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SHALLOW SAND BARS AND NEARSHORE PROCESSES

Detailed daily topographic maps of beach and inner nearshore areas indicate a cyclic pattern of processes and responses in this environment. This pattern is the result of complex interaction between shoreline configuration, nearshore sand bars, and environmental variables such as barometric pressure, wind velocity, breaker height, and longshore currents. The key indicator in this pattern is barometric pressure. As it changes there are corresponding changes in coastal processes which thereby cause morphologic changes in the beach and inner nearshore area.

A model can be constructed which is characterized by the following sequence:

(1) During high-pressure and low-energy conditions, a shallow discontinuous sand bar is present with somewhat regularly spaced rip channels. The shoreline is sinuous with protuberances (cusps) behind the sand bars and embayments adjacent to rip channels. Slow-moving longshore currents and small waves prevail. Waves break on sand bars and cause their shoreward migration. Shoreline sinuosity is increased as protuberances grow and embayments are slightly eroded.

(2) Falling barometric pressure results in increased wind velocity and subsequently in greater wave height. The resulting rapid longshore currents are deflected by the sinuous shoreline and rip currents are formed. These rip currents excavate channels in the bars and new sand bars are formed as sediment accumulates in the relatively low-energy areas between rip channels. As a result there is apparent migration of the bar form.

(3) When wind, waves, and longshore currents decline, conditions return to those described in (1) above, but with the bar displaced alongshore with respect to its original position.

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BASAL MARINE AND DELTAIC DEPOSITS OF PENNSYLVANIAN AGE IN WESTERN KENTUCKY

Sedimentary rocks of Early Pennsylvanian age unconformably overlie Mississippian rocks of Chester age in the western Kentucky coal field. Regional truncation of the formations of Chester age and the existence of a series of southwestward-trending channels, commonly incised 200–300 ft into the formations of Chester age, are the main evidence of the unconformity. The main channels are filled with sandstone and shale; the smaller, shorter channels mainly are filled with shale. In the study area, well cuttings containing sparse microfossils, fragments of macrofossils, sandy and oolitic limestone, and glauconite indicate a marine environment during late phases of the filling of the channels. Both the sediments filling the Pennsylvanian channels and the remnant hills of Mississippian rocks between the channels are overlain by deposits of a former river and delta system that presently form a deep freshwater aquifer in the study area. The geometry of this Pennsylvanian river and delta system indicates the distribution of offshore barrier bars, lagoons, tidal channels, delta-front distributaries, and a bar that was probably formed by long-shore currents. Production and shows of oil and gas from laterally equivalent Pennsylvanian sandstone are peripheral to the barrier bars on their former seaward side.

Because the marine transgression probably extended across much of western Kentucky and part of Illinois, other examples of the depositional model suggested here may be present in a much larger area. An understanding of the complex details of early Pennsylvanian deposition may be obtained by applying the principles of the model to adjacent areas.

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PALEOTOPOGRAPHY: KEY TO LOCATING CONCEALED STRUCTURE AND RELATED PETROLEUM TRAPS

Recognition that bedrock structure is reflected by modern topography in many areas has helped in successful exploration for petroleum reservoirs. However, application of this relation in other areas has proved unsuccessful. In such areas, older geologic patterns are concealed by divergent younger ones. Mapping of buried topography related to the older structural patterns may be an exploration technique deserving consideration.

Two established oil regions in Nebraska—one in the southern part of the panhandle (D-J basin) and the other in the southwestern part of the state (Cambridge arch area)—have no recognizable relation between modern topography and underlying petroleum reservoirs. However, mapping of buried unconformities shows a definite relation between the occurrence of oil fields and paleosurfaces. In western Nebraska, oil and gas fields producing from Cretaceous sandstones coincide with paleotopographic ridges on the pre-Tertiary surface with striking regularity. Similarly in southwestern Nebraska, oil fields producing from Pennsylvanian strata coincide fairly well with paleotopographic highs on the pre-Cretaceous surface.

This relation between established oil reservoirs and overlying paleotopography in 2 entirely different geologic regimes indicates a predictability pattern that should be utilized in future development in these and other petroleum-producing regions.

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LATE PALEOZOIC TECTONISM IN CENTRAL COLORADO

Detailed mapping and stratigraphic and sedimentologic studies within thick sequences of Pennsylvanian and Permian strata of central Colorado show that most of the major faults called "Laramide" underwent significant displacements in the late Paleozoic. Abrupt eastward facies changes from fine- to coarse-grained sediments and from gray to red strata, and abrupt thinning of the section across the faults indicate that the north-northwest-trending Gore, Mosquito-Weston, Williams Range, and Elkhorn faults were offset as much as 8,000–9,000 ft during the deposition of the Minturn and Maroon strata during the Pennsylvanian and Permian Periods. The Hartsel uplift was faulted as much as 6,000–8,000 ft along its bounding, north-northwest-trending Agate Creek and Santa Maria faults, thereby splitting South Park into several local depositional basins during the Pennsylvanian and Permian.

Lithofacies evidence within Madera (Minturn) strata, and a Permian angular unconformity between the lower and upper members of the Sangre de Cristo Formation show that the north-northwest-trending Pleasant Valley fault was offset as much as 11,000 ft during the Pennsylvanian and Permian. Abrupt facies changes within the Madera and Sangre de Cristo Formations, overlap of the Crestone Conglomerate onto Precambrian rocks, and the presence of unconformities within the late Paleozoic section indicate that several faults in the Crestone (Sangre de Cristo Range) and southern Wet Mountain areas were displaced significantly in the late Paleozoic.

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Displacements Across, and Strain in, Orogenic Belts

The production of accurate palinspastic maps demands knowledge of displacements across orogenic belts. Traditionally this has involved attempts to measure linear crustal strains (ϵ) across orogenic belts by fabric studies, unraveling folds, unscrambling thrusted superposed facies, *etc.* The inherent problems of this approach (*e.g.*, distinguishing between stratal and crustal shortening) and the consequent difficulties of making meaningful strain measurements are minor compared with the complexities imposed by relating orogenic strain to displacements across consuming plate boundaries. It is possible in a general way to convert relative plate displacements (D) and displacement rates ($\dot{D}$) directly into gross shortening and shortening rate values across a particular Mesozoic-Tertiary orogen (*e.g.*, Mediterranean fold belt). This has little meaning, however, for ϵ and $\dot{\epsilon}$ values in orogens for the following reasons. 1. Relative plate displacement vectors change with time. 2. Most of D is not converted into orogenic crustal strain, but is lost by subduction. Only where continental collision has occurred is there a chance that ϵ and $\dot{\epsilon}$ are direct functions of D and $\dot{D}$. 3. ϵ and $\dot{\epsilon}$ may be related to second-order consequences of plate motion; for example, high-level spreading and gliding of marginal nappes. 4. Mechanically significant rates depend upon determining instantaneous $\dot{\epsilon}$ and this in turn depends on the width of a zone deforming homogeneously at an instant of time. Using Le Pichon's $\dot{D}$ values across the Alpine Himalayan fold belt, $\dot{\epsilon}$ values vary from 1.27×10[illegible] (ϵ concentrated in Indus suture) to 1.59×10^{-15} (ϵ across 900 km wide seismic belt from the Zagros crush zone to the Caspian Sea). These rates are far slower than rates (5×10^{-2} – 10[illegible]) at which ductile strains have been achieved in laboratory experiments. Brittle and semi-brittle structural behavior is common in orogenic belts and suggests that natural instantaneous $\dot{\epsilon}$ values are much higher than those calculated from $\dot{D}$. This may be a function of ϵ being concentrated instantaneously in narrow fault zones or, by incremental strain propagation, across a particular zone. Even these factors, though, do not seem to modify $\dot{\epsilon}$ enough (*e.g.*, in a 1-cm wide thrust zone in the Himalayas where $\dot{D} = 5.6$ cm/yr., $\dot{\epsilon} = 1.8 \times 10$[illegible]). Yet, brittle deformation is evidenced by shallow earthquakes suggesting either that ϵ is concentrated along hairline fractures or that large strain accumulations precede rupture. Orogenic strains, however, are small compared with displacements across orogenic belts. The displacements can only be calculated from oceanic magnetic anomaly fitting and, less accurately, from paleomagnetic data from stable forelands and cratons.

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Injection Wells and Operations Today

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Conical-Columnar Stromatolites and Subtidal Environment

Several distinct varieties of stromatolites are present in dolostones of the Proterozoic Dismal Lakes Group, Great Bear Lake region, Northwest Territories. Comparison of the stromatolite types with respect to abundance of associated sedimentary structures (cross-laminations, ripple marks, oolites, desiccation cracks, evaporite casts, intraformational conglomerates) supports the concept that stromatolite morphology is closely related to environment. As in modern analogues, water turbulence appears to be a particularly significant determinant of morphology.

On the basis of textures, associated sedimentary structures, and comparison with modern algal stromatolites, most stromatolites of the Dismal Lakes Group appear to have formed in either supratidal or intertidal environments. However, conical-columnar stromatolites ("Conophyton"), for which a modern analogue is lacking, are confined largely to a prominent dolostone unit in which sedimentary structures indicative of turbulence are almost totally absent. The paucity of such structures, coupled with consideration of the stromatolite morphology during growth, suggests that conical-columnar stromatolites may be characteristic of a subtidal environment. Maintenance of a vast field of conical surfaces in an intertidal or supratidal environment without reduction or fragmentation of the apices seems unlikely.

The relation of the conical-columnar stromatolites to flat-bedded subjacent strata renders interpretation of origin by deformation untenable, and continuity of lamination within and between the columns refutes a diagenetic origin. The Dismal Lakes dolostone unit consisting mainly of conical-columnar stromatolites is interpreted as a Proterozoic subtidal algal reef of unusual persistence in space and time.

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Model of Cretaceous Paleogeography and its Consequences

Growing acceptance of continental drift as expressed in the plate tectonics model leads to consideration of its use as a basis for investigating certain aspects of paleogeography and paleobiogeography. As a first step the geophysical, stratigraphic, and paleontologic data for the Cretaceous, with particular reference to mid-Cretaceous events were examined.

The final separation of South America and South Africa dates from about Aptian Albian time, which implies that the Mid-Atlantic Ridge as a relief feature dates from about that time. Unless there was compensating downwarping a change in the volume of the oceanic basins would occur. The stratigraphic records of Africa, North America, and Western Europe show that the major transgressive and regressive movements are synchronous and that a major transgression began about that time, perhaps reflecting the ridge activity.

Major changes can be seen in the biogeography of mollusks, forams, and other groups between the Early and Late Cretaceous. Pre-Albian marine faunas in the Pacific regions are linked by a large number of taxa with faunas in the Atlantic-Mediterranean region. After the mid-Cretaceous there is a reduction in the cos-