hydraulic energy has the strongest influences on the morphotypes and distributions of the macroborings. An equivalent macroboring assemblage dominated by sponges and bivalves prevails in both the shallow back-reef zone and the deep fore-reef zone, both of which are low-energy settings. Boring assemblages in more turbulent zones within the reef consist of polychaete and sipunculid worms, sea urchins, and barnacles, with sponges and bivalves less dominant and less abundant. Other environmental factors which may be important locally include: nutrient availability, photic energy, sediment size and sedimentation rate, competition for substrate, and predation pressure upon the live coral tissue. Shape parameters for different boring types are provided as a means of identification and as an indication of the environmental control upon boring shape. An understanding of the variability of boring types with respect to the ambient environment within modern reefs facilitates the use of borings as paleoenvironmental indicators within Cenozoic carbonate systems.

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Early Diagenesis, Atherton Formation (Quaternary), Northern Indiana: A Guide to Understanding Early Cement Distribution in Nonmarine Sandstones

In the area studied, the Atherton Formation accumulated primarily as outwash deposits dominated by trough and wedge cross-bedding. Within sand (86% of deposits; $Q_{77}F_8L_{15}$) and polymictic pebble gravel (14%) units, local cements of calcite (99%) and limonite/hematite (1%) are present. The distribution of these cements was controlled by at least three factors: (1) position within the deposit relative to the land surface, (2) average grain size, and (3) primary stratification.

Over 90% of cement zones are within 7 m (23 ft) of the present land surface. Meteoric waters made more acidic by decaying organic material locally dissolved carbonate framework grains. As pore fluids continued to move downward and laterally, cementation occurred. On a second level, higher permeability zones associated with sediment of larger grain sizes was an important factor influencing the location of cementation. Cemented horizons are present in 48% of pebble and sandy pebble gravels (contact and pore lining types) and 17% of sands and pebbly sands (contact, pore lining, and occluded types). Moreover, within sand units primary stratification was a parameter that influenced the location of cementation sites. In wedge cross-bed sets, cement zones parallel inclined laminations; in trough cross-beds, 79% of the cement is concentrated in the lower one-third of bed sets near trough axes or immediately below a trough's basal erosion surface. Cement zones were preferentially developed along internal curved laminations within cross-bed sets. Higher permeability concordant with stratification, the result of excellent sorting and coarser grain sizes within individual sand laminations, primarily controlled cement distribution at this level.

Carbonate cements in the Atherton range from a trace to 6 mole % $MgCO_3$ ($\overline{X} = 3.6$ mole %) with traces of Fe in 16% of the samples analyzed (205 total analyses). The calcite and Mg-calcite generally form a mosaic of anhedral crystals, although distinct rhombohedra are present in some pores. The source for Mg and Fe is believed related to the dissolution of dolomite and Fe-bearing silicate framework grains. The limonite/hematite cements are present as rare, pore-filling patches.

A comparison of the percent of carbonate grains in uncemented sand ($\overline{X} = 10 \pm 1\%$) and within cemented zones ($\overline{X} = 7 \pm 1\%$) of similar grain size indicates an information loss during very early diagenesis on the order of 20 to 30% of the carbonate framework component. Therefore, the original proportion of carbonate framework grains in ancient calcite-cemented sandstones may be greatly underestimated due to grain destruction during diagenesis.

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Depositional Environments of Pennsylvanian Upper Strawn Group in McCulloch and San Saba Counties, Texas

Upper Strawn Group (Desmoinesean) represents a transition to fluvial facies from progradational deltaic facies. The lower part of the upper Strawn is composed mostly of horizontally bedded, fine-grained sandstones and shales of a distal delta-front origin. These sandstones and shales exhibit foreset bed dips of up to 15°. In addition to the dipping foreset beds, the delta-front facies on occasion contain small listric normal faults, resulting from periodic higher rates of sedimentation. The middle parts of the upper Strawn consist predominantly of massive, fine to medium-grained, mature sandstones which represent distributary-mouth-bar deposits, as well as other proximal delta-front deposits such as distributary channels. The upper part of the upper Strawn consists of fluvial trough cross-bedded sandstones and chert-pebble conglomerates. These overlie the deltaic facies and indicate the final stages of upper Strawn deposition. The upper Strawn is overlain by the Adams Branch limestone and shales which represent marine transgression and subsequent shallow-marine deposition.

The upper Strawn Group in McCulloch and San Saba Counties, Texas, represents continued filling of the Fort Worth basin during Desmoinesean time. The upper Strawn overlies the lower Strawn, an older, deeper water facies, in most parts of the study area. The upper Strawn overlies the Atokan age Marble Falls Limestone in an isolated section of the study area due to its position there on the Concho arch.

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Prediction of Fracture Development as a Function of Structural Position

Fracturing is a mechanism for strain in rock. In many folds developed in sedimentary rock, fracturing is the primary mechanism of strain. The amount of strain produced by fracturing is a function of the amount of offset on individual fractures and the fracture spacing. As a consequence, the assessment of strain in the rock, either by direct measurement or with models, can be used to predict relative fracture density or spacing through a structure. The radius of curvature approach, commonly used to assess fracture distribution on folds, is based on this strain approach, but it is appropriate only for special situations. The shortcomings of the radius of curvature approach are demonstrated, qualitatively, with outcrop examples of thrust-associated anticlines.

Numerical modeling is an alternative and more general technique for predicting the strain, and hence fracture density, developed in geological structures. Comparison of measured shear fracture (microfault) density with the strain derived from numerical models of forced-folded sandstone illustrates the viability of this approach. In addition to strain, numerical models predict the orientation of the principal stress and the magnitude of the mean stress. Whereas it is accepted that principal stress orientations dictate fracture orientation and sense of offset, the effects of mean stress on fracture development are not well established. It appears, however, that mean stress influences the amount of offset and opening on fractures, factors very important to production in fractured reservoirs.

The appropriateness of a numerical model depends completely on the specified input which consists of: (1) the boundary condition that produced the structure, and (2) the material behavior of the rock. Consequently, it is possible that a model with improper input may produce the desired fold geometry yet provide inaccurate information pertinent to fracture prediction. Thus, debate over the nature of boundary conditions, such as exists in thrust terrane, has implications even in the realm of fracture prediction.

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Clay Mineral Catalysis and Petroleum Generation

Kerogen, the major organic component of sediments and sedimentary rocks, is the immediate precursor of petroleum hydrocarbons. Recent studies of kerogen maturation during burial diagenesis show that decarboxylation of fatty acid constituents and C-C bond cleavage of hydrocarbon groups, both attached to the kerogen polymer, lead ultimately to petroleum-hydrocarbon formation. The low temperature range over which this occurs (60 to 110°C, 140 to 230°F) has suggested that the clay mineral matrix may play a role in catalyzing these important reactions.

Kinetic studies of clay-organic reactions have demonstrated the effectiveness of clay catalysis in organic acid decarboxylation and cracking reactions and suggest the mechanisms involved.

Kinetic constants deduced for these reactions from the natural maturation of kerogen during diagenesis reveal a further complication in sediments. Because kerogen is a solid, relatively immobile polymer, structural rearrangement is necessary to bring reacting groups in contact with catalytic sites. Mechanical movement plays a role in promoting catalytic activity.

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Stages of Eocene Lake Uinta, Piceance Creek Basin, Colorado

Recent stratigraphic studies have greatly improved our knowledge of the relation between the facies of the Green River Formation in the Piceance Creek basin, thus allowing for a more precise interpretation of the development of Eocene Lake Uinta through time.

In general, the evolution of Lake Uinta can be divided into six main stages. During the first stage, which is represented by almost half of the preserved Green River section in the central part of the Piceance Creek basin, there were two lakes, one located in the Uinta basin and one in the Piceance Creek basin. Freshwater mollusks occur throughout the stratigraphic section representing this period of time, suggesting that the lake was at least periodically fresh. These two lakes should probably not be rightfully called Lake Uinta, since a single lake did not exist. The second stage begins with the Long Point transgression in which the lake in the Piceance Creek basin transgressed across the Douglas Creek arch and connected with the lake in the Uinta basin. The area under water was quadrupled, and Lake Uinta, as envisioned by Bradley, came into being. During the following stages, Lake Uinta extended unbroken between the two basins. Low-grade, clay-rich oil shale is the dominant lithology from this stage, with the exception of some nearshore areas where shallow shelves began to form. Freshwater mollusks are found in rocks of the second stage, but are not common in rocks of later stages of Lake Uinta in the Piceance Creek basin. The third stage began with an abrupt increase in the kerogen content of the offshore oil shales. In the marginal lacustrine areas, however, there was no noticeable change. Here, marginal shelves, which began to form immediately after maximum Long Point transgression, continued to prograde into the lake. Large fluctuations in water level are suggested by rapid changes in facies on the marginal shelves. Thick, ripple-laminated sandstones were deposited during rising water, and deep meandering channels formed when water level dropped.

The water level appears to have been much more stable during the fourth stage. Thick stromatolites and tufa mounds interlayered with laminated carbonate-rich mudstone are the dominant lithologies found in the marginal shelf deposits. Laminated, kerogen-rich, dolomitic oil shale was deposited in the center of the lake. Carbonate content increased in all Lake Uinta sediments during this stage; and for the first time, the saline mineral nahcolite is found associated with oil shale. At the beginning of the fifth stage, water level gradually rose, bringing intermitted oil-shale deposition over about the outer half of the marginal shelves. Nahcolite deposition in the offshore oil shales ceased during transgression but began again once water level stabilized. In fact, most of the nahcolite and halite in Lake Uinta sediments were deposited during this comparatively long stage. This higher lake level brought some peculiar changes to the marginal shelves. Oil shale is commonly interlayed with ripple-laminated siltstones and fine sandstones, ranging in thickness from a few inches to as much as 70 ft (21 m). These clastic sequences can be traced toward the center of the lake where they form lean zones in the oil-shale section.

The final stage of Lake Uinta in the Piceance Creek basin begins with a major transgression, represented approximately by the base of the Mahogany Ledge, a rich oil-shale sequence. Lake Uinta expanded to its maximum extent in the early part of this stage, possibly expanding to near the limits of the sedimentary basin. Infilling of the lake began at maximum transgression when a rapidly prograding shelf complex, composed largely of volcanoclastic sediments, started at the north shore of Lake Uinta and reached the southwest corner of the basin before halting. Lake Uinta evidently persisted in this limited area considerably longer than elsewhere in the basin.

The stratigraphic model presented here demonstrates that Lake Uinta evolved with time, and that each succeeding stage represented an accumulation of characteristics acquired during the preceding stages. Geochemical models that have been proposed to explain the unique oil shale and saline deposits from Lake Uinta should be reexamined in light of this more complete stratigraphic picture.

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Structural and Thermal History of Piceance Creek Basin, Colorado, in Relationship to Hydrocarbon Occurrence in Mesaverde Group

The purpose of this study was to reconstruct the structural and thermal history of the Piceance Creek basin to try to predict the occurrences of hydrocarbons in the Upper Cretaceous Mesaverde Group. A vitrinite reflectance map of basin-wide coal zone and several coal rank cross sections using vitrinite data was constructed. Isopach maps were used to reconstruct the burial history. In general, the Mesaverde Group can be divided into two parts: a lower mixed marine and nonmarine part, and an upper, largely nonmarine section. Vitrinite reflectance values range from R_o .50 to R_o 2.1, and indicate that both the nonmarine and marine Mesaverde are within the range of thermal gas generation throughout the basin, with the possible exception of the upper part of the nonmarine Mesaverde along the extreme west and