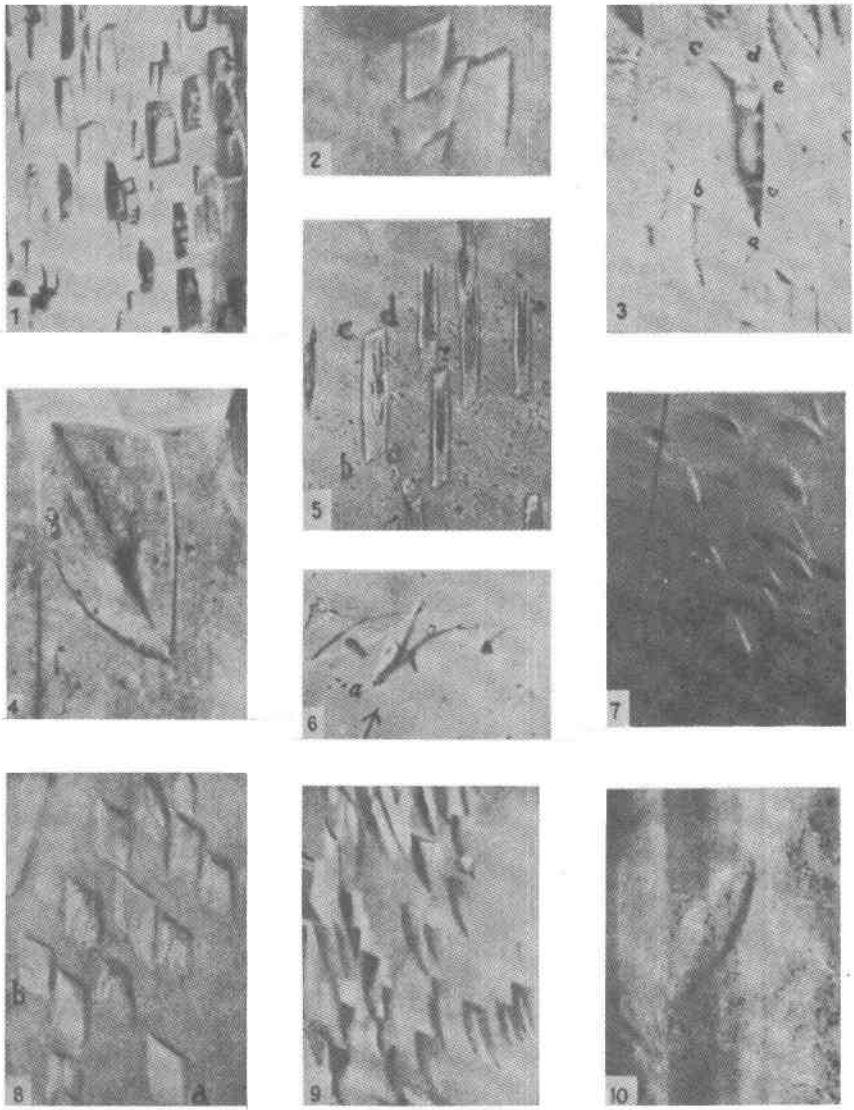

Photographs by Arthur P. Honess.

ETCHING FIGURES OBTAINED ON THE PRISM FACES OF WILLEMITE

For explanation see pages 59-61
Nos. 1, 2, 3, 5, 6 and 8 are X300; 4, 7, 9 and 10 are X180

PLATE 1

THE AMERICAN MINERALOGIST

VOL. II MAY, 1917 No. 5

A STUDY OF THE ETCHING FIGURES OF THE HEXAGONAL-ALTERNATING TYPE OF CRYSTALS.

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Several minerals of the hexagonal-alternating type have been investigated with reference to etch figures. Traube[1] obtained distinct figures on the negative rhombohedron of the first order of dioptase with KOH. These are triangular in outline, with the three sides unequal, the longest side parallel to the shorter diagonal of the rhomb face; the angle opposite this side is 120°. The figures on adjacent faces of the rhombohedron become congruent after a revolution of 120° about the *c* axis, but are not symmetrical and indicate, therefore, an absence of planes of symmetry in the crystal. The figures of the prism, according to Traube's description, are similar but less pointed, and, like those of the rhombohedrons, indicate no planes of symmetry. Traube also remarked the likeness which exists between the etchings on the rhombohedron $30\bar{3}4$ of willemite and those on $02\bar{2}1$ of dioptase. The hexagonal-alternating symmetry of willemite has been demonstrated by Penfield[2] on crystals from the Merritt Mine, New Mexico, and also by means of the natural etchings occurring on those from the Sedalia Mine, Colorado. Dolomite has been given considerable attention owing to the fact that for years its true symmetry was not definitely known. Von Kobell and Haushofer,[3] upon finding differently oriented figures upon the same crystal face, were unable to decide definitely the correct type of the mineral. Gaubert[4] believed the dark iron-bearing dolomites to be tetartohedral, but considered the white varieties to be of the calcite type, a conclusion quite at variance with the form of the corrosion figures produced by H_2SO_4 and HCl. Tschermak[5] in his investigation of dolomite, assigned the mineral to the hexagonal-alternating type, after having established its symmetry by etching with HCl and H_2SO_4, cleavage-rhombohedron pieces being used. The HCl

[1] *Neues Jahrb. Min. Geol.*, Beil. Bd., **10**, 454, 1895-96.
[2] *Z. Kryst. Min.*, **23**, 73, 1894.
[3] Cited by Tschermak, *Min. Petr. Mitt.*, **4**, 102, 1881.
[4] *Z. Kryst. Min.*, **37**, 92, 1903.
[5] *Min. Petr. Mitt.*, **4**, 102, 1881.

figures are very different from those developed on calcite by the same solvent, being triangular and asymmetrical, with the shortest side turned toward the pole of the rhombohedron; of the two other sides, one extends almost parallel to the short diagonal of the rhomb, the other is distinctly curved, turning to the right or left, as the crystal is a right or left form. The figures produced by H_2SO_4 are quite different from those previously described, being quadrilateral, with one side curved; they are much longer than broad, with one end narrower than the other. These figures also are asymmetrical, and turned in opposite directions on the right and left-handed forms. Complex dolomite crystals, like quartz, often reveal both symmetrical and asymmetrical etchings upon the same face, and, when twinned, the HCl figures resemble very closely those of calcite; but simple crystals unmistakably indicate by their etched forms the tetartohedral character of dolomite. The writer has observed asymmetrical triangular figures on black dolomite crystals from Teruel, Spain. Three forms, $10\bar{1}1$, $40\bar{4}1$, and 0001 are present, but only the steep rhombohedron revealed distinct etching.

Dioptase

The dioptase crystals used for investigation are from the noted Russian locality, Altyn Tübe in the Kirghese Steppes. The crystals are simple in form and quite transparent. Well defined etchings were obtained by fused KOH, after about a minute's time. The figures on the prism are not triângular as described by Traube, but leaf like in form, with the two longer boundaries curved, and meeting in a point, producing a figure without planes of symmetry. (See diagram A.) A third short line extends in a diagonal direction across the face, intersecting the two curved lines. The figures are therefore bounded by two curved surfaces and one small plane. The longer axes of the figures extend parallel to the prism edges; and figures on adjacent prism faces point in opposite directions, indicating a hexagonal-alternating axis *c*. The second-order rhombohedron, immersed in HCl, etched more rapidly, revealing many long, slender, triangular pits extending parallel to the rhomb edges, but asymmetrical in outline; occasional figures have curved margins. (See diagram A.) A scarcity of suitable material has rendered the investigation of the dioptase etch figures rather difficult, and there is a little doubt in the mind of the writer that the crystal form indicated in diagram A is $11\bar{2}0$. There is at any rate no mistake in the form of the etching itself, and it is hoped that further investigation may verify the results, which at present are not conclusive. The two forms etched conform, however, to the symmetry of the type.

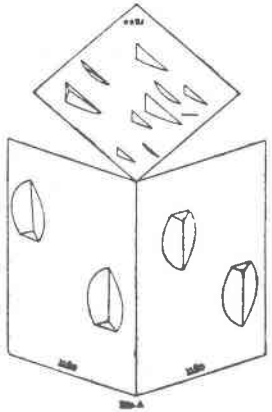
Willemite

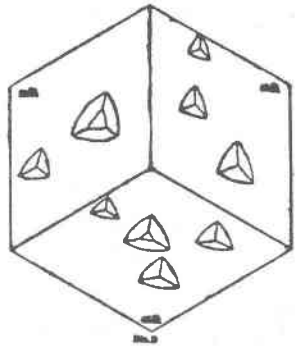
The willemite crystals investigated were obtained from Franklin Furnace, N. J. and are like those described by Palache and Gra-

ham.[6] They are small, greenish-yellow crystals, very clear and having a fine luster. Practically all of these crystals are elongated vertically, with the prism $11\bar{2}0$ well developed. The prism $10\bar{1}0$, with few exceptions, is very narrow, and is often only a mere line. The crystals are terminated by rhombohedrons of three orders, with $31\bar{2}1$, $21\bar{3}1$, and 1011 the best developed forms. The face $21\bar{3}1$ and a cleavage plate parallel to the base were etched with several different solvents, the best results being obtained with fused KOH, and NaOH, especially when mixed. Dilute solutions of HNO_3, H_2SO_4, and HCl were also used, but these did not prove satisfactory, as the figures produced show but little relief and are indefinite in outline.

Rhombohedron

The etch figures in Diagram B represent those on the third-order rhombohedron, as obtained by KOH, after immersion for thirty seconds in the solvent. The figures are triangular in shape with all sides curved; two sides are a little shorter than the third, but, being equal, produce a symmetrical figure with asymmetrical





orientation. While the figures are symmetrical with regard to a plane bisecting the larger angle and the longer side, the figures are so oriented upon the face of the rhombohedron as to indicate that there are no planes of symmetry in the crystal.

Prisms

Excellent etchings were obtained on the $11\bar{2}0$ prism by the alkali fusions. Photo 1 (see frontispiece) represents the figures produced by NaOH, acting for 25 seconds. In general appearance the figures are axe-shaped, with the longer sides extending in the direction of the prism edges, and slightly divergent and curved. The narrow end of the figures is bounded by a straight line intersecting the lateral boundaries almost at right angles, and extending approx-

[6] *Z. Kryst. Min.*, **53**, 332, 1913.

imately parallel to the intersection of the second-order rhombohedron and the second-order prism. The other extremity of the figures is bounded by a more oblique line, sometimes a little curved but usually straight, and intersects the lateral lines of the figure at an angle of 100°. Thus the form of the etch pits indicates that no planes of symmetry are possible.

The figures produced by fused KOH on the same crystal form are quite different from those previously described, and they also differ perceptibly in shape as the time of solution is prolonged. Repeated immersions of two or three seconds each gave many faint grooves extending parallel to the prism edges; after twenty seconds, these developed into well defined figures. (See Photo 2.) These etchings, although very distinct, show but little relief under high magnification; the depressions are shallow, and the lateral faces very small and the latter apparently meet the bottom of the pits perpendicularly, as illustrated in the photograph. As to general outline they are bounded by three margins, two straight, the other curved, the shorter intersecting the longer straight line at an angle of 108°, indicating the absence of symmetry planes.

If the solution be prolonged to thirty-five seconds, the resultant etch forms are quite different; they are longer, deeper, much more definite and limited by five margins instead of three. (See photo 3.) The depressions are composed of five lateral faces and the bottom; four of these slope gradually to the base of the pit, while the fifth stands approximately perpendicular. The surface angles as measured are: *a* 45°, *b* 135°, *c* 75°, *d* 135°, *e* 150°. The figures are elongated parallel to the prism edges. Repeated immersions to the extent of fifty seconds produced on a similar crystal two large, well-defined figures. (See photo 4.) This form of figure is more simple than that previously described; there are three limiting lines, all of which are curved. The bottom of the pit is now only a mere line, formed by the intersection of two curved surfaces, which form the walls and which intersect the prism face at two points. The photo also shows the position of the figure upon the prism $11\bar{2}0$; to the left of the pit the prism edge may be seen extending at an angle of 27° to the general direction of elongation of the figure. The etch figures reveal no planes of symmetry, but their position and form clearly indicate the hexagonal-alternating symmetry of the *c* axis.

Sodium and potassium hydroxides having been used separately to obtain etchings, a mixture of equal parts by weight was thoroly fused and a small crystal immersed in this for several seconds. The figures produced are exceptionally well-defined, and are scattered over the prism face, so that they can be studied in detail. (See photo 5.) There are four boundary lines, two longer, slightly curved and extending in a direction generally parallel to the prism edges, and two shorter, cutting the longer ones obliquely, varying but 18° from the perpendicular on one end of the figure and 30° on the other. The longer faces are slightly

curved outward and meet the gently sloping planes at the ends of the figure, as is well illustrated in the photo. The surface angles as measured roughly are *a* 120°, *b* 60°, *c* 108°, *d* 72°. The figures reveal no planes of symmetry, but their position and form indicate a vertical hexagonal-alternating axis.

Other solvents used in this investigation were nitric, sulfuric, acetic and citric acids, and altho some well defined figures were produced, as illustrated in the photographs, many of them are only shallow depressions with no apparent form or direction. The best figures were obtained by the action of the weaker acids for longer periods of time; acetic and citric acids are especially desirable for etching this mineral. The other two, if used, should be very dilute; Photo 6 illustrates the etch figures produced by dilute H_2SO_4. Upon examination these figures are seen to be entirely different from any before obtained; individual figures are rather indefinite, but taken as a group, they illustrate the asymmetrical character of the face. In detail, the pits are composed of five curved surfaces, each becoming narrower as it approaches the bottom, which is an irregular pentagon. Three of these lateral faces dip rather abruptly, the other two ascend very gradually to the surface of the crystal and fade away into a mere shadow, the intersection of which with the crystal face is barely discernible under high magnification. The intersections of the various lateral planes with one another and with the base are well shown in the photograph by the shaded lines. The angle *a* of the figure measures approximately 55°, and the line bisecting this angle intersects the prism edges at 45°. The figures, by their form and position, accord with the symmetry of the type. Photo 7 represents a more primitive stage of the figure just described.

The results obtained on $11\bar{2}0$ by hot 30% acetic acid acting for two and one-half hours, may be seen in Photo 8. The figures are quadrilateral and in the mature stage are composed of four faces meeting in a point at one end of the pit. The upper margin of the mature figures is decidedly the more distinct and in all cases is a straight line taking a direction of 115° with the prism edge. The lower margin of the figures as illustrated in the photo is less distinct and uncertain and in some cases slightly curved. The primitive forms (See *a* and *b*) have little relief, but in outline are very similar to the mature figures. The figures are all elongated in the direction of the prism edges and reveal no planes of symmetry.

Photo 9 represents the etchings produced on $11\bar{2}0$ of willemite by hot concentrated citric acid, acting for five minutes. The figures are elongated and pointed at one end, in the immature forms, but this sharp termination is gradually replaced by a short face as solution continues. The broader end of the etching is marked by a very distinct straight line which extends in a direction at 110° to the prism edges. Both lateral boundaries of the figures are curved outward, but the curvature is neither uniform nor

equivalent on both sides, consequently the figures are asymmetrical in accordance with the type.

The prism $10\bar{1}0$ is but slightly developed on these crystals, and being the more soluble form was beautifully etched by hot 25% HCl, acting for ten seconds. (See photo 10.) The limitations of the narrow face are readily discernible on either side of the etch figure, which extends in a diagonal direction approximately the entire width of the face. The etching is a simple oval form, pointed at either end. The inclination of the figures to the prism edges approximates 30°, therefore revealing no planes of symmetry.

Base

The base 0001 being absent on the crystals used, small cleavage pieces were etched with dilute HCl. The figures are simple triangular pits turned asymmetrically to the crystal edges.

(*To be concluded.*)

MIRABILITE FROM THE ISLE ROYALE COPPER MINE, HOUGHTON, MICHIGAN.

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During the fall of 1916 the Mineralogical Laboratory of the University of Michigan received from Professor A. C. Lane of Tufts College a sample of a fibrous mineral which upon investigation proved to be the rather uncommon mineral mirabilite. The material was obtained by Dr. Lane and Mr. A. H. Wohlrab, assistant to the superintendent of the Isle Royale Copper Company, from the 26th level, Shaft No. 2 of the Isle Royale Mine. Subsequently Mr. Wohlrab furnished another sample but this was from the "old workings of the No. 1 Shaft." I am greatly indebted to these gentlemen for so kindly placing this material at my disposal.

The material consists of a mass of colorless interlocking fibers, clear and transparent for the most part, and frequently very much twisted and bent. A small amount of clayey matter is present as an admixture. Upon exposure to the air, the fibers soon crumble to a white powder.

A preliminary examination before the blowpipe showed the presence of much sodium, sulfur and water, with traces of potassium, chlorine, calcium and aluminium, the last two being contained in the clayey material referred to above. Quantitative analysis yielded the result of table 1.

The mineral was first dried in an air bath at 130°C. until it showed a constant weight. This served to drive off all water. The fact that the water content, and consequently the molecular ratio, is somewhat lower than the theoretical value is easily accounted for when it is considered that the original material taken for analysis had already been partially dehydrated by exposure to air. Upon solution in water an insoluble residue of earthy