as a means of handling scout information. Well locations, formation tops, rock-type thicknesses within a stratigraphic interval, and paleontological and depth zone data can be recorded in numerical form on cards or tape for computer input. From such input the computer can calculate structure, isopach, and various types of lithofacies, biofacies, and environmental data for map preparation. Card or tape computer output can be printed rapidly on data sheets and then plotted manually on maps, or automatic plotting equipment may be used to print the output directly on base maps.

Second derivative calculations based on gravity and magnetic data can be performed rapidly on a computer. The results can be automatically plotted so that the maxima and minima are readily apparent without manual contouring.

Computer-automatic plotter systems can accept locations and data values for large numbers of points and produce contoured maps based on the input values.

For a map containing 1,000 irregularly spaced data points, several months would be required to perform the computations on a desk calculator to separate the observed data into regional and local components. These calculations are performed on the IBM 650 in one hour and on the IBM 704 in two minutes.

Computers are available within major companies, and to smaller organizations and independents through service bureaus. Converting large volumes of geological data to a form suitable for computer input can be done economically with proper planning by computer-oriented geologists. The exploration geologist should become sufficiently familiar with computers to recognize problems in which they can be used advantageously.

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PALEOECOLOGY OF SCOTTISH MISSISSIPPIAN MARINE TRANSGRESSION

A complete vertical column of the 2.8 mm. thick shale grading upward into the Upper Mississippian Second Abden Limestone at Fife, Scotland, was studied in an attempt to elucidate changes in its depositional environment and fauna from that of a near-shore terrestrial area (represented by the underlying fireclay) to the minor reefal development in the limestone.

Three thousand macrofossils belonging to 50 species, and 8,000 microfossils comprising 70 species were collected. The relative abundance of all species was calculated for equal quantities of rock in each of the 125 shale layers, which are approximately 2 cm. thick.

On the basis of certain indigenous macrofossils as well as on the microfauna and lithologic character, 4 topozones were recognized: (1) *Lingula squamiformis* and *Streblopteria ornata;* (2) *Crurithyris urei* and *L. squamiformis;* (3) *Schizophoria resupinata* and *Eomorginifera longispina;* (4) *E. longispina*, corals and bryozoans. Each succeeding topozone is more truly marine than its predecessor. The lowest (number 1) indicates deposition in conditions similar to those of the intertidal Wattenschlick deposits of the north German coast whereas the uppermost topozone (number 4) reflects conditions fast approaching those developing in the overlying limestone.

The succession of faunas in the shale indicates the marine transgression of the area. Reversal of such a series would indicate regression of the sea on shoaling. Recognition of a similar succession of faunas—perhaps over a much longer stratigraphic interval—may be useful in determining the position of the margins of former basins of sedimentation and in determining former transgressions and regressions of the sea.

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SEDIMENTARY BASINS AND PETROLEUM EXPLORATION IN JAPAN

Deposition of marine sediments has occurred in different parts of Japan and its offshore areas at intervals from early Paleozoic time to the present. Most rocks of the Paleozoic sedimentary basins are now complex in structure and many have been metamorphosed; no indications of oil have been discovered in these rocks and they hold little promise for the future. Mesozoic sedimentary rocks are also complex in structure. Although no oil has been produced from them, a limestone of Jurassic age is slightly petroliferous and oil seeps are known from Cretaceous rocks in Hokkaido.

During Tertiary time thousands of meters of marine sediments were deposited in a geosyncline which extended along the western part of northern Japan. In late Pliocene and Pleistocene time crustal movements separated the Tertiary rocks into several basins. Petroleum exploration is presently concentrated in these Tertiary basins and their extensions offshore beneath the Japan Sea. Most oil so far discovered is trapped in small anticlinal structures which trend north-northeast.

Oil production in Japan was first officially recorded in 1874. Production in 1891 was 63,523 barrels. Development continued and in 1936 production reached 2,457,503 barrels. Much of this oil came from the Yabase field which was discovered in 1934. After 1939 production fell.

Exploration received new impetus during the American Occupation of Japan, especially through the leadership of Hubert G. Schenck. Deeper producing horizons were discovered in old fields, including the Yabase, and study and exploration of untested areas, particularly in Hokkaido, were undertaken.

Current exploration is carried on principally by the Japan Petroleum Exploration Co., Ltd., and the Teikoku Oil Co. The former is drilling anticlinal structures that were located by seismic surveys off the northwestern coast of Honshu. Tests of an offshore well completed in 1960 produced 1,800 b/d. Teikoku Oil Co. has concentrated its exploration program on the extension of proved fields. Total production has increased and 3,675,047 barrels of petroleum were produced in 1960.

Future exploration will include additional offshore drilling, testing of deeper formations in proved fields, and further exploration of unproved areas of Cretaceous and Tertiary sediments.

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FLUID FLOW IN VARIABLE DENSITY GROUND-WATER SYSTEMS

Current hydrodynamic theory is valid, in part, only for systems in which ground-water density is constant. Ground-water density is a function of salinity, temperature, and pressure. In the strict sense, constant density systems do not exist in nature on a regional scale.

A new concept of hydrodynamic analysis is presented in which actual flow-inducing pressure gradients are mapped. These gradients are, in reality, the flowing pressure forces that cause ground waters to migrate through rocks. Basic data needed to map these flowing pressure forces are (1) structural configuration of the aquifer, (2) ground-water density distribution in the aquifer, and (3) formation pressures. The flowing pressure gradients are both modified by and used to interpret changes in aquifer transmissibility (permeability-thickness/viscosity) between pressure control points.

A comparison between actual flow-inducing pressure gradients in an aquifer and other representations of water potentials, such as h_w, indicates possible errors in depiction of flow rate and direction by the latter. By disregarding ground-water density variations, in some methods of analysis, we can seriously misinterpret hydrodynamic phenomena.

When the flowing pressure forces in an aquifer are known, it is a simple matter to derive oil potentials in terms of these new quantities. This is done in essentially the same manner as shown by Hubbert in 1953. The mapping of flow-inducing pressure gradients provides us with a simpler and more accurate way of describing dynamic ground-water systems.

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Internal Structure of Massive Sandstones

The structure of 306 samples of seemingly homogeneous massive sandstone from 74 formations was studied by use of radiography. This technique consists of placing a large thin slice of rock directly upon photographic film and exposing it to an X-ray source from a standard medical or industrial X-ray unit. The image recorded on the emulsion depends on differences in X-ray absorption by the various constituents in the rock sample. Density variations between quartz and heavy minerals, clays, and other minor impurities are recorded on the radiograph and clearly outline the internal structure of the rock.

The results of this study show that sandstones that seem to be homogeneous, massive, and completely structureless in outcrop and hand specimen actually contain a definite systematic arrangement of grains into small structural units. These units may be horizontal laminae, cross-laminae, micro-cross-laminae, disrupted bedding, or other types of stratification. A massive bed may contain only one structural type or several types in various combinations. The type of structure present seems to be related to grain size. Micro-cross-laminae and disrupted bedding are most common in the fine-grain deposits, whereas large-scale cross-laminae are restricted to coarser sediments.

It is concluded that massive sandstones do not represent special environmental conditions but were formed by the same processes that produce well stratified deposits. On the basis of this study it is doubtful that any sandstones are completely structureless and isotropic throughout.

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Direct Printing of Contour Maps of Facies Data by Computer

A Burroughs 220 computer is being used at Stanford for fitting contour maps to facies data. The computer fits a smoothly curving parabolic surface to the data and then prints a contour map of the surface. Human error in fitting the contours is virtually eliminated. The method is particularly useful where direct contouring of data values is difficult or meaningless because of appreciable random fluctuations and error. The map printed by the computer smooths over the irregularities and shows the general trends. The contoured surface is fitted so that the sum of the squares of the numerical differences of the actual data above and below the surface is the least possible.

This method has been useful in mapping facies variations in a Pennsylvanian limestone bed in New Mexico and variations of modern unconsolidated carbonate sediments in the Gulf of Mexico and adjacent coastal swamps of the Everglades in southern Florida. Ratios, percentages, and average grain diameters mapped in these applications revealed systematic trends that were previously obscure.

Areas mapped by this method must be rectangles, but sampling localities, which may be measured stratigraphic sections, oil wells, or places where sediment samples were obtained, can be arranged irregularly within a rectangle. An arbitrary geographic coordinate system is established so that each locality is described by two coordinate values. The coordinate units may be feet, miles, or, as has been proved convenient, tenths of an inch scaled off the map. The coordinate values and the value to be contoured for each locality form the basic data fed to the computer.

The general instructions for the method are fed from paper tape into the computer's memory before the computation begins. In addition, the computer must be instructed as to the contour interval and the dimensions of the map that it is to print. The contours printed out by the computer consist of individual bands of a letter or symbol, such as A, B, and $. Each band spans one contour interval, and blank bands alternate with printed bands.

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Cross Stratification in Sands of Red River, Louisiana

Sedimentary structures of two modern point bars on a meandering part of the Red River near Shreveport, Louisiana, were investigated by trenching. On one of them, the Beene point bar, 12 sets of trenches, 2–8 feet deep, were dug with a tractor-powered shovel. The trenches ranged from 25 to 250 feet long, and were dug in T-shaped and X-shaped patterns. The point bars consist mainly of fine-grained, well sorted sands, commonly interbedded with and overlain by thin silt layers. Gravelly sands occur in the deeper parts of some of the trenches.

The most abundant type of sedimentary structure is trough (or festoon) cross stratification. Individual trough sets range in size from 1 cm. thick, 5 cm. wide, and 15 cm. long, to at least 1.5 feet thick, 8 feet wide, and 33+ feet long. In any one section, the size of the trough sets tends to decrease upward. The smaller sets are "microtrough" ripple laminae, and occur in the siltier sands and silts. The surface expressions of these ripple laminae appear to be cuspate ripples. The longitudinal axes of trough sets measured at 8 different localities on the Beene point bar have a strong preferred orientation parallel with the local, adjacent, stream flow direction. The resultant vectors obtained by summing observations on individual cross-stratification planes at each locality also point downstream, but have much weaker magnitudes because of the variability associated with the diverse orientations of cross strata within any individual set. In addition to the cross-stratified sands, beds containing parallel, horizontal laminae also occur locally in the siltier sands.

Spoon-shaped depressions on the surfaces of the bars, oriented with the tips of the "spoons" pointing downstream, may represent scours incompletely filled with trough-shaped cross laminae. At the upstream end of one of these scours, cross-laminae in the upper part of the sand which partially fills the scours are overturned downstream. Overturning occurred before deposition of any overlying strata and probably during rapid subsidence of river level.