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.

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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.

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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 bacteria to stabilize vast layers of metal sulfides, the feasibility of which has been experimentally demonstrated by Baas Becking.

(c) *Epidiagenesis* (writer's term) is the "meteoric phase," during which tectonic emergence of the basin occurs. The ascending waters (of high pH) are replaced by or mixed with descending CO_2^- and oxygen-rich waters of meteoric origin (pH7, or even less when they drain from some lakes and streams). Pyrites commonly are oxidized, and the liberated iron forms Liesegang diffusion rings throughout porous rocks like sandstone, or along the joint planes of impervious types. Limestone develops karst features. Calcitic fossils that escaped syndiagenetic destruction may now be reduced to hollow casts.

Continental-shelf sediments under eustatic oscillations may pass through several epidiagenetic interludes before anadiagenesis, this leading to early lithification of carbonate layers. In a thick rock sequence containing several unconformities, multiple incidences of anadiagenesis and epidiagenesis are expected.

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Applied Carbonate Petroleum Geology Symposium: Introduction

The 1966 A.A.P.G. Research Symposium is entitled "Applied Carbonate Petroleum Geology." It consists of papers that deal with salient aspects of carbonate-rock analysis methods which can be applied clearly and readily to petroleum exploration and development. The main purpose of this symposium is to reduce much of the highly specialized, advanced work that has been accomplished over the past decade, in both methods of analysis and interpretation, into essentials meaningful to the geologist engaged in day-to-day activities of petroleum exploration and development. This includes such subjects as: petrophysics, paleoecology, petrography, geochemistry, geostatistics, simulation of depositional processes, carbonate-rock nomenclature, paleogeologic and lithofacies analyses, and area case histories.

Throughout the symposium the central theme is methods of analysis and resulting geological interpretations. Wherever possible, the occurrence of petroleum is correlated with the geological aspects discussed.

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Astronaut Training Program in Geology and Geophysics

The geologic training program for the first 29 astronauts began in February, 1964, and has consisted of four phases. The first phase emphasized training in the principles of geology, geophysics, mineralogy, and petrology. Phase II was designed to provide extensive experience in a wide spectrum of terrestrial geology having lunar application, with particular emphasis on volcanic and impact geology. Phase III emphasized training in carrying out terrestrial geologic mapping, geophysical studies, and sampling procedures. Phase IV is presently underway, and consists of terrestrial simulations of Apollo missions.

In all phases of the training program, field work has been heavily emphasized. The field trips have been to classic geologic localities and have been led by recognized experts on each area. The first three phases of the training included 14 field trips totaling 41 days in the field, in addition to 135 hours of classroom instruction.

The operation of the training course has been a cooperative effort of the Astrogeology Branch of the U.S.G.S. and the Lunar Surface Technology Branch of the Manned Spacecraft Center of N.A.S.A.

A complete geology classroom has been set up at the Manned Spacecraft Center including most of the teaching aids and equipment available in the average modern geology department.

The astronauts have strong backgrounds in the physical sciences and have proved to be excellent students. With the intensive and specialized training that they have received, they will provide the scientific community with uniquely qualified representatives for early lunar exploration.

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Foraminiferal Paleoecology of Upper Miocene Montesano Formation, Western Washington

The Montesano Formation, which ranges in age from late Miocene to questionable early Pliocene, is exposed in an area of approximately 250 square miles of Grays Harbor County in western Washington. It averages 2,500 feet in thickness and consists predominantly of fine- to medium-grained sandstone, with mudstone, pebbly sandstone, and conglomerate locally significant. The formation possibly represents the last marine incursion in a depositional basin that existed generally as a strongly negative feature through most of the Tertiary.

Paleoenvironmentally significant faunas from the Montesano Formation include: (1) rock-boring pelecypods, (2) *Chione-Spisula* molluscan assemblages, (3) a *Miliammina fusca* fauna, (4) a *Buliminella elegantissima* fauna, (5) a *Nonionella* fauna, (6) a *Bolivina* fauna, (7) a *Uvigerina peregrina hispidocostata* fauna, and (8) a *Bolivina seminuda* fauna. The succession of these assemblages, the associated quantitative microfaunal trends, and the sedimentary evidence indicate that the formation was deposited in a sea that first transgressed from west to east over Grays Harbor basin and then regressed. In the western part of the basin, water depths increased progressively from zero to more than 3,000 feet. On the east, deposition took place initially in the littoral zone, later the outer shelf, and finally under probable tidal sand-flat conditions. A local laminated mudstone unit contains an impoverished fauna suggestive of a partly closed basin about 2,000 feet deep with a sill at about 800 feet. Graded bedding, convolute structures, channels filled with shallow-water deposits, and a high percentage of displaced fauna indicate that much of the sediment was emplaced by turbidity currents and slumping. Planktonic Foraminifera indicate that late Miocene sea-surface temperatures in the Grays Harbor area were of the order of 10–15°C. A small terrestrial flora reflects a mild temperate climate.

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Relations Among Shear Strength, Physical, and Acoustical Properties of Sediment Cores from Eastern Pacific

A series of sediment cores ranging in length from