tions and between the Evanston and lower Wasatch Formations show the Uintas to have risen in two distinct pulses. The earliest rise may have begun by Maestrichtian time and the latest rise, forming the north flank fault system, culminated in the Eocene.

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Possible Volcanogenic Origin of Uranium at Anderson Mine, Yavapai County, Arizona

Uranium mineralization in Miocene sediments at the Anderson Mine, 70 km northwest of Wickenburg, Arizona, is interpreted to have been volcanogenic on the basis of geologic setting, absence of uranium-depleted source rocks in the vicinity, and geologic similarities to the Aurora uranium prospect in the McDermitt caldera, Nevada.

The Anderson deposit formed in moat sediments within the McLendon caldera. The caldera is identified by a sediment-filled basin coincident with a circular, −25 mgal gravity low centered 5 km (3 mi) south of the mine. A thick apron of andesite, near-source lahar, and rhyodacite forms a crescentic outcrop pattern that partially encircles the gravity low. Ash-flow tuff, interpreted to have erupted during caldera collapse, crops out approximately 30 km (18 mi) south of the mine.

Contrary to previous interpretations, the volcanic rocks of McLendon caldera are unlikely source rocks for uranium in the Anderson deposit. The lavas and ash-flow tuff from the volcano have average Th:U ratios of 4.5 and 2.4, respectively. Both ratios are close to or within the magmatic Th:U range of 2.5-5, indicating minimal uranium depletion. If the uranium did not come from volcanic rocks, it could have been provided to the sediments through hot-spring systems from a late-stage, uranium-enriched differentiated source.

The occurrence of the Anderson and Aurora deposits within caldera moat sediments strongly suggests a genetically similar, volcanogenic model. Other geologic similarities include silicified zones, fossil hot springs, thin-laminar bedding, stacked ore bodies, association of anomalous manganese and molybdenum, and the presence of carnotite and coffinite.

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Overview of Petroleum Activities in Utah, 1972-1982

After a decade (1962-72) of relatively slow petroleum activity in Utah, the past 10 years have seen a substantial increase. Although the production of petroleum has steadily declined since 1975, the number of wells drilled has generally increased from year to year.

The petroleum activity is centered mainly in four different areas within the state: the Paradox basin (southeastern Utah); the Uncompahgre uplift (central eastern Utah); the Uinta basin (northeastern Utah); and the thrust belt area (northeast central Utah).

The Paradox basin includes 43 oil and gas fields that primarily produce from the Paradox Formation. The Uncompahgre uplift includes 23 fields, most of which produce gas from the Dakota-Cedar Mountain formation. The Uinta basin includes 58 fields with over 95% of the production coming from the Green River and Wasatch Formations. The thrust belt area includes nine fields that produce condensate and gas almost entirely from the Twin Creek and Nugget formations.

Drilling activity in the first three areas has been relatively constant, with in-fill operations within known fields accounting for most of the drilling. The thrust belt has been the center of increasing activity since the initial Pineview discovery in 1975.

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Extensional Tectonics of Eastern Basin-Range/Overthrust Belt: Inferences on Structural Style from Reflection Data, Surface Geology, and Rheologic Models

Interpretations of over 1,500 km (900 mi) of industry-related reflection data in the Cordillera have revealed the following styles of late Cenozoic deformation: (1) the widespread development of asymmetric eastward-tilted basins that are bounded by low to moderate-angle planar and listric faults, and (2) five en echelon, low-angle reflections interpreted as regional detachments. Some steeply dipping planar and listric normal faults may be partly controlled by the presence of Mesozoic thrust structures, but this hypothesis is not applicable universally. In some cases, ends of normal fault segments are apparently determined by the positions of sidewall ramps and other cross-strike displacement transfer zones of Mesozoic age. Alternatively, several major normal faults, particularly those in Tertiary volcano-tectonic complexes, have no obvious relationship to Mesozoic structures. The low-angle reflections interpreted as a set of detachments extend east-west at least 200 km (125 mi) and dip gently westward from 3 km (2 mi) beneath the western Colorado Plateau to over 10 km (6 mi) at the Utah-Nevada border. The structural style of low-angle and listric faults cannot be reconciled easily with classic brittle failure theory, but the interpreted termination of normal faults at or above the frictional/quasiplastic transition may occur as shallow as $\approx$ 7 km (4 mi). Rheologic models of an extending upper crust suggest a vertically stratified model: brittle from the surface to as shallow as 7 km (4 mi), then variably ductile. The shallow depth of the upper ductile layer has important implication for controlling fault geometry and therefore the locations of fault-related basins.

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Paleoenvironmental Interpretation Based on Foraminifera of Coal-Bearing Almond Formation, Little Snake River Coalfield, Wyoming

The Upper Cretaceous Almond Formation (Mesaverde Group) in south-central Wyoming represents deposition in a variety of marginal marine environments. Foraminiferal assemblages recovered from cores and outcrops of the Almond in the Cow Creek area reflect this environmental diversity.

The Almond Formation is about 450 ft (135 m) thick and is divided into 2 informal members, both of which contain coal. Coals in the upper 100 ft (30 m) of the upper member are thin, but the lower member contains several thick beds. The coal-bearing parts of both members are characterized by repetitive coarsening-upward bay-fill deposits of mudstone and sandstone, commonly overlain by coal. A major coarsening-upward sequence in the lower part of the upper member is capped by sandstone interpreted to be a marine shoreface deposit. Fine-grained rocks in both members contain foraminifera.

Three foraminiferal assemblages are defined on the basis of faunal density, diversity, dominance, and taxonomic composition. A low-diversity agglutinated benthic assemblage interpreted as a hyposaline salt-marsh fauna occurs in the fine-grained rocks of the lower member. A high-diversity mixed agglutinated and calcareous benthic assemblage interpreted as a hyposaline bay to lagoon fauna occurs in shales in the lower part of the upper member. A moderate-diversity agglutinated benthic assemblage that occurs in fine-grained rocks in the upper part of the upper member is interpreted as an intermediate hyposaline salt marsh to interdistributary bay fauna.

These variations in benthic foraminifera populations provide significant insight into water characteristics in otherwise homogeneous sediments. The combination of lithologic and faunal studies provides improved paleoenvironmental interpretation over either method used independently.

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Marine Sandstone "Rolls" in a Coal Mine in Northern Wasatch Plateau, Utah

Coal seam undulations, locally called rolls, are a common but poorly understood geologic feature in underground coal mines of the Wasatch Plateau coal field of central Utah. Rolls may detract from coal mineability by: (1) creating steep grades that are difficult for mining machinery to negotiate, (2) providing low areas where mine water pools, and (3) adding diluting material which decreases coal quality. Rolls found in Skyline Mine 3 involve local, abrupt changes in elevation of the top and base of the lower O'Connor A coal seam. The change in elevation ranges from 5 to 30 ft (1.5 to 9 m) along a horizontal distance of 30-150 ft (9-46 m) and may exceed 3,000 ft (915 m) along strike. Mapping indicates the rolls are subparallel with a mean strike of N25°E. Changes in thickness of coal lithotypes and the coal seam itself commonly occur across the rolls.

Though a reliable model is not known which fully explains rolls, enough information exists to suggest a likely explanation. The rolls parallel the thickest portion of the Storrs Sandstone Tongue of the Starpoint Sandstone, an ancient littoral sandstone system. This and roll morphology suggest rolls are the steep sides of accretion ridge troughs which comprise the upper surface of the Storrs Sandstone tongue.

Study of the rolls has increased the reliability of their prediction, enabling the engineering staff to make appropriate changes in the mine plan in order to minimize the adverse effects on mineability.

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Red Beds of Middle Pleistocene Olorgesailie Formation, Kenya

Middle Pleistocene lake sediments of the Olorgesailie Formation from the East African Rift Valley of Kenya contain red beds, with colors ranging from moderate orange pink to dark reddish brown (Munsell color chart). Two distinct mechanisms of hematite formation, distinguished by thin section and scanning electron microscope study, have produced the red sediments.

In the first mechanism, hematite was formed in situ by dehydration of limonitic minerals. The limonitic minerals formed in soils of the source area and were transported to the depositional site mainly by adhering to clay particles. The elevated pH of the depositional environment accelerated the rate of hematite formation, producing ultrafine red coating on the clays. Red sediment formed by this mechanism occurs both as an undisturbed bed and as a reworked intraclast conglomerate.

In the second mechanism, hematite is precipitated from ground water, possibly at elevated temperatures produced by the interaction of basaltic magma with water-saturated sediment. The hematite occurs in three forms: as cement within diatomaceous clay, as replaced or stained plant material, and within siliceous sinters. The sinters are red, have a pumice-like texture, and include diatoms that show effects of dissolution. These characteristics indicate formation of the sinters by boiling of near-surface water-saturated sediment. Red beds formed by this mechanism are redeposited and each of the three hematite forms dominates in specific localities.

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Lateral Accretion Channel Deposits in Athabasca Delta: Potential Modern Analog to McMurray Formation

"Epsilon cross-stratification" refers to large-scale, alternating sand and mud couplets that dip at right angles to the paleocurrent direction. This feature is of major concern when producing oil from ancient meandering river point-bar deposits. Mud epsilon cross-strata act as impermeable barriers to the movement of hydrocarbons within the reservoir. This and other related problems have been prevalent in steam enhanced recovery from the bitumen-rich middle member of the McMurray formation.

Research on epsilon cross-stratified lateral accretion deposits has been focused for the most part on the study of ancient deposits. Investigation into the modern occurrence of these features has been limited in scale (0.5 m or 1.6 ft deep channels) and numbers of observations. Many unanswered questions remain as to the location of depositional environment (meanders in fluvial, tidal, or deltaic systems) and detailed sedimentologic characteristics.

A recent investigation has found mud epsilon cross-strata in lateral accretion point-bar deposits in the Athabasca upper delta plain in northeastern Alberta. The overall sedimentologic trends of these particular lateral accretion deposits, including the variability, continuity, thickness, and geometry of the mud epsilon interbeds, has given new insight into the complex nature of these deposits and occurrence of depositional setting.

Many aspects of the lateral accretion in the Athabasca upper delta plain appear very similar to the ancient lateral accretion deposits of the middle McMurray. Comparative sedimentology of the modern and ancient deposits may lead to a better understanding of these deposits. This may in turn allow for optimum site selection for in-situ steam injection and recovery wells as well as prediction of potential fluid movement patterns.

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Economic Potential for Upper Cretaceous and Lower Tertiary Rocks Near Helper, Carbon County, Utah

Exceptionally good exposures of Late Cretaceous and early Tertiary rocks in the western Book Cliffs area near Helper, Utah, allow detailed study of nearshore clastic sediments. The Mancos Shale is an organic-rich, silty shale, interrupted regularly by tongues of fine to medium-grained sandstone that thin to the east. The Garley Canyon and Emery Sandstones, which are the two main sandstone members in this area, exhibit a prograding clastic shoreline sequence from open-marine and lower shoreface to upper shoreface environments. Thinner sandstones also crop out in the area that indicate minor pulses of deltaic progradation and exhibit one or more of these facies. These sandstones pinch out eastward, and are offset by normal faults to the west; therefore, hydrocarbon accumulation is likely to occur in areas to the west.

The coal-bearing Blackhawk Formation is also well exposed within the study area, and is interpreted as a wave-dominated delta complex. Coal-forming swamps were situated directly on beach ridges. Several of these economically important coal seams pinch out westward (landward) within the study area. This stratigraphic interplay between terrestrial sedimentation and the coal-forming swamp environment provides details for refining coal exploration models.

Upon completion of regional stratigraphic analyses, thickness variations in Upper Cretaceous and lower Tertiary formations may provide a more precise indication for the time of crustal uplift associated with the San Rafael swell.

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Shallow-Water Clastic Sediments of Great Blue Formation and Manning Canyon Shale, Oquirrh Basin, Utah

An east-west belt of clastic sediments in the Mississippian Great Blue Formation and Manning Canyon Shale thickens and coarsens westward and contains terrestrial plant and palynomorph assemblages. These clastic sediments were derived from the Antler highlands in central Nevada. The depositional axis of the clastic belt or proto-Oquirrh basin is probably related to a basement weakness that controlled the east-west-trending Uinta basin. The geometry of the belt is illustrated by isopach maps and cross sections. An isopach map of the total Mississippian clastics in eastern Nevada and Utah and an east-west cross section through the Oquirrh basin demonstrate that the clastics thicken and coarsen westward and indicate a western source. A north-south cross section illustrates how the clastic sediments were restricted to the east-west clastic belt. In contrast to previous interpretations that assumed that the clastic sediments were shed westward from the craton into deep water, field evidence suggests that they were shed eastward from the rising Antler mountains into very shallow water.

Terrestrial plants preserved in shales and sandstones of the Great Blue Formation and the Manning Canyon Shale suggest that the clastic sediments were deposited in a transitional environment such as lagoons, distal flood plains, and deltas. Palynomorph assemblages in the shales lack marine forms and also indicate shallow-water deposition. In addition, surface gamma-ray patterns of measured sections are typical of transitional facies sequences such as deltas and nearshore environments.

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Complex Interaction of Eolian and Marine Sedimentation in Permian White Rim Sandstone, Elaterite Basin, Southeast Utah

Two depositional units distinguished in the Permian White Rim Sandstone of the Elaterite basin indicate episodes of both eolian and marine sedimentation. The lower unit is a thick section of large-scale, high-angle, cross-bedded quartzarenite. The tabular cross-bed sets average 2.6 m (8.5 ft) in height and contain inversely graded translatent strata and small ripple trains with high ripple indices. Some exposures reveal large barchan dune forms. This lowest unit comprises most of the formation and is sharply cut and scoured by the overlying unit. The upper unit is a thin veneer that ranges from 1 to 5.3 m (3 to 17 ft) in thickness and possesses