Smith, G. F. H., and G. T. Prior (1911) On fermorite, a new arsenate and phosphate of lime and strontia and tilasite, from the manganese-ore deposits of India. *Mineral. Mag.* **16**, 84–96.
Strunz, H. (1937) Titanit und Tilasit. *Z. Kristallogr.* **96**, 7–14.
Williams, S. A. (1970) Tilasite from Bisbee, Arizona. *Mineral. Rec.* **1**, 68–69.
Zachariasen, W. (1930) The crystal structure of titanite. *Z. Kristallogr.* **73**, 7–16.

American Mineralogist
Vol. 57, pp. 1884–1889 (1972)

DEVELOPMENT OF (120) PRISM FACES OF NATURAL TOPAZ

M. S. Joshi and R. K. Taku,
Department of Physics, Sardar Patel University, Vallabh Vidyanagar, Gujarat State, India.

Abstract

Growth hillocks observed on (120) prism faces of natural topaz crystals are illustrated. Their formation follows a sequential order: triangular, trapezium-shaped and finally semi-circular. Natural etch pits have outlines similar to the growth pyramids. The same sequential development of etch pits is established by controlled laboratory etching. From the observations of growth forms and etch pits the mechanism of development and growth of (120) prism faces of natural topaz crystals is worked out.

Introduction

Microtopographical studies of habit faces of crystals often prove useful in understanding the mechanism of development and growth of such faces in particular, and of crystals in general. In addition, if study is also made of laboratory etching on such faces, it might help to understand better the mechanism of growth. Fruitful attempts have been made by Joshi and Kotru (1968). The present paper is a report of such studies in the case of (120) faces of natural topaz crystals.

The crystal faces were thoroughly cleaned and were coated with silver films in a vacuum coating unit and were then examined under a metallurgical microscope. Occasionally, use was also made of the electron microscope.

In the present investigation, the hydrothermal etching technique exploited by Joshi and Kotru (1969), and Joshi *et al.* (1970) for quartz crystals was employed to advantage. The crystal faces under study were etched in steam in a steel bomb at 310°C for about 12 hours. The pressure under these conditions was estimated to be about 100 bars.

Observations and Discussion

Examination of (120) faces of natural topaz crystals revealed the presence of trapezium–shaped growth hillocks (Fig. 1a). On some faces tetragonal growth hillocks were also observed (Fig. 1b). Both varieties of hillocks reported here are strictly oriented and have their longer sides parallel to *c*. Occasionally ellipitical growth hillocks with their major axes parallel to *c* were also observed (Fig. 1c). According to Buckley (1951) all natural hillocks should be treated as produced by growth when they show a degree of symmetry corresponding to that of faces. The hillocks reported here, in fact, fit in well with the symmetry of the face on which they occur.

Some faces revealed the presence of strictly oriented, densely populated trapezium–shaped and semi–circular natural depressions (Fig. 1d). In isolated regions very tiny triangular depressions were observed (Fig. 2a). Figure 2b, an electron micrograph, shows closely–spaced triangular depressions. We suggest that all these depressions are etch pits formed due to natural etching.

In order to understand the origin of these natural etch pits, etching experiments were carried out on some of the (120) faces which were found to be devoid of any structures. Crystal faces were etched in steam, as described. Etch pits thus produced are illustrated in Figure 2c. Both trapezium–shaped and semi–circular pits were obtained, and may be compared with those shown in Figure 1d. Figure 2d also shows tiny triangular etch pits. These may be compared with those illustrated in Figure 2a. The above described natural depressions and etch pits have their bases strictly parallel to *c*.

In our etching experiments we have found that in the early stage of etching, triangular pits alone are obtained which are small to begin with. On further etching these tiny triangular pits grow deeper and wider and as a result there is intergrowth of pits. We believe that intergrowth of pits along the normal to *c* causes their vertices to be truncated, resulting eventually in trapezium–shaped pits. With further progress of etching the corners of trapezium–shaped pits get truncated and finally become smooth and round, leading to almost semi–circular pits. In light of these observations, we suggest that etch pits found on naturally etched crystal faces should have been formed in nature in the same sequential manner, *viz.* triangular, trapezium–shaped and semi–circular. We accept that mechanism of etching is the reverse of

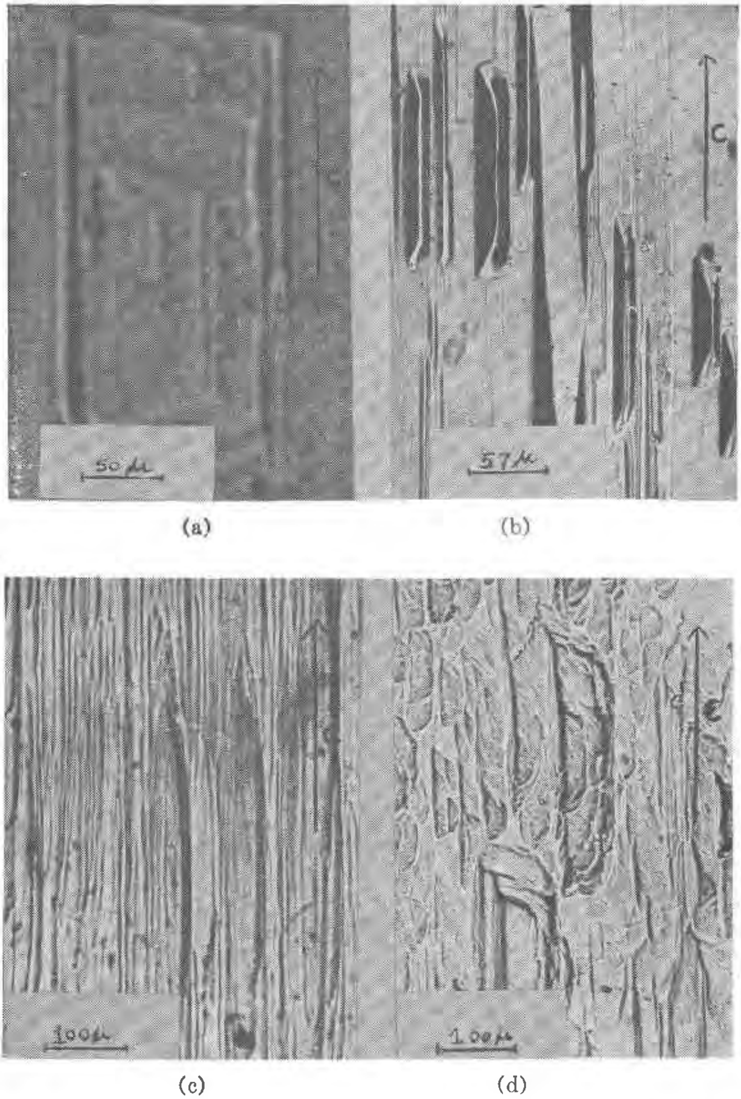

Fig. 1. Growth hillocks and natural pits: (a) a trapezium-shaped growth hillock; (b) tetragonal growth hillocks; (c) elliptical growth hillocks; (d) semi-circular depressions.

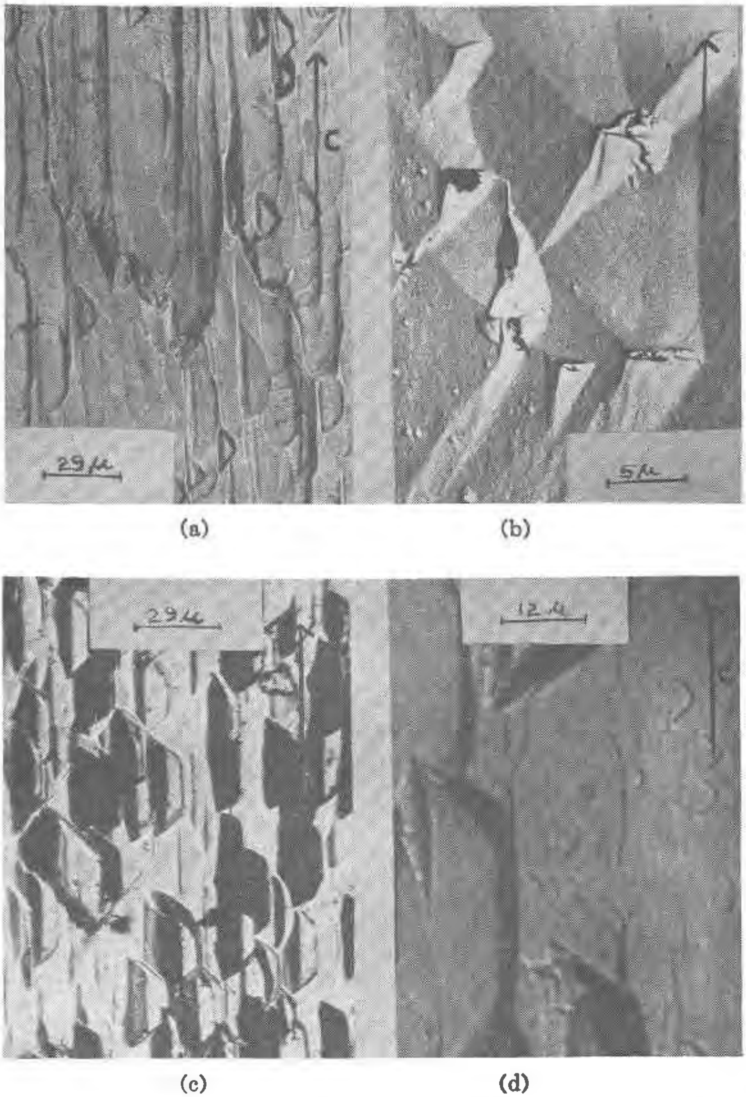

FIG. 2. Natural and hydrothermal etch pits: (a) tiny triangular depressions in isolated regions; (b) closely spaced triangular depressions at a higher magnification; (c) trapezium-shaped and semi-circular etch pits due to hydrothermal etching; (d) tiny triangular hydrothermal etch pits in isolated regions.

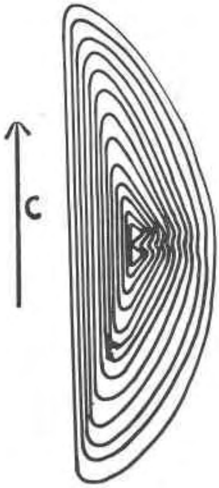

FIG. 3. A schematic diagram illustrating formation of almost semi-circular growth hillocks.

that of growth as suggested by Johnston (1962) and we advocate that the similar mechanism in the same sequential order is responsible for the formation of growth hillocks reported here. We have, in fact, observed tiny triangular growth hillocks on these faces. Such triangular growth hillocks later on turn into trapezium-shaped and finally result in semi-circular growth hillocks. Formation of hillocks in this sequential manner is attributed to interaction of triangular growth hillocks in a direction normal to *c*. Another possible mechanism of formation of a semi-circular growth hillock as a result of lateral interaction of two neighbouring triangular growth hillocks is schematically represented in Figure 3. Both the types of mechanisms are probable.

These faces should have grown and developed by two dimensional spreading and piling up of growth sheets on (120) faces; these sheets, being triangular in outline to begin with, become trapezium-shaped with the progress of growth and finally semi-circular, giving rise to growth hillocks reported here. The sequential development of etch pits produced by laboratory etching substantiates our proposed explanation for the mechanism of formation and development of growth hillocks and hence the mechanism of growth and development of (120) faces of natural topaz crystals.

ACKNOWLEDGMENTS

R. K. T. wishes to thank U. G. C., Government of India, for financial assistance.

References

Buckley, H. E. (1951) *Crystal Growth.* Wiley, New York.

Johnston, W. G. (1962) Dislocation etch pits in non-metallic crystals. *In* J. E. Burke, ed., *Progress in Ceramic Science, v. 2.* Pergamon Press, New York.

Joshi, M. S., and P. N. Kotru (1968) Hillocks on first-order prism faces of synthetic quartz. *Amer. Mineral.* **53**, 825–939.

———, and ——— (1969) Hydrothermal etching of matched fractured prism faces of quartz. *Kristallogr.* **14**, 516–518. [Transl. *Sov. Phys. Crystallogr.* **14**, 427–428].

———, ———, and M. A. Ittyachen (1970) Hydrothermal etch method to study dislocations in quartz. *Kristallogr.* **15**, 103–111. [Transl. *Sov. Phys. Crystallogr.* **15**, 83–89].

American Mineralogist
Vol. 57, pp. 1889–1893 (1972)

TREMOLITE WITH HIGH RICHTERITE–MOLECULE CONTENT IN KIMBERLITE FROM BUELL PARK, ARIZONA

Ken–ichiro Aoki,
Institute of Mineralogy, Petrology and Economic Geology, Tohoku University, Sendai, Japan

and

R. V. Fodor, Klaus Keil, and Eric Dowty,
Department of Geology and Institute of Meteoritics, The University of New Mexico, Albuquerque, New Mexico 87106, U.S.A.

Abstract

Tremolite of a composition suggesting solid solution between the ideal end members tremolite and richterite occurs in kimberlites from Buell Park, Arizona. Analysis by electron microprobe gave SiO_2 57.9, TiO_2 0.05, Al_2O_3 1.1, Cr_2O_3 0.06, FeO 2.4, MnO 0.07, MgO 23.5, CaO 10.8, Na_2O 2.3, K_2O 0.51, F 0.35, $-O = F$ 0.15, total 98.89, corresponding to 57 mol % tremolite, 31 mol % richterite, and 12 mol % other amphibole components. The structural formula is $(Na_{0.288}K_{0.088})(Ca_{1.574}Na_{0.319})(Mg_{4.763}Fe^{2+}_{0.273}Mn_{0.008}Cr_{0.007}Ti_{0.005}Al_{0.051})(Al_{0.125}Si_{7.875})O_{23}$. Space group is $C2/m$, cell parameters are $a = 9.876 \pm 0.002$, $b = 18.065 \pm 0.005$, $c = 5.281 \pm 0.002$Å, $\beta = 104°40' \pm 1'$, $V = 911.4 \pm 0.3$Å^3. The mineral apparently formed as a primary phase in a kimberlite magma under upper mantle conditions.

The possible presence of amphibole as one of the most important hydrous minerals in the upper mantle has been suggested by many