

SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C.

Avhandlingar och uppsatser.

N:o 427.

ÅRSBOK 33 (1939) N:o 7.

SOME GRAPHS  
ON THE CALCULATION OF  
GEOLOGICAL AGE

BY

FRANS E. WICKMAN

WITH ONE PLATE



*Pris 0.50 kr.*

STOCKHOLM 1939

KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER

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### Abstract.

Graphs for the calculation of geological age are given, which allow an accuracy in reading of 1 %. The graphs for He-Ra-Th; Pb<sup>206</sup>-UI; Pb<sup>208</sup>-Th; Pb<sup>207</sup>-Pb<sup>206</sup>, have been constructed and are reproduced.

In an interesting paper<sup>1</sup> Norman B. Keevil has made a critical study of old formulas for the calculation of geological age and has replaced them with new approximation formulas, which he has developed from a general equation<sup>2</sup> by expansion of the exponentials.<sup>3</sup> As a result it becomes necessary, in the case of old rocks, to make corrections as to the ages first calculated.<sup>4</sup> This seems impractical, especially as the desired accuracy does not exceed 1 %. It seems better to use graphs, since in this way the numerical calculations are reduced to a minimum.

In constructing the graphs the following principle has been applied: that it shall be possible to calculate the ages below 100 M. Y. (million years) with an accuracy of at least 1 M. Y. and the ages above 100 M. Y. with as a rule an accuracy of 1 %.

The following graphs have been constructed: a) He-Ra-Th, which is primarily intended for the Ra- and Th-percentage appearing in ordinary rocks. b) Pb<sup>206</sup>-UI, Pb<sup>208</sup>-Th, Pb<sup>207</sup>-Pb<sup>206</sup>, which are intended for the calculation of age of radioactive minerals.

No graphs Pb<sub>total</sub>-U-Th and Pb<sub>total</sub>-U have been constructed, since we cannot regard a determination of age according to the lead method without isotop analysis as satisfactory.

The general equation<sup>2</sup> reads:

$$N = n_1 N_{UI} (e^{\lambda_{UI}t} - 1) + n_2 N_{Th} (e^{\lambda_{Th}t} - 1) + n_3 N_{AcU} (e^{\lambda_{AcU}t} - 1) + n_4 \dots$$

where

N = the number of atoms of stable end products of radioactive disintegration formed in any interval of time greater than that required for equilibrium to be established (reached in several thousand years)

n<sub>1</sub> = the number of atoms of the end product resulting from the disintegration of one UI atom after equilibrium is reached in the series

n<sub>2</sub> = similarly the number of atoms arising from the disintegration of one thorium atom

<sup>1</sup> Am. Jour. Sc.-Vol.: 237, No. 3, March, 1939.

<sup>2</sup> l. c. p. 197—198.

<sup>3</sup> l. c. p. 202—206, 212—214.

<sup>4</sup> l. c. p. 206, 212.

$n_3$  = similarly the number arising from the disintegration of one actino-uranium atom

$n_4$  = the number of atoms of endproduct due to other radioactive series, is quite negligible compared to the other terms and need not be considered

$N_{UI}$  = the number of atoms of UI at the present time  $t$

$N_{Th}$  = the number of atoms of Th after time  $t$

$N_{AcU}$  = the number of atoms of AcU after time  $t$

$\lambda_{UI}$  = the disintegration constant of UI

$\lambda_{Th}$  = the disintegration constant of Th

$\lambda_{AcU}$  = the disintegration constant of AcU

a) The He-Ra-Th graph. By inserting constants (table I) in the general equation, so that we get He in cc. and Ra and Th in gm., we get.

$$\frac{\text{He}}{\text{Ra}} = \frac{\text{Th}}{\text{Ra}} \cdot 5.818 \times 10^2 (e^{\lambda_{Th}t} - 1) + 2.681 \times 10^8 [8(e^{\lambda_{UI}t} - 1) + 0.05(e^{\lambda_{AcU}t} - 1)]$$

We note that the equation is linear in He/Ra and Th/Ra. Thus, taking these as variables, we have a system of straight lines, one for each  $t$ -value. These are the lines drawn in the graph for a number of  $t$ -values (plate I; drawn in logarithmic scale). In using the graph one must naturally interpolate between adjacent lines.

Example: We have a rock with He =  $7.76 \cdot 10^{-5}$  cc/gm, Ra =  $1.65 \cdot 10^{-13}$  gm/gm Th =  $0.96 \cdot 10^{-6}$  gm/gm. From these values we get the quotients: He/Ra =  $4.70 \cdot 10^8$  and Th/Ra =  $5.80 \cdot 10^6$ . Reading the age from the graph, we get 860 M. Y. If we calculate the age according to Keevils' equations<sup>1</sup> we get with the simple approximation formula 930 M. Y. With the use of the correction formula this value is changed to 860 M. Y.

b) By inserting constants, so that we get Pb, UI and Th in grams, we get the equations:

$$t = 1.515 \times 10^4 \log_{10} \left( 1 + 1.156 \frac{\text{Pb}^{206}}{\text{UI}} \right) \quad (t \text{ in M. Y.})$$

$$t = 4.62 \times 10^4 \log_{10} \left( 1 + 1.116 \frac{\text{Pb}^{208}}{\text{Th}} \right) \quad (t \text{ in M. Y.})$$

$$\frac{\text{Pb}^{207}}{\text{Pb}^{206}} = R = \frac{1}{138.4} \cdot \frac{e^{\lambda_{AcU}t} - 1}{e^{\lambda_{UI}t} - 1} \quad (t \text{ in years})$$

We note that we have only two variables in each equation. Therefore we can easily construct a graph that gives the connection between  $t$  and the experimentally determined quantity. These graphs are reproduced in fig. 1-3.

<sup>1</sup> l. c. p. 203 and 206.

**Table I.**

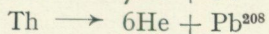
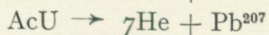
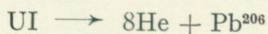
Constants (after Keevil l. c.)

$\lambda_{\text{UI}} = 1.52 \times 10^{-10} \text{ yr}^{-1};$	$T = 4.56 \times 10^9 \text{ yr.}$	UI = 238.1
$\lambda_{\text{AcU}} = 9.72 \times 10^{-10} \text{ yr}^{-1};$	$T = 7.14 \times 10^8 \text{ yr.}$	AcU = 235
$\lambda_{\text{Th}} = 4.99 \times 10^{-11} \text{ yr}^{-1};$	$T = 1.39 \times 10^{10} \text{ yr.}$	Th = 232.12
		Ra = 225.97
		He = 4.002

$$\frac{N_{\text{UI}}}{N_{\text{AcU}}} = 139.0 \pm 1.0; \quad \frac{N_{\text{UI}}}{N_{\text{Ra}}} = 0.95 \frac{\text{UI}}{\text{Ra}}$$

Mol. vol. He = 22,420 cc; Avogadros' number:  $6.02 \times 10^{23}$ 

Reactions:



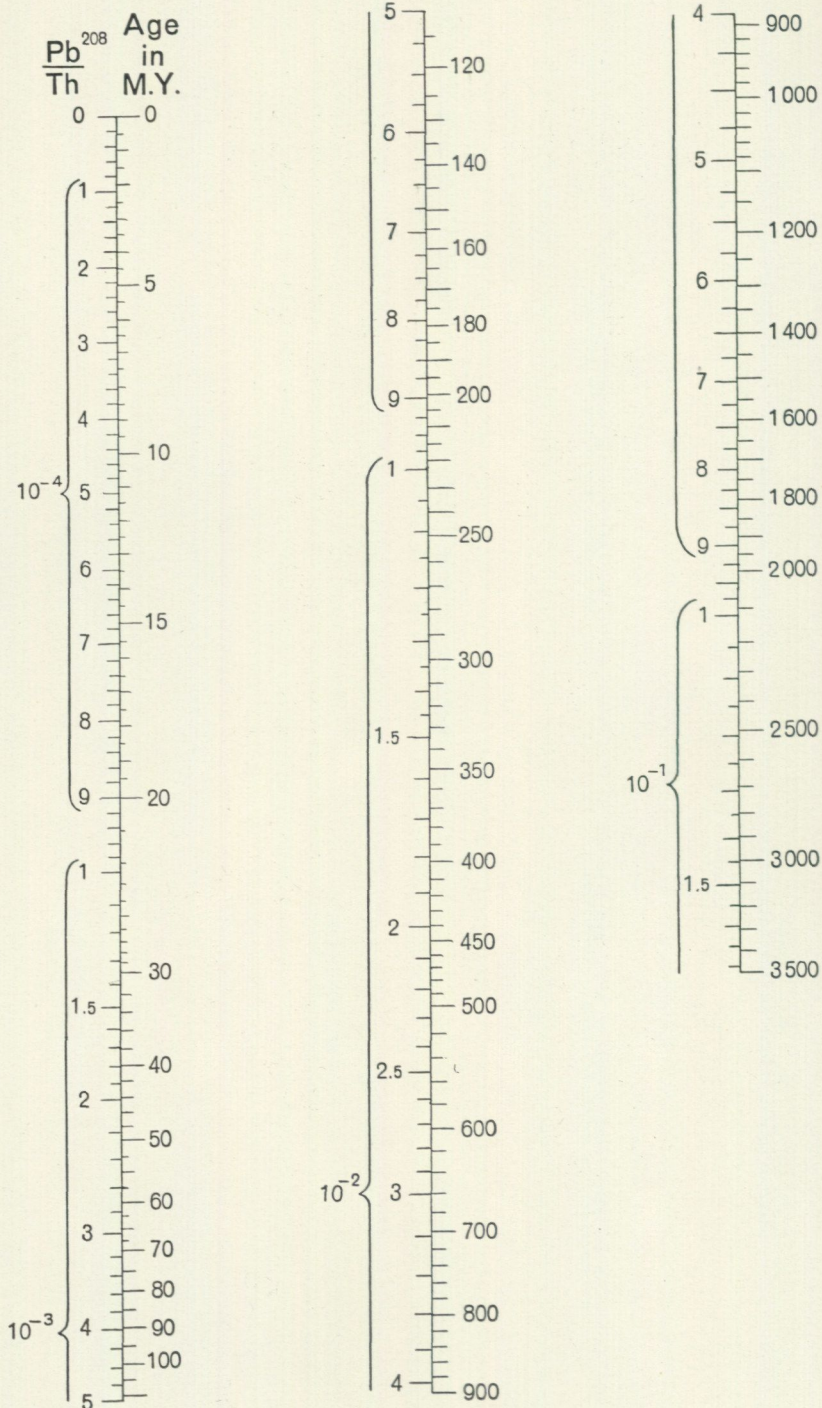


Fig. 1.

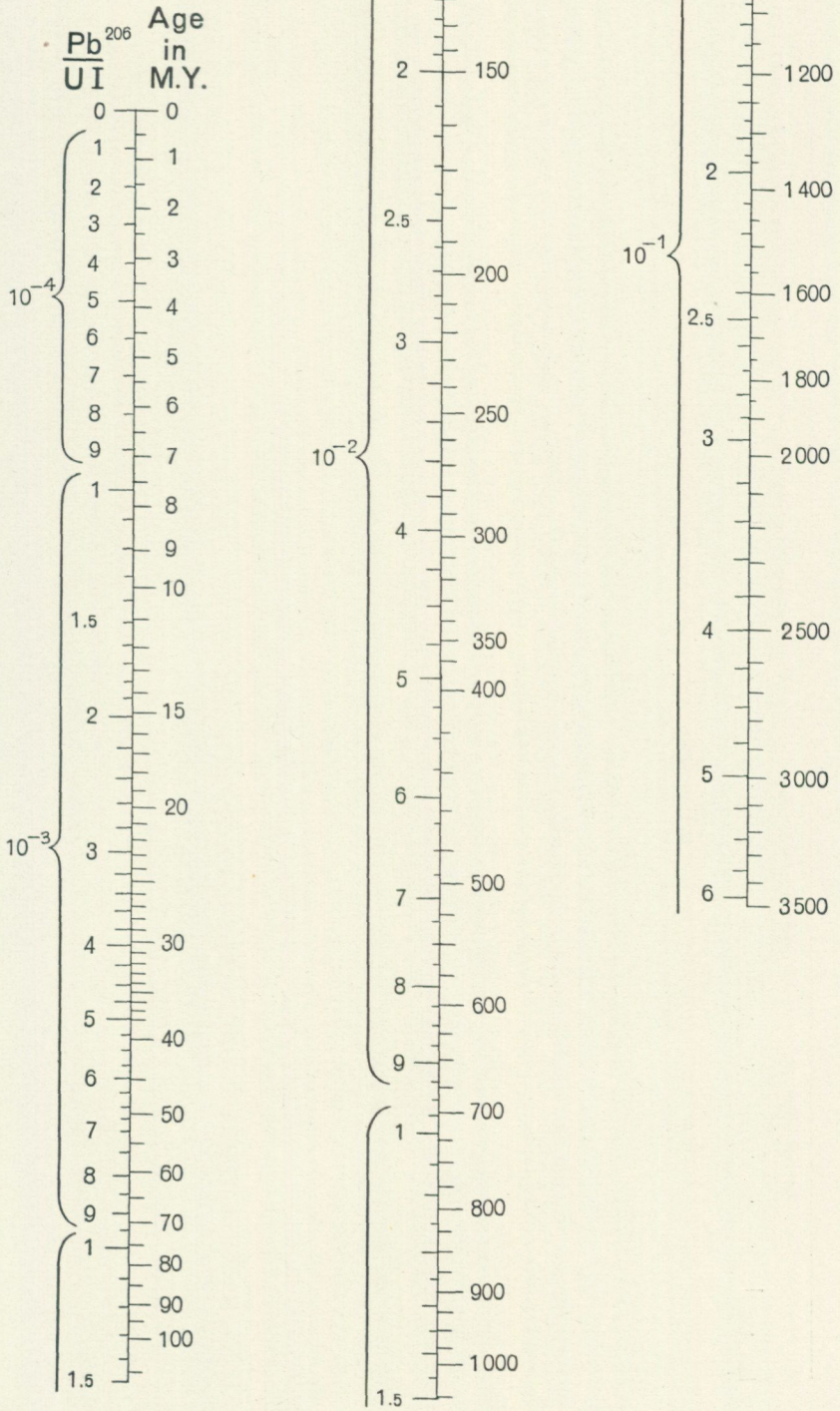


Fig. 2.

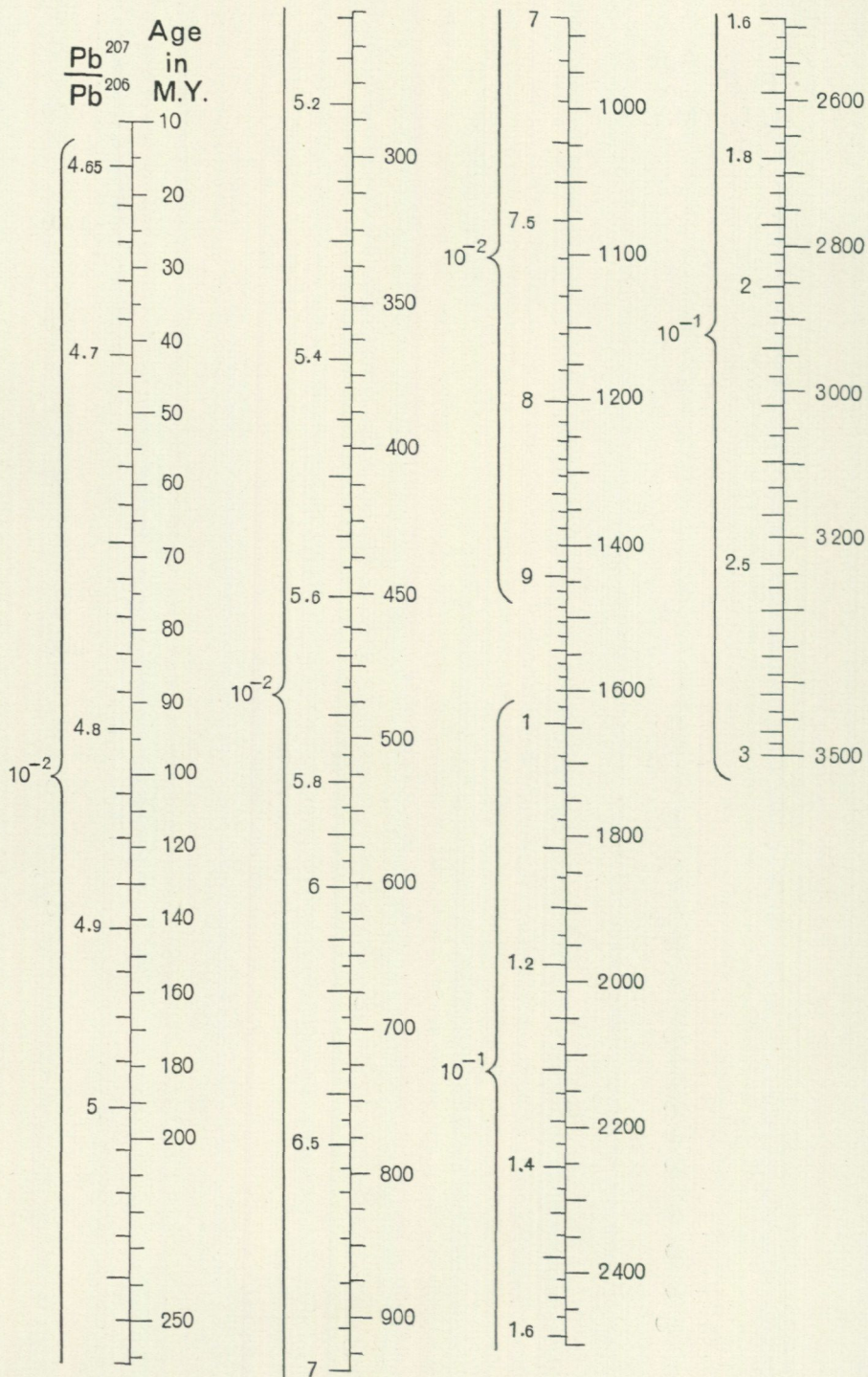
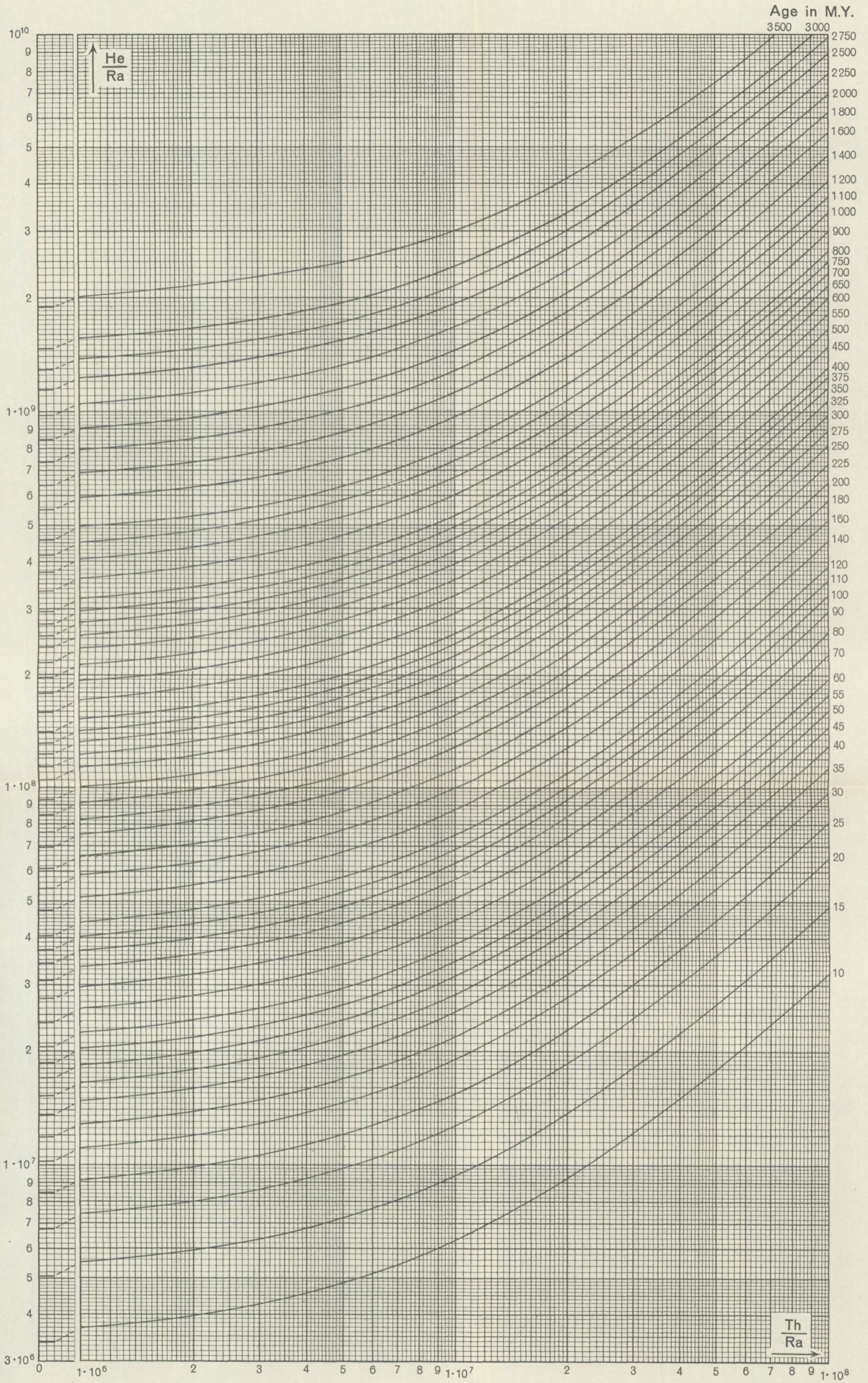


Fig. 3.



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