Recent dolomite has now been found in several geologic environments—in restricted marine environments, closed basins, and reefs. Other than reefs, these occurrences cannot account for the enormous amount of dolomitic rock in the record. One might say that the dolomite problem is in reality a magnesium problem for the main difficulty seems to be to get sufficient magnesium in solution to dolomitize calcite or aragonite. It is probable that many regional dolomites are formed by the action of interstitial waters, of sufficient magnesium activity, on a calcitic or aragonitic precursor.

The isotopes of carbon and oxygen have played a significant role in unraveling prior history of carbonate deposits. Oxygen isotopes have been extremely useful in developing a paleotemperature scale for determining the ecological environment of ancient marine organisms. Carbon-isotope composition has been used to differentiate between marine and nonmarine limestone deposits. However, these data must be interpreted with care; recent work has indicated that, above the water table and in a tropical environment, extensive carbon-isotope alteration may occur which can greatly change the isotopic composition of any or all carbonate minerals above the regional water table. Also, evaporative processes may alter the isotopic composition of a solution and of the minerals precipitating from it; these effects can lead to erroneous interpretations of ancient geologic environments.

Trace element and isotopic studies of the carbonate rock minerals and similar studies of the coexisting aqueous phase can aid greatly in understanding the environment of deposition, diagenetic changes which have occurred, in predicting regions of porosity development and dolomitization, and in unraveling conditions in the geologic past.

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ALGAL CRUSTS FROM BAHAMAS

Lithified crusts are common on the Holocene carbonate tidal flats of Florida, the Bahamas, the Caribbean, the Arabian Gulf, and Western Australia. Because these crusts form at the surface by early cementation, they will preserve primary features diagnostic of the environment. One example is the preservation of algal filaments and storm layers in the aragonitic crusts on the tidal flats of northwest Andros Island, Bahamas. These thin (0.01–5.0 cm) surface algal crusts occur at about the same elevation (just above "normal" high-water mark) in three subenvironments of the tidal flats: (1) on the backslope of beach storm-ridges, (2) on the backslope of natural levees of tidal creeks, and (3) on the inland algal marsh.

The upper surface of the crusts, although essentially flat, is characterized by low knobs and mounds. Internally these knobby crusts show two kinds of structure: (1) overlapping planar to crescentic layers of radiating fibers (100 μ across) or thicker columns (500 μ across), which in plan view have a marked honeycomb structure (the voids may or may not be filled with pelleted mud); and (2) thin (<5 mm) uncemented laminae of loose, soft, ovoid, aragonitic pellets. The fibrous and columnar structures replicate the tufted structure of mats of the filamentous blue-green alga *Scytonema* (mainly *Crustaceum* sp.) now living on the tidal flats. The pellet layers are deposited mechanically during winter storms. "Frozen-in" these crusts then is a remarkable record of soft parts of the indigenous algae and of the sedimentation during the annual northwesterly winter gale season.

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NANNOFOSSILS, PROBABILITY, AND BIOSTRATIGRAPHIC RESOLUTION

The appearance of a new species or disappearance of an old species may be considered a biostratigraphic event. If simultaneity does not exist, each first and last occurrence can be separated into a sequence of events. If dispersal rates are high compared with evolutionary rates, the sequence should be the same in all sections. The stratigraphic record is then divisible into several increments ("concurrent range zones") equal to the number of events minus one. Most fossils do not satisfy the requirements of occurrence and distribution, but calcareous nannofossils are admirably suited for refining biostratigraphic resolution. For example, Upper Cretaceous strata contain about 82 distinctive species of coccoliths which have their first and last occurrences in Cenomanian-Maestrichtian strata, so that as many as 163 increments may be distinguishable in this interval.

Biostratigraphic correlation now may be defined as the probability that a specified assemblage belongs at a certain point in a sequence of events. The correlation depends on three factors, each of which may be expressed in statistical terms: (1) the probability that the events used to define a biostratigraphic increment are in the true order, (2) the probability that the species used to define the superjacent or subjacent increment is absent, and (3) the probability that the critical species determinations are correct.

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RECOGNITION OF SHALLOW MARINE ENVIRONMENTS

Shallow-marine environments encompass a great variety of conditions from shoreline to a depth of about 600 ft. In sedimentary rocks, these environments are inferred most readily from diverse assemblages of fossils whose modern relatives are marine. Some sparse and restricted biotas may represent fully marine environments in which certain factors were unfavorable to many types of organisms. Many unfossiliferous black shales represent a foul environment that supported no benthonic life and are inferred to be marine mainly by stratigraphic relations. Marine environments that lack significant sedimentation would be represented in the record only by a submarine paraconformity.

Recognition of marine subenvironments is possible through direct lithic analogy with distinctive modern sediments of known depositional environments, such as oölite, sea-margin carbonate laminites, and certain organism-controlled features such as reefs. In less distinctive marine facies, subenvironments are difficult to discriminate because visible differences may have resulted from a complex interplay of many variable factors that did not coincide to produce unique subdivisions. Ecologic consideration of fossil assemblages may distinguish clear-water from turbid-water, or soft-substrate from hard-substrate environments. Petrographic considerations also allow environmental inference. The presence of calcilutite indicates a quiet-water environment that might be either shallow and protected from water agitation by a physical barrier, or deep and protected by water depth itself. The presence of calcarenite composed of whole shells exhibiting little fragmentation or abrasion might indicate only local organic proliferation or lack of dilution by fine sediment. In contrast, calcarenite composed of fragmented, abraded, well-sorted, skeletal grains indicates water turbulence and winnowing of fines, processes which are more probable in shallow water.

Environmental syntheses based on stratigraphic, petrographic, and paleontologic criteria can bring into focus certain aspects of ancient marine environments that are difficult to determine from the record. On a local scale, detailed facies mapping in undeformed rocks may allow detection of original topography that controlled facies changes. On a larger scale, systematic lithic variation along the outcrop of an entire stage of rocks may provide a regional picture of the lateral succession of ancient marine environments across an epicontinental basin. Perhaps one of the best modern laboratories to study analogs of ancient marine epicontinental deposition is the Sahul-Arafura shelf and Gulf of Carpentaria between orogenic New Guinea and cratonic Australia.

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CONTINENTAL MARGINS AND PETROLEUM GEOLOGY

(No abstract submitted)

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CONTINENTAL MARGINS FROM VIEWPOINT OF PETROLEUM GEOLOGIST (KEYNOTE ADDRESS)

Major features of the earth's surface are its continents and its ocean basins—which in turn reflect fundamental differences between continental and oceanic crusts. The broad zone of separation, or junction, between the continental and oceanic domains has been called the *continental margin.* It particularly includes the seaward part of the continental shelf, the continental slope, and the landward part of the continental rise.

Many of the most exciting events in the history of our planet have been concerned with the interplay between continental and oceanic crust and between continents and oceans; and the continental margin represents the stage where, throughout earth history, this drama has been played.

Important elements of the continental margin are the outer shelf, the borderlands, the marginal plateaus, the slope, the base of the slope, the rise, and the marginal trenches. The origin of these features and the nature of their sediments and local structures are the essence of geology. Of particular interest to the petroleum geologist are also the sediment-rich semi-enclosed basins or seas associated world-wide with the continental margin, the barrier ridges and reefs so commonly developed near the rim of the continental slope, and the growing evidence for impressive vertical movements of basin floors.

Great advances in our understanding of the processes active at the continental margins have come from the subsea geological and geophysical studies of the last decades, and rapid additional progress may be expected from the stimulus of "the new global tectonics"; but current hypotheses are still largely in a developmental stage. Factual data are still woefully inadequate. Moreover, continuing studies are needed, not only of the present continental margins but also of the past continental margins.

For the petroleum geologist, it is significant that through the ages the continental margin has been the great mixing bowl in which has been brewed the bulk of the world's petroleum and from which the bulk of its petroleum production to date has been derived. The continental margin should be the fruitful meeting ground of the petroleum geologist, the geologist of the oceans, and the student of earth history.

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DEPOSITIONAL ENVIRONMENT OF AN UPPER CRETACEOUS DELTAIC SANDSTONE IN SOUTHEASTERN UNITED STATES

A detailed sedimentologic, mineralogic, and paleontologic study of an Upper Cretaceous sequence of clastic sediments in Alabama and Georgia has defined three regional deltaic facies for the Cusseta Sand.

Fluviatile and upper delta.—This facies is medium- to coarse-grained, poorly sorted sandstone and kaolinitic clay, with cut-and-fill structures, and unimodal trough-type cross-stratification.

Delta front.—The delta-front facies includes carbonaceous, micaceous siltstone and sandstone and mixed kaolinitic and montmorillonitic clay, abundant small mollusks and ostracods, estuarine and tidal channel deposits, bimodal cross-stratification, and *Ophiomorpha* borings associated with well-sorted, cross-bedded, "barrier-island" sandstone.

Prodelta.—The prodelta facies is fine- to coarse-grained, calcareous, glauconitic, fossiliferous sandstone and montmorillonitic clay. The mollusks *Ostrea* and *Anomia* are dominant, and there are abundant calcareous benthonic and planktonic Foraminifera.

Paleocurrent and light- and heavy-mineral data demonstrate southward transportation of immature sediments derived from a high-rank metamorphic and acid-igneous source in the southern Appalachians and Piedmont Plateau.

The Cusseta Sand has been interpreted previously as a basal unit in a transgressive sequence. The present study indicates that it represents the final coarsening upward or destructional phase of a positive regressive sequence. Previous difficulties in correlating thin discontinuous sandstone bodies in Alabama with the Cusseta Sand in Georgia are explained by their interpretation as barrier-island bars which developed during the destructional phase of the deltaic sequence.

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SEDIMENTARY CYCLES IN GREEN RIVER FORMATION (EOCENE): MODIFICATION OF WALTHER'S LAW

Along Raven Ridge in northeastern Utah, the Parachute Creek Member of the Green River Formation contains contemporaneous sedimentary cycles that range in environment from fluvial through "deep" la-