Lenticularity of both major and minor sedimentary units makes correlation between sections difficult, though siltstone sequences may be traced for several miles. The Boss Point Formation is underlain conformably by Hopewell Group redbeds, and the lowest siltstone sequence in most places is red, with "kunkar" nodules indicating semi-arid conditions. Higher siltstones are predominantly gray, with a partial return to oxidizing conditions near the top. The gray color probably results from increased or more constant river flow rather than a climatic change, being associated with greater thicknesses of coarse clastics.

Palaeocurrents indicated by cross-bedding and plant fragments show that the coarser northern sediments were deposited by currents flowing south and east, while elsewhere the flow was north and east. In conglomeratic beds plant fragments tend to be oriented parallel with the current direction, but they are perpendicular in finer-grained rocks.

The palaeogeography indicated is a delta forming between northeast-southwest-trending metamorphic ridges. A large northeasterly flowing river on the site of the Bay of Fundy supplied most of the detritus, and streams flowing off the Caledonia Mountains deposited the conglomeratic beds, probably mixing with detritus from a south-flowing river entering the delta near Dorchester, which may have flowed into the adjacent Moncton basin from the southwest.

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BIG GEOLOGY FOR BIG NEEDS

If we are to continue the current rates of petroleum demand and production, it will be necessary to obtain more petroleum during the next 37 years, or by 2000 A.D., than during the past 100 years. And, if discovery of new deposits is to continue as the most important source of petroleum, then the question becomes:" Is there that much oil yet to be discovered within the United States?" This is a geological question.

As has happened so often in the past, one or more of the chief ingredients for a discovery may lie staring us in the face, sometimes for years, before being put into the discovery recipe. The petroleum industry has gradually developed a great many fine geological administrators who deal with reports from highly trained specialists—but the administrators move farther and farther away from the rocks and the specialists become more and more specialized and more microscopic in their outlook. Needed are more experienced geologists in between, who are still with the rocks and able to integrate the various specialized elements of structure, stratigraphy, and fluids into a discovery picture.

Two situations typical of the "in between" problems, with their import to discovery.

1. One is the arched, updip, wedge-out of a potential reservoir rock coupled with a downdip flow of the water. The flanks of every fold, large or small, from the surface to the basement and in every sedimentary area, both productive and non-productive, offer innumerable opportunities for petroleum discovery.

2. The second is the simple fact that many oil fields and oil provinces—including some of the largest—occur in close association with truncated reservoir rocks. Large volumes of potential reservoir rocks, with many unconformities, well known and staring us in the face, but as yet unexplored, are potentially productive on a large scale.

The answer from this "Peek at the Deep" seems to be, "There is enough potential, favorable geology to supply a normal expected demand." The big question that remains is "Will there be sufficient incentive to do the exploring?" And this is in the realm of economics and politics.

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FLOATING DRILLING METHODS OPEN AREAS FOR OIL EXPLORATION

Until recent years, prospecting for oil has been limited to land areas. While marine drilling methods date back as far as the early 1900s, the most concerted effort to develop inundated properties began in the Gulf of Mexico off the Louisiana Coast in 1947. First attempts to drill in open water utilized the platform-tender method, still in use today. It appeared obvious that cheaper methods of wildcatting were required, as the expense of installing the platform was prohibitive in the event of a dry hole. The solution was found in the submersible drilling barge, a mobile platform for exploratory work.

Approximately 50 submersible barges were constructed for use in the Gulf of Mexico. Existing leases were in water depths of 100 feet and less. Enormous reserves were discovered in this area and it was assumed that substantial reserves should likewise be found on all of the Continental Shelf. Immediately, water-depth limitations for available equipment were reached and again it became necessary to search for new solutions to the inherent problems.

The drilling equipment for this new project would necessarily be required to operate in open water of depths as great as 600 feet and be capable of drilling to 15,000 feet with a minimum of risk and shut-down time due to weather. This paper discusses the evolution of one such piece of equipment, the problem involved in its design and the results of operation in deep water. In this way, new areas have been opened to oil exploration.

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STRUCTURE OF THE ARGENTINE CONTINENTAL MARGIN

Long lines of end-to-end seismic refraction profiles, shot parallel with the coast line, have defined several major sediment-filled depressions on the Argentine continental shelf. Two large elongate depressions which trend perpendicular to the coast and extend out to the edge of the continental shelf in the Province of Buenos Aires, are the only ones presently known. Extensions of land basins exhibiting a similar seismic sequence of layers were found to close on the continental shelf in the Golfo San Jorge, Magellan Straits, and Tierra del Fuego regions.

The section of shelf lying between the Province of Buenos Aires and Tierra del Fuego exhibits a marked lithologic change from that to the north and south. Undoubtedly the northern Patagonian Mesozoics extend well out onto the continental shelf in this region and may be part of the seaward extension of the central craton of Argentina. The basins, therefore, are associated with the evolution of a central craton, a dominant continental mass of enormous proportions which has influenced the geologic history of Argentina.

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CONTINENTAL GEOPHYSICS

Assembly maps may now be made of regional gravity

and magnetic maps on a continental scale. These may be used to assemble such maps as the basement structure and the derived structure of the Mohorovicic surface itself, including a fault-block mosaic of the continent. The relations shown help establish contour control for additional maps showing such measurements as age of basement rocks, hydrodynamics, and heat flow. A knowledge of such "deep" maps assists in the construction of paleogeographic maps. It is the thesis of this paper that the factors establishing these maps play a fundamental part in the accumulation of oil and gas and the survival of trap areas.

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SANDSTONE POROSITY—HOW DEEP?

Sandstone porosity and permeability tend to decrease with depth. Controlling factors are complex and there is no accurate method of computing the depth to which commercially interesting porosities might extend.

The optimistic view is that quartz is an exceedingly strong material and that short-time crushing experiments indicate that porosities persist to depths roughly double those drilled to date. Other experiments involving saline waters, elevated temperatures and pressures, and times measured in days, show that quartz sand is very much weaker than its theoretical strength and that failure and compaction is progressive over the longest times investigated. As in natural sandstones, experimental consolidation of quartz sands involves two distinct processes, compaction and cementation. Both are accelerated by high temperatures, moving water solutions, and large "overburden" pressures.

Highest porosity might be expected for pure, well sorted and rounded sands of the type examined experimentally. Conditions resulting in porosity reduction in these sands to some minimum value,—say 15 per cent,—should produce similar or greater reduction in most oil sands. Assuming sands are water-bearing and depth is constant, then temperature is the most important variable affecting pore reduction. Experiments indicate the effects of time and temperature are interchangeable, the log of time being a linear function of absolute temperature.

Compaction curves for dry quartz sand at room temperature and for saline water-saturated sands at pressures and temperatures simulating burial, are roughly parallel with trends of maximum porosities in natural sands. These trends seem to be temperature-dependent. If published temperature gradients for the Gulf Coast are accepted, then rough extrapolations indicate that pure quartz sands would be reduced to 15 per cent maximum porosity at depths less than 20,000 feet in the Galveston area and somewhat deeper, perhaps 25,000–27,000 feet, on the Mississippi Delta. These figures are for young Cenozoic sediments. Similar porosities should be attained at lesser depths within older formations.

Scarcity of reliable temperature data sharply limits the accuracy of this type of analysis. Good temperature logs of a few deep wells within a region would be of great value in estimating deeper drilling possibilities.

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APPLICATION OF MULTIVARIATE STATISTICAL TECHNIQUES TO THE STUDY OF THE CHEMICAL COMPOSITION OF SANDSTONES

The technique of discriminant function has been applied to data previously presented (Middleton, 1960, G.S.A. Bulletin) in order to confirm that the chemical composition of sandstones varies significantly with the tectonic environment of the basin of deposition. After rejection of all sandstones with less than 5% Al_2O_3, the remainder were distributed between three classes: A, eugeosynclinal sandstones; B, exogeosynclinal sandstones and others; C, taphrogeosynclinal sandstones.

Discriminate function coefficients (which correspond with rules for the assignment of sandstones of unknown tectonic setting to a tectonic classification) have been calculated for the three groups, based on the original data, a logarithmic transformation and an Arc sin square-root transformation. By the logarithmic transformation (for example) the discrimination is highly significant, and the probability of misclassification is as follows: between A & B, 0.17; between A & C, 0.06; between B & C, 0.13.

The reliability of the discriminate function was tested empirically by its application to 19 eugeosynclinal sandstones and 4 exogeosynclinal sandstones whose analyses were not used to calculate the function. Of these, only 2 eugeosynclinal sandstones and one exogeosynclinal sandstone were misclassified. The number misclassified corresponds closely with prediction, and the use of the technique may be considered to be vindicated, in spite of the failure of the data to follow closely the assumptions of the mathematical model.

An attempt has also been made to use factor analysis to indicate significant groupings of chemical variables and to suggest the basis for a chemical classification of sandstones.

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ECONOMICS OF OFFSHORE OIL AND GAS PRODUCTION

The petroleum industry, truly seaborne in many ways, is active in waters ranging from Alaska to the Persian Gulf. It is producing from sizeable oil and gas fields located far from shore, drilling from floating platforms, completing wells beneath the sea, even floating refineries to far-off shores—accomplishments that were visionary a few short years ago. Important, significant reserves of oil and gas have been found in the submerged lands and much of the world's future supplies of petroleum energy will come from beneath the sea.

But the industry's sea legs still are shaky in some respects and rougher sailing is ahead. There is a critical imbalance in the ratio of expenditures to returns. There is continuing Federal-State conflicts on offshore development which conceivably could spread to other points of difference. Discernible future trends of offshore development will require new technological developments with attending higher costs, placing even greater strain on the rate-of-return structure.

The situation today demands a new era of enlightened industry and governmental statesmanship if there is to be a continuation of successful offshore development.

Specific steps and proposals are suggested to attain this vital objective.

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TECTONIC PATTERN OF MIDDLE AMERICA

From a study of the major tectonic features—Precambrian outcrop, post-Precambrian metamorphic outcrops, major intrusives, eruptive centers, folds and fold belts, and fractures and faults—of an area in the