

bonate sediments is poor in proteinaceous constituents and relatively depleted in aspartic acid.

Aspartic acid-rich protein and humic substances bind or complex with metal ions in proportion to the concentration of carboxyl groups present. Blockage of carboxyl groups to make them inactive destroys the ability of the OM to bind metal ions. Many, if not most, of the carboxyl groups available for metal-ion complexation in both calcified protein and aspartic acid-rich humic substances are on aspartic acid. Thus, this amino acid provides a significant portion of the metal-binding ability of the different types of OM.

Aspartic acid-rich OM is preferentially adsorbed by calcite compared to quartz. Again, the carboxyl group is the likely function to be involved in this adsorption. Blockage of carboxyl groups significantly reduces the ability of humic substances to adsorb to calcite. The similarity in geometry, charge, and composition enables the carboxylate anion ($-COO^-$) to substitute for the carbonate anion (CO_3^{2-}) in complexing calcium ion or adsorbing to calcite surfaces.

Competition between organic and inorganic ions for dissolved species and surface adsorption sites is driven by the requirement of the system to remain electroneutral. Concentration variations in dissolved organic and inorganic ions in the pore waters brought about by bioturbation and organic and inorganic diagenesis result in variations in the tendency of OM to affect the chemistry of the system. Most of the $CaCO_3$ formed in the marine environment consists of skeletal material. This $CaCO_3$ contains proteinaceous OM that is thought to be involved in formation of the mineral phase (biological calcification). By analogy, naturally-occurring OM of somewhat similar composition and properties and with identical functional groups may also be involved in the precipitation of $CaCO_3$ in the sedimentary environment (geological calcification).

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Submarine Fan Sedimentation, Ouachita Mountains, Arkansas and Oklahoma

More than 10,000 m (33,000 ft) of interbedded sandstones and shales comprise the Upper Mississippian and Lower Pennsylvanian flysch succession (Stanley, Jackford, Johns Valley, Atoka) in the Ouachita Mountains of Arkansas and Oklahoma. Deposited primarily by turbidity current and hemipelagic processes in bathyal and abyssal water depths, these strata form major submarine fan complexes that prograded in a westerly direction along the axis of an elongate remnant ocean basin that was associated with the collision and suturing of the North American and African plates.

A longitudinal fan system is visualized as the depositional framework for these strata which were deposited in a setting analogous to the modern Bengal fan of the Indian Ocean. Facies analysis of the Jackfork Sandstone indicates that inner fan deposits are present in the vicinity of Little Rock, Arkansas; middle fan distributary channel and crevasse splay deposits occur at DeGray Dam, Arkansas; and outer fan depositional lobe deposits are present in southeastern Oklahoma. Basin plain equivalents are postulated to exist as far away as the Marathon region in west Texas.

Boulder-bearing units (olistostromes) with exotic clasts were shed laterally into the Ouachita basin, primarily from its northern margin. These olistostromes occur throughout the fan succession in all facies (i.e., inner, middle, and outer fan). This relationship may serve as a useful criterion for recognizing simi-

lar fan systems in the rock record.

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The Occurrence of *Cycladophora* (?) *davisiana* Ehrenberg in the Gulf of California

The ecological behavior of the radiolarian *Cycladophora* (?) *davisiana* (particularly in high latitudes) has produced a large interest among radiolarian specialists. This species has been considered an environmental indicator, as well as a potential inter-hemispheric stratigraphic marker.

The geographic and stratigraphic distribution of *C. davisiana* Ehrenberg in the Gulf of California is analyzed in the present study. In the southern part of the Gulf, particularly at the water front formed by the encounter of the California Current and the Gulf water itself, its relative abundance in the surface sediments is comparable to that reported in the Sea of Okhotsk. Below the influence of the water front indicated above, *C. davisiana* has a stratigraphic behavior similar to the one reported in high latitudes.

It was previously hypothesized that the high productivity of *C. davisiana* in high latitudes is favored by water freezing and subsequent ice melting. The Gulf of California has not experienced ice forming processes; thus in this study it is suggested that the productivity of *C. davisiana* is favored by the strong mixing created by the formation of some water fronts.

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The Geomorphic Evolution of the Taylor Black Prairie Between the Trinity and Colorado Rivers

The Taylor Black Prairie is an interesting and complex area that has been, heretofore, relatively ignored as a distinct geomorphic unit. Therefore, the purpose of this study is to describe the region as it exists at the present time and to speculate on its overall evolutionary development.

Based on descriptive geomorphic variables including geology, landform morphology, soil type and distribution, surface gravure, vegetation type and distribution, and land use, the Taylor Black Prairie may be subdivided into three north-to-south trending geomorphic areas. These are, from west to east, the Lower Taylor Prairie, the Wolfe City scarp, and the Upper Taylor Prairie. There is also present, in the southern region of the study area, a relatively distinct small exposure of high gravels located between Little River and Brushy Creek. Because these gravels are geographically restricted within the study area, and because they are dissimilar petrologically from the Cretaceous strata upon which the north-to-south prairies are developed, they constitute a distinct geomorphic area.

The dominant active processes in the Taylor Black Prairie are soil erosion and mass wasting. These are acting under present climatic conditions to shape and modify and topography of this region.

The geomorphic evolution of the Taylor Black Prairie is related to the deposition of Tertiary Uvalde Gravel in the central Texas region. These sediments were carried by major rivers from the edge of the southern High Plains eastward through valleys entrenched in Paleozoic and Comanchean rocks. The less-resistant Gulfian and Tertiary rocks allowed valley widening, thus forming braided alluvial streams that deposited humid alluvial fans.

Topographic development was further enhanced by changes in climate and fluvial response during glacial and interglacial periods. Glacial periods were characterized by increased rainfall which resulted in downcutting and erosion of the divides by major rivers. Interglacial periods were characterized by a rise in regional base level accompanied by fluvial aggradation. The net effect has been a reversal of topography in which the Uvalde Gravel, which occupied the bottom of river valleys at the time of deposition, now caps the highest divides. Studies of modern erosion rates indicate that man's activities, mainly agricultural, have greatly increased the rate of landscape evolution.

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Intertidal Cementation: Some Geochemical, Mineralogical, and Petrographic Considerations

The chemistry, mineralogy, and petrography of intertidal cements are dependent on the chemical and physical characteristics of the waters from which they were precipitated—as well as on the biota this water supports. The study of Holocene cementation in Boiler Bay, St. Croix, Virgin Islands, is well suited to illustrate the basic constraints that the chemistry, mineralogy, and petrography of the cements place on any model of beach rock origin. Boiler Bay contains a well-developed beach rock pavement cemented on its western extremity by rhombohedral-bladed, circumgranular magnesian calcite cement, and on its eastern end by acicular, circumgranular aragonite cement. These facts indicate that, although the precipitational fluid was dominantly marine and cementation occurred under phreatic conditions, western beach rock cements were precipitated under a different geochemical regime than were those cements in the east. Pelleted magnesian calcite micrite cements that are characteristic of the seawardmost parts of the beach rock pavements (as well as submarine cements occurring in offshore reefs) were found by scanning electron microscopy to be biologic in origin. Backbeach cemented zones are characterized by low to high magnesian calcite, rhombohedral, equant-to-bladed circumgranular crust cements. This combination of cement mineralogy-petrography indicates fresh to marine, phreatic precipitational conditions in the backbeach area. Cement chemistry, particularly magnesian carbonate content in the calcites and strontium contents of aragonite and calcite, indicates that the beach rocks of western Boiler Bay were precipitated from mixed marine-fresh meteoric waters, and that the eastern Boiler Bay beach rocks were precipitated from normal marine waters with no freshwater influence. Backbeach cements of western Boiler Bay show a complete gradation of cement fabric, mineralogy, and chemistry that would indicate a classic fresh-marine water mixing zone. Hydrogeochemical studies of beach and near-beach interstitial waters confirm that western Boiler Bay is a locus of freshwater influx into the marine system. It would seem, then, that the mineralogy of Boiler Bay beach rock is controlled by fresh-marine water mixing.

Artificial substrate experiments, using the western Boiler Bay observation wells, pinpoint the locus of cementation in this area as being within the fresh-marine water mixing zone near the upper surface of the water table. In addition, these experiments indicate that cement growth can be independent of substrate mineralogy and that organic coatings on cement substrates may ultimately be one of the major controls over initial cementation patterns. Finally, the experimental approach in the intertidal environment may well enhance our understanding of controls over carbonate cementation.

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Jurassic Subsurface Calcite Cementation, Central Gulf of Mexico

Calcite cements of subsurface origin have received increased notice in the past several years, particularly in Jurassic Smackover sequences of the Central Gulf by Moore and Druckman in 1981. Initially, documentation of the subsurface origin of these cements centered about petrographic evidence: fractured grains encased in poikilitic cements as well as pressure dissolved grains covered with cement. Although petrographic data did indicate some burial prior to cement precipitation, burial depth at the time of cementation remained uncertain because of our general lack of knowledge relative to the failure of carbonate grains under confining pressure, elevated temperatures, and changing fluid compositions. Subsequently, study by Klosterman in 1981 and Moore and Druckman in 1982 of the two phase fluid inclusions common to these cements indicated that elevated temperatures (85 to 112°C; 185 to 234°F) and saline brines similar to present Smackover fluids may have been present at the time of cement formation. If indeed the precipitation fluids were similar to present Smackover brines (ten times more saline than seawater with a $\delta^{18}\text{O}$ composition near +5), the -6.5 $\delta^{18}\text{O}$ composition of most of these cements is compatible with a temperature of 90°C (194°F) because of the strong temperature dependence of oxygen isotope fractionation. Final confirmation of the deep subsurface origin of many of these cements may well rest with their apparent equilibrium with present Smackover brines relative to radiogenic strontium. Most Smackover brines and associated post composition poikilitic calcite cements analyzed to date show an enrichment in radiogenic strontium well above Jurassic seawater values, whereas adjacent grains have radiogenic strontium compositions near that of Jurassic seawaters. Trace element composition of these deep subsurface cements, particularly relative to total strontium, present an enigma. Although present Smackover fluids have a high Sr/Ca ratio (almost four times greater than seawater), the late subsurface cements that have presumably been derived from these fluids have Sr compositions averaging only 200 ppm, well below the values predicted by using Katz et al's 1972 distribution coefficient (1,350 ppm) or Kinsman's 1969 distribution coefficient (3,000 ppm). These discrepancies certainly indicate that kinetic and compositional controls over trace element distribution coefficients must be reassessed for the carbonate system in the subsurface environment.

The most common subsurface cement (demonstrably post compaction, coarse, clear, single unzoned crystals of a poikilitic habit) generally represents a very late stage diagenetic event. A second type subsurface cement, much less common than the first, that generally consists of an interlocked mosaic of coarse crystals, usually fills large sheltered voids, such as gastropod molds, that exhibit a complex iron zonation as seen by staining or cathodoluminescence. Isotopic composition of these zoned calcites consistently show a progressive depletion of $\delta^{18}\text{O}$ of some 4 per mil, from center to crystal termination. The lightest composition overlaps the -6.5 $\delta^{18}\text{O}$ of the late stage unzoned poikilitic cements described. These calcites, based on petrography and stable isotopic composition, seem to represent an intermediate stage of diagenesis and burial. Dissolution associated with progressive pressure solution during the first stages of burial is the most logical source of the carbonate needed for the calcite precipitation of the zoned cements. A potential source for the carbonate needed to form the late stage poikilitic calcites is deep subsurface calcite