lithologic-summary logs compiled from detailed measured sections. These techniques have the common advantage of objective automatic generalization, so that meaningless details are minimized and important lithologic trends can be seen. Many of the systematic variations in rock content thus revealed can be traced with confidence across the outcrop and into the subsurface.

Shale comprises about 80 per cent of this 900-foot-thick body of rocks; limestone of several distinctive types makes up the remainder. Formations recognized include, in ascending order, the Lexington Limestone of recent Kentucky usage and the Kope, Dillsboro, Saluda, and Whitewater Formations. The recently defined Tanners Creek Formation can not be distinguished on a strictly lithologic basis, and it is therefore included in the Dillsboro. The Lexington and the Saluda are dominantly carbonate units; the Dillsboro and Whitewater are principally shale but include significant quantities of limestone; and the Kope is almost entirely shale. The boundaries of these formations can be rather closely identified on the several types of logs mentioned above, and refinements usually are possible where original detailed data are available. Intermediate beds and horizons also can be identified and traced for considerable distances.

In dealing with apparently disorganized rock sequences of this type, it is essential to utilize or devise techniques to elicit generalizations from the confusing maze of data.

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SPACE PROGRAM APPLICATIONS OF TECHNIQUES, METHODS, AND INSTRUMENTATION UTILIZED IN PETROLEUM EXPLORATION

(No abstract submitted.)

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GEOLOGY—FOR HUMAN NEEDS

There is no factor vital to the human race into which geology does not explore or participate in some manner, however remote, and, whether the public is aware of it or not, it is true that our science of geology is among the most important in the future welfare of the world's peoples. Based on this premise, the writer briefly reviews the history of the science of geology, cites examples of items of human needs attributable to geology, and discusses why the science of geology is being called on now, more than ever before, to meet new challenges to participate in projects to help meet the ever-growing needs of mankind.

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NOMENCLATURE OF CARBONATE ROCKS

For three years the Carbonate Rock Subcommittee of the A.A.P.G. Research Committee has been compiling data for approximately 500 terms that are used in describing and naming limestone and dolomite. With the great advance in knowledge about these rocks, resulting mainly from studies associated with the occurrence of petroleum in reefs and limestone banks, the body of nomenclature is expanding constantly. Contributing to the proliferation, but not without "mixed blessings," are investigations of ancient rocks, modern sediments, environments of deposition, dolomitization, mineral species, grain-sizes, fabrics, and diagenetic processes.

The subcommittee will assemble these terms, dissect them, illustrate their important concepts, and publish the results. By means of the illustrations to accompany the final report, the subcommittee hopes to consolidate the best contemporary ideas and at the same time prevent further confusion and synonymy in this highly complex family of petroliferous rocks.

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CONSOLIDATION CHARACTERISTICS OF SEA-FLOOR SEDIMENTS

Twenty-seven laboratory consolidation tests were made on predominantly silty-clay sediments from eight Atlantic cores, two Mediterranean cores, and two Pacific cores from the continental slope, rise, and deep-sea floor. Values of the coefficient of consolidation, determined over the pressure ranges of 0–0.05 and 8–16 kg./cm.^{2}, ranged from 2×10^{-4} cm.^{2}/sec. for the lower pressures to 34×10^{-4} cm.^{2}/sec. for the higher pressures. Compression indices computed from the relationship of the void ratio to the logarithm of pressure (e log p) ranged from 0.3 to 1.5.

Results of these tests show that the strength characteristics of sea-floor sediments are dependent upon the environments of deposition. Deep-water sediments generally are stronger than expected (they are "overconsolidated"). Evidence supporting this generalization, in addition to the consolidation data, is demonstrated by (1) the computed ratio of shear strength to effective overburden-pressure values (c/p) of about one to four, which are appreciably higher than the normal values of 0.2-0.4, and (2) the relatively small reduction of porosity with increasing depth below the water-sediment interface in homogenous sediment. The explanation for the observed relationship of deep-sea sediments exhibiting characteristics of overconsolidation is found in the very slow rates of deposition, great age, and the presence of appreciable amounts of clay minerals, volcanic detritus, and siliceous (Radiolaria) and calcareous (Foraminifera) biogenous matter. It is postulated that solutions of these materials in the sediments may yield iron, manganese, silica, and calcium carbonate that, together with the clay minerals, result in a kind of interparticle bonding having the effect of cementation, although actual cementation is not visible. These cementation effects are believed to be the cause of strengths greater than those expected.

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COMPUTER SIMULATION OF MARINE-ORGANISM COMMUNITY ENVIRONMENTS

Computers can be used to re-create the behavior of ancient marine-organism communities with surprising effectiveness. Organism communities and their environments have been represented symbolically in a three-dimensional mathematical model embodied as a series of computer programs for *IBM 7090/7094* computers. Factors affecting environmental conditions, such as depth of water, distance from shore, water turbulence, deposition of sediment, and salinity, can be adjusted by changing the numbers fed into the

computer, thus regulating the model. By advancing the model through increments of geologic time, the response of the organism communities can be observed. This approach provides an experimental means of dealing with problems in which experimentation has, heretofore, been largely or wholly closed.

The model may be used by initially populating the sea floor with organism communities whose behavior is to be studied. Each community is assigned certain properties which affect its response to different water depths, presence of mud and sand, and other environmental factors. These properties can be finely adjusted so that the communities "behave" more or less like their actual ancient counterparts, competing with each other and adapting to changing conditions. The adjustments can be made on a trial-and-error basis until satisfactory results, as determined by comparison with observed distribution of fossils, are obtained.

Recent work with the model has dealt with environmental responses of leaf-like calcareous algae of the late Paleozoic. These algae were widespread in shallow Pennsylvanian and Early Permian seas, locally creating thickened banks or reefs. Today, some of these algal deposits serve as large oil reservoirs in southeastern Utah, northern Oklahoma, and West Texas. Exploration for these reservoirs will be enhanced if the environmental response of the organisms that created them can be determined experimentally and this knowledge used effectively in an exploration program.

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DATE OF SILICIFICATION AND RELATIVE STRENGTHS OF BIOGENIC CALCITE IN PLASTICALLY DEFORMED PERMIAN LIMESTONE, UBEHEBE PEAK AREA, CALIFORNIA

A thick sequence of alternating bioclastic limestone and other clastic beds of Early Permian age has been steeply tilted, but the rocks appear to have retained their sedimentary structure, even in detail. Microscopic examination shows, however, that at many places the limestone beds have undergone intense plastic flow. Most of the calcite shells, except crinoid ossicles, have been attenuated beyond recognition. Each crinoid ossicle was secreted by the animal as an anhedral crystal of calcite and each contained a biologically imposed, cribriform lattice structure and such pores or external canals or processes as the biologic or skeletal function required. It is widely accepted that calcite crystals in marble are weak, but the anhedral calcite crystals in these ossicles show astonishingly little deformation even where surrounded by flow lines of calcite shell material and the usual "shadow structures" in the low-pressure areas. The cribriform lattice and general form of many ossicles show some degree of warping and lamellar twinning in the crystal structure, but in all samples the crinoid plates were far more durable than any of the associated biogenic calcite.

Shells of *Triticites* and *Pseudofusulina* are present. Their well-known keriothecal wall structures serve not only as a measure of the extreme extent of attenuation locally, but also show that the plastic flow represents adjustments between particles of a fineness to and beyond the limits of visual resolution. Relatively little fracturing accompanied the deformation. Parts of a few fusulinid shells were agatized. The silicified parts of shells are undeformed, but the unsilicified parts are attenuated, showing that silicification preceded the plastic flow and that it can not have been a product of Recent exhumation and weathering. The adjacent igneous intrusions and associated deformation of these Permian beds have not yet been dated more accurately than Triassic to Miocene. Numerous examples of the greater durability of echinoderm ossicles than that of other calcite shells, even in environments of low-grade metamorphism, have been observed or reported, but the samples discussed here exceed by far any known differences in display of strength.

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PETROLEUM MIGRATION AND ACCUMULATION: PALEOHYDROGEOLOGIC CONCEPT

The intimate associations of petroleum and water can be treated geologically as pertaining to primary and recurrent migration and accumulation by recognizing the paleohydrogeologic cycles and cyclic stages, beginning with origin and diagenesis of fluids, and continuing to an end point of orogenesis and metamorphism.

The so-called stratigraphic, anticlinal, and fault traps are local fluid anomalies when measured with (1) reservoir-pressure gradients, (2) isobars (superposed on subsurface structure contours), and (3) permeability gradients inside and outside of reservoir rock bodies.

The concept is presented in an attempt (1) to widen professional horizons and make it possible for geologists to concur with mineral economists, who state that the future reserves of oil and gas are limited only by contemporary economics, and (2) to make geologists aware that future discoveries of oil and gas are limited only by their imperfect understanding of migration and accumulation.

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CORAL PINNACLE SEDIMENTATION, ALACRÁN REEF LAGOON, MEXICO

Coral pinnacles growing in Alacrán Reef lagoon can be characterized by three different depositional environments. These are: (1) pinnacle crest—a rigid framework of living colonial corals and unconsolidated sediment which is poorly sorted, consisting of 2.5φ coral sand, with relatively high permeability, 20% calcite (90% aragonite), and 1-1.7% magnesium; (2) pinnacle slope—a transitional environment which accumulates very poorly sorted mixtures of gravelly coral, *Halimeda* sand and silt, having relatively low permeability, 10% calcite (90% aragonite), and 1% magnesium; and (3) lagoon floor—a topographic basin in which is accumulated poorly sorted 4.5φ *Halimeda* and *Halimeda*-fecal pellet silt, having relatively low permeability, 10% calcite (90% aragonite), and 0.75% magnesium.

Observed diagenetic processes are: (1) pelleting of lagoon-floor mud, (2) formation of galleries in the rigid framework by lithophagid pelecypods and in coral and mollusk sediment grains by boring algae, (3) growth of euhedral aragonite crystals in grain cavities, and (4) recrystallization of coral grains. Expected diagenetic processes in the future are cementation and dolomitization of pinnacle-crest sand, compaction of lagoon-floor mud, and mold-porosity formation in the rigid framework and in sediments of all three environments.