strike from the outcrop section; the nearly perfect vertical sequence of lithology in a core compensates for the loss of lateral exposure in outcrop. Correlation of the outcrop section with electric logs permitted mapping of the distribution of the rock-stratigraphic units, and the resultant geometric interpretation precluded a delta interpretation for this particular stage of Mesaverde deposition in this area.

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RECOGNIZING ESTUARINE AND TIDAL CREEK SANDBARS BY BIOGENIC SEDIMENTARY STRUCTURES

Estuarine and tidal creek sandbars bear many similarities to fluvial channel sandbars in their physical sedimentary structures, but are considerably different with respect to biogenic sedimentary structure. Consideration of these biogenic structures with current-produced physical sedimentary structures and with facies geometry produces unique, readily recognizable, paleoenvironmental indicators.

The abundant burrowing fauna collectively found in estuarine and tidal-creek bars represents species which are individually characteristic or very common in other intertidal environments, such as beach (burrowing shrimp, *Callianassa major*), tidal flat (burrowing shrimp, *Callianassa atlantica*, and polychaete worms *Onuphis* and *Diapatria*), marsh (fiddler crab, *Uca*), estuarine channels (burrowing shrimp, *Upogebia*), and sand flats (acorn worm, *Balanaglossis*). Other biogenic structures found in tidal creek bars include tracks, trails, and markings produced by more typical subtidal organisms such as the sand-collar snail, *Polinicies;* hermit crab, *Clibanarius;* blue crab, *Callinectus;* mantis shrimp, *Squilla;* and feeding depressions made by rays.

Two subenvironments are found on most of the tidal creek sandbars studied and each contains a characteristic suite of biogenic and physical sedimentary structures. The channel side of the bar consists predominantly of sand and preserves a record of megaripples and small current ripples. Associated with these structures are burrows of *Onuphis, Callianassa major, Callianassa atlantica,* and *Uca.* Energy is less and muddy sand accumulates on the side of the bar away from the channel current. Ripple laminae generally are not developed here and bioturbated sediments comprise the principal structures. A great density of burrows is found in this subenvironment, and *Upogebia, Diapatria,* and the razor clam, *Tagelus,* are typical burrowing forms.

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GEOLOGICAL RESERVOIR ANALYSIS, MADISON FORMATION, ELK BASIN FIELD, WYOMING-MONTANA

The Elk Basin field is in the northeast end of the Big Horn basin, on the Wyoming-Montana state line. The structure is a NW-SE-trending asymmetrical anticline, approximately 8 mi long and 4 mi wide, with about 5,000 ft of structural closure. Oil production from the Madison Formation was discovered in 1946, and the Madison has supplied more than 75 MM bbl of oil within 5,100 productive acres from a closure of about 1,400 ft. A recent core study of the Madison reservoir shows that it can be divided into several separate, distinct, geologic and production units.

The Madison carbonate sequence has been altered greatly and distorted by groundwater erosion as a result of the formation of karst topography, by subsequent solution brecciation in Late Mississippian-Early Pennsylvanian time, and by selective remineralization in some areas of the field. The overall effects are the collapse of sections of the upper Madison—up to 300 ft thick—into brecciated rubble zones, thereby removing blocks from effective communication with each other. There are areas of remineralization which, because of redeposition of dissolved carbonates, silica and anhydrite into pore space and fractures by the downward percolating groundwater, have caused local, relatively tighter zones, forming, in effect, local stratigraphic traps. Zones of insoluble reside of clay and rock fragments form an effective barrier between the "A" and "B" producing zones, and account for the different reservoir characteristics of these zones.

An important effect of the groundwater action has been the removal of the more soluble limestone, leaving the less soluble dolomite and thereby forming the good secondary porosity found in the Elk basin Madison. The development of this secondary porosity can be correlated and subdivided into readily recognizable and distinct zones. This shows a certain degree of continuity, which is necessary in evolving an efficient drilling and flooding program. Electric-log and core evaluation of other Big Horn basin fields which penetrate the Madison indicate the existence of a situation similar to that in the Elk Basin reservoir, except that the Madison in other fields generally does not have such pronounced karst-solution development.

The above-mentioned variations can be unified into a practical working hypothesis for reservoir engineering analysis; the hypothesis so developed provides a useful three-dimensional reconstruction of the Elk basin Madison reservoir. Application of the hypothesis has led to a dramatic production response within the reservoir. The practical success of the hypothesis has important exploration implications; specifically, the exploration geologist must understand known producing reservoirs before effective exploration for new reservoirs can be carried out successfully.

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VARIATIONS IN LATE PENNSYLVANIAN MOLLUSCAN FAUNAS

Certain nearshore facies of the upper half of the Pennsylvanian System in the Mid-Continent region are characterized by faunas which are dominantly molluscan. Although individual faunules are reasonably well known, few comparisons have been made between successive faunas. Five molluscan faunules ranging in age from Desmoinesian to Virgilian were examined on the specific and supra-specific levels. The abundance of individual species, genera, and families within each formation, variations in the abundances with time, and the phylogenetic changes aid in the interpretation of the paleoecologies of these unusual populations.

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COMPARISON OF RECENT AND ANCIENT COARSE-GRAINED POINT BARS[1]

Sequences of sedimentary structures in modern point-bar deposits of the Amite River in east Baton Rouge Parish, Louisiana, are analogous to features ob-

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[1] Publication authorized by the Director, Bureau of Economic Geology, The Univ. of Texas at Austin.

served in Eocene Simsboro deposits in Milam County. Texas.

Annual rainfall of approximately 60 in., channel pattern slightly to highly meandering, average stream gradient of about 5 ft/mi, and bank stabilization by dense vegetation are major parameters controlling Amite deposition of coarse sand and pebble-gravel sediment. Stratification types are related directly to specific depositional features, and include (from thalweg to overbank): thalweg (large-scale cross-stratification), lower point bar (trough cross-stratification, avalanche beds), chute bar (parallel laminae, avalanche beds, trough fill), chute fill (parallel inclined laminae, climbing ripples), and overbank (parallel inclined laminae, mud drape, avalanche beds).

Fundamental differences between point bars of streams transporting coarse-grained bed load and streams having fine-grained bed load are: muddy floodplain deposits are associated only with fine-grained bed-load streams; upper point-bar sediments with ripple cross-stratification and parallel inclined laminae occur only in fine-grained fluvial deposits; chute-front avalanche beds are common in coarse-grained fluvial deposits but are not found in fine-grained fluvial deposits. Coarse-grained fluvial deposits do not show the upward decrease in grain size that is reported to characterize fluvial sediment.

The Simsboro consists mainly of thalweg, lower point-bar, and chute-bar deposits; chute-fill and overbank deposits are preserved only in the last depositional sequence.

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INTRODUCTION TO SYMPOSIUM

(No abstract submitted)

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CONTINENTAL SHELF POSITIONS DURING GEOLOGIC TIME

Exploration of continental shelves and slopes requires a thorough understanding of the implications of the sea-floor-spreading hypothesis. If the Americas and Eurafrica once were joined, as sea-floor spreaders allege, no great intellect is required to see that the geology of the circum-Atlantic shelves and slopes would be different than if the Atlantic Ocean had always existed. Most sea-floor-spreading advocates believe that the Atlantic basin first opened during Jurassic or Early Cretaceous time. If true, drilling for pre-Jurassic objectives in certain areas is senseless. However, if sea-floor spreading has *not* taken place, pre-Jurassic objectives may underlie almost all shelf and slope areas. Similar conclusions can be made for the shelves and slopes surrounding the Indian Ocean.

Sea-floor spreading also would affect the circum-Pacific margins, which should contain strongly deformed post-Jurassic sediments. Drilling objectives in the circum-Pacific shelves should be mainly in young strata, principally of Tertiary age. This seems to be true around most of the Pacific rim, and sea-floor-spreading proponents cite the youthful geology of the circum-Pacific as evidence for their viewpoint.

Although the problem of sea-floor spreading is unusually complex, the problem can be summarized simply: can the hypothesis be proved or disproved? The correct answer to this question will affect world mineral economics for decades to come.

Numerous facts of geology and geophysics contradict the hypothesis of sea-floor spreading. A combination of Ushakov's, Talwani *et al.*'s, and Melson *et al.*'s models of the mid-ocean ridges explains the linear magnetic anomalies of the ridges, their topography, the distribution of rock types on the ridges, their gravity expresssions, and the Sykes' "transform-fault" solutions on the basis of *known* processes, as opposed to *inferred* processes. G. D. Afanas'yev's discovery that most metamorphic rocks of the Indian Ocean ridge system have Proterozoic (Riphean) and Paleozoic K-Ar dates severely damages the sea-floor-spreading concept as it has been applied in the Indian Ocean. Rezanov has proved that paleomagnetic methods cannot be used to determine ancient polar positions, or to demonstrate continental separations. Maxwell's, Glangeaud *et al.*'s, and Watson and Johnson's studies of the Mediterranean Sea region eliminate both spreading and closing of that sea since late Paleozoic or earlier time. A problem which is even more baffling is that of the *immaculati: i.e.,* the presence of flat-lying, undeformed sediments in parts of the deep ocean basins where strong deformation is predicted by sea-floor spreading. Such areas include (1) fracture zones which cross the mid-ocean ridges (undeformed sediments as old as Paleocene are exposed in these fracture zones), (2) abyssal plains, (3) continental slopes and rises (except for gravity-slide blocks), and (4) island-arc trenches. Why does a strongly deformed Early Jurassic to Eocene fold belt extend from the Cape Verde Islands to Tunisia? How does one account for the presence of bathyal to abyssal Jurassic sediments in the Cape Verde Islands, beneath the Hatteras Abyssal Plain, and elsewhere?

Almost conclusive evidence against sea-floor spreading comes from the fields of climatology, meteorology, and biology-paleontology. The field of meteorology is particularly critical, but few geologists, geophysicists, or oceanographers have studied this science. Salomon-Calvi, one of Wegener's staunchest advocates, concluded before his death that widespread continental glaciation would be impossible without an adequate supply of moisture and, therefore, that separation of the southern continents was essential from Mississippian through Permian times. Rukhin's recent analysis of late Paleozoic tillite distribution is even more conclusive because of the wealth of climatology data available to him.

To test Salomon-Calvi's and Rukhin's conclusions, the writer prepared detailed maps of coal, evaporite, and tillite distributions by age and epoch from late Proterozoic time to the present. The evaporite-coal-tillite distribution patterns shown on the maps differ appreciably from previously published compilations, and coincide very closely with the distribution pattern of modern deserts, evaporites, peat bogs, and till deposits. Meteorological and ocean-current analyses of these maps show that the distribution of these rock types *requires,* for the past 1 billion years, an ocean basin-continent distribution nearly the same as that of today. If the continent and ocean-basin distribution of the past was significantly different from that of today, the distribution patterns of pre-Holocene evaporites, coals, and tillites cannot be explained. The maps even show that the position of the horse latitudes has not changed appreciably for 1 billion years. The maps do *not* eliminate some polar tilting since Proterozoic time, but such tilting is not required to explain the patterns.