dolomite of the Manetoe facies occurs across a broad area of at least 15,000 sq km in the southern Mackenzie Mountains of the Northwest Territories. Through most of this area it is stratiform and confined to a thin ($<$100 m thick) stratigraphic interval under a shale unit within a lower Paleozoic carbonate sequence. Some large vertical developments of the Manetoe facies, such as at the Kotaneelee and Pointed Mountain gas fields, occur in the eastern part of this region where the overlying shale of the Headless Formation is thin. These large dolomite masses have a core of dolomite-cemented breccia and are surrounded by a halo of replacement dolomite. Solution-collapse breccias and large solution cavities are common throughout. Quartz and bitumen are the final vug infillings. The pronounced curvature of Manetoe dolomite crystal faces is similar to that displayed by many Mississippi Valley-type dolomites.

These dolomites are nearly stoichiometric with a mean of 51 mole % $CaCO_3$, and they exhibit a high degree of cation order. The range of carbon isotope values ($+1.33$ to -2.99 δC^{13}PDB) and a sodium concentration of ~100 to 350 ppm are typical for this type of dolomite. But the range of oxygen isotope values (-8.03 to -17.33 δO^{18} PDB), the extremely high strontium content of ~200 to 1,000 ppm, and an iron content less than 120 ppm is atypical and must reflect precipitation from a medium of unusual composition, enriched in strontium but depleted in iron and in the O^{18} isotope.

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Rb-Sr Dating of Illite Diagenesis

In the Woodford Shale (Upper Devonian), apparent Rb-Sr ages decrease as clay grain size decreases, which in turn correlates with increasing abundance of diagenetic illite. Analyses of the fine-clay size fraction ($<0.2\mu$) from widely spaced wells in the Delaware basin of west Texas, plot on a single isochron indicating an age of 300 ± 4 m.y. (Middle Pennsylvanian). At this time the Woodford was buried only 200 to 600 m; consequently diagenesis must have been triggered by a circumstance other than deep burial. Possibly diagenesis was accomplished by hydrothermal fluids moving toward the craton out of the Ouachita geosyncline, which at that time was experiencing horizontal compression. These fluids may have been responsible for petroleum migration and lead-zinc mineralization.

In the Frio Formation (Oligocene) of the Texas Gulf Coast, samples of fine clay-size material ($<0.06\mu$) from the 3 to 5 km depth interval in a single well also provide a well-defined isochron corresponding to 21.6 ± 2.2 m.y. Burial here was possibly so rapid that transformation of smectite to illite approximated an episodic event over the entire depth interval. Alternatively, because the sediment is geopressured, the age might record the time of geopressure development which was accompanied by a rapid rise in temperature.

Clay diagenesis at the surface is illustrated by a paleosoil developed on Pennsylvanian shale in the Llano uplift of central Texas. The paleosoil was buried by Cretaceous basal conglomerate and records the time of marine transgression 119 ± 3 m.y. ago. Constituents of the shale were degraded by soil-forming processes which erased previous isotopic memory, then reconstituted by coming in contact with marine water. This field relation offers a new way to date directly a time of sedimentary deposition.

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Was the Mannville Group the Source for Alberta's Heavy Oils?

The Western Canadian basin hosts about 12 billion bbl of conventional oil in Devonian to Cretaceous reservoirs. Lower Cretaceous heavy-oil sands contain 1,300 to 2,600 billion bbl in place. They represent the biodegraded remnants of supergiant conventional deposits, the source for which has been thought to be mature rocks of the equivalent-age Mannville Group. This work shows, however, that the Mannville rocks alone are incapable of generating the required volume of hydrocarbons.

Volume of hydrocarbons generated in the Mannville under central Alberta was calculated by combining measured geochemical and geologic data with a model (modified from Lopatin's method) for thermal maturation. Original hydrocarbon generative capacity of the Mannville rocks was calculated from geochemical analyses of immature samples. Using average values for TOC (1.3%) and Rock-Eval Hydrogen Index (100 mg HC/g TOC), maximum hydrocarbon generation per unit volume of source rock was calculated. The maturation model was then employed to estimate the extent to which maximum yield has been achieved.

Total volume of source rock in the basin was obtained from isopachs of Mannville shale. Multiplication of actual oil generation per unit volume by source rock volume gave a generated volume of 450 billion bbl. Inclusion of oil generated in the Foothills belt would less than double this number. These calculated values are exceedingly optimistic, however, because they ignore inefficiencies in expulsion and migration. It is therefore clear that the Mannville Group cannot be the major source of the heavy oils. Dominant contributions probably come from Paleozoic and other Mesozoic rocks.

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Petroleum Geology of Central Beaufort Sea, Northwest Territories, Canada