13,000 ft. or more of clays, sandstone, and conglomerate, is regarded as of lacustrine origin; and the upper, 2000 ft. of massive conglomerates, as torrential. The oil is found in the lower Fars group, the detrital limestones forming the reservoir; at Maidan-i-Naftun the wells all flow under strong pressure, and after ten years of remarkable production show no signs of exhaustion.

The geological history of the region seems to be one of extraordinary interest. The strata, from the base to the top of the Fars series, were deposited in a quiescent basin, and the thickness of beds between different horizons remains very constant. At the close of the Fars period folding began; the strata were thrown into open folds, and the overlying Bakhtiari series varies greatly in thickness, being thickest in the synclines, and least over the anticlines; towards the close of the period the synclines became filled up with sediment, and the upper Bakhtiari conglomerates spread over the whole. Then, according to the authors, a series of earth movements set in, continuing to the present and giving rise to a very complicated series of structures; fan, or, as they call it, Omega, structure was developed, and a series of thrust-faults which came right up to the surface and were partly determined by accidents of surface relief. In some cases the folds are completely overlaid by one overthrust extending beyond the next, and at Maidan-i-Naftun this is said to have been prevented only by the action of the Karun River, which flows for some miles in a gorge 800 ft. deep between the Tembi thrust-fault, which hades towards the oilfield on one side, and the back fault of the next fold, which hades in the opposite direction. The authors believe, in short, that the faulting and folding of this region were not only superficial, but also of recent date and continued, with a gradual relaxation, to the present day; they regard the surface features as largely due to the movements caused, to some extent, as determining this faulting, and consider that the advancing fronts of the overthrust blocks have been worn away by surface denudation, concomitantly with their advance by the action of the tectonic processes.

The Ahwaz-Pusht-i-Kuh region presents much the same features, with less intense disturbance; but in Qishm Island the identification of the rock series with that of the Bakhtiari country is doubtful, and the structure is very different, the rocks being disposed in a series of gentle domes along an axis running through the length of the island, these domes being subsidiary to a larger dome, exposing an inlier of the Eocene Hormuz series. Four explanations of this dome are discussed: that it is due to the intersection of two open folds of different dates, that it is of the same nature as the salt domes of Texas, that it is due to a laccolitic intrusion, and that it is due to the compression of the softer Miocene strata against a pre-existing boss of Eocene, round and against which they were deposited. No opinion is offered as to the relative probability of these, but the general features seem more in consonance with some cause analogous to the second and third, though the material to which the local uplift was due may have been neither salt nor a plutonic intrusion. Neither this nor the Ahwaz-Pusht-i-Kuh district has proved oil-bearing in a commercial sense, though indications have been found and both are being tested.

We may express a hope that, the absolute embargo on publication having been lifted, more of the large amount of geological information which is in possession of the Anglo-Persian Oil Co. and of the Indian Government may be made accessible. There can be no commercial reason for secrecy, as the company has a monopoly of the whole country, and the political reasons have been largely, and may soon be completely, removed. The value of publication will be great, as the region is one of extraordinary interest both in its structural aspect and as regards its bearing on the principles which underlie the origin and distribution of petroleum.

THE CONSTITUTION OF THE EARTH'S INTERIOR.[1]

THE problems of the interior of the earth are primarily of a physical character, and, in the final appeal, only to be decided by mathematical treatment; but this, in its turn, must be based on observation, and, therefore, it comes that this discussion is prefaced by a statement of the results which have been obtained by the sciences of observation. The preparation of this statement is simplified by the fact that the problems fall naturally into two tolerably distinct groups: (1) those relating to the outermost layer, amounting at most to 1 per cent. of the radius, and (2) those of the deeper portions, extending to the centre.

The latter may be taken first. Records of the transmission of mass waves set up in connection with earthquakes show two well-marked groups representing two forms of wave-motion, presumably the longitudinal and transverse, and a steady increase of the rate of transmission, with no very marked break in regularity, up to a distance of about 120° from the origin. Beyond that the first phase, of longitudinal waves, shows a decrease in velocity, and the second phase, of transverse waves, which, though so conspicuous at lesser distances, are no longer represented in their typical form, but are replaced by a record of different character, probably not due to any form of wave which has followed the direct path from the origin, and markedly delayed from the time at which they should have arrived had the same relative rate of propagation been maintained as at lesser distances. The depth reached by waves emerging at 120° from the origin is about half the radius from the centre of the earth, and the conclusion to be drawn is that down to that depth the material of which the earth is composed is sufficiently rigid against stresses of short duration, and sufficiently isotropic to permit the transmission of the two forms of elastic waves and to give rise to their separation by reason of the different rates of travel. Further, it seems that down to a depth of half the radius there is no marked change in the character of the material, but at greater depths there is a change in physical character to a material, or form of matter, which is no longer able to transmit the distortional waves, or, if capable, can only do so with a great diminution of intensity and at about half the rate in the lower layers of the outer shell; in other words, the material in the central nucleus has a very low degree of rigidity, even against stresses of only a few seconds' duration. The limit between the central nucleus and outer shell lies between four-tenths and five-tenths of the radius, measured from the centre of the earth; the transition between the two is apparently gradual, and not sufficiently abrupt to give rise to reflection of the waves at the junction of the two.

Turning to the outer layers, we have, next the surface, partly material which has been disintegrated by the processes of surface denudation, transported, deposited, and resolidified, and partly rock which has not undergone these processes, but is thoroughly cooled and solid in every sense of the word. These

[1] Synopsis of the opening of a discussion at a meeting of the British Association Geophysical Committee on November 19, by R. D. Oldham, F.R.S.

rocks have been subject to very considerable mass-movements and deformation, the displacements amounting in extreme cases to as much as ten miles in the vertical and one hundred miles in the horizontal direction. The ultimate cause of these movements is unknown; they can only be directly observed in the outermost skin, and are probably taken up in a different form in the deeper layers, but require that beneath the outer solid layer—which for convenience, and because some name is required, is commonly called the crust—there must be material which has some of the properties of a fluid, but not necessarily more than the power of change of form when exposed to stress of sufficient magnitude and duration. The thickness of the outer crust has been estimated by several distinct lines of deduction, all of which agree in giving a figure of about twenty-five miles, and this may be taken as indicating the order of its magnitude. The only means of arriving at any idea of the nature of the transition from the crust to the underlying material is in the reflection of earthquake waves; this is ordinarily treated as taking place at the surface of the earth, but there are grave difficulties in the way of accepting this interpretation. A more probable one is that reflection takes place at the under-surface of the crust, indicating a somewhat abrupt transition from the solid and rigid crust to the more yielding layer below. Whether this is a separate layer or merely the outermost part of the shell capable of transmitting both forms of elastic waves is still unknown.

The general result is that three distinct divisions can be recognised in the interior of the earth :—(1) The outer crust of solid matter possessing a high degree of rigidity, whether against permanent or temporary stress, of comparatively small thickness amounting to about ½ per cent., and not more than 1 per cent., of the radius; (2) a shell of material of thickness about one-half of the radius which has a high rigidity as against stress of the duration involved in the production of the tides, or of shorter duration, but, in the outer part at least, a comparatively low power of resistance to stress of secular duration; and (3) a central nucleus of material which has a very low degree of rigidity, even against stress of only a few seconds' duration. The transition from the first to the second of these three divisions is somewhat abrupt, sufficiently so to give rise to reflection; between the second and third the passage is more gradual, and lies at about four-tenths or five-tenths of the radius from the centre of the earth. These three divisions may be further reduced to two—the outer layer, which in geology is known as the crust, not from any implication of the nature of the rest of the earth, but merely in recognition of a difference in character; and the central core, consisting of the rest of the earth.

HYDRO-ELECTRIC POWER SUPPLY.[1]

LARGE works have been established for supplying Bombay with water-power for its numerous mills and factories, which have hitherto used steam-power, to the extent of more than 100,000 h.p. Coal in most of India is too expensive to allow competition with other countries for many products, though the raw materials are grown or found in India, and labour is cheap and docile, while highly educated Indians abound. To Bombay coal has mostly to be carried about 1200 miles.

The water-power now provided is very much cheaper than power from coal or oil, gives a better "drive," and frees Bombay from the clouds of deleterious smoke which the poor Indian coal gives.

The works take advantage of the very heavy rainfall on the precipitous edge of the Western Ghats, about 2000 ft. above, and about forty miles from, Bombay. As the rain falls only during three or four months of the year and the watercourses are dry all the rest of the year, it was necessary to store water sufficient to give about 100,000 h.p. for ten or twelve hours a day during about nine months of the year.

Three lakes are formed by four masonry dams, ranging from nearly ¾ mile long and 34½ ft. high to nearly 1½ miles long and 96 ft. high. Two of these form a "monsoon" lake of sufficient capacity to provide power during the longest "breaks" in the monsoon, and thus give an uninterrupted supply of power for three months and more. The other lakes are for storage, and maintain the power during the eight or nine months in the year when no rain falls.

The monsoon rain on the Western Ghats, though always heavy, is very variable in amount. The least annual amount during the last forty-eight years was 82 in. on the edge of the Deccan plain, and the greatest amount during the past eleven years, in which special gauges have been fixed, on hilltops as well as in plains, is 546 in., which fell in a little more than three months, 460 in. falling in about two months. The minimum fall of 82 in. is very exceptional, and the maximum given may be equally so. The combined available capacities of the two storage lakes is about 10,100,000,000 cubic ft., whilst the water required to give 100,000 h.p. ex turbines for nine months, allowing for the great loss by evaporation and by soakage and for friction in the pipes and turbines, is 6,700,000,000 cubic ft. The excess capacity is given owing to the very variable amounts of the monsoon rains, so as to carry on the balances in years of excessive rainfall to make up for the occasional short monsoons. It was arrived at by assuming the works had been completed forty years ago, there being one rain-gauge record covering that period—which includes four minimum years' fall—and deducting from each year's supply the amount which would have been used, lost by evaporation, run to waste, or carried on to the next year, which gives the excess capacity required for a sufficient number of years.

The amount of 546 in. measured at one hill station in the lakes catchment is not more than has been measured in two or three out of the past fifty odd years at Cherrapunji, in the Assam Hills, which has the heaviest rainfall hitherto known; but there rain falls during seven months of the year, so that the amount measured for this work for that particular year may claim to be the heaviest rainfall ever yet measured.

The works are notable for the following reasons :—They are the largest of the many similar hydro-electric works which have been constructed during the past ten or twenty years, taking into consideration the great head used, combined with the large discharge of water. The first is equal to about five times the height of St. Paul's Cross, and the latter is greater than the summer flow of the River Thames during five months. They are also the first works to store water for power for use during about three-fourths of the year. One of the masonry dams, taking the exposed face area, is probably the largest yet constructed. The works are probably unique, considering the very heavy rainfall and the very steep rocky slopes, giving the greatest discharge perhaps ever recorded. The catchment area of the two lakes is only 16½ square miles, while of this the full lakes area is about 7⅓ square miles.

The water is led from the monsoon lake and from

[1] Abstract of a paper on "The Tata Hydro-electric Power-supply Works, Bombay," by Mr. R. B. Joyner, read at the Institution of Civil Engineers on November 19.