Storm-tossed sand and cobbles on windward beach ridges show other diagenetic effects, including disintegration caused by decay of organic matrices and by solution of particles below the fresh-water table. Conversely, cementation and pore filling in some beach-ridge sands represent incipient lithification.

The extensive outcrops of Pleistocene limestone afford a study of post-lithification diagenesis affecting lithofacies which are analogous with nearby Recent sedimentary facies. Replacement of most of the component grains of this rock by low-magnesium calcite, a change not seen in Recent sediments, tends to obliterate boundaries of recognizable grains. Boring by various organisms, leaching by percolating water, and filling of pores further modify the rock's texture; however, its primary fabric remains readily recognizable.

ELLS, GARLAND D., Department of Conservation, Lansing, Michigan

ALBION-SCIPIO TREND: MICHIGAN'S SYNCLINE OIL FIELDS

The Albion-Scipio trend is a remarkable series of synclinal oil and gas traps formed in rocks of Middle Ordovician age. Except for Silurian reefs, most of Michigan's oil and gas traps are related to anticlines—many to fracture systems on their flanks. The Albion-Scipio trend is a conspicuous exception because oil and gas occur only in synclines between low-relief anticlines. Nearly 59 million barrels of oil, 3.5 million barrels of L.P.G., and 50 billion cubic feet of gas have been produced since its discovery in 1956. Cumulative oil production alone exceeds 70 times the total produced from all other Middle Ordovician reservoirs discovered in Michigan prior to 1956.

The Albion-Scipio trend is not a single, simple syncline. It consists of several coalescing, linear, and narrow oil fields, each less than a mile wide. Development drilling has resulted in the merging of several fields into a narrow productive area nearly 24 miles long. Several small fields, not yet joined to the central reservoir area, extend the full length of the trend, nearly 35 miles. More than 550 producing wells and 400 dry holes have now been drilled on 20-acre and 10-acre drilling units. Closely spaced wells provide excellent control for geologic investigations. Oil reservoirs are found in fractured and dolomitized limestone in the Trenton Limestone and Black River Group. Individual synclines are offset but are joined together by narrow, fractured, and dolomitized productive areas which curve around the ends of the anticline, thus forming a nearly continuous oil reservoir. The Trenton Limestone is overlain by thick shale units. Except for a few very thin shale units, the Trenton and Black River consist only of carbonate rock.

Most wells are completed as flowing wells with potentials of several hundred barrels of oil per day, but are prorated to 110 barrels per day. Porosity and permeability differ considerably from well to well, and in different parts of the trend. Most porosity is intercrystalline, but large vugs and open fissures also are present. Original bottom-hole pressure averaged about 2,050 psi. at the northern end of the trend and about 1,600 psi. at the southern end. Most of this difference is related to the difference in depth.

Many Trenton tests drilled on the southern edge of the Michigan basin, west of the Washtenaw anticlinorium, have not revealed definite Trenton anticlinal structures such as those found in the anticlinorium. Total differences in relief west of the anticlinorium are of about the same magnitude as in the trend. Studies suggest that the Trenton surface in this region is one of many low-relief flexures having about the same magnitude of relief as those found along the trend. In this region, one other field with characteristics similar to those of the trend has been found. It is the Hanover field, about 6 miles northeast of the trend. Discovered in 1959, Hanover has produced nearly a million barrels of oil from nine wells. Other reservoirs probably exist in this region, but they will be hard to find.

FAIRBRIDGE, RHODES W., Columbia University, New York, New York

DIAGENETIC PHASES

Diagenesis, interpreted as all those changes that may occur in or to a sediment after deposition—short of dynamic or high-temperature metamorphism—is a major process of the geocycle, potentially leading to sedimentary lithogenesis. However, this process may be subdivided into distinctive geochemical phases, each of which tends toward an equilibrium condition, only to be upset by the introduction of a new set of environmental parameters. An intermediate phase may be bypassed or reinstated repeatedly.

From the moment of deposition of a sediment grain to the eventual exposure to weathering and erosion, there are ideally three principal phases.

(a) *Syndiagenesis* (term proposed by Bissell, 1959) is the "bacterial phase," during which the sediment's organic matter provides the nutrient for vigorous bacterial metabolism and various "in-fauna." In an oxygenated basin there is a secondary subdivision into the following: (1) an upper oxygenated layer, where CO_2 is the principal organic waste product and the pH will be 7 or less; carbonate shells tend to dissolve unless present in overwhelming numbers; and (2) a lower layer beneath a boundary marked by zero redox potential ($Eh = 0$); here there is no free O_2 and the principal bacterial flora utilize CO_4^{--} ions of the connate sea water, leading to sulfite and sulfide production, and commonly the formation of pyrite nodules. In barred basins the $Eh = 0$ boundary is above the sediment-water interface and the upper layer is eliminated. Other modifications occur in fresh-water and supersaline basins.

(b) *Anadiagenesis* (writer's term) is the "compaction and cementing phase," during which the progressive new sediment accumulation and loading of the buried sediment lead to closer packing of grains and the slow expulsion of connate water. Organic geochemistry is replaced by inorganic reactions. By molecular filtration, clay adsorption, base exchange, *etc.*, the connate residual solutions become progressively stronger, commonly until brines evolve. Important authigenic minerals are formed. Mg-rich brines favor dolomite metasomatism. Complete cementation leads to connate-water entrapment, but diaclastic revival during further subsidence or tectonics may remobilize the circulation. In some basins igneous activity leads to introduction of juvenile water and elements, including metallic ions. It is postulated that at times in the past these have joined the ascending connate fluids, emanating in submarine springs to enrich bottom waters, with which "raw materials" it has been possible for syndiagenetic bac-