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ENVIRONMENTAL INDICATORS IN MORRISON FORMATION, NEW MEXICO

Ripple marks and cross-bedding have been studied at more than 160 localities in the lower part of the Morrison Formation (Jurassic), Rio Arriba County, New Mexico. The cross-bedding represents running water, and hence ground slope, during the time of Morrison deposition. As during the times of Chinle (Triassic) and Entrada (Jurassic) deposition, the ground slope was down toward the west-northwest. (A check of cross-bedding higher in the Morrison Formation, and in overlying Dakota sandstones, showed a slope toward the northeast.)

Average ripple-mark spacing in the lower Morrison sandstones was 3.43 cm (maximum, 7.0 cm; minimum, 0.7 cm). Approximately 60 percent of the examples exhibited perfect symmetry. With four exceptions, ripple indices were in the range, $RI = 5.0$ to $RI = 15.0$. A study of ripple-mark straightness and parallelism also was made. All of the computed parameters indicate a wave origin, except for the 40 percent of the examples having slight-to-moderate asymmetry. This latter observation cannot be used, despite other evidence, to deny a wave origin. Modern ripple marks of this type commonly appear in water less than 2 or 3 m deep.

Wave-tank observations indicate that similar ripple marks are formed by waves having heights of less than 5 cm and lengths (between crests) of 2 or 3 m or less. The fetch necessary to generate such waves can be measured in hundreds of meters. The lower Morrison ripple mark fields are, therefore, assigned to a shallow lake or pond origin.

Ripple-mark crest orientations are approximately north-south, and the direction of transport, deduced from asymmetry, was toward the west-northwest; hence a current bias (down the regional slope) may have been important in providing asymmetry to these wave-formed features. The orientation requires, however, that the wind blew from either east or west. This is not in agreement with wind direction deduced from eolian cross-bedding and eolian ripple marks in the Entrada Formation in the same area.

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REVERSED-CLIMBING RIPPLES AND SAND-WAVE DEPOSITION IN ARKANSAS RIVER

This study of modern river deposits substantiates and extends flume studies of "regressive" ripples and sand waves by Jopling (1961) and Allen (1965). As first proposed by Jopling, "regressive" ripples are a sequence of climbing ripples oriented in a direction opposite that of the general current flow. At the risk of introducing another new term, they are herein termed "reversed climbing ripples" rather than "regressive" ripples, because regression has a specific meaning in geology.

Four types of sedimentary features were observed in an exposure of a large (4.5 ft high and 35 ft long) sand wave in a cut bank of the Arkansas River near Tulsa, Oklahoma. In downstream sequence they are: (1) accretionary foresets with tangential bases; (2) avalanche foresets with abrupt basal contacts; (3) re-

versed climbing ripples; and (4) normal or "progressive" ripples.

The accretionary foresets show a progressive decrease in mean grain size down the foresets, have an angle of slope (28°) less than that of the avalanche foresets (31.5°), and contain no reversed climbing ripples. In contrast to this, the avalanche foresets show a progressive increase in mean grain size down the foresets, a steeper slope, and development of reversed climbing ripples.

The change from accretion to avalanche foresets apparently was the result of a decrease in current velocity. As velocities decreased, excessive deposition took place near the head of the foresets resulting in oversteepening and avalanching. At the same time a reverse eddy formed near the toe of the sand wave and produced the reversed climbing ripples.

The reversed climbing ripples are finer grained (2.82 vs. 2.43ϕ), poorer sorted, and more strongly fine-skewed than the foreset deposits. In the accretion foreset sands the sorting decreases progressively from top to bottom. The accretionary foreset sands tend to be more positively skewed near the base than they are near the top, whereas the avalanche foreset sands tend to be more positively skewed near the top and more nearly symmetrical near the base.

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CLAY-MINERAL DIAGENESIS IN ATOKA (PENNSYLVANIAN) SANDSTONE, CRAWFORD COUNTY, ARKANSAS

Chemical and mineralogic evidence indicates significant clay-mineral diagenesis in a shallow (237 ft) core of Atoka (Pennsylvania) sandstone from Crawford County, Arkansas. This core spanned a complex sequence of interbedded sandstone and shale that is at least partly marine.

Clay shales are dominated by illite with significant amounts of kaolinite and minor amounts of chlorite. Increasingly sandy shales contain progressively more chlorite and less kaolinite; illite remains the dominant clay-mineral component. The clay fractions ($<2\mu$) of sandstones are dominated by chlorite with lesser amounts of illite and no kaolinite.

The strong contrast between the clay-mineral contents of these closely interbedded sandstones and shales suggests a diagenetic change that occurred primarily in the sandstones because of their greater permeability. The chlorite of the sandstones most likely has been formed authigenically with concurrent destruction of kaolinite.

Elimination of kaolinite from sandstones by differential sedimentation seems unlikely because (1) it is doubtful that natural mechanical processes could produce the perfect separation of kaolinite found in these rocks, and (2) numerous studies of Recent and ancient sediments indicate that kaolinite commonly is concentrated in sandstones rather than eliminated from them.

Clay-mineralogical changes in the sandstones may be part of an overall pattern of diagenesis in an alkaline, reducing environment that also included the formation of siderite rhombohedra and significant solution of silica (as indicated by straight or embayed contacts of quartz grains).

Much of the discussion on the origin of clayey sediments in modern deposits has been devoted to the relative importance of provenance *versus* environmental

alteration or segregation. With respect to ancient deposits, however, approaches confined to these factors are inadequate where diagenesis of clay minerals has occurred, as it apparently has in the Atoka sandstone and sandy shale.

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BERMUDA CARBONATE PLATFORM: QUANTITATIVE ANALYSIS OF DEPOSITIONAL ENVIRONMENTS

The responses to attrition and redistribution of the skeletal elements of the major sediment-contributing taxa govern interpretation of the depositional environments of skeletal carbonate sediments. The sediments, biotas, and physical conditions of the Bermuda platform provide data for such an integrated interpretation.

Inward from the margin of the Bermuda carbonate platform there is a succession of environments: (1) a reef-front terrace; (2) a reef tract; and (3) a shallow central lagoon. The southwestern half of the lagoon is characterized by reef flats and clusters of patch reefs; these subdivide the lagoon into small basins. The northeastern half occupies a single large basin. The beaches of the Bermuda Islands, a series of Pleistocene dune ridges on the southern edge of the platform, constitute a fourth environment. Carbonate muds are found on deeper bottoms in the more protected basins, molluscan-algal sands in the less protected basins and at the shallower depths, and coralline-foraminiferal-algal sands in the reef tract and reef-front terrace.

Trend-surface analysis of sedimentary and biotic data (based on approximately 300 grab samples and supported by direct observations made by snorkeling and SCUBA diving), stratified according to depth, indicates a clear correlation with factors in the physical environment. The sediment textural parameters are related to those organisms contributing to the sediment and are related to the depositional environment by discriminant function and factor analysis. Artificial "sediment" obtained from the breakdown of hard parts of assemblages of Bermuda organisms in laboratory tumbling-barrel experiments compare closely with sediments on the platform.

The sedimentary record is a product of (1) the ecologically controlled distribution of organisms, (2) the size distributions resulting from the breakdown of the hard parts of the major sediment contributors, (3) the sorting and transport of the skeletal detritus, and (4) the degree of mixing of sediments derived from different environments.

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GEOLOGY AND EXPLORATION OF SICILY AND ADJACENT AREAS

Surface seeps first attracted attention to industrial exploration for hydrocarbons in 1901. The first major success occurred after passage of the Sicilian petroleum law of 1950; three major structural accumulations have been discovered—Ragusa (1954), Gela (1956), and Gagliano (1960). Recoverable reserves of Ragusa are estimated at 110 million bbl and Gela at

120 million bbl. Although in-place oil at Gela is calculated at 1.2 billion bbl only 10 percent is expected to be recovered. Gagliano reserves are not fully defined although a minimum of 700 Bcf of gas and 20 million bbl of condensate is estimated. Development drilling is still underway at Gagliano and Gela.

Commercial production is limited to the Central Tertiary basin and the Ibelo Mesozoic platform. The Central basin is characterized by a thick series of normally sedimented Pliocene and Miocene clastics interrupted with chaotic gravitational slides. Gagliano produces from multi-pay Miocene-Oligocene sandstones.

The Ibelo platform is represented primarily by carbonate sedimentation, and Ragusa and Gela produce from a thick dolomite of Triassic age.

Volcanic activity which began in the Jurassic continues to the present day and intrusive and extrusive rocks commonly are associated with the producing reservoirs.

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PENNSYLVANIAN-PERMIAN HORSESHOE ATOLL, WEST TEXAS

The Horseshoe atoll is composed of bedded bioclastic limestone and limestone detritus that accumulated in the interior part of a developing intracratonic basin during late Paleozoic time. The reef environment was established early in the basin history and retained because of the lack of significant terrigenous clastic filling in the basin interior. Mixed types of bioclastic debris accumulated cyclically and the upper level of the reef complex was maintained near sea level as basin subsidence continued. About 1,800 ft of limestone accumulated during the Pennsylvanian, and primary dips as great as 8° developed along the margins of the atoll. During early Permian time the reef was restricted to the southwest side of the atoll where more than 1,100 ft of additional limestone accumulated before death of the reef. Continued tilting of the reef complex after burial elevated Pennsylvanian pinnacles along the east side of the atoll 1,400 ft higher than Permian pinnacles along the west side. The updip migration of hydrocarbons was uninhibited, and reef pinnacles along the eastern half of the atoll are full to the spill point. The Scurry reef is the largest single area of closure on the Horseshoe above the oil-water contact. It includes approximately 69,000 productive acres and has a maximum oil column of 765 ft. The reef was discovered in 1948 with reflection-seismic methods. Production from the Scurry reef exceeded 500 million bbl by the end of 1967, and this represents approximately 60 percent of the oil produced from the Horseshoe atoll.

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GOLDEN LANE FIELDS, VERACRUZ, MEXICO

History of oil in Mexico is related closely to the development of a series of aligned discoveries located in the central part of the Tampico embayment from San Diego de la Mar to San Isidro. This series of aligned discoveries is known as the "old Golden Lane," whose cumulative production to December 1967 is near 1.25 billion bbl of oil. In 1908 the first