

Etching of Pyroxenes and Their Exsolution Lamellae

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Abstract

Hydrofluoric acid fumes tarnish the polished surface of augite a dark brown and pigeonite a pale brown, whereas orthopyroxene is virtually unaffected. These differences aid in the study of exsolution lamellae in these pyroxenes.

During a study of the pyroxenes from a quartz-diorite dike in eastern Connecticut, etching of polished thin sections with hydrofluoric acid was found to produce striking contrasts between grains of pigeonite, augite, and orthopyroxene when observed in reflected light. These etch differences proved very useful in bringing out exsolution lamellae that were otherwise undetected in most specimens unless X-ray work was done. Contrast between the host pyroxene and the lamellae in transmitted light, such as that illustrated by Robinson *et al* (1971), was not obtained in these specimens. With the exception of partially weathered samples, exsolution was not detected in thin sections or grain mounts.

Polished thin sections are placed over concentrated hydrofluoric acid for 10 to 15 minutes and then washed with distilled water and allowed to dry. Samples must be kept within a few millimeters of the surface of the acid, otherwise no contrast is produced between the different pyroxenes. The exact colors produced depend on the duration of the etch and the thickness of the films developed. Augite has the thickest film and appears brownish in reflected light. Pigeonite is paler and, because of the thinness of the film, often has distinctive interference colors. Orthopyroxene is white and appears virtually unaffected by the hydrofluoric acid fumes.

Although this etching technique was found useful in giving a rapid means of distinguishing pigeonite from augite, its real value is in the identification of exsolution lamellae. Single crystal X-ray work can be done to identify the lamellae, but this is time consuming and provides little textural information. The electron probe can also be used, but this often gives only qualitative results since the lamellae are commonly too fine to be resolved by the electron beam.

Pigeonite in the Connecticut dike was first iden-

tified optically and was thought to be homogeneous as there is no sign of exsolution in thin sections. However, etching revealed the presence of abundant, approximate (001) lamellae (Robinson *et al*, 1971) of material that etched similarly to coexisting augite (Fig. 1B). Single crystal X-ray work confirmed the identification of these lamellae as augite. Similarly, the augite grains in these rocks appear homogeneous, but etching shows them to contain approximate (001) lamellae of pigeonite (Fig. 1A). The augite contains no lamellae of orthopyroxene even though this mineral occurs as a coexisting phenocrystic phase.

The margins of large orthopyroxene grains in the central part of the dike contain intergrown clinopyroxene which forms either the typical "inverted pigeonite" texture or a more graphic intergrowth referred to by Hess (1960, p. 34) as exsolution of the Palisades type. These are too fine to make any standard optical measurements practicable, but etching reveals that some of this intergrown material is augite and some is pigeonite. In addition, both the augite and pigeonite contain approximate (001) lamellae of the other with spacings similar to those in independent grains of these minerals in the same rock (Fig. 1C). Although X-ray work confirmed the identification of these phases, it was the etching that revealed the relationships between them.

The pyroxenes from this dike all have Mg/(Mg + Fe) ratios in excess of 0.5. In testing the applicability of the technique to pyroxenes of different compositions and origins, two metasedimentary rocks containing both augite and orthopyroxene, one from Coventry, Connecticut, and the other from Grenville township, Quebec, were etched. These pyroxenes with Mg/(Mg + Fe) ratios of approximately 0.5 behaved in the same manner as the more

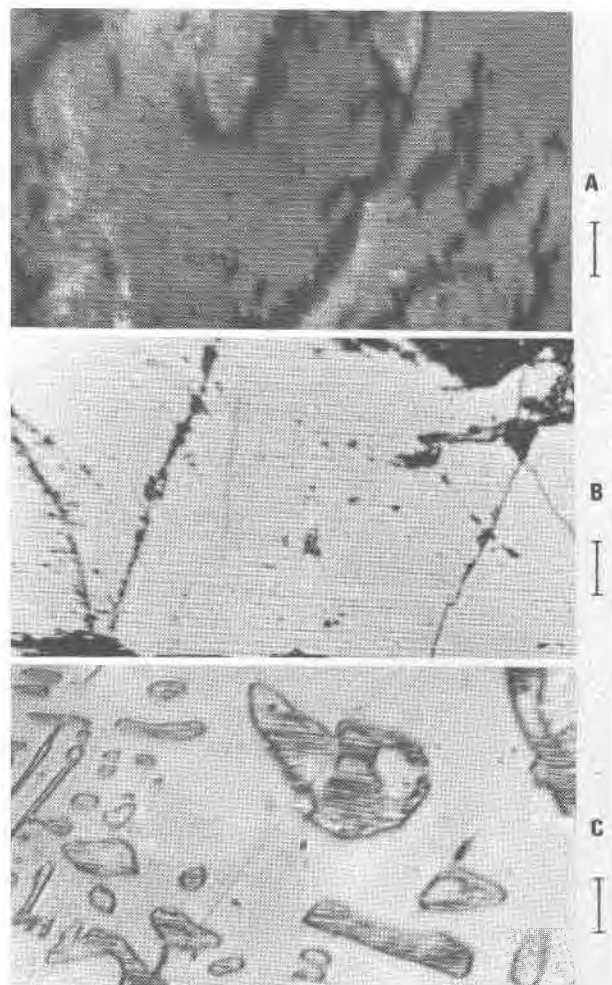


FIG. 1. A. Etched surfaces of augite with pigeonite lamellae;

B. Pigeonite with lamellae of augite;
 C. Orthopyroxene containing blebs of augite which in turn contain lamellae of pigeonite.
 All specimens are polished thin sections viewed under reflected light. Scale bar = 10 μ m.

magnesian ones from the diabase, and in addition, the augites were found to contain (100) lamellae of orthopyroxene which appear under reflected light as white streaks against a dark iridescent background.

There has been much discussion concerning the nature of lamellae in bronzites of the Bushveld type. Hess and Phillips (1938) attributed these to exsolution of a high calcium clinopyroxene, Henry (1942) to strain, and Boyd and Brown (1969) to exsolution of a phase that is not as calcium-rich as augite. Although electron microscopy indicates the presence of 1000 Å wide lamellae of augite in Stillwater bronzite (Champness and Lorimer, 1972), it is not clear that these are entirely responsible for the lamellar structure in which lamellae can be up to a micron or two in width. Etching of Stillwater bronzite indicates that although lamellae of augite are present, the main lamellar structure produces no etch differences, suggesting little if any compositional difference between lamellae.

References

- BOYD, F. R., AND G. M. BROWN (1969) Electron-probe study of pyroxene exsolution. *Mineral. Soc. Amer. Spec. Pap.* **2**, 211–216.
- CHAMPNESS, P. E., AND G. W. LORIMER (1972) Exsolution in an orthopyroxene. *Geol. Soc. Amer., Abstracts Programs*, **4**, 468.
- HENRY, N. F. M. (1942) Lamellar structure of orthopyroxenes. *Mineral. Mag.* **26**, 179–188.
- HESS, H. H. (1960) Stillwater igneous complex, Montana. *Geol. Soc. Amer. Mem.* **80**.
- , AND A. H. PHILLIPS (1938) Orthopyroxenes of the Bushveld type. *Amer. Mineral.* **23**, 450–456.
- ROBINSON, P., H. W. JAFFE, M. ROSS, AND C. KLEIN (1971) Orientation of exsolution lamellae in clinopyroxenes and clinoamphiboles: Consideration of optimal phase boundaries. *Amer. Mineral.* **56**, 909–939.

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