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 o f 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 $\delta^{18}O$ composition near +5), the -6.5 $\delta^{18}O$ 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 $\delta^{18}O$ of some 4 per mil, from center to crystal termination. The lightest composition overlaps the -6.5 $\delta^{18}O$ 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