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SEDIMENTARY BRECCIA IN BAYPORT LIMESTONE AT BELLEVUE, MICHIGAN

The Late Mississippian Bayport Limestone contains a breccia, 1–5 ft thick, between undisturbed, nearly horizontal beds of marine limestone. Fractures and spaces between limestone fragments are filled with crystalline pyrite and calcite. The breccia appears to be the result of breaking by shearing and dislocating movement, but apparently was formed without disturbing strata above or below.

Hypotheses such as tectonic movement or hydrothermal or volcanic intrusion have been rejected because of field evidence. The main sedimentary hypotheses considered are: (1) Reef talus or backreef breccia produced by storm wave action. The stratigraphy, clast-type, and orientation rule against this hypothesis. (2) Weathering breccia where joints, opened by solution, later were buried deeply and underwent collapse. This hypothesis, proposed by Taylor, is rejected by Parker because of lack of evidence of an erosion surface and lack of a distinct preferred orientation in the vein pattern. (3) Gypsum-anhydrite hydration and dehydration, plus solution hypothesis. Long-term episodes of hydration, dehydration, and solution of thin lenses of evaporites have brecciated the limestone layer. Parker believes that the gypsum-anhydrite lenses originally were interbedded with the limestone as products of normal evaporite sedimentation during a low sea level in the Late Mississippian. Frosted quartz grains in the brecciated limestone, as well as in the underlying nonbrecciated limestone suggest the presence of nearby land, perhaps arid. Actual evidence of any evaporite lenses are lacking at Bellevue and constitute Taylor's main objection to this theory.

A last stage of groundwater solution and precipitation of pyrite and calcite cemented the breccia.

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INFLUENCE OF DEEP SEA DRILLING PROJECT ON CONCEPTS OF GLOBAL TECTONICS

The concept of sea-floor spreading has been examined in the Atlantic and Pacific oceans by paleontologic dating of the sediments that lie in contact with acoustic basement. Despite errors that could be introduced by burial of sediments by sills, paleontologic dating limitations, and deep-sea currents creating a hiatus at the basement-sediment contact, there is an extraordinarily good relation between age of the basal sediments and distance from the ridge crest. Based on these data, an average Cenozoic spreading rate in the north Atlantic is 1.2 cm/yr, in the south Atlantic 2.0 cm/yr, and in the equatorial Pacific 12 cm/yr. By extrapolating spreading rates Heirtzler *et al.* proposed an age scale for the identifiable magnetic anomalies that typify a spreading sea floor. The ages of the basal sediments recovered by drilling agree very well with the time scale to about 45 m.y. ago. From 45 to 70 m.y. ago the agreement is also good, but the age of the basal sediment appears consistently lower than the proposed time scale. The sediments indicate there may be significant mineralization associated with the basal sediments. Samples should make possible reconstruction of oceanic circulations of the past and the dependence of these circulations on arrangement and emergence above sea level of land masses. Migration of the crust relative to effects related to the rotational poles of the earth, such as the equatorial zone, can be deduced.

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OIL-IMPREGNATED LACUSTRINE AND FLUVIAL SANDSTONE IN GREEN RIVER FORMATION (EOCENE), SOUTHEASTERN UINTA BASIN, UTAH

Oil-impregnated sandstone, in units up to 75 ft thick, are present in the lower Green River Formation in the P.R. Spring area, southeastern Uinta basin. Reserve estimates indicate that there may be about 3.7 billion bbl in place.

A total of 308 paleocurrent measurements were made at 13 localities in the upper Wasatch Formation (Paleocene-Eocene) and the lower Green River Formation. Of these measurements, 123 were from fluvial sandstone and 185 were from lacustrine sandstone.

Streams flowed northward into Lake Uinta in the P.R. Spring area. The considerable scatter in the fluvial paleocurrents suggests that the streams had low gradients and were meandering. Many of the fluvial sandstone bodies are oriented approximately north-south.

Lacustrine paleocurrents are generally southeasterly, representing dominantly onshore lake currents. Thus, the shorelines trended northeast through much of the area, although in local embayments shorelines were oriented northwest.

The paleocurrent patterns of fluvial and lacustrine sandstone are both unimodal with equal distribution of directions. The 2 environments can be differentiated, however, on the basis of paleocurrent orientations. Fluvial currents flowed northward; lacustrine currents were southerly.

Both fluvial and lacustrine sandstones are mostly arkose. Potassium feldspar is more abundant than plagioclase. Quartz-feldspar ratios are greater for lacustrine sandstone than for fluvial sandstone. Lacustrine sandstone contains more quartz and authigenic carbonate and less feldspar, "coarse" mica, and matrix than fluvial sandstone. Some lacustrine sandstone is also characterized by intraclasts, oolite, fossil fragments, and analcime in contrast to fluvial sandstone.

Most of the oil-impregnation is in lacustrine sandstone. Detailed sedimentological study has led to the discovery of new intervals. Such studies will also be useful when these and similar reservoirs are developed.

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SEDIMENTARY STRUCTURES AND BEDDING ALONG EPHEMERAL STREAMS

Sedimentary structures are useful for interpreting conditions of deposition of sediments. Experimental studies utilizing flumes indicate the possibility of quantitative interpretations that are based on sedimentary structures. In order to bridge the gap between experimental studies and sedimentary rocks, ephemeral streams in northeastern Utah have been observed. Ephemeral streams serve as natural experiments, exhibiting all the complexity of real processes and some of the control of the laboratory.

A variety of structures was observed along stream courses. With few exceptions, all of the structures resulted from infrequent floods and were developed during waning phases. In contrast, most of the bedding was deposited during maximum flood conditions. Erosional structures observed include various types of scours, rills, tool marks, microterraces, and mud balls. Structures produced by transportation and deposition were ripple marks (10 varieties), lineations (3 varieties), and imbrication. Postdepositional structures include desiccation cracks (6 varieties), surface markings, salt-crust features, algal mats, and sand volcanoes. Bedding types observed were horizontal parallel and discontinuous, small- and medium-scale trough cross-stratification, medium- and large-scale low angle wedge cross-stratification, inclined channel fill-bar complex, ripple stratification, high angle avalanche front cross-stratification, and convolute bedding. Within the channel, inclined bedding is dominant, but on bars, low angle cross-stratification is the most abundant type of bedding.

Several factors combined to control the occurrence of specific structures and bedding types. Stream velocity is the most important factor, but particle size, time, water depth, and local channel irregularities are also significant.

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SUBMARINE SLOPE EROSION ALONG PERMIAN BANK MARGIN, WEST TEXAS

Recent sea floor investigations, such as those of the western Atlantic-Blake Plateau region by Heezen and Stetson and coworkers, indicate extensive erosion by deep ocean currents on flat surfaces and on steeper submarine slopes. Evidence of small-scale submarine erosion of lithified crusts or skeletal material is increasingly being recognized, but few examples of ancient unconformities are known that represent appreciable erosion in a deep marine environment. Forming the 2 major unconformities of the Leonardian and Guadalupian strata of the Guadalupe Mountains of Texas required extensive erosion; that this erosion and the creation of numerous small channels and diastems in associated strata occurred in a continually submerged, relatively deep, marine environment best fits the present geologic data.

The 2 unconformities are roughly parallel. They form the upper and lower boundaries of the dark basinal carbonates of the Cutoff Formation. The lower unconformity, disconformable shelfward, steepens basinward to 5–10° and truncates over 200 m of essentially flat-lying Victorio Peak bank margin carbonates before flattening basinward. This unconformity probably inherited the relief of a gentler bank margin depositional profile. Erosion steepened and caused bankward slope retreat for possibly hundreds of meters. The upper unconformity locally intersects the lower and is onlapped by about 300 m of the Brushy Canyon Formation, composed largely of deep water sandstones.

These unconformities and associated diastems are generally smooth, sharp surfaces, showing scant evidence of the environment of erosion, but broad gentle undulations, and spoon-shaped, possibly closed depressions, some with tens of meters of relief, appear characteristic of both unconformities. Several V- to U-shaped basin-trending channels are present locally.

The mid-Permian bank margin of the classic Guadalupe Mountain area appears to furnish an outcrop analog for some of the processes of both deposition and erosion along deep submarine slopes. The possibility that deep marine erosion created many unconformities of the geologic record should be considered seriously.

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SEDIMENTARY ENVIRONMENTAL CONTROL OF SANDSTONE-TYPE URANIUM DEPOSITS

Uranium deposits of the Rocky Mountain area are present in fluvial sandstones that were derived from granitic highland source areas and deposited in adjacent intermontane basins. The sandstones are arkosic to arkose in composition and contain a small percentage of carbonized plant debris and pyrite, medium grained to conglomeratic in size, subrounded to angular in shape, and are poorly to moderately sorted. The sandstones intertongue and are interbedded with green mudstone.

The host sandstone sequence represents a change in tectonic and/or climatic conditions. A local or regional unconformity is present at the base of the sequence and the character of the rocks is commonly substantially different. The climate was temperate and humid, and the groundwater level was very near the surface. The oxidation-reduction potential was low, which caused the carbonization of woody debris and the formation of pyrite, a condition also favorable for the precipitation of uranium and the other commonly associated metals. The depositional pattern of the aggrading streams was influenced by both tectonic and topographic elements of the area being buried.

Following deposition and burial further tectonic events induced changes in the hydrodynamic system which caused an invasion of the reduced sediments by an oxidizing cell that obtained much of its energy from the oxidation of the pyrite. The oxidizing cell mobilized the uranium and other susceptible elements and swept them ahead. Where the cell encountered resistance from variations in thickness of the sandstone units its progress was impeded, therefore areas of pinchouts or intertonguing of sandstone and mudstone tend to be favorable areas for the localization of uranium mineralization.

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LOWER CRETACEOUS ROCKS IN GULF COASTAL PLAIN OF UNITED STATES

Rocks of Early Cretaceous (Comanchean) age underlie most of the Gulf coastal plain. Their thickness varies from zero at the updip subsurface pinchout in the eastern region and less than 2,000 ft at the outcrop in central Texas to about 7,000 ft at the downdip limit of control.

Carbonates make up most of the section west of the East Texas embayment; alternating carbonates, terrigenous clastics, and some anhydrite compose the section in eastern Texas and adjacent parts of Louisiana and Arkansas; and sandstone and shale, with some beds of limestone and anhydrite, represent the Lower Cretaceous in the eastern region. The percentage of carbonates increases seaward in all segments of the Gulf Coast.

Deposition was in shallow open-sea to restricted marine, deltaic, coastal-interdeltaic, and coastal-plain