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RAPID DETERMINATION OF THE APPROXIMATE COMPOSITION OF AMPHIBOLES AND PYROXENES

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ABSTRACT

Published determinative curves for amphiboles and pyroxenes have been recalculated with the use of a Bendix G-15 computer. The new curves are plots of the indices of refraction measured on a (110) cleavage flake and the extinction angle on the flake versus composition. The new curves are suggested for use in rapid reconnaissance of numerous specimens, and as a useful preliminary to more complete measurements.

INTRODUCTION

The use of refractive indices measured on cleavage flakes (n_1 and n_2) for the purpose of identification of rock-forming minerals was early suggested by Tsuboi (1923) for the plagioclase series. Later (1924), Tsuboi presented formulae for calculation of n_1 and n_2 from more fundamental optical and crystallographic parameters for a number of other mineral groups. Tomita (1934) presented additional formulae, and calculated n_1 and n_2 for a number of analyzed pyroxenes. In spite of the fact that the formulae have been available for some time, they have been little used. Pabst (1928, p. 363–367) and Wager and Deer (1939, p. 77–79) used the refractive indices n_1 and n_2 to estimate compositions of amphiboles and pyroxenes respectively. Emmons and Gates revived the use of Tsuboi's plagioclase curve (1948), but the use of n_1 and n_2 for other mineral groups has been limited.

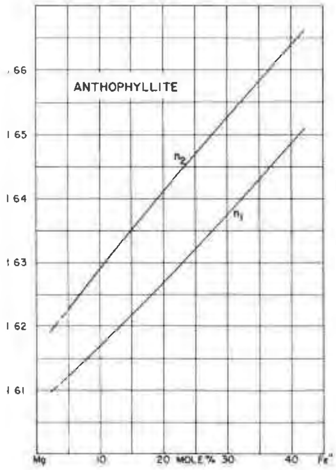
COMPUTATIONS

It may be presumed that calculations have not been made for other mineral groups because of the time consuming nature of the computations. This element of time may now be reduced to a minimum by the use of electronic computers. The results of calculations, shown here as curves, were obtained by use of a Bendix G-15 computer, using the Intercom 500 programming language. Primary data were read from published curves noted in captions accompanying the curves. All results were spot checked with slide rule, desk calculator, and stereographic net. The formulae used are given in the appendix. Values of n_1, n_2, and extinction angle were calculated at 5 per cent composition intervals.

METHOD AND USE OF MEASUREMENTS

Care must be used to select grains which lie on (110). No convenient conoscopic test is possible; but, if small grains of uniform interference

(*Text continued on page 899*)



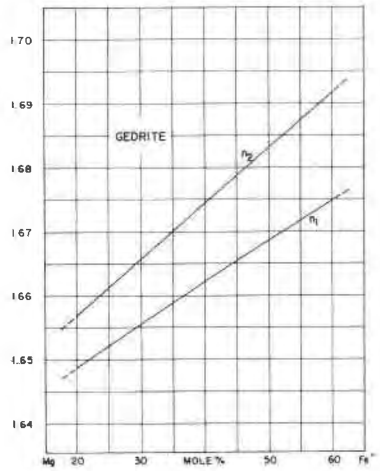


FIG. 1. (Left) The anthophyllite series. Primary data from Tröger (1956, p. 71).
FIG. 2. (Right) The gedrite series. Tröger (1956, p. 71).

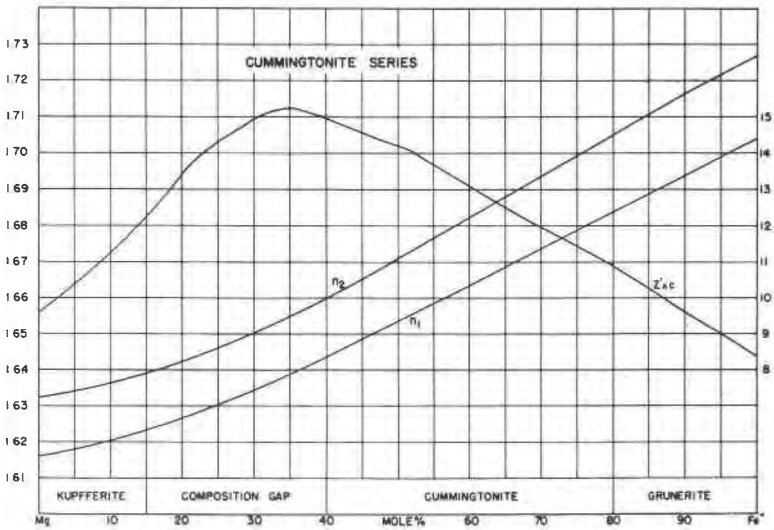


FIG. 3. The cummingtonite series. Winchell (1938, p. 332).

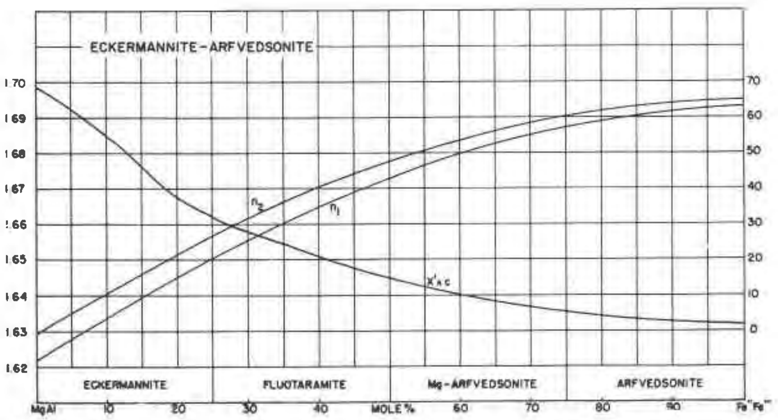


FIG. 4. The eckermannite-arfvedsonite series. Tröger (1956, p. 74).

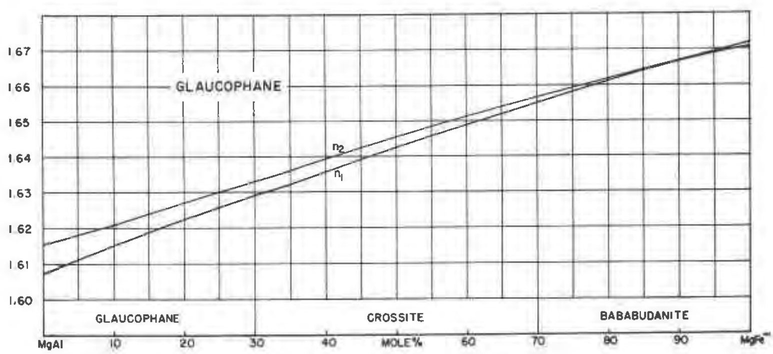


FIG. 5. The glaucophane series. Tröger (1956, p. 73). Values of δ' not given because variation is too slight to be diagnostic.

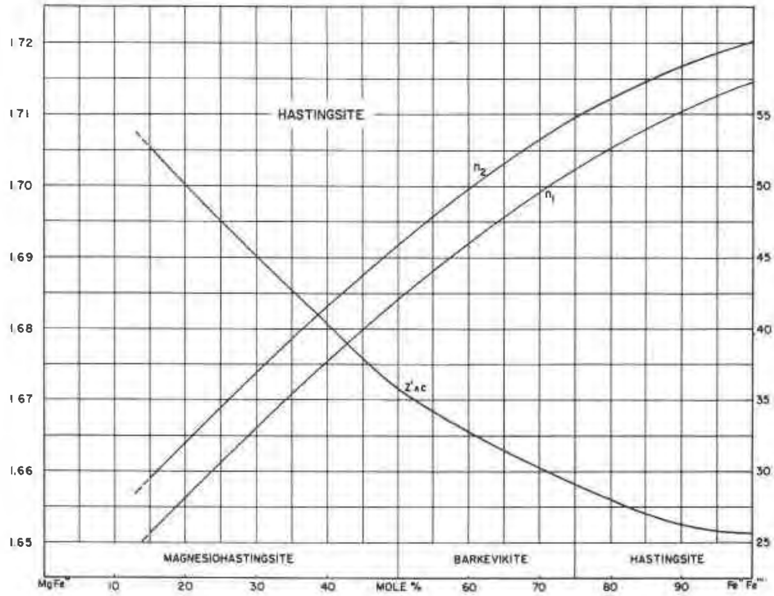


FIG. 6. The hastingsite series. Tröger (1956, p. 75).

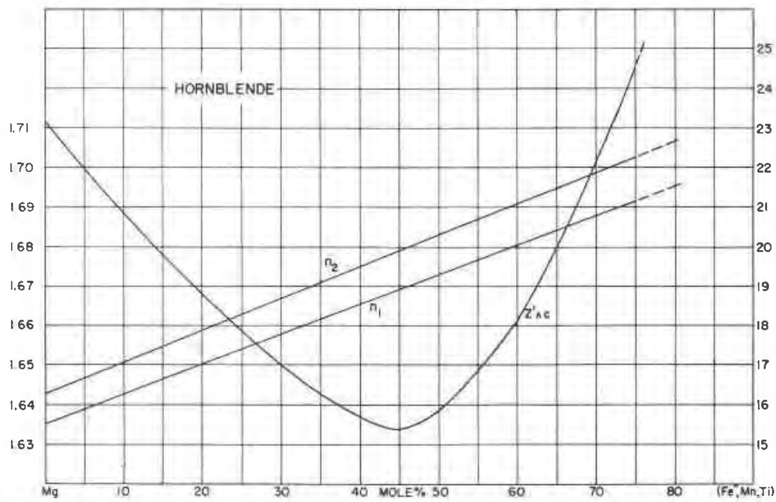


FIG. 7. The hornblende series. Tröger (1956, p. 77).

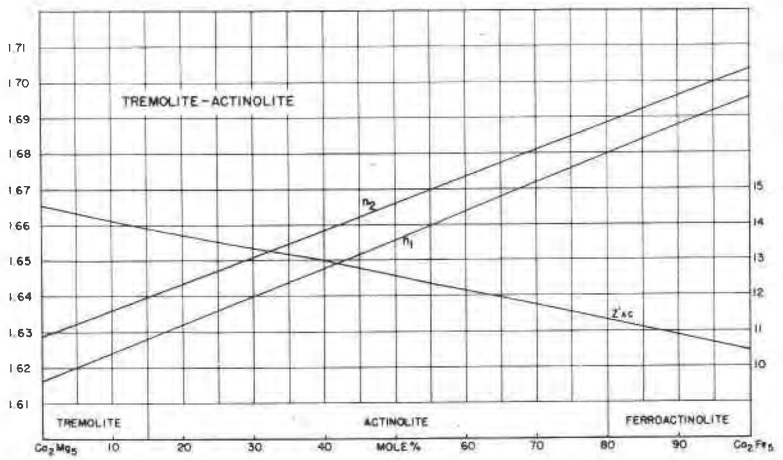


FIG. 8. The tremolite-actinolite series. Tröger (1956, p. 72).

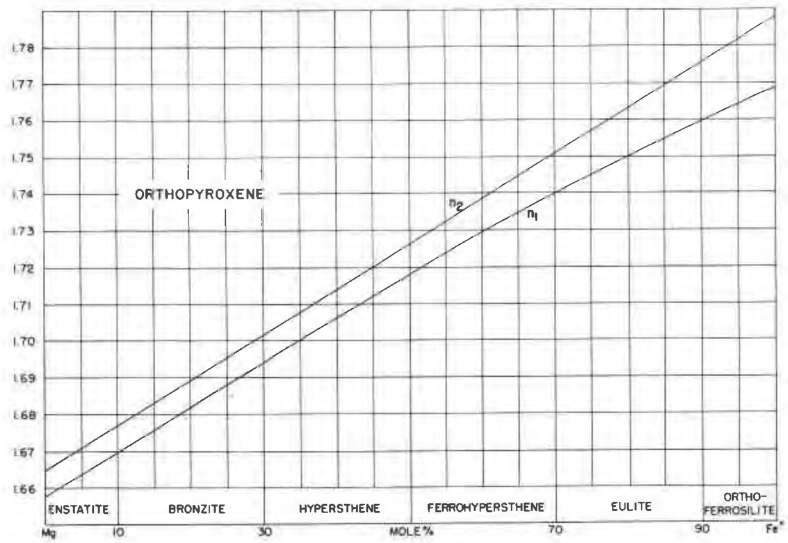


FIG. 9. The orthopyroxene series. Hess (1960, p. 27)

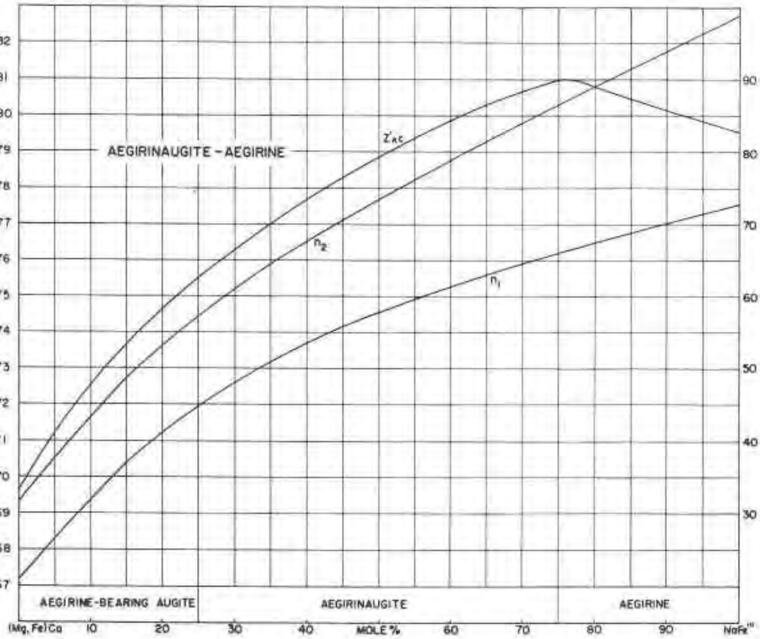


FIG. 10. The aegirinaugite-aegirine series. Larsen (1941, p. 48).

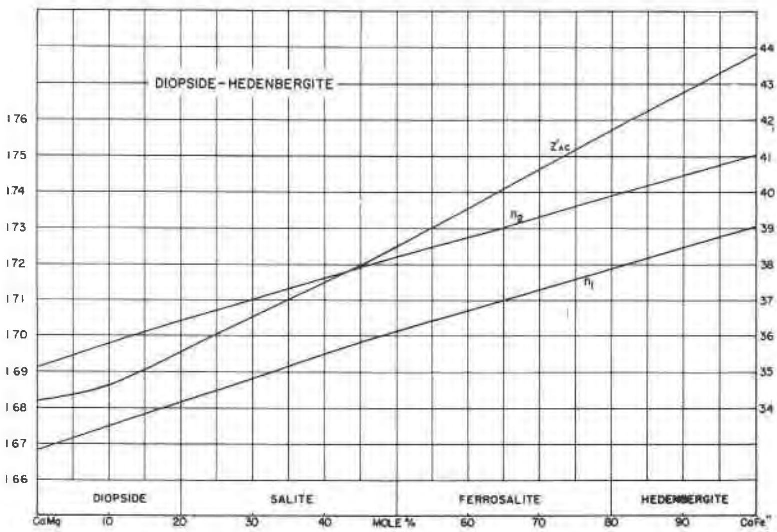


FIG. 11. The diopside-hedenbergite series. Hess (1949, p. 641–642).

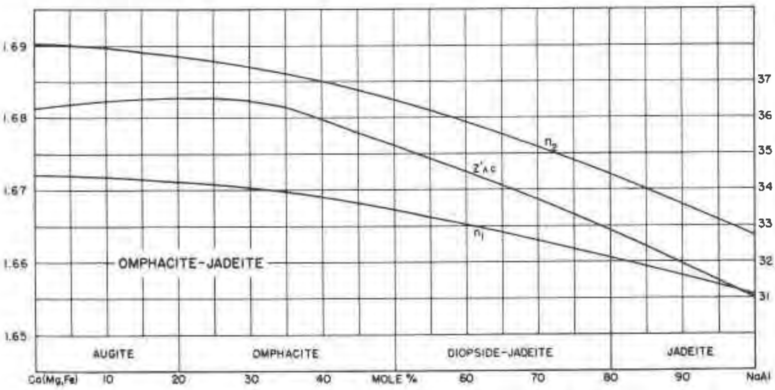


FIG. 12. The omphacite-jadeite series. Tröger (1956, p. 63).

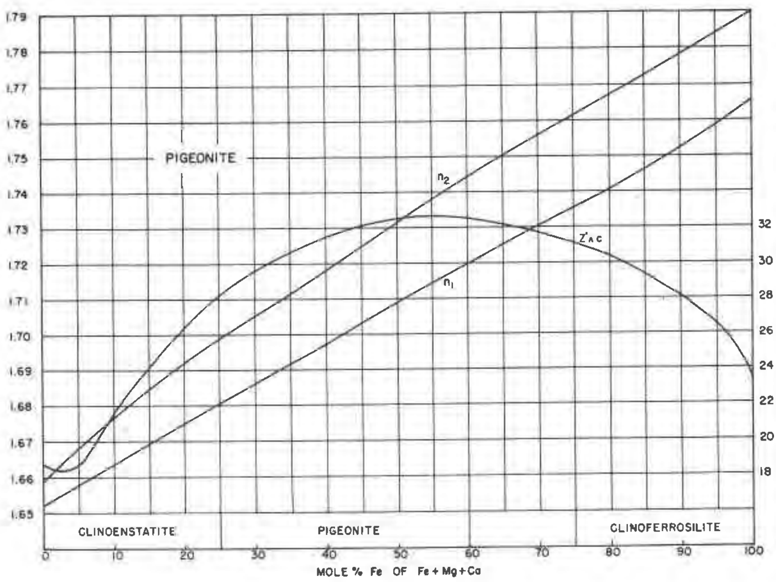


FIG. 13. The pigeonite series. Hess (1949, p. 63).

color are selected, the results are reproducible. It is suggested that composition determinations with these curves would be useful for studies of variation in chemical composition in which a large number of samples are to be studied, and that such determinations would be of value as a preliminary step to more precise (and laborious) determinations by other methods. It is not suggested that measurements of n_1 and n_2 should be considered a substitute for determination of α, β, and γ, and other optical-crystallographic information; since these data should always accompany mineral analyses.

Acknowledgments

The writer is indebted to Professor Adolf Pabst of the University of California, Berkeley for first suggesting the utility of the method. Dr. V. J. Varineau, director of the University of Wyoming Computer Laboratory; and C. R. Dunrud, student at the university, both gave valuable suggestions about programming.

Appendix

Formulae used for computations are as follows: Where the optic plane is parallel to (010) and $b=y$

$$\left.\begin{aligned}(n_1)^2 &= \frac{2\gamma^2\alpha^2}{(\gamma^2+\alpha^2)+(\gamma^2-\alpha^2)\cos(\psi-\psi')}\\(n_2)^2 &= \frac{2\gamma^2\alpha^2}{(\gamma^2+\alpha^2)+(\gamma^2-\alpha^2)\cos(\psi+\psi')}\end{aligned}\right\}\qquad\text{(I)}$$

in which

$$\left.\begin{aligned}\cos\psi &= -\sin(\Omega-\delta)\sin K\\\cos\psi' &= \sin(\Omega-\delta)\sin K\end{aligned}\right\}\qquad\text{(II)}$$

where

$$\Omega = Vz,\qquad \delta = c\wedge z,\qquad K = \perp(110)\wedge b\qquad\text{(Tsuboi, 1924, p. 24).}$$

Where the optic plane is perpendicular to (010) and $b=x$, relation (I) applies with

$$\left.\begin{aligned}\cos\psi &= \sin\Omega\cos K+\cos\Omega\sin K\sin\delta\\\cos\psi' &= -\sin\Omega\cos K+\cos\Omega\sin K\sin\delta\end{aligned}\right\}\qquad\text{(III)}$$

(Tomita, 1934, p. 48).

Where the optic plane is perpendicular to (010) and $b=z$

$$\left.\begin{aligned}(n_1)^2 &= \frac{2\gamma^2\alpha^2}{(\gamma^2+\alpha^2)-(\gamma^2-\alpha^2)\cos(\psi-\psi')}\\(n_2)^2 &= \frac{2\gamma^2\alpha^2}{(\gamma^2+\alpha^2)-(\gamma^2-\alpha^2)\cos(\psi+\psi')}\end{aligned}\right\}\qquad\text{(IV)}$$

in which

$$\left.\begin{aligned}\cos\psi &= \sin\phi\cos K+\cos\phi\sin K\sin T\\\cos\psi' &= -\sin\phi\cos K+\cos\phi\sin K\sin T\end{aligned}\right\}\qquad\text{(V)}$$

where

$$\phi = Vx\qquad T = c\wedge x,\qquad K = \perp(110)\wedge b.$$

For determination of the extinction angle, δ'; where the optic plane is parallel to (010) and $b=y$

$$\delta' = (\theta + \theta')/2 \qquad \text{(VI)}$$

in which

$$\left.\begin{aligned} \tan\theta &= \tan(\delta+\Omega)\cos K \\ \tan\theta' &= \tan(\delta-\Omega)\cos K \end{aligned}\right\} \qquad \text{(VII)}$$

(Tomita, 1934, p. 48).

Where the optic plane is perpendicular to (010) and $b=x$, relation (VI) applies with

$$\left.\begin{aligned} \cos\theta &= \frac{\cos\delta\cos\Omega}{\sin\psi} \\ \cos\theta' &= \frac{\cos\delta\cos\Omega}{\sin\psi'} \end{aligned}\right| \qquad \text{(VIII)}$$

in which ψ and ψ' may be found by relation (III) (Tomita, 1934, p. 48). Where the optic plane is perpendicular to (010) and $b=z$, relation (VI) applies with

$$\left.\begin{aligned} \cos\theta &= \frac{\cos T\cos\phi}{\sin\psi} \\ \cos\theta' &= \frac{\cos T\cos\phi}{\sin\psi'} \end{aligned}\right| \qquad \text{(IX)}$$

in which ψ and ψ' may be found by relation (V).

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