books along cleavage traces and that grade into the turbid argillic part of the groundmass (Fig. 1). The blades and fibers range in length from nearly submicroscopic sizes to as much as 2 mm. Maximum width of the blades is about 0.1 mm. The blades and fibers have positive elongation, imperfect nearly parallel extinction, and strong birefringence (about 0.04), and are optically positive with moderate 2V. Locally they show cleavage that is both nearly parallel to and nearly normal to the length of the fibers. N_x is about 1.60, N_z about 1.64.

Comparison of *x*-ray powder films (Fig. 2) of pectolite from the peridotite with films of pectolite from Patterson, New Jersey, confirmed optical identification. *d*- values and intensities of the *x*-ray reflections (Table 1) for both the pectolite from the Hills Pond peridotite and the New Jersey sample proved identical.

Thanks are due Mr. Cecil T. Welch of Toronto, Kansas, who gave the writer permission to log drill core taken under Mr. Welch's supervision and to collect samples from the core.

REFERENCES

Bloxam, T. W. (1954), Rodingite from Girvan-Ballantrae complex, Ayrshire: *Min. Mag.*, **30,** 525–528.

Dana, E. S., and Ford, W. E., (1932) A Textbook of Mineralogy, 4th ed. John Wiley and Sons, Inc., New York.

Mountain, E. D. (1931), Crystals from the Kimberley mines. *Trans. Royal Soc. South Africa,* **20,** 65–78.

Parsons, A. L. (1924), Pectolite and apophyllite from Thetford Mines, Quebec. *Univ. of Toronto Studies, Geol. Ser.,* **17,** 55–57.

Wagner, H. C. (1954), Geology of the Fredonia quadrangle, Kansas. U. S. Geological Survey Map GQ49.

THE AMERICAN MINERALOGIST, VOL. 44, SEPTEMBER-OCTOBER, 1959

A PENETRATION-TWIN IN OLIVINE

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A porphyritic alkali basalt (A.U. thin-section 3560) from Khyber Pass, Auckland, contains numerous euhedra of olivine set in a finely felted groundmass of plagioclase, pyroxene, magnetite and glass. The olivine phenocrysts range in size up to 0.9 by 0.5 mm. and vary in composition from Fo_{84} to Fo_{90}. Their habit is fairly constant, the commonest combination of forms being $\{010\}+\{110\}\pm\{120\}$, together with $\{101\}+\{021\}$. True twinning was observed only in the one grain herein described, but the thin-section also contains euhedral olivine with "translation lamellae" oriented parallel to (100).

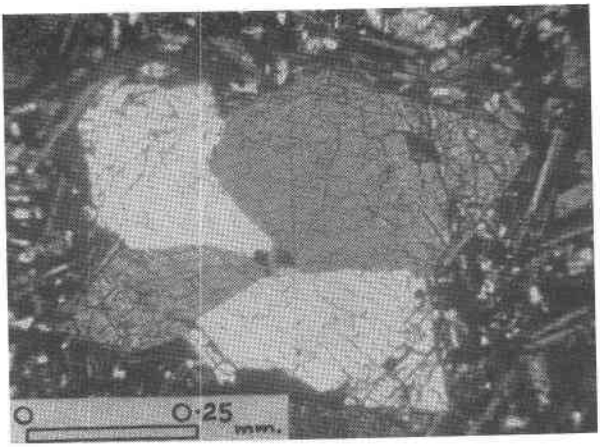

FIG. 1. Photomicrograph of olivine penetration-twin.

The penetration-twin has developed in a grain which, under crossed nicols, clearly consists of two idiomorphic individuals of approximately equal size (Figs. 1 and 2). The plane of the thin-section is almost normal to the Z vibration direction (=*a*) common to both individuals, so that the faces shown in Figs. 1 and 2 lie in the common zone [100]. Measurements around this zone reveal a slight difference in habit, for individual 1 displays the forms {010}+{021} whereas individual 2 contains {010}+{021}+one face of {001}. In both individuals there is an imperfect (010) cleavage and a distinct (001) parting.

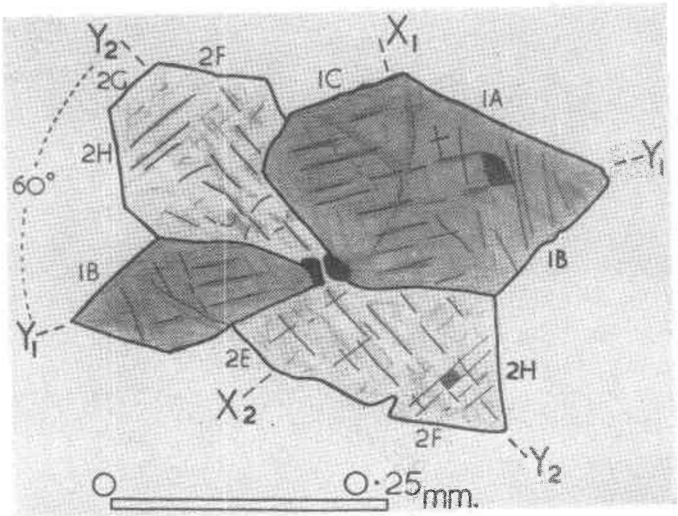

FIG. 2. Camera lucida drawing from Fig. 1, with face labels and optical directions. 1A—(021), 1B—(021), 1C—(010), 2E—(010), 2F—(021), 2G—(001), 2H—(021).

A stereographic lower hemisphere plot of the optical directions within the penetration-twin is given in Fig. 3. The two sub-individuals 1 and 2 in the twin share a common Z ($=a$) vibration direction, with the result that on the plot $Z_1=Z_2$ while X_1Y_1 and X_2Y_2 lie on the great circle normal to Z_{1-2}. The degree of rotation of X_1 from X_2 and of Y_1 from Y_2 was measured as 60°, with an estimated manipulative error of $\pm 1°$. Face poles have also been inserted on Fig. 3. On the universal stage there is potentially a serious tilt error involved in the location of such face normals, but nevertheless the pole plots are quite close to the angular dispositions listed by Dana (1949, p. 597) for rational faces in this zone.

The stereographic plot shows that the twinning axis (labelled TA) must lie in the common zone [100] and make an angle of $30° \pm 1°$ with both Y_1 ($=c_1$) and Y_2 ($=c_2$). Assuming an axial ratio close to $a:b:c=0.46:1:0.59$ of forsteritic olivine and utilizing Dana's (1949, p. 597) interfacial angles, the pole of the twin axis coincides on the stereogram with the theoretical position of the face pole for (011). The law is thus twin axis $=\perp(011)$ or twinning plane $=(011)$. A similar twin for olivine has been reported in Dana's System (1909, p. 452).

The limitation of rotation, in this case 60°, in the zone [100] is imposed by the structure parallel to (100). Projection of the structure of olivine

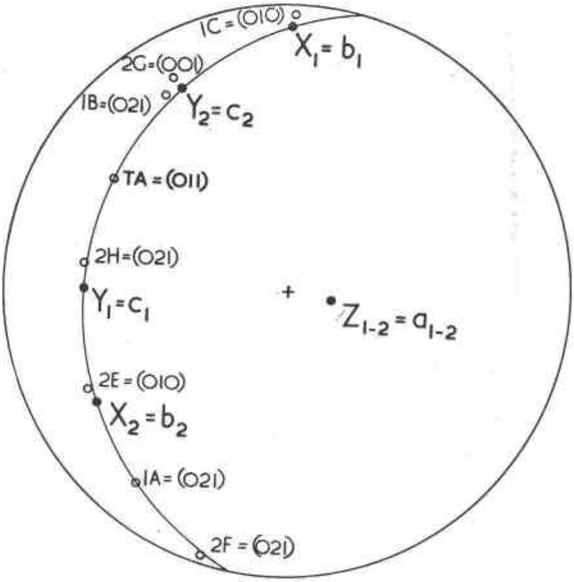

FIG. 3. Lower hemisphere projection of optical directions and face poles for the penetration-twin.

shows that a pseudohexagonal symmetry exists *within the tetrahedra* in the plane of (100), the atomic structure being similar in the trace directions of (001), (031) and ($0\bar{3}1$). Alternative structures can therefore be built upon these planes which lie at an angle of 60° to each other.

References

Dana, E. S. (1949), *A Textbook of Mineralogy.* New York: John Wiley and Sons, 4th edition.

Dana, J. D. (1909), *System of Mineralogy.* New York: John Wiley and Sons, 6th edition.

THE AMERICAN MINERALOGIST, VOL. 44, SEPTEMBER–OCTOBER, 1959

COMPROMISE GROWTH SURFACES ON PEGMATITE MINERALS

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Many crystals of pegmatite minerals display growth surfaces that form polygonal, step-sided pyramids. These are the "roots" of the crystals; the other parts display normal development, commonly with euhedral terminations. A search of available geological literature has failed to reveal a satisfactory explanation of this phenomenon.

The explanation offered here is that these anomalous pyramidal surfaces are the result of simultaneous growth of two adjacent crystals with different growth velocities. This process was described by Johnsen (1923) and is reviewed in Buckley (1951, p. 125–128).

Consider that crystal A, with growth velocities V and V', has reached the stage shown in Fig. 1*a*, and crystal B, with growth velocities v and v' first begins to develop at point x. At some time later the two crystals have reached the stage shown by the solid lines in Fig. 1*b*, in which crystallization of crystal A has continued after crystal B has ceased to grow. The angles that the sides of crystal B make with the growth directions are ϕ and ϕ', and simultaneous growth has taken place over the common distance S.

The resultant surfaces on crystal B are not in any rational way related to the axial systems of either crystal. They are called *compromise* surfaces and are the result of compromises between the relative growth velocities of the two substances.

If, for some reason, growth of crystal A ceased before crystal B ceased growing, crystal B could then terminate euhedrally outside crystal A (Fig. 1*c*). This is the situation occasionally encountered in pegmatites. In such examples the angle ϕ' cannot be measured. The only example in which ϕ' can be measured is that in which crystal B stops growing, even if only for a brief period, while growth of crystal A continues.