source of hydrocarbons in the Lower Cretaceous Muddy Sandstone of the Powder River basin. This sandstone has a geographic distribution similar to that of the Mowry and much of the Skull Creek.

Illite/smectite mixed-layer clay in the Mowry and Skull Creek Shales of eastern Montana and western North Dakota is unaltered. No significant amounts of hydrocarbons have ever been found in the Muddy Sandstone of this area. Hydrocarbons in the Muddy Sandstone occur within or immediately adjacent to areas in which the smectite component of the illite/smectite in the Mowry and Skull Creek Shales has undergone alteration to illite during burial diagenesis. Anomalous decreases in the total organic carbon content of the Mowry and Skull Creek Shales lie within areas of illite/smectite alteration and coincide with the deeper parts of structural basins which developed after deposition of the Mowry and Skull Creek. These regional variations in illite/smectite alteration and total organic carbon content reflect thermal maturation and are not provenance controlled. They are useful indicators of areas where the potential source rocks have been subjected to temperatures adequate to generate hydrocarbons. The degree of illite/smectite diagenesis in the Mowry and Skull Creek of the northern Rocky Mountains-Great Plains region is thus of exploration significance in the search of hydrocarbons in this area.

CANDELARIA, MAGELL P., Atlantic Richfield Exploration Co., Denver, CO

Permian Upper Yates Formation Carbonate/Siliciclastic Depositional Patterns, Northwestern Shelf, Guadalupe Mountains, New Mexico

Sedimentological field study of the upper three sandstones of the upper Yates Formation (Permian, Guadalupian), Guadalupe Mountains, New Mexico, has shed considerable light on the shelf depositional environment, morphologic profile, and temporal relationships of alternating carbonate and siliciclastic deposition. Outcrops were examined in detail, and 31 stratigraphic sections were measured, described, and correlated within the region 5 km (3 mi) shelfward of the Capitan reef and encompassing an area of 180 km^2 (69 mi^2).

The three sandstones in the upper 15 to 30 m (49 to 98 ft) of the Yates are continuously traceable across the study area as thin, nonchanneled sheet sandstones 0.5 to 8 m (1.6 to 26 ft) thick. They exhibit no deepening or "shoaling-upward" sequences; no beach or tidal sedimentation features; and no vertical repetitive sedimentation patterns. Primary sedimentary structures are rare, obscure, small scale ($\leq$ 20 cm; 8 in., height), and discontinuous. All structures indicate subaqueous deposition. From the sandstones nearest the Capitan, the shelfward progression of sedimentary structures indicates shelfward diminution of hydraulic energy. Sandstones are largely abiotic suggesting maintenance of inhospitable marine conditions (mesohaline?) during siliciclastic deposition.

Evidence for a marginal mound shelf profile during sandstone deposition is inconclusive. A localized area of fenestral porosity in the lowermost sandstone unit, and a narrow region of probable fossil caliche along the Yates/Tansill formational contact of the upper sandstone, both suggest local emergence of a paleotopographic high located 1.5 to 3.0 km (.9 to 1.8 mi) and 1.5 to 3.25 km (.9 to 2 mi) respectively, shelfward of the Capitan. All three sandstones continuously overlie the area of the marginal mound as inferred from the underlying carbonate facies, hence a marginal mound was not present or had no affect on transport of siliciclastics across the outer 5 km (3 mi) of the shelf.

Each sandstone is characterized by a sharp, subplanar erosional base, and typically grades upward into peritidal carbonates, which exhibit along the shelf crest of the marginal mound one or more 1 to 2 m (3 to 6 ft) shoaling-upward hemicycles which commonly built up to depositional fill-level in response to episodic shelf subsidence of 1 to 2 m (3 to 6 ft). The eroded fill-level carbonates of the shelf crest underlying two of the three sandstone intervals were diagenetically micritized analogous to incipient pedogenesis prior to subsidence and burial by subaqueously deposited siliciclastics. Local emergence of 1 to 2 m (3 to 6 ft) relief could explain the inferred pedogenesis, with siliciclastic deposition being favored by subsidence and greater water depth which governed siliciclastic transport processes.

The following depositional sequence is repeated twice in the study interval: subaqueous deposition of siliciclastics across the eroded surface of the underlying carbonate unit; upward siliciclastic gradation into peritidal carbonates characterized by one or more 1 to 2 m (3 to 6 ft) shoaling-upward hemicyclic deposits which proceeded to fill-level; local emergence with concomitant subaerial erosion and micritization; subsidence and renewed subaqueous siliciclastic deposition. Reconnaissance observations from the middle Yates and lower Tansill reveal numerous analogous sandstone/carbonate relationships.

The sandstone intervals interbedded with shelf crest carbonate facies comprise sandstone/carbonate shoaling-upward hemicycles; contrary to current interpretation the sandstone represents the basal "deeper" water deposition, the carbonates represent the "shoal water" deposition.

CANNON, P. JAN, Planetary Data, Fairbanks, AK

Importance of Radar Look Direction in Petroleum Exploration

Structural features which can be readily mapped from radar imagery are those features which are represented by some elements of physical relief. These structural features are usually fractures or physical discontinuities in the rock materials, which can be seen because of the effects of selective or differential erosion. These effects are seen on radar imagery in two distinct manners. First is the linearity of physical features, and second is the discontinuity of tone, shape, texture, and/or pattern. The discontinuity of tone, shape, texture, or pattern is created by differential erosion of the terrain on one side of a fracture in respect to the other side.

The ability of a remote sensing system to enhance minor physical features is the most important aspect in mapping structural features. The available tonal contrast is of secondary importance. The direction of illumination is also important in the mapping of structural features as determined by studies on the Alaskan Peninsula.

Maps showing the major structural features of the study area were compiled from real aperture radar imagery, synthetic aperture radar imagery, and Landsat MSS imagery. Three simple frequency diagrams were produced from maps of the study area showing the major structural features. The frequency diagram of the linear features taken from real aperture radar imagery, shows a strong bimodal distribution. The two major directions indicated are approximately 50°W and 50°E. The frequency diagram of the linear features taken from synthetic aperture radar imagery also shows two major directions of orientation. The two major directions are approximately 70°W and 20°E. The frequency distribution for Landsat MSS imagery is trimodal showing major orientations of approximately 60°W, 10°E, and 60°E. All three frequency diagrams are strikingly different.

What is shown in the frequency diagram is preferential enhancement of linear features by a particular direction of illumination. Field reconnaissance indicated three major directions of fracturing, 55°W, 55°E, 15°E, presented here in order of decreasing dominancy. These directions show up in relation to directions of illumination. Along a line of illumination there will be two triangular areas, one on either side of the line, in which the maximum enhancement of linear features will occur. These areas are the zones of maximum shadow effects. When radar imagery is acquired with two directions of illumination, the two directions should not be at 180° to one another. The second direction of illumination should be about 120° from the first direction of illumination. In an area in which Landsat data are available, the direction of illumination for the radar imagery should be acquired 120° from the direction of illumination of the Landsat data.

CARLTON, RONALD R., Union Oil Co. of California, Casper, WY, and C. E. PROUTY*, Michigan State Univ., East Lansing, MI

Dolomitization and Dedolomitization Models in a Fractured Reservoir, Reed City Oil Field, Michigan

Hydrocarbon production in the Michigan basin is essentially from pinnacle reefs or fractured reservoirs. The latter represents linear production zones which only recently have been demonstrated as related to shear faults and accompanying shear folds.

Dolomite distribution of the Middle Devonian Traverse, Dundee, and Detroit River producing formations in several linear fields were studied by X-ray diffraction of well samples at 20 to 60-ft (6 to 18 m) intervals. The epigenetically formed porous dolomite reservoir rock is intimately related to the shear faults (channelways for rising high Mg/Ca ratio fluids) and to the resulting shear folds, the latter showing dolomite/calcite ratios increasing generally from outer closure to the fold axes.

The Reed City field (anticline) of western Michigan represents a dramatic exception to this picture with the dolomite/calcite ratio increasing from outer closure to maximum part way up the limbs then decreasing to the axis. The Traverse Formation (highest stratigraphically) shows dedolomitization throughout 540 ft (165 m); the Dundee, throughout the entire 60 ft (18 m); and the Detroit River (the lowest target) in the upper 20 ft (6 m) but not in the lowest 30 ft (9 m). This lowest zone is the only unit not dedolomitized, a fact perhaps commensurate with its low stratigraphic position at the bottom of (and apparently beyond the reach of) the descending high-calcium, low-magnesium waters what brought about the dedolomitization.

A change from dolomite to calcite is witnessed by zonation of dolomite rhombs, which show on staining a ferroan dolomite core followed by successive layers of ferroan calcite and calcite in the outer layer. The individual calcite rhombs are usually pseudomorphic after the dolomite. Clear dolomite rhombs (dolomitizing stage) and calcite rhombs (dedolomitizing stage) often occur along microstylolites.

The presence of anhydrite and gypsum in this field likely supplied the $CaSO_4$ considered important to the dedolomitization process with the general reaction: $CaSO_4 + CaMg(CO_3)_2 = 2CaCO_3 + MgSO_4$. Iron found in the ferroan dolomite, ferroan calcite, and iron hydroxide in the dedolomitized rock probably came from pyrite, an important constituent of the original microcrystalline limestone country rock. The dedolomitization model would call for a shallow water to exposed oxidizing environment, possible with the position of this area astride the "West Michigan Barrier" that separates a lagoonal facies from a more open sea facies to the east. Thus, waters with a high Ca/Mg ratio passed down the same shear faults that earlier were channelways for the rising high Mg/Ca ratio waters.

On the bases of isopach, structure and dolomite/calcite (Isodol) maps, one can piece together a reasonably chronological sequence of pre-Dundee shear faulting and folding, post-Traverse upward migration of dolomitizing fluids, upward migration of hydrocarbons along the shear faults, downward-moving dedolomitizing fluids, and a later episode of faulting (especially shear cross-faults).

CARPENTER, DONALD J., Chevron Resources Co., Golden, CO, and MARTIN B. GOLDHABER, U.S. Geol. Survey, Denver, CO

Geochemical Evaluation of Proposed Ore Genesis Models for Colorado Plateau Tabular-Type Uranium-Vanadium Deposits

The elemental, isotopic, and mineralogic examination of core samples from the Tony M orebody, a typical Colorado Plateau tabular-type, uranium-vanadium deposit, located in the Henry structural basin of south-central Utah, allows a critical evaluation of proposed ore genesis models. Uranium mineralization is concentrated into two horizontally oriented tabular horizons hosted within the Salt Wash member of the Jurassic Morrison Formation. The ore zones are not strata bound and rise stratigraphically toward the center of the ancestral Henry basin. Preservation of fossil plant debris and the lack of oxidative destruction of iron disulfide minerals in the interval between the uranium-enriched units argue this zone is not the oxidized tongue formed by a roll-type mineralizing process. The selenium-molybdenum trace element pattern is also inconsistent with the roll-front model.

The necessary interbedding of gray lacustrine mudstones and nearshore lacustrine sandstones, as required by the lacustrine-humate model, is present within the Tony M deposit. However, absence of quantitatively significant amounts of transported humic substances either associated or remote from mineralization suggests that mudstone-derived organic acids were not involved in uranium localization.

Vanadium oxide is the major vanadium-bearing phase within the lower uranium lense whereas vanadium is partitioned within chlorite in the supra-adjacent barren zone. Such a sharp vertical break in vanadium mineralogy implies vanadium deposition within two chemically different environments.

The lower ore zone is characterized by isotopically light ($\delta^{34}S \cong -26‰ - 46‰$) FeS_2. Bacterial sulfate reduction is shown to be the most likely fractionating agent. The uniformity of the sulfur isotopic composition of the iron disulfide minerals requires a non-depletable sulfate reservoir. Dissolution of gypsum ($\delta^{34}S \cong +14‰$) occurring below the Tony M orebody is demonstrated to be a plausible sulfur source thereby establishing the presence of a sulfate brine. From this data we conclude that the solution-interface model, which postulates uraniferous meteoric fresh water flowing over a denser brine, best explains the genesis of this deposit.

CARR, DAVID L., ALAN J. SCOTT, Univ. Texas, Austin, TX

A Spectrum of Late Paleozoic Siliciclastic Shelf-Bars, Sacramento Mountains, New Mexico

Study of several Pennsylvanian-Permian shelf sandstones in the northern Sacramento Mountains, New Mexico, suggests that siliciclastic shelf-bars were migrating on a high-energy shelf adjacent to the Pedernal uplift. These shelf-bars had sufficient relief, 2 to 6 m (6.5 to 20 ft), to provide the clear-water, agitated conditions requisite to carbonate grain-shoal development in areas of low clastic influx. The carbonate and siliclastic cycles can be