LETTERS TO THE EDITOR

GEOPHYSICS

Growth of the Earth's Core

To his recent communication[1], proposing that the cause of convection in the mantle is chemical, Dr. Stacey added a note in proof attacking the idea used by me[2,3] of a gradual growth of the Earth's core to give a tentative explanation of continental drift. He makes the objection that the settling of the Earth's core from an undifferentiated Earth, formed by the accretion of iron and silicate bodies like the meteorites, would release an amount of energy greater by an order of magnitude than that which would have been conducted through the Earth's surface since 3,000 million years ago, when I suggest separation began, supposing the geothermal gradient had always its present value. I do not think Stacey's objection is valid. I have a detailed paper in preparation giving an account of the thermal history of the Earth, assuming that convection in the mantle is possible: naturally this differs radically from the thermal history of the Earth previously presented by those[4] who have only assumed conduction in the mantle.

It is possible here only to make the following points:

(1) If the Earth was formed by the accretion process, and if the heat generated at the surface of the developing planet by impacts is radiated off into space, then the initial temperature of the Earth would have varied from 0° C at the surface to about 800° C at the centre, owing to the adiabatic gradient. It is possible, if the planet accumulated sufficiently fast, for some of this energy to be trapped within the Earth and it is of course possible to suppose that the short-lived radioactive isotopes, for example, aluminium-26, might also contribute initial heat, but again this assumes a very rapid collection of matter. There seems no strong reason to postulate much initial heat.

(2) If the radioactivity of the silicates composing the Earth's mantle is that of chondritic meteorites, which now generate $1\cdot6\times10^{-7}$ joules/g/year, and the radioactivity of the iron core is negligible as is the case for iron meteorites, the temperature of the Earth would have risen by only 1,800° C in the last 4,500 m.y., even if no heat escapes. Also H. C. Urey (private communication) believes that this is probably an over-estimate, as the chondritic meteorites may be over-rich in potassium. One may therefore deduce that on this theory there has had to be another source of heat in the Earth's interior, for the lowest estimate ever made of the temperature at the core mantle interface is in excess of 3,000° C and probably is much greater.

The gravitational energy released in the process of forming the dense core may reasonably be identified as the likely source. Urey[5] calculates the heat generated as being between $1\cdot67\times10^{31}$ joules and $2\cdot19\times10^{31}$ joules assuming that no changes in temperature have occurred. About a tenth of this heat has been lost through the surface; perhaps a twentieth has gone to melt the core, supposing the latent heat is 100 calories/g (mass of core is 2×10^{27} g). Also, the increase in gravitational energy in the expansion of the Earth consequent on the Earth's temperature rising through, say, 4,000° C is considerable. Assuming the volume coefficient of expansion to be 3×10^{-5}, an increase in volume of 12 per cent is to be expected. This requires the gravitational energy to increase by 2 per cent. As the total gravitational energy of the Earth is about 2×10^{32} joules, half the energy released by separation of the iron core has been accounted for.

The remaining energy, between $7\times$ and 12×10^{30} joules, is available for heating up the Earth to its present temperatures. The mass of the Earth is 6×10^{27} g, so that the increase in temperature lies between 1,000° C and 2,000° C, of the order of that required.

The fallacy in Dr. Stacey's argument lies in the fact that it is tempting to believe that a system of convection currents will carry away exactly the heat generated, but the proviso must be added that the heat sink is adequate. But it is quite clear, from the present-day values, that the heat conducted through the crust is insufficient, and if the Earth's initial temperature were low it could scarcely be otherwise. The convection currents will, of course, distribute the heat generated uniformly through the 'fluid' part of the mantle and the general temperature of this will rise. The thermal gradient through the crust will therefore increase with time.

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[2] Runcorn, S. K., *Nature*, **193**, 311 (1962).
[3] Runcorn, S. K., *Nature*, **195**, 1248 (1962).
[4] Jacobs, J. A., *Handbuch der Physik*, **47**, 364 (Springer-Verlag, 1956).
[5] Urey, H. C., *The Planets* (Yale Univ. Press, New Haven, 1952).
[6] Urey, H. C., in *Physics and Astronomy of the Moon*, edit. by Kopal, Z., 481 (Academic Press, 1962).

Photometric Observations from the Southern Hemisphere of 5577A Emission from the Aurora on October 28, 1961

In a recent communication[1] Silverman reports unusual fluctuations in 5577*A* airglow emission intensity on October 28–29, 1961, at Sacramento Peak (geomagnetic latitude 41·6° N.). Silverman gives a curve, consisting of readings taken at 10-min intervals for the period 0200–1100 h U.T. on October 29, 1961. The peak intensity for that night is almost 450 and the minimum about 50, the units being unstated. It is of interest to compare these results with some recorded around 1200 U.T. October 28, from a similar experiment at Lauder, New Zealand (170° E., 45° S. geographic; 50° S. geomagnetic).

The Lauder photometer points continuously to the zenith and views an angle of 0·5°. The instrument was designed to search for rapid fluctuations in the airglow and uses a photon pulse-counting technique; the wavelength is selected with a dielectric filter having a half-width of 70*A*. It came into operation early in September 1961 and recorded 5577*A* emission until December 1961—the same period as that reported by Silverman.

On the night of October 28, 1961, a bright aurora was observed at Lauder. This aurora, which consisted of an active rayed arc, was the brightest observed here during the whole of 1961. The sky was clear in the zenith, and during the period 1135–1235 U.T. the curve reproduced in Fig. 1 was recorded by the photometer. Until 1141 the recorded intensity was at the normal airglow-level, although the aurora in the south had been bright for an hour or more. The rays rose higher in the sky until at 1144 they reached the zenith and the photometer went full scale with the recorder at normal sensitivity. (At 1147 the recorder sensitivity was reduced by one half, at which setting it remained for the rest of the night.) The rays stayed in the zenith for only 3 or 4 min and then retreated to the south. By 1230 the auroral display had quietened to no more than a glow. The moon rose at 1208, and after 1235 the photometer record was contaminated by moonlit cloud. For the period 0900–1200 K_P was 5, rising to 6 for the period 1200–1500 U.T.