$= -100°$. The apparent lateral spreading of these three ridges is partly a consequence of the distorted mapping.

If the angular positions of the nearest neighbours in regular close packing are superimposed on Fig. 2 they do not seem to show a significant relationship to the positions of the peaks and ridges.

The structure of the angular distribution is clearly that which is imposed by the condition of close packing and can be considered analogous to the short-range structure displayed in the radial distribution. The relative angular distribution of the molecules in monatomic liquids cannot be found by diffraction methods and so it is not possible to compare our results on the model with experimental data for real liquids. However, it seems likely that the angular distribution of random close packing is directly related to the geometrical structure of simple liquids.

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[1] Scott, G. D., *Nature*, **194**, 956 (1962).

GEOPHYSICS

Terrestrial Flow of Heat in the Brent Crater

DURING the summers of 1961, 1962 and 1963 temperature gradient measurements were made in a hole drilled in the Brent Crater[1], which is thought to be of Cambrian age and is about three miles north of Cedar Lake in Algonquin Park, Ontario. This hole, which was started on March 10, 1959, and completed to 3,489 ft. on May 23, 1959, mainly passes through limestones and shales for the top 750 ft. and then through a complicated series of rocks ranging from indurated tuffs to porous breccias. By the time the first measurements were made in 1961 the hole had become blocked at a depth of 1,285 ft.

The thermal conductivities of the rocks were determined from *in situ* measurements at 8 points along the hole from 100 ft. through 1,200 ft. Since details of the technique and methods used to reduce the data and check the accuracy of the results will be published elsewhere, only a brief description will be given here.

The thermal conductivity probe is essentially a cylindrical heater with a length to diameter ratio of not less than 20 (ref. 2), and with the present arrangements the accuracy of a single conductivity determination is not much better than 10 per cent. A number of different probes have been used involving different materials and slightly different end geometries; they have been checked against one another by repeating measurements at given points along the hole. However, they all have bottle brush type seals[3] at each end and the temperature measurements are made by either a single, or a multiple, differential thermocouple with the cold junction located 18 in. below the lower seal and the hot junction, or junctions, located on the outer surface of the probe and equidistant from each end of the probe. Both a.c. and d.c. heating methods have been used, with more consistent results from the d.c. methods, the heat input being such that rises of temperature between 2° and 5° C are observed. The output from the thermocouples is amplified (this is not always necessary with multiple thermocouples) and either recorded continuously or measured at specified times on a portable potentiometer.

The mean thermal conductivity of the rocks below 800 ft., which range from indurated tuffs to porous breccias, was found to be 0·0056 cal/cm sec °C, with a standard deviation of 0·0007. Above 800 ft. the conductivity was found to be 0·0086 ± 0·0019; if one particularly high result, which may have been due to leaky seals, is ignored—the value is 0·0079 ± 0·0014.

For the determination of the temperature gradient, different sets of temperature measuring equipment were used in each year. In 1961 a straightforward Wheatstone bridge arrangement was used; in 1962 a prototype version of the 1963 equipment[4] was used. In each year the temperature–depth relation exhibited a small but definite curvature and for this reason a least squares quadratic equation, rather than the more usual straight line equation, has been fitted to the results for each year. The relationships over the range 300–1,285 ft., with the standard deviation of the measured temperature from the fitted curve, are as follows:

$$\begin{array}{ll} 1961 & \theta = 5{\cdot}066 + 4{\cdot}751 \times 10^{-3}\,Z - 4{\cdot}698 \times 10^{-7}\,Z^2 \;(\pm\,0{\cdot}03°\,\mathrm{C}) \\ 1962 & \theta = 4{\cdot}698 + 5{\cdot}366 \times 10^{-3}\,Z - 6{\cdot}507 \times 10^{-7}\,Z^2 \;(\pm\,0{\cdot}02°\,\mathrm{C}) \\ 1963 & \theta = 4{\cdot}660 + 5{\cdot}531 \times 10^{-3}\,Z - 7{\cdot}300 \times 10^{-7}\,Z^2 \;(\pm\,0{\cdot}02°\,\mathrm{C}) \end{array}$$

Where θ is the temperature at the depth Z ft. from the surface.

It can be seen that the temperatures have been slowly changing over the years, and that between 1961 and 1963 the gradient has changed by 14 per cent at $Z = 0$ and by 6 per cent at $Z = 1,000$. However, between 1962 and 1963 the changes in gradient are 3 per cent at $Z = 0$ and $< 0{\cdot}3$ per cent at $Z = 1,000$; all changes are referred to the 1963 values. These data are consistent with the behaviour of a borehole returning to equilibrium after disturbance of the temperatures by drilling fluid, although the possibility that the upper regions of the hole are disturbed by subterranean water flows cannot be entirely ruled out.

Since the portion of the hole above 700 ft. has not quite returned to equilibrium only the lower 500 or 600 ft. is used to compute the terrestrial heat flow from the foregoing results; the value so found is 0·73 µcal/cm²/sec and may be as much as 15 per cent in error due principally to the scatter in the values of thermal conductivity. This somewhat low value is consistent with low values of heat flow found elsewhere in shield areas throughout the world[5-9].

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[1] Millman, P. M., Liberty, B. A., Clark, J. F., Wilmore, P. L., and Innes, M. J. S., *Pub. Dominion Obs.*, **24**, No. 1 (1960).

[2] Blackwell, J. H., *Canad. J. Phys.*, **34**, 412 (1956).

[3] Beck, A. E., Jaeger, J. C., and Newstead, G. N., *Austral. J. Phys.*, **9**, 286 (1956).

[4] Beck, A. E., *J. Sci. Inst.*, **40**, 452 (1963).

[5] Jaeger, J. C., and Thyer, R. F., *Geophys. J.*, **3**, 450 (1960).

[6] Saull, V. A., Clark, T. H., Doig, R. P., and Butler, R. B., *Canad. Min. Met. Bull.*, **55**, 92 (1962).

[7] Beck, A. E., *Nature*, **195**, 368 (1962).

[8] Lubimova, H. A., *Abst. Upper Mantle Symposium, I.U.G.G.* (1963).

[9] Sass, J. H. (private communication).

Anomalous Galenas and the Continuous Diffusion of Lead

IN the investigation of the isotopes of 'common lead' it was found[1] that anomalous galenas from a given area produce lead isotope ratios which, when represented on a ^{206}Pb/^{204}Pb versus ^{207}Pb/^{204}Pb plot, delineate a straight line. Russell and Farquhar suggested that this result would be produced if common lead with normal or non-anomalous isotopic composition were mixed with radiogenic lead. Thus the position of a point along the line would be determined by the ratio of common lead to radiogenic lead. Assuming this process to have occurred, then Russell and Farquhar gave arguments to set limits bounding the time interval within which uranium could have generated radiogenic lead of the requisite kind. They further showed that if one could say that the uranium started producing new radiogenic lead at a time t_1, then