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.

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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).

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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.

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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 explained by a relatively simple progradational cyclic model without invoking major sea level fluctuations.

A typical cycle contains 3 major components: (1) shelf-bar stones; and (3) interbar siltstones. **Shelf-bar sandstones, 1 to 6 m (3 to 20 ft) thick, are typically overlain by carbonate grainstone/ packstone facies 1.5 to 6 m (5 to 20 ft) thick, which are** grainstone/packstone facies, 1 to 6 m (3 to 20 ft) thick, which are in turn overlain by siltstones, 1 to 6 m (3 to 20 ft) thick, thus completing the cycle, 4 to 18 m (13 to 59 ft) total thickness.

Shelf-bar sandstones in the Holder Formation (Virgilian) are lenticular concavo-convex sand bodies, 2.5 to 6 m (8 to 20 ft) thick, with flat depositional bases. Average grain-size (4 $\phi$ - 0 $\phi$) and maximum clast size (12 mm, 0.5 in.) increases upward. Seaward dipping (W - NW) accretion foresets, up to 0.6 m (2 ft) thick, and bimodal trough cross-stratification, 10 to 30 cm (4 to 12 in.) thick, characterize lower sandstone facies. Hummocky cross stratification, 7 to 9 cm (2.8 to 3.5 in.) thick, 1.2 to 2.5 m (3.9 to 8 ft) wavelength, is common along accretion foreset surfaces and the tops of many of these sets are rippled and burrowed. Syndepositional deformation structures are common. Missourian and Virgilian shelf-bar sandstones were rapidly deposited by storm-induced currents and were modified by fair-weather tidal oscillatory flow and biological processes.

In contrast with Virgilian shelf-bar sandstones, Wolfcampian bars are thinner, 1.5 to 2 m (5 to 6.5 ft) thick, coarser grained, and locally have erosional bases. Bimodal through cross-stratification is well-developed at the expense of seaward dipping accretion foresets which if present, are poorly developed. Hummocky cross-stratification and burrows are rarely present, whereas ripples and syndepositional deformation structures are common. Average grain size coarsens-upward crudely. These Wolfcampian shelf-bars were deposited in shallow water subject to strong tidal currents, which winnowed finer sediments, produced distinct bimodality in sedimentary structures, and prevented the bars from achieving significant depositional relief.

Carbonate units, 1 to 5 m (3 to 16 ft) thick, decrease in micrite and increase in abundance of allochems upward in the vertical sequence. Sedimentary structures are similar to those of the associated siliciclastic shelf-bars, indicating a change in sediment-supply without significant change in hydrodynamic conditions. Carbonate units are thinner, 1 to 2 m (3 to 6.5 ft), become less important volumetrically in Wolfcampian sediments as compared with those in Virgilian rocks.

The spectrum of high energy siliciclastic shelf-bar sandstones, and the presence of fan-deltaic and fluvial deposits in overlying sediments (Wolfcampian) suggests that the shelf adjacent to the Pedernal uplift continuously prograded into the Orogrande basin. Shifting clastic influx along depositional strike caused drastic local changes in shoreline configuration, longshore currents, and subsequent clastic and carbonate sediment distribution patterns.

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Conodont Paleoecology of Lower Triassic Thaynes Formation

The Lower Triassic (Smithian) Thaynes Formation represents a broad spectrum of paleoenvironments. Samples arranged along a generalized depth-salinity environmental gradient from tidal flats to a relatively deep, commonly dysaerobic, basin yielded a conodont fauna of 30 form elements. Association and similarity analysis were used to group the conodont elements into eight conodont entities, reflecting both biologic association (multielement apparatuses) and ecologic association (biofacies). Simple chi-square tests and discriminant analyses, using the eight conodont entities, and indicate presence of three distinctive conodont biofacies related to the generalized environmental gradient. The restricted inner shelf biotope was characterized by a conodont fauna dominated by *Parachirognathus*. The outer shelf biotope was distinguished by a diverse conodont fauna including the distinctive form *Furnishius*. The biotope farthest offshore consists of a low diversity conodont fauna composed primarily of species of *Neogondolella*. Some early Triassic conodonts such as *Neospathodus* and *Ellisonia triassica* are ubiquitous, and provide the foundation for a inter-basinal conodont zonation. Early Triassic conodont biotopes can be arranged along a generalized environmental gradient that probably reflects changes in hydrographic factors (e.g., salinity, temperature, and energy) which affected the distribution of conodonts.

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Dominant Distributions and Niches of Polycystine Radiolarians in Modern Oceans

Approximately 400 to 500 relatively common polycystine radiolarian "species" live in the modern oceans. About 200 species live in shallow (0 to 200 m; 0 to 656 ft), temperate and tropical waters (the "upper warm water sphere"); 40 to 50 in high latitude (poleward of subtropical and polar convergences) shallow waters; 150 to 200 in deep (greater than 200 m; 656 ft) waters, most of which appear to be tropical submergent (shallow in high latitudes and diving as tropical submergent or tropical avoidant forms); and about 40 to 50 eurybathyal forms. In general, spumellarian "family groups" of the warm water sphere (surface to subsurface) include the beloids, collosphaerids, saturnulids, artiscids, phacodiscids, spongasterids, dictyocoryids, spongurids, pylonids, lithellids (loosely coiled), and stylodictids; with the spongotrochids, spongopylids, tholonids, lithellids (tightly coiled), and orosphaerids being dominantly intermediate and deep water (cold water sphere) forms. In general, nassellarian family group of the warm water sphere and transition-central waters include the lophophaenids; sethoperids, sethophormids (complex), carpocanids, eucyrtidids, pterocoryids, cannobotryids, spyroids, and artostrobids (not robust). Plectopyramids, artostrobids (robust), sethoperids, sethophormids (simple), and theocalyptrids dominate in either the transition-central (lower warm water sphere) or cold water sphere.

Polycystine radiolarian species and family level groups appear to fit into four basic broad "nutrition niches:" nannoherbivore-carnivore; bacterivore; detritivore, in association with symbiotic algae; and, perhaps an osmotrophic niche. At the family level these groups dominate the following oceanic habitats: nannoherbivore-carnivore the broad shallow warm water sphere, with algal symbiotes dominating the subtropical anticyclonic gyres, eastern equatorial, and shelf subregions; bacterivores in subsurface and deeper (nutricline and deeper); and, detritivores and perhaps osmotrophs the deep ocean.

A positive relationship exists between the degree of eutrophism in the epipelagic region, and underlying mesopelagic and deeper radiolarian standing crops. Radiolarians are usually sparse in waters overlying the continental shelves. However, those radiolarians harboring symbiotic algae (collosphaerids, artiscids, spyroids, spongasterids, dictyocoryids, etc) are more tolerant of shelf waters. Radiolarians harboring symbiotic algae are also dominant in the oligotrophic subtropical anticyclonic gyres and the eutrophic eastern tropical regions. Acantharian and diatom bloom conditions exclude polycystine radiolarians from these bloom areas (many nearshore areas and the photic zones poleward of polar convergences).

These modern day dominant patterns of radiolarian distribution appear to have been initiated in the early Neogene and