and many of the trace elements within these shale members probably were coincident with areas of optimum trophism and biologic productivity. The paleogeographic relations suggest that the trophic regions were areas of upwelling in the Phosphoria sea adjacent to shoals near the eastern flank of the basin. The richest phosphorite beds, mostly pelletoidal, are near the base and the top of each shale member, and the organic carbon and the residual hydrocarbon contents of the phosphorite beds are low in comparison to the other strata. The beds richest in organic carbon are near the middle part of both members, where phosphorite content is low and residual hydrocarbon content is high. The deposition of both phosphorite and organic matter that is precursor to petroleum seems to be directly related to areas of inferred upwelling and biomass concentration, but the sediments have been differentiated into dominantly phosphorite beds and dominantly petroleum source beds by chemical or mechanical factors.

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Radiolarian Biostratigraphy and Paleoecology of Eastern Part of Southern Peninsula of Haiti

Radiolarian taxa, which occur intermittently in Upper Cretaceous to lower Paleogene pelagic calcareous sediments in the southern peninsula of Haiti, are found to correlate with those of the equatorial-tropical realms. Like these assemblages the Haitian taxa show high species diversity, despite secondary alteration of their compositional make-up that may be due to post-depositional diagenetic dissolution.

A small fraction of these taxa appear to be cosmopolitan species that overlap with boreal assemblages. Occurrences of the colder water taxa are erratic through time and show a positive relation with the acme of the recurrent assemblages.

The apparent rhythmic pattern of Radiolaria occurrence throughout the time span investigated suggests that paleoecologic conditions over the southern peninsula were similar to those that prevailed over most of the Caribbean Atlantic province from Cretaceous to the Paleogene.

Similarly, it is surmized that periodic fluctuations in the prevailing climatic conditions induced recurrent variations in the oceanic circulation patterns, which then gave rise to intermittent radiolarian productivity. These relatively short pulses of radiolarian productivity are less pronounced in the Haitian deposits than in their deep-sea counterparts not only because of the superimposed effects of diagenetic dissolution, but also because of their relatively higher carbonate content. This is interpreted to represent paleobathymetric differences in the paleo-Caribbean sea, with the site of the southern peninsula being then at relatively shallower depth with respect to the CCD.

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Importance of Secondary Porosity in Sandstones to Hydrocarbon Exploration

Terrigenous sandstones in many basins owe their reservoir quality to secondary porosity that developed by the dissolution of detrital framework grains (chiefly feldspar) and cement minerals (chiefly calcite and evaporite minerals). This dissolution event is responsible for changing tight sandstones to porous and permeable sandstones slightly prior to the major episode of hydrocarbon migration. Dissolution of most non-evaporite minerals is accomplished by formation water containing carbon dioxide generated during the thermal or bacterial breakdown of hydrocarbons. Dissolution porosity is commonly well developed at 6,000 to 9,000 ft (1,829 to 2,743 m), but gradually is lost during deeper burial stages by recementation (chiefly by ferroan calcite, ferroan dolomite, and kaolinite). During sandstone burial, variations in the simple scheme of cementation → decementation → recementation is complicated in basins with complex "plumbing" systems and those that experience uplift. For example, dissolution porosity in some uplifted sandstones develops during invasion by meteoric water flowing downdip.

Dissolution porosity in sandstones can be suspected from certain log responses and water-saturation characteristics, but is best identified from clues visible in thin sections made of dyed, epoxy-impregnated perm plugs. Clues to secondary porosity in thin section include: (1) oversized pores formed where framework grains have been dissolved; (2) patchy distribution of carbonate or evaporite cement; (3) honeycombed feldspar grains; (4) fossil molds; (5) grains whose margins were etched by previous cement; (6) broken silicate grains that formed when rapid compaction followed removal of cement minerals; and (7) quartz grains that have been reduced to shards when calcite, which invaded quartz along hairline fractures during cementation, was dissolved. Secondary porosity is not likely to develop good reservoir quality in sandstones whose primary porosity was lost chiefly by compaction. Sandstones with abundant clay clasts, fecal pellets, glauconite, or micaceous rock fragments can lose all effective porosity by ductile grain deformation. A knowledge of sandstone composition is important to predicting reservoir quality.

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Terrestrial Sedimentation Associated with Strike-Slip Fault Movement in Middle Carboniferous of Nova Scotia, Canada

The Carboniferous Minas basin of Nova Scotia developed along the dextral strike-slip Glooscap fault. During the early Namurian, the West Bay Formation was deposited in the Parrsboro area of this basin. This formation consists mainly of siltstone with symmetrical ripples and desiccation features and thin beds of detrital ferroan calcite and is interpreted as a playa lake deposit. To the northeast, lower Namurian lacustrine sediments of the Hastings Formation crop out over much of Cape Breton Island. The Hastings and West Bay Formations may have been deposited in the same lake complex, and the Parrsboro and Cape Breton areas, now 225 km apart, were probably adjacent.

During the middle Namurian, the West Bay Forma-

tion was folded. The formation may have been compressed as it was translated through a concave part of the Glooscap fault.

The 1,800-m thick Parrsboro Formation was then deposited in the Parrsboro area during the late Namurian and early Westphalian. The Parrsboro Formation consists of fining-upward sandstone units, thin sandstone beds, and mudstones with roots. It is interpreted as a fluvial and lacustrine sequence. The great thickness of the formation may be due to the formation of an extension basin in a convex part of the fault system. A basal conglomerate of the Parrsboro Formation was derived from the east, presumably from the uplifted area at the concave part of the fault. Throughout the rest of the formation a gradual change in the paleocurrent direction from eastward to southwestward may be due to migration of the depocenter of the extension basin.

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Preliminary Molluscan Biostratigraphy of Gulf of Alaska Tertiary Province

Studies of large collections of mollusks from numerous measured stratigraphic sections in the Gulf of Alaska Tertiary province permit recognition of eleven molluscan zones within the Poul Creek and Yakataga Formations. Correlation of these zones throughout the province illustrates the time-transgressive nature of the boundary of the two formations—a transgression across four molluscan zones between Kayak Island to the west and the Lituya district to the east. The age variation of the base of the Yakataga Formation is from earliest early Miocene to late Miocene. The use of these molluscan zones elucidates the disconformable relation between the two formations and the local absence of entire zones.

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Porosity Evolution of Niagaran Thornton Reef, Northeastern Illinois

The Thornton Reef has long been a model of reef sedimentology, but as thick tar occurs in the upper 22 m of the porous and deeply eroded buildup, Thornton is also a well-exposed fossil oil field.

Thornton Reef is about 2 km in diameter and bowl-shaped in cross section. The reef consists of radially and steeply dipping flank beds of dolomitized crinoidal wackestone and minor coral boundstone. Reef porosity (5 to 10%) is dominantly secondary, consisting of fossil molds, vugs, intercrystal voids, and fractures. At time of deposition porosity was probably high (50 to 70%), and consisted largely of intraparticle and interparticle pores of all sizes. Abundant hardgrounds and palisade-cemented grainstones suggest major reduction of depositional porosity by syndepositional submarine and marine phreatic carbonate cementation. Secondary dolomite preferentially replaced abundant fine-grained carbonate sediment but only partly replaced fossils. Leaching removed the remaining calcitic parts of the fossils, slightly enhancing porosity. Extensive fracturing of the reef began at deposition and continued throughout the reef's geologic history, producing fractures that may extend hundreds of meters laterally. The fractures may be open or filled with syndepositional carbonate or younger terrigenous sediment. Thornton Reef's superb exposures and reservoir scale assure its importance to geologists studying reef facies and porosity.

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Eastern Green River Basin—A Developing Giant Gas Supply from Deep Overpressured Upper Cretaceous Sandstones

During the past 4 years, a previously unexplored 3,000 sq-mi (4,828 sq km) overpressured area in the eastern Green River basin has developed into a major gas province which should ultimately produce more than 20 Tcf of gas. Production is from lenticular sandstones in the Upper Cretaceous Lewis Shale and Mesaverde Group. Abnormally high fluid pressure gradients of .5 to .86 psi/ft are caused by the generation of natural gas from coals in the Mesaverde Group and perhaps from other source rocks. Gas generation from coals is believed to increase exponentially with increases in temperature and depth. Therefore, the largest volumes of gas and the highest pressures have been generated in the deepest parts (15,000 to 20,000 ft, 4,572 to 6,096 m) of the basin. The deepest areas are sparsely explored but may prove to be the most productive parts of the overpressured area for the following reasons. (1) Higher pressures result in more gas in the available pore space. (2) Sufficient gas should have been generated at these depths to fill all available pore space in Mesaverde and Lewis sandstones. More total pay should thus be expected than in shallower areas where water production is a common problem. (3) Higher pore-fluid pressures increase the ease with which natural fracturing of rock