71/3

GEOLOGY OF THE DEEP-SEA FLOOR

AT the recent meeting of the British Association at Newcastle upon Tyne, six papers were given before the Geological Section on problems concerning the deep-sea floor. There was, in addition, an evening lecture by Prof. Hans Pettersson[1], the leader of the Swedish Deep-Sea Expedition, 1947–48, in which he described the results so far obtained from investigations on the material brought back by the expedition. Judging by the enthusiasm at both the sectional meeting and the evening lecture, the study of the deep-sea floor is of general interest. This is doubtless due to the fact that the deep-sea floor, covering approximately two-thirds of the earth's surface, is an almost unexplored region, and the solution of its problems, requiring the application of many sciences, will have an important influence on other earth sciences.

Chronology of Deep-sea Deposits and Climatic Oscillations

For the interpretation of the changing phases in oceanic evolution, as revealed by sedimentary and biological investigations on long cores, it is necessary that there should be methods of establishing the age, or at least of correlating significant horizons. Prof. Pettersson's paper on "The Chronology of the Ocean Floor" dealt with the methods used for correlation in deep-sea cores; first the radioactive method, second the mineralogical method, third the pollen analysis method, and fourth the biological method. As the duration of the Pleistocene was approximately one million years, it is impossible to measure time by the slow disintegration of uranium into stable end-products. In deep-sea deposits the content of uranium is surprisingly low (about $1 \cdot 8 \times 10^{-6}$ gm. per gm.) as compared with the theoretical value in equilibrium with the relatively high radium content found in the topmost layers of deep-sea cores. This high content of radium was explained by Prof. Pettersson as being a result of the precipitation from sea-water of the element ionium, along with ferric hydroxide. Such a hypothesis would explain the low radium content of sea-water (about 1×10^{-13} gm. per litre) as compared with its theoretical equilibrium value with the dissolved uranium of about 5×10^{-13} gm. per litre. Prof. Pettersson explained the possibility of determining the average rate of sedimentation on the deep-sea floor during the past ten thousand years on the assumptions that (*a*) eighty per cent of the ionium produced from the uranium in sea-water is precipitated and that this proportion has remained constant; (*b*) that the rate of accumulation of ionium has remained constant; and (*c*) that no radium of different origin has entered into the deposit. The rate of sedimentation arrived at by this method is, according to Prof. Pettersson's calculations, in agreement with the generally accepted value for red clay.

An alternative method of determining age during the latter half of the Pleistocene is by determining the changing concentration of radium with depth in the core. Dr. W. D. Urry[2] has shown that, if it is assumed that a constant concentration of elements of the uranium-238 series has been deposited with time, it is possible to give quantitative equations governing the growth and decay of these elements, and, in consequence, an age to any particular horizon in a core can be assigned from a knowledge of the radium distributed. This promising method is now being applied to cores taken during the cruise of the *Albatross*; but it is only suitable for the latter half of the Pleistocene.

Concerning the mineralogical methods of establishing correlations, Prof. Pettersson pointed out both the use of ash bands in establishing isochronic surfaces and of detailed mineralogical analysis. He particularly referred to the work of Dr. M. N. Bramlette and Dr. W. H. Bradley[3] on the North Atlantic cores, and gave a tentative correlation of the uppermost volcanic layers found in long cores from the Tyrrhenian Sea with the historical eruptions of Mt. Vesuvius. There are unfortunately limitations to correlations by the mineralogical method owing to differentiation both in the atmosphere and the sea, and the method can only be used for relative chronology of volcanic outbursts earlier than historical times. Dealing with the pollen analysis method, Prof. Pettersson considered that there are possible applications on a limited scale in the case of cores collected near islands or continental coasts. It was his opinion that the biological method, depending on the statistical distribution of planktonic organisms sensitive to temperature changes, is the most promising.

The importance of planktonic foraminifera as temperature indicators was demonstrated in a paper by Mr. C. D. Ovey, of the British Museum (Natural History). From a study of nine deep-sea floor samples from different latitudes, Mr. Ovey gave a clear proof that specific species of foraminifera are sensitive to temperature variations. The changes in the proportions of 'cold', 'temperate' and 'warm' species, determined by counting about a thousand specimens (those smaller than 125 μ in diameter were ignored), were followed from the Southern Ocean to the Arctic, and the general correlation between the percentages of these groups and the surface sea temperature was pointed out. For example, Mr. Ovey found that a sample from lat. 66° 38′ S., long. 178° 47′ W., where the sea temperature is nearly 0° C., consisted of 98·8 per cent cold species (predominance of *Globigerina dutertri* and *G. pachyderma*), whereas near to the equator (lat. 0° 1′ S., long. 15° 16′ W.), where the surface temperature was 24° C., the warm species (mainly *Globigerinoides sacculifera, G. rubra, Globorotalia menardii*) composed 97·1 per cent of the sample. At an intermediate locality (lat. 32° 32′ S., long. 1° 23′ W.), where the surface temperature was 17·5° C., temperate forms (mainly *Globigerina inflata, G. bulloides, Globorotalia truncatulinoides*) made up 89·7 per cent of the sample. It is evident from Mr. Ovey's paper, as well as from similar work carried out by Dr. Phleger[4], of Woods Hole Oceanographic Institute, that when there is more information about the geographical distribution of individual living species, as well as the temperature limits within which breeding can proceed, it may be possible from a knowledge of the percentage distribution of cold, temperate and warm species at any horizon in a core to assign approximate temperature limits to the surface of the ocean. In conclusion, Mr. Ovey indicated that past climatic oscillations can be determined from statistical investigations on fora-

minifera isolated from different horizons in a core. Work on these lines will shortly be undertaken on a core 15·4 m. in length, kindly supplied by Prof. Pettersson.

Nature of Deep-sea Basins

The origin and date of formation of deep-sea basins is of special significance to those interested in the distribution of fauna and flora. Three important papers were given which have a considerable bearing on this subject. The first, by Prof. Ph. H. Kuenen, of Holland, dealt with the formation of the continental shelf. This feature has been attributed to marine erosion, to deposition on the continental slope, and to deposition on subsiding foundation with or without warping or faulting. In the opinion of Prof. Kuenen, the continental shelf off Cape Hatteras (lat. 35° 14′ N., long. 75° 32′ W.) originated through the formation of a sedimentary prism to the east of the late Jurassic coastline, which was situated slightly to the east of Cape Hatteras. The weight of the sediment would cause isostatic subsidence, and in consequence a broad strip some 50–150 km. subsided. Prof. Kuenen explained that the shelf would grow both towards the continent (that is, westward) by top-set beds and towards the open ocean (eastward) by fore-set beds. Eventually, however, elevation would proceed eastward from the continent, as there would be a tendency for the coastal region to regain local isostatic equilibrium. In consequence of this the coastal region, which was originally bent down through the weight of sediment, would rise. In support of this theory Prof. Kuenen mentioned (*a*) that the information obtained from oil wells drilled in the Cape Hatteras coastal area[5] indicates a prism of Upper Cretaceous and Tertiary strata resting on a weathered granite surface; and (*b*) that the gravity investigations of Prof. Vening Meinesz[6] prove that on the continental shelf there is no appreciable divergence from isostatic equilibrium, which, in Prof. Kuenen's opinion, indicates that three-quarters of sedimentary volume on the continental shelf is due to isostatic subsidence.

The floor of the Indian Ocean with special reference to the Arabian Sea was described by Lieut.-Colonel R. B. Seymour Sewell, who was the leader of the *John Murray* Expedition of 1933–34. The Arabian Sea is divided into two basins by the Arabian or Carlsberg Ridge, which runs in an arc from Socotra to near the Chagos Archipelago. To the south-west lies a second ridge—the Seychelles or Mascarene Ridge—bearing the Seychelles group of islands at its northern end and Mauritius at its southern extremity. Continuing south from the Arabian Ridge is the Mid-Indian Ridge, which is crowned by the islands of New Amsterdam and St. Paul, and this merges into the Kergaelen–Gaussberg Ridge. It is not yet known whether this ridge is continuous throughout its whole length. Colonel Seymour Sewell discussed the date of formation and nature of these ridges, and expressed the view that they are of early Tertiary age. In the case of Providence Reef[7] there is definite evidence that its foundations are early Tertiary in age. The coastal regions of the Arabian Sea are characterized by a series of scarp faults, and in some areas there are indications, for example, along the Makran and Baluchistan coasts, that the faulting was late Tertiary. Colonel Seymour Sewell recalled that basalts[8] have been dredged from the Arabian Ridge as well as in the basin to the north-east, and that these are both chemically, as well as in their radium content, quite distinct from the Deccan Trap. He further referred to the work of Dr. H. G. Stubbings[9], who from a foraminiferal analysis of short cores from the Arabian Sea obtained evidence for four cold phases.

Some of the geophysical methods for the exploration of the deep-sea floor were described by Mr. B. C. Browne, of the Department of Geodesy and Geophysics, Cambridge. The 1938 and 1946 gravity surveys to the west of the British Isles, carried out in the submarine H.M.S. *Tallent*, were described. On the continental shelf the isostatic anomaly is on the average + 7 milligals with a scatter of ± 10 mgl., while to the west of the continental shelf the average isostatic anomaly is + 11 mgl. with a scatter of ± 19 mgl. The high scatter over the deep-sea, as compared with that over the continental shelf, can be explained on the assumption that blocks of granite are set in a matrix of basalt, or alternatively if there are large pools of sediment. As Mr. M. N. Hill, of the Department of Geodesy and Geophysics, Cambridge, has recently found by seismic refraction methods a very considerable thickness of sediments in the East Atlantic Basin, it would seem more likely that the latter hypothesis is correct.

Surface of Deep-sea Floor

A paper was read by Dr. J. D. H. Wiseman, of the British Museum (Natural History), on manganese nodules found on the surface of the deep-sea floor of the Arabian Basin. Manganese nodules which occur abundantly in oxidizing environments have aroused interest for more than three-quarters of a century, but their origin is still obscure. In the Arabian Basin they are associated with red clay and are largely composed of manganese, iron and water. They contain, in addition, unusual amounts of nickel, copper, cobalt, barium and radium. The shapes of the nodules are generally spherical, hemispherical, tetrahedral or potato-shaped, and from an examination of the internal structure Dr. Wiseman concluded that the tetrahedral nodules originated through the fragmentation of spherical nodules. Definite confirmation about the fragmentation of spherical nodules and the deposition at a later date of a secondary manganese layer is given by the distribution of radium in tetrahedral nodules. According to determinations kindly made by Dr. J. H. J. Poole, of Trinity College, Dublin, the radium content of the secondary peripheral layer is practically constant (11×10^{-12} gm. per gm.), while immediately below this layer the content is much lower ($0{\cdot}9 \times 10^{-12}$ gm. per gm.), and towards the centre no radium could be detected. It is clear from these determinations that the original nodule was spherical with increasing radium content towards the periphery, and that it afterwards broke into tetrahedral masses, around which a secondary layer of manganese material was deposited. In the Arabian Basin nodules a delicate microcellular structure has been detected. The cells are of an average diameter of 0·1 mm. and are arranged in a radial direction. They are capped by concentric layers of a dark-brown isotropic substance.

Future of Oceanic Exploration

It is clear from the papers referred to above that, with the rapid development of new techniques for the exploration of the deep-sea floor, our knowledge of oceanic evolution will rapidly be removed from the realm of geological speculation. It may, for example, be possible, when more investigations have been made, to determine the origin and date of formation of the deep-sea basins, as well as that of the major tectonic features. The considerable thickness of sediment overlying the rock substratum in the East Atlantic Basin suggests, on the assumption that the rate of sedimentation approximates to the rate in the latter half of the Pleistocene, that at least part of this basin is of considerable age. It is now possible, according to a personal communication from Prof. W. Weibull, to distinguish seismic reflecting layers which are separated by only 20 m., and the Swedish Deep-Sea Expedition found in the East Atlantic Basin three reflecting surfaces at 1,540 m., 2,220 m. and 3,460 m. This great thickness of sediment is in general agreement with that found by recent seismic refraction surveys carried out by the Department of Geodesy and Geophysics at Cambridge, and such sedimentary pools would, as previously noted, account for the large scatter of the isostatic gravity anomalies over the ocean, as compared with the much smaller scatter over the continental shelf.

Important events during the Pleistocene or even earlier are revealed by sedimentary investigations on the long cores which can now be obtained using the Kullenberg piston core sampler; and by means of statistical studies of planktonic organisms sensitive to temperature changes, it is possible to obtain a record of climatological changes during the Pleistocene, and to test the various theories concerning the origin and dating of these climatic changes. It would, for example, be significant to know whether these changes synchronize or alternate in the southern and northern hemispheres.

The International Commission on Oceanography held its third meeting at Newcastle, and it was strongly urged that as a result of recent developments in deep-sea research international co-operation is desirable, and with this in view the Commission examined the desirability of establishing an international union or bureau. J. D. H. WISEMAN

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5716

THE UNIVERSITY OF MANCHESTER UNIVERSAL HIGH-SPEED DIGITAL COMPUTING MACHINE

By Dr. T. KILBURN

THE electronic computing machine described here has been developed in the Electrical Engineering Laboratories at the University of Manchester under the general direction of Prof. F. C. Williams, and with the active assistance of the Telecommunications Research Establishment, Malvern.

The use of electronics in machines of this type follows from the requirement for high-speed operation. A further consequence of this requirement is the desire to eliminate, so far as possible, the necessarily slow process of human intervention, which is essential at every stage of the solution if conventional methods of computing are used. The minimum extent to which this intervention could be conveniently reduced would be to present to the machine an oral or written statement of the problem, in much the same way as problems are presented to a human computer. Research in electrical engineering and mathematics has produced computing machines at Manchester, Cambridge and in the United States, of a type which approximate to this ideal. However, a simple statement of the problem is insufficient. The problem must be programmed, that is, it must be split up into a series of simple operations which the machine can perform. Each operation is represented by an instruction, and these instructions, and the data which they control, are coded in a form which the machine can interpret. During the actual solution of the problem by the machine, however, the need for human intervention is entirely eliminated, for all the data—instructions and numbers—are loaded into the machine initially. The solution then occurs at a speed determined only by the electronic circuits used. To permit this initial loading, the machine must have a 'memory' or storage facility. One storage system used in the Manchester machine has been fully described elsewhere[1]. It is clear that as the capacity of the storage is increased, the programming of problems becomes easier; for mathematical operations common to many problems may be programmed, and introduced permanently into the storage of the machine. It will then be necessary to construct only 'master programmes', which call upon these 'sub-programmes' appropriately, and a nearer approximation to the ideal is achieved without further engineering being necessary.

The important engineering requirements resulting from the above discussion are as follows: (i) representation and interpretation of data; (ii) storage, and input and output devices; and (iii) computing circuits. These items are now discussed with reference to the machine at Manchester.

Representation and Interpretation of Data

The binary system of numbers[1] is used throughout the machine, because of the simplicity and economy with which it can be represented electrically. In this system of numbers, it is only necessary to represent the digits 0 and 1. Thus, in a machine operated in the 'series' mode, the binary number 10101 (decimal 21) is conveniently represented by a train of negative pulses occurring sequentially on a single wire, as shown in Fig. 1.

Now, if the stored items of data are considered to exist in numbered 'addresses', s, in the main storage of the machine, and if, further, the operations or functions, f, which the machine can perform are numbered, then it follows that an instruction, in its simplest form, consists of two numbers (s, f), and may be represented in the same way as a number. In fact, instructions and numbers differ only in the way in which they are used by the machine. Instruc-

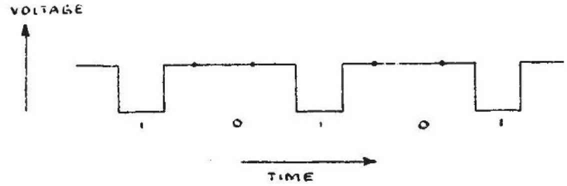

Fig. 1