References

ALLRED (A. L.), and ROCHOW (E. G.), 1958. Journ. Inorg. Nuclear Chem., vol. 5, p. 264.
BURNS (R. G.), and STRENS (R. G. J.), 1966. Science, vol. 153, p. 890.
GHOSE (S.), 1965. Min. Mag., vol. 35, p. 46.
STRENS (R. G. J.), 1966. Chem. Communications, p. 519.
WHITTAKER (E. J. W.), 1960. Acta Cryst., vol. 13, p. 291.

Optical properties and composition in the orthopyroxene series

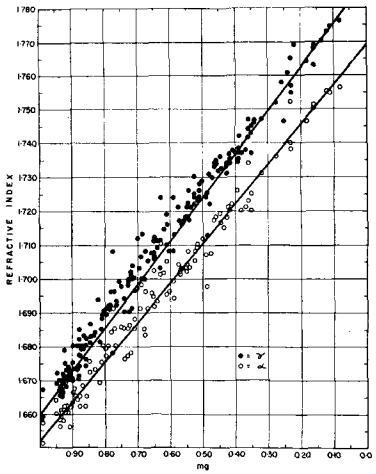
THE general relationship between optical properties and composition in the orthopyroxene series has been well established for some years. Deer *et al.* (1963) have given a recent summary of the previous work and presented new diagrams relating refractive indices, birefringence, and optic axial angle with $mg = Mg^{2+}/(Mg^{2+}+Fe^{3+}+Fe^{2+}+Mn^{2+})$ for 37 selected orthopyroxenes. The refractive indices, specific gravity, and cell sizes of natural En_0Fs_{100}, $En_{50}Fs_{50}$ and $En_{100}Fs_0$ have been calculated by regression both for pure, Al and Ca-free compositions and for compositions including added Al and added Al with Ca (Winchell and Leake, 1965) using over 200 analysed orthopyroxenes.

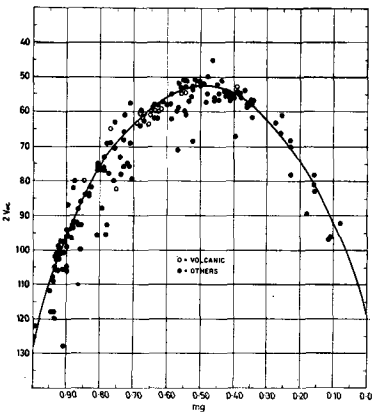
None of the previous diagrams relating composition and optical properties have used more than a small selection of the available data and many do not give the data upon which the correlations are based (e.g. Poldervaart, 1950). It is difficult, therefore, to ascertain the accuracy with which *mg* can be estimated from optical properties. Accordingly the relationship between refractive indices and *mg* was computed for 240 orthopyroxene analyses by reduced major axis regression, using a programme written by P. Harvey.

The results, which are plotted in fig. 1, were $mg = 15{\cdot}315-8{\cdot}661\alpha$ with a standard error of $0{\cdot}07mg$ and $mg = 14{\cdot}082-7{\cdot}870\gamma$ with a standard error of $0{\cdot}05mg$. These lines agree very well with those given by Deer *et al.* (1963). The standard error $= \sqrt{\Sigma(mg-mg_c)^2/(n-1)}$ in which *mg* is the chemically determined *mg*; mg_c is the calculated *mg* from the refractive index and *n* is the number of samples.

A manually drawn line on a plot of optic axial angle against *mg* (fig. 2) is similar to that given by previous workers including Deer *et al.* (1963) except that the inflection is less acute with the lowest $2V_\alpha$ being 52·5° compared with 48·5°. It is, however, significant that the 19 volcanic orthopyroxenes plotted show no consistent difference of 2V

compared with plutonic and metamorphic orthopyroxenes. This is contrary to some previous diagrams (e.g. Kuno, 1954; Deer *et al.*, 1963), which did not include all the available volcanic orthopyroxenes; and because the curve for plutonic and metamorphic orthopyroxenes was





FIGS. 1 and 2: FIG. 1 (left). Plot of 123 α and 205 γ determinations against *mg* ($= Mg^{2+}/(Mg^{2+}+Fe^{2+}+Fe^{3+}+Mn^{2+})$) for orthopyroxenes. FIG. 2 (right). Plot of $2V_{\alpha}$ against *mg* for 19 volcanic orthopyroxenes and 147 other orthopyroxenes.

slightly higher than the present line, this resulted in an apparent discrepancy between the plots from the different environments. It seems, therefore, it is no longer necessary to explain why volcanic orthopyroxenes near to En_{50} in composition should have different 2V from other En_{50} orthopyroxenes when no such difference is apparent for bronzites. The standard error of determination of *mg* from 2V is 0·08*mg*, greater than that obtained using the refractive indices, a fact already generally appreciated.

As the calculated standard errors include errors in the chemical determinations it seems likely that with careful determination of γ, *mg* can be estimated to within 0·03*mg* providing the pyroxene is not abnormal in minor constituents.

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References

DEER (W. A.), HOWIE (R. A.), and ZUSSMAN (J.), 1963. Rock forming minerals, vol. 2, Longmans, Green, London.
KUNO (H.), 1954. Amer. Min., vol. 39, p. 30.
POLDERVAART (A.), 1950. *Ibid.*, vol. 35, p. 1067.
WINCHELL (H.) and LEAKE (B. E.), 1965. *Ibid.*, vol. 50, p. 294.

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An axinite–epidote–tourmaline vein cutting amphibolite, western Connemara, Eire

A quartz–axinite–epidote–plagioclase–tourmaline vein has been found cutting amphibolite of the Ballyconneely mass to the north of Roundstone, in west Co. Galway. The veins are usually 2 to 3 cm wide, and are near, and possibly related to, a large quartz porphyry dyke. The dyke has been intruded along a fault plane, and the veins are parallel to a series of shears in the amphibolite. The intrusion of the dykes was a late phase of the main Galway Granite intrusion (see Leggo, Compston, and Leake, 1966, pp. 93–94). The country rock is a recrystallized, medium-grained, plagioclase–hornblende schist. Some quartz is present in most samples, and retrograde metamorphism has left the assemblage plagioclase–hornblende–quartz–chlorite–epidote. Veins containing much epidote material are common throughout the area, and evidence the local redistribution of material that occurred during the metamorphisms.

The axinite is a manganese-poor variety, pale clove-brown in thin section. The tourmaline and epidote are both iron-rich, and are blue-green and green respectively in thin section. The plagioclase that remains in the veins is extensively altered to a sericite–saussurite aggregate, and its composition cannot be determined by optical means. The quartz is of several generations, some appearing to be extremely late. The petrographic evidence indicates that the following mineral changes have occurred: