SUMMARIES OF ADDRESSES OF PRESIDENTS OF SECTIONS

THE INTERIOR OF THE EARTH

THE subject of the presidential address to Section A (Mathematics and Physics), given by Dr. R. Stoneley, was "The Interior of the Earth". Dr. Stoneley emphasized that since the interior of the Earth is not accessible, except by boring into the outer layers, knowledge of the properties of the interior is obtainable only indirectly, and often by a long chain of inference. Until the quantitative formulation of the laws of science, man's ideas on this subject were mainly uncontrolled speculations.

Before the present century, the shape of the Earth was known from geodetic measurements to be approximately an oblate spheroid of ellipticity about 1/297, a value confirmed by the variation of gravity with latitude. Laboratory measures of the constant of gravitation, combined with the value of gravity, gave the mass of the Earth, or equivalently its mean density. From the observed period of the precession of the equinoxes (26,000 yr.) the knowledge of the ellipticity, following Clairaut's theory of the figure of the Earth, gave the moment of inertia about the polar axis—a value too small to be consistent with the idea that the Earth can be a uniform solid, and implying condensation towards the centre. Towards the end of the nineteenth century a model was proposed by Wiechert which proved to be the precursor of the distribution of density now generally accepted; he envisaged a metallic core, of about the density of iron, of radius about 0·78 of the Earth's radius, with a rocky shell (or 'mantle', as it is now called) surrounding it.

Some evidence concerning the elasticity of the Earth was forthcoming from the observed free period of the variation of latitude, which for a completely rigid Earth should be about 305 days, and in fact is about 428 days: the lengthening is attributable to the finite rigidity of the Earth, which calculation shows to be of the order of that of steel. The study of Earth-tides agrees with this result. This evidence was insufficient for the determination of the variation of elasticity with depth.

Great advances have been made in the present century by the study of the records of earthquakes made at stations all over the world, generally far removed from the epicentre (that is, the place below which the shock occurs). In records taken at angular distances up to 108° from the epicentre, the first pulse to arrive is one of compression or dilatation (called P) like a sound wave; this is followed later by a distortional wave called S, and these waves, P and S, travel through the body of the Earth from the focus of the shock to the station. By analysing the times of travel to various distances one can find both the track of the ray and the wave velocity at all depths reached. At distances greater than 108° the appearance of the record changes, and the interpretation is that there is a sudden change at a depth of about 2,900 km. from a rocky mantle to a fluid core, which refracts the P pulses and does not transmit the S pulses; the core thus behaves as a fluid. The change of properties is sharp, for waves reflected at the core are received by surface stations at suitable distances. The many reflected, refracted and transformed pulses found on the records corroborate these findings. When the density is known, the elastic constants can be determined from the velocities of P and S; the density distribution is found by successive approximation, combining earthquake data with the known moment of inertia of the Earth, and making the reasonable assumption that the density does not anywhere diminish with depth. There appears to be a dense 'inner core' of radius about one-fifth of that of the Earth.

The structure of the continents and the ocean floor can be diagnosed by a study of the 'surface elastic waves', which are confined mainly to the outer layers. Where there happen to be a number of stations within 1,000 km. of an epicentre some information is forthcoming about the layering of the continents. Most shocks occur within a few tens of kilometres of the surface, but some deep-focus shocks take place at depths down to about one-tenth of the Earth's radius.

The determination of the temperature gradient in borings determines, where the heat conductivity is known, the rate of outflow of heat, which is much the same in all localities. This heat may in part be primitive, but its estimation depends on the Earth's thermal history, which is at present very uncertain; most of the outflow can be ascribed to generation of heat by the radioactive disintegration of elements in the outer layers, notably uranium, thorium and potassium. The difference in the layering of the continents and the oceans, however, poses problems that are still to be solved.

Magnetic observations are regularly made at a number of stations all over the Earth. In addition to the general (or 'dipole') field, there are fluctuations such as the solar daily and the lunar semi-diurnal variations; further, there are the storm-time variations attributable to changes in the Sun's activity. The analysis of these variations by Chapman and others indicates a marked increase in the electrical conductivity at a depth of the order of 400 km., a depth at which both the density and the velocity of earthquake waves appear to undergo a marked increase with depth. The origin of the dipole field has been the subject of much research work; most suggested explanations have been proved inadequate. The idea that the Earth acts as a self-exciting dynamo has been shown by Bullard to be a possible solution of the problem, but the analysis is intricate, and full details are yet to be worked out. The observed secular changes in the direction of the magnetic field at any place have been ascribed by Bullard to a movement in the core like that of a small number of large vortices circulating in a general westward direction.

A striking corroboration of the present picture of the density and elasticity of the Earth has been achieved in the past year by applying a 'frequency analysis' to earthquake records, to gravimeter observations and to Earth-tide data for some days following the large Chile earthquake of May 22, 1960. The periods of a number of free vibrations of the Earth had been calculated numerically, and the frequency diagrams show sharp peaks agreeing closely with the predicted periods.