natural magmas should lie on the ternary cotectic curve ? " (my italics). Such remarks by Dr. Nockolds are excellent examples of *Petitio Principii*, a fallacy all too common in discussion on the plutonic rocks. We can study plutonic rocks, but we cannot study plutonic magmas. To maintain that a given plutonic rock originated from a magma is no more than a hypothesis, and as such requires evidence for its support. If the evidence favours a magmatic origin then the question of the origin of the magma arises. Supporters of the hypothesis of solid diffusion do not deny that there have been magmas ; they trace the stages leading up to their origin. Dr. Nockolds evidently forgets that the " reasonable scientific hypothesis " that he supports is based on his *choice* of a parental magma.

DONALD B. McINTYRE.

GRANT INSTITUTE OF GEOLOGY,
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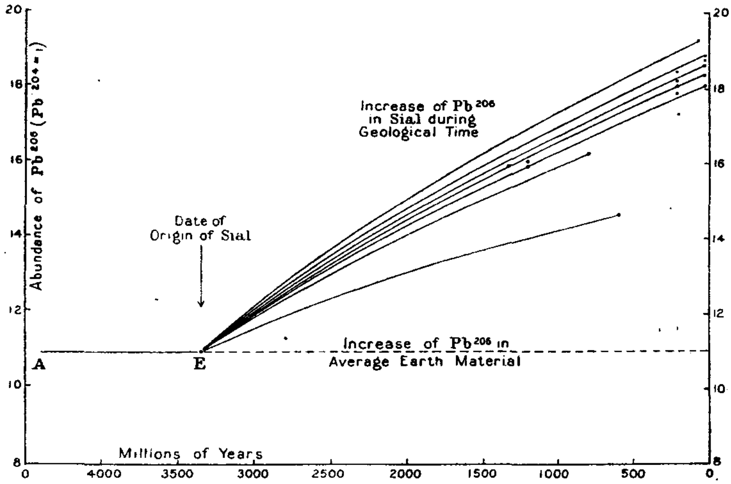
10th February, 1947.

AN ESTIMATE OF THE AGE OF THE EARTH

SIR,—In his letter to the *Geological Magazine* (this volume, p. 57) Professor Kuenen expresses his belief that my recent estimate of the age of the earth refers not to the time of origin of the earth as a planet, but to the time of origin of " the materials forming the earth ". I had not overlooked the fundamental distinction to which Professor Kuenen directs attention ; this and many other points not yet discussed will be fully dealt with in a detailed paper that is now being prepared. Meanwhile, however, I must make it quite clear that what I have determined is the most probable age of the rock material containing that dispersed rock-lead from which—by localized concentration brought about during various metallogenic epochs—lead ores have been formed. Geological and geochemical data (and also the results of the investigation under discussion) all consistently indicate that the source of the lead ores is the sialic part of the continental crust ; or, in other words, that lead ores represent concentrations from the granitic layer and its sedimentary and metamorphic derivatives. Accordingly, the age I have determined refers to the time when the granitic layer separated from average earth material during the consolidation of the globe. It is generally considered to be highly probable that the earth was originally gaseous and that the period of consolidation, up to the time of formation of a solid crust, was relatively short. Jeffreys, for example, estimates that " the earth probably became solid within 15,000 years of its ejection from the sun ". Even if this estimate were wrong by a factor of a thousand, the age of the granitic layer would not be appreciably different from the age of the earth.

The point raised by Professor Kuenen would be a serious one—and would indeed make the problem insoluble—if the ratio Pb/U in sialic material were the same as in average earth material. It is, however, easy to show that in sialic rocks the ratio Pb/U is far lower (i.e. U is relatively much more abundant) than in average earth material.

The average U content of earth material can be assessed by considering the outward heat flow. This amounts to about 40 cals./sq.



cm./year, of which not more than half can be ascribed to the heat generated by the disintegration of uranium, the balance being derived from Th and K and from ancestral heat. The rate of production of heat from 1 gm. U in equilibrium with its radioactive descendents (UI and AcU series) is ·74 cals./year. Thus in the long pyramidal pencil beneath each sq. cm. of the continental crust down to the earth's centre the total amount of U is 20/·74 = 27 gm. The mass of the pencil is $6{\cdot}36 \times 10^8 \times 5{\cdot}53/3 = 11{\cdot}7 \times 10^8$ gm. The average U content of this material is therefore ·023 p.p.m. In sialic rocks the average U content is about 3·5 p.p.m.

For lead the relevant data are :—

Sedimentary rocks	20 p.p.m.	(Goldschmidt, 1937)
Granitic rocks	20 ,,	(Sandell and Goldich, 1943)
Basaltic rocks	5 ,,	(,, ,, ,,)
Stony meteorites (silicates)	2 ,,	(Goldschmidt, 1937)
Stony meteorites (troilite)	60 ,,	(,, ,,)
Nickel-iron meteorites	60 ,,	(,, ,,)

On the meteorite analogy (taking the mass ratio earth/core as $\frac{1}{3}$) the average Pb content of the earth would be 22 p.p.m., without taking

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troilite into account. Only three determinations of Pb in ultrabasic rocks have been made (Hevesy and Hobbie, 1931) and these, so far as they go, suggest that such rocks contain more lead than stony meteorites. The average Pb content in the real earth is therefore likely to be higher than 22 p.p.m.

From the available data it may reasonably be concluded that sialic material contains about 150 times as much U as average earth material, and that Pb/U in average earth material is probably more than 150 times higher than in sialic material, possibly 250 times higher. This means that since the moment when the granitic layer came into existence, its dispersed content of primeval lead has been modified by continuous additions of Pb^{206} and Pb^{207} (besides Pb^{208} from Th—not here considered) at a rate at least 150 times as great as it would have been in average earth material, if the latter had continued to exist as such. This striking and sudden change in rate is made clear by the adjoining diagram, which shows the variation in time of the abundance of Pb^{206} (relative to $Pb^{204} = 1$) in the two kinds of material. A similar diagram could be constructed to show the corresponding increase of Pb^{207}. The point E indicates the abundance of Pb^{206} (x) at the time (t_0) of the origin of the granitic layer. If average earth material had previously existed (e.g. in the sun) its abundance of Pb^{206} would have varied—almost inappreciably—along the line AE. If the average earth material had continued to exist, its abundance of Pb^{206} would have varied along the dotted line from E to the present day. But in the sialic material that originated at E, Pb^{206} varied along the curves linking E to the points representing the abundances of Pb^{206} in actual lead ores of known ages. There are several such curves (not all are drawn) because the regional distribution of U in sialic material is not uniform.

My method of determining the age of the earth is essentially this: starting with the points representing the abundances of Pb^{206} (and of Pb^{207}) in dated lead ores, the point E is found at which the curves most nearly come to a focus. This focus refers only to the material of the granitic layer and is quite independent of any considerations involving the average material of the earth. The time of origin of the granitic layer is, in fact, a zero point from which the age of the granitic layer can be measured, and that, for all practical purposes, is indistinguishable from the age of the earth.

REFERENCES

Goldschmidt, V. M., 1937. *Norske Videns.-Akad. Skrift Oslo, Mat. Nat. Kl.*, No. 4, pp. 93–4.
Hevesy, G., and Hobbie, R., 1931. *Nature*, 128, p. 1038.
Holmes, A., 1946. *Nature*, 157, p. 680. See also *Nature*, 159, 1947, p. 127 for a revised estimate of 3,350 m.y.

JEFFREYS, H., 1929. *The Earth*, Cambridge, p. 79.
KUENEN, Ph. H., 1947. *Geol. Mag.*, 84, p. 57.
SANDELL, E. B., and GOLDICH, S. S., 1943. *Journ. Geol.*, 51, pp. 99 and 167.

ARTHUR HOLMES.

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11th February, 1947.

SIR,—My criticism of Holmes's paper, although evidently unfounded, has induced him to clarify a point that I know had troubled others besides myself, in advance of his detailed treatment. In spite of being a wiser man, I need therefore be no sadder.

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24th February, 1947.

CHILLED AND "BAKED" EDGES AS CRITERIA OF RELATIVE AGE

SIRS,—As an old campaigner, who is for ever grateful for the assistance he has received from corrections by fellow-workers, may I say how much I enjoyed the January–February number of the *Geological Magazine*? There are at least two divergent schools of petrology at work in the British Isles, and the more we get together, so as to tackle simultaneously identical problems, the quicker we shall arrive at satisfactory agreement. The principle of a reserved area is abhorrent to my consciousness of the sanctity of Science.

The title adopted for this correspondence is attractive. Scottish geologists, including many who are Scottish by choice rather than birth, have paid special attention to the lessons to be learned from chilled edges. The earliest case on record seems to be that of James Hall, who in 1798 announced deductions derived from a study of chilled edges of dykes at Monte Somma. Later, the cult of chilled edges was developed by masters such as Clough and Peach. Harker, however, never fully appreciated their value. This is well seen in a remark he once made in combating criticism I had advanced of his interpretation of the Sgurr of Eigg: "For some of my friends on the Geological Survey this matter of chilled edges seems to have become, in these latter days, a kind of cheap and infallible touch-stone" (*G.M.*, 1914, p. 307). Sallies such as this I have always greatly enjoyed as enlivening debate and at the same time recording opinion.

The letter in your last issue, upon which I wish to comment, is by D. B. McIntyre and Doris L. Reynolds (*G.M.*, 1947, p. 61). It begins