SVERIGES GEOLOGISKA UNDERSÖKNING

SER. **C.** Avhandlingar och uppsatser. **N:o 458.**

ÅRSBOK 37 (1943) N:o 7.

A GRAPH FOR THE CALCULATION OF THE AGE OF MINERALS ACCORDING TO THE LEAD METHOD

BY

FRANS E. WICKMAN

WITH ONE PLATE

Pris 1 krona

STOCKHOLM 1944

KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER

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In a previous paper (1) the present writer published some graphs facilitating the calculation of the age of minerals and rocks. They were intended to be used in connection with the helium method and the lead method, but in the latter case only when the isotopic composition of the lead content had been determined. No diagram for minerals with unknown isotopic composition of lead was constructed, as such age determinations cannot be considered satisfactory.

However, mass spectrometers of suitable construction are still very rare and the number of investigated specimens small. Furthermore there is a large number of older analyses only calculated according to the well-known 0.36-formula (2), which is not well founded.

Keevil (3) was the first to develop sound formulas, but they are complicated to use on old minerals and are not well fitted for ages over 1,500 MY. Therefore a graph giving ages over 100 MY with a max. error of 1 % and ages under 100 MY with an error of max. 1 MY, would be of great value, especially if the numerical work could be made quite as simple as or perhaps simpler than that required in the 0.36-formula.

From the geological point of view the disintegration equation can be written as follows

$$N_{Pb} = N_{UI}[\exp(\lambda_{UI}t) - 1] + N_{AcU}[\exp(\lambda_{AcU}t) - 1] + N_{Th}[\exp(\lambda_{Th}t) - 1] \quad (1),$$

where

N_{Pb} is the number of lead atoms generated in the time t,
N_{UI} is the number of UI atoms after the time t,
N_{AcU} is the number of AcU atoms after the time t,
N_{Th} is the number of Th atoms after the time t,
and λ_{UI}, λ_{AcU} and λ_{Th} the disintegration constants of UI, AcU, and Th.

In equation (1) it is presumed that no other disintegration series gives lead as a stable endproduct.

According to Nier (4) the ratio N_{UI}/N_{AcU} is 139. Substituting this value in equation (1) and if it is rewritten with weight per cent instead of number of atoms, we get

$$\frac{Pb}{M_{Pb}} = \frac{UI}{238}[\exp(\lambda_{UI}t) - 1] + \frac{UI}{139 \cdot 238}[\exp(\lambda_{AcU}t) - 1] + $$
$$+ \frac{Th}{232}[\exp(\lambda_{Th}t) - 1] \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2),$$

where Pb, UI, and Th are measured in weight per cent and M_{Pb} denotes the atomic weight of lead.

As UI = 0.992 U, we can write instead of (2)

$$\frac{Pb}{M_{Pb}} = \frac{U \cdot 0.992}{238}[\exp(\lambda_{UI}t) - 1] + \frac{U \cdot 0.992}{139 \cdot 238}[\exp(\lambda_{AcU}t) - 1] + $$
$$+ \frac{Th}{232}[\exp(\lambda_{Th}t) - 1] \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (3).$$

If the terms are rearranged and the equation divided with (U + Th) we get, finally

$$\frac{Pb}{U+Th} = \frac{U}{U+Th}\Big[M_{Pb} \cdot 4.16 \cdot 10^{-3}[\exp(\lambda_{UI}t) - 1] -$$
$$- M_{Pb} \cdot 3.00 \cdot 10^{-5}[\exp(\lambda_{AcU}t) - 1]\Big] +$$
$$+ \frac{Th}{U+Th} \cdot M_{Pb} \cdot 4.31 \cdot 10^{-3}[\exp(\lambda_{Th}t) - 1] \quad . \; . \; . \; . \; . \; . \quad (4).$$

This equation is linear in Pb/(U + Th) and U/(U + Th) for constant t-values, if the variation of M_{Pb} is neglected. For, if Pb/(U + Th) is called y and U/(U + Th) x, then Th/(U + Th) is equal to (1 — x), and the equation can be written

$$y = \text{const} \cdot x + \text{const} \cdot (1 - x).$$

M_{Pb} has the value 208 in pure thorium minerals, and in pure uranium minerals it is slightly more than 206. In minerals containing both uranium and thorium the atomic weight varies between 206 and 208. If an M_{Pb}-value of 207 is used, the error must decrease 1/2 per cent and therefore this value has been used.

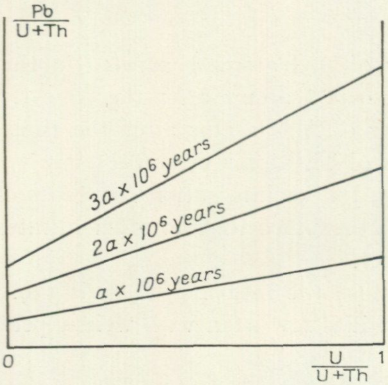

Fig. 1. The appearance of a graph schematically drawn according to equation (4).

Fig. 1 shows schematically the appearance of a graph drawn according to equation (4). The same graph is given on the plate, but in this case the ordinate is drawn in logarithmic scale. The age values have been chosen with so small intervals as to permit readings being made with errors of maximum one per cent.

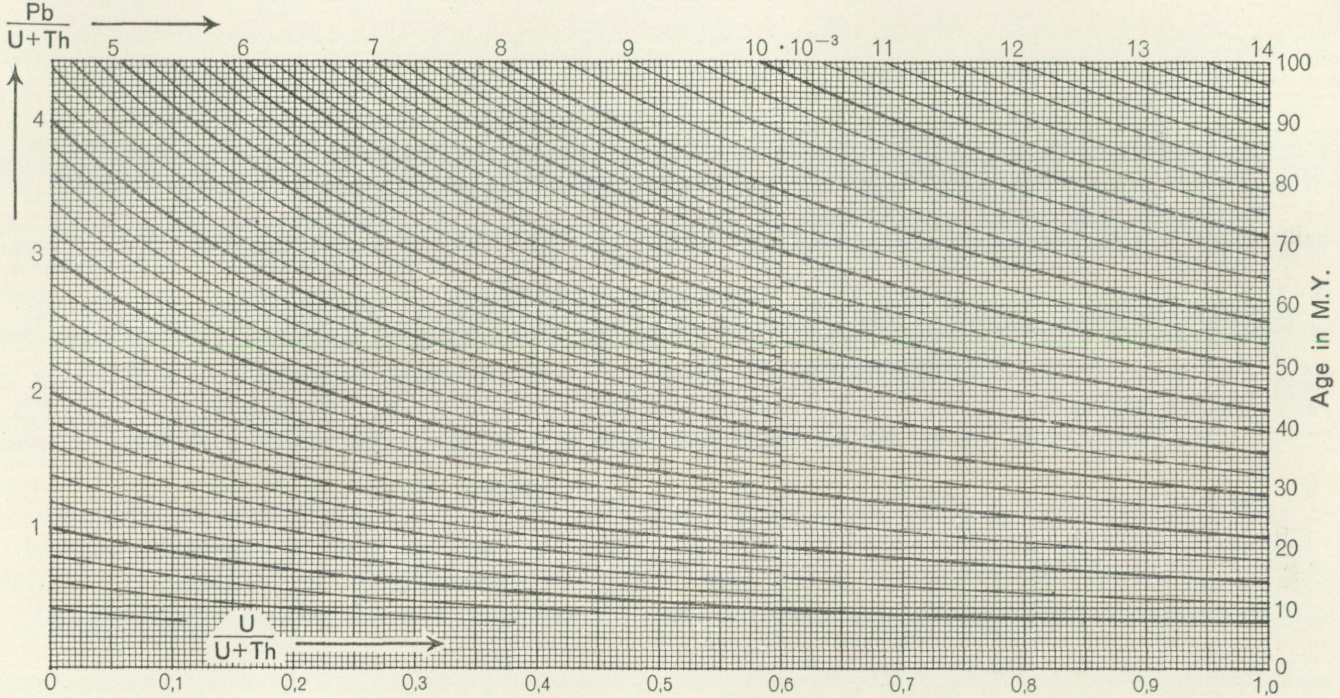

Fig. 2. Special graph for the calculation of ages between 10—100 MY.

For the range between 0 and 100 MY a special graph (fig. 2, p. 5) has been drawn, as a logarithmic one would have been too large. To that end the variables have been interchanged. The age is set off along the ordinate and the U/(U + Th) values along the abscissa. The family of curves consists of different Pb/(U + Th) values. This graph can be used down to 10 MY.

The following values of the disintegration constants have been used (cited from (5)).

$$\lambda_{UI} = 1.535 \times 10^{-10} \text{ years}^{-1}$$
$$\lambda_{AcU} = 9.72 \times 10^{-10} \text{ years}^{-1}$$
$$\lambda_{Th} = 4.99 \times 10^{-11} \text{ years}^{-1}$$

Finally, two examples, to show how the large graph is to be used. The small graph is used in a similar way.

Example 1: According to Hecht and Kroupa an analysis of uraninite from Manitoba yielded the following values: U = 38.41 %, Th = 9.11 %, Pb = 13.67 %. This gives (U + Th) = 47.52, U/(U + Th) = 0.808, Pb/(U + Th) = 0.288, and these last two values give the age 1,950 MY.

Example 2: According to the same analysts an analysis of monazite from Manitoba yielded the following values: U = 0.12 %, Th = 12.67 %, Pb = 1.21 %, and from this (U + Th) = 12.77, U/(U + Th) = 0.0094, and Pb/(U + Th) = 0.0948. With these values the graph gives an age of 1,995 MY.

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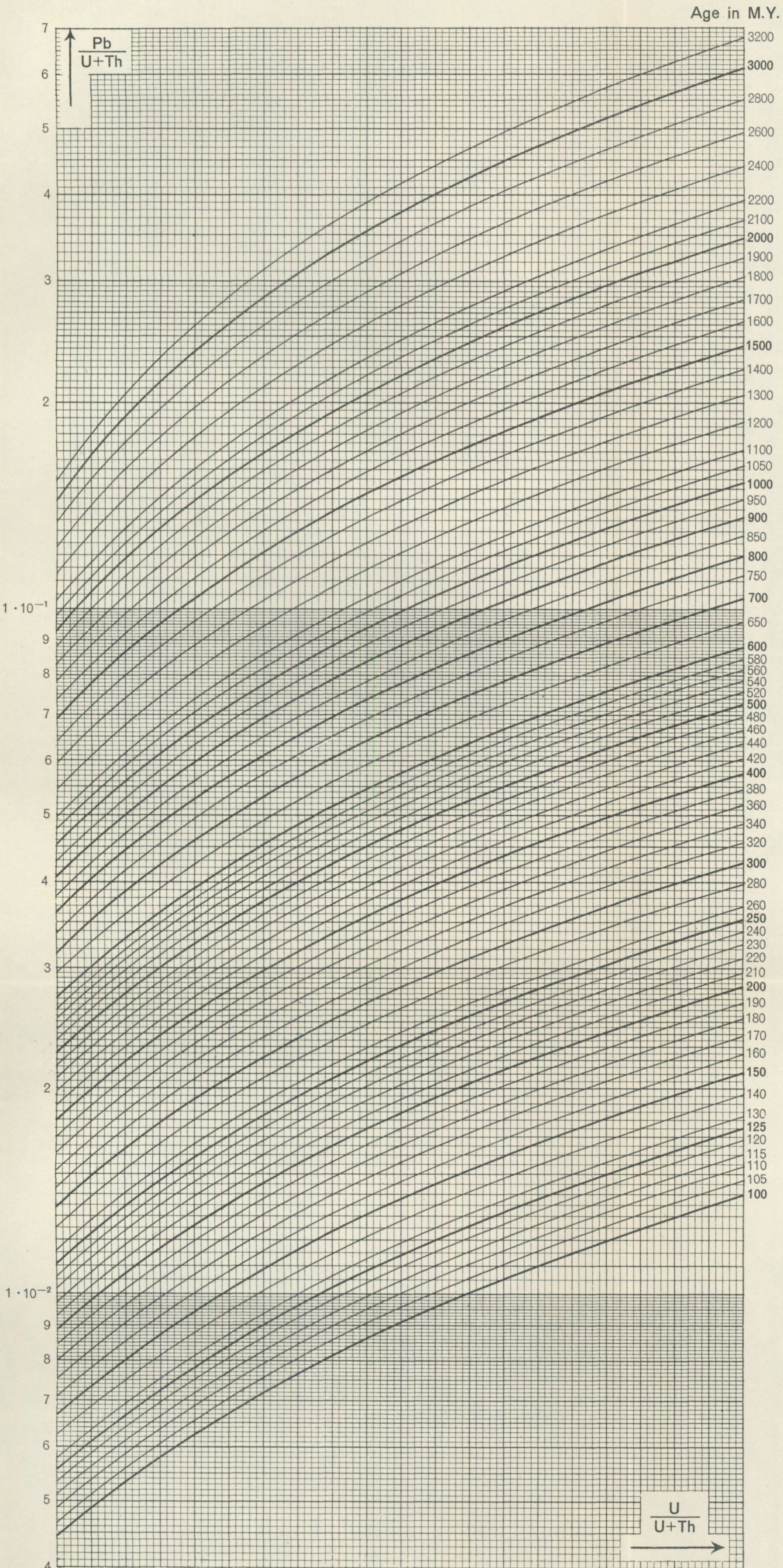

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