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