An *x*-ray powder photograph of this mineral taken by Richard P. Marquiss of the U. S. Geological Survey matched a mineral described as gorceixite from Dale County, Alabama (Charles Milton et al., this issue).

This work is part of a program being conducted by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

OPTICS OF THE EOSPHORITE-CHILDRENITE SERIES

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Hurlbut (1950) discussed the evidence that the childrenite-eosphorite series $Mn_{1-x}Fe_xAl(PO_4)(OH)_2(H_2O)$ is indeed a continuous isomorphous series, citing examples with $x = 0.04$, 0.14, 0.16, 0.23, 0.32, 0.33, 0.39, 0.47, 0.85, and 0.91, and giving in summary a variation diagram relating the optical properties and specific gravity to the weight per cent of FeO as determined by chemical analysis. Hurlbut's Table 2, summarizing the data on which his diagram is based, shows two apparently discontinuous changes. The optic orientation is practically constant with $X = b$ and $Z \wedge c = 3°$ to $8°$ throughout the eosphorite half of the series ($x < 0.5$), then changes to $X = b$ and $Y \wedge c = 6°$ to $8°$ for childrenite ($x > 0.8$); moreover, in the interval $0.5 < x < 0.8$, for which there are no data, the dispersion of 2V also reverses.

These changes can be explained easily if the curves for $n_\perp$ and $n_\parallel$, representing the refractive indices for the principal vibration-directions that are respectively almost perpendicular and almost parallel to c, cross one another in the neighborhood of $x = 0.6$ to 0.7; analogous changes of axial plane are well known in other mineral series such as lithiophilite-triphylite, and always result in a change of the dispersion of 2V in passing through the composition for which $2V = 0°$, in addition to the exchange of positions by two of the principal vibration directions—either X and Y, or Y and Z. In such a case there should also be a small range of compositions with crossed-axial-plane dispersion, *i.e.*, with the optic plane for one end of the spectrum at right angles to that for the opposite end; such a condition is easily recognized by abnormal interference colors in certain grains and thin sections of the mineral. Dispersion of 2V, if observable in such minerals, is $r > v$ on one side of the uniaxial composition and $r < v$ on the other. The obvious test of this hypothesis for eosphorite-childrenite is to find or make a crystal of manganoan childrenite with composition near $x = .65$, and observe whether such a crystal has

small 2V; with good luck, one might even hope to find a crystal with crossed-axial-plane dispersion and abnormal interference colors.

Lacking a crystal of the necessary composition, we may turn to the other available optical data to seek internal evidence concerning this hypothesis. For example, if precise enough refractive index figures are available, one may compare the goodness of fit, (a) between the data
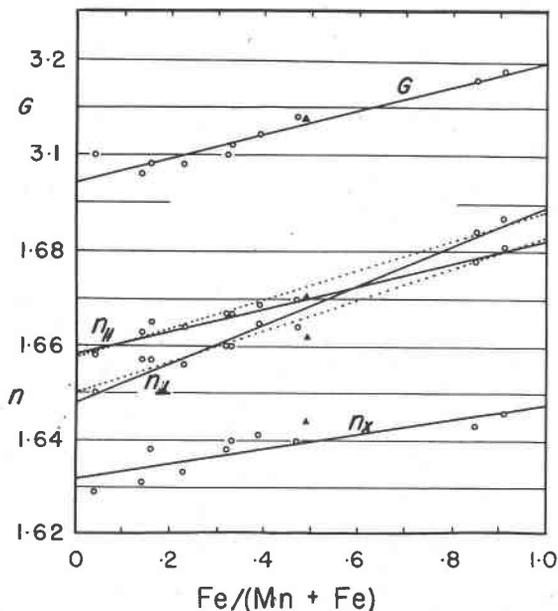

FIG. 1. Variations in physical properties in the Eosphorite—Childrenite series (modified from Hurlbut, 1950). The lines represent the regression equations (2) given in the text.

Dotted lines are n_y and n_z according to Hurlbut's interpretation; the solid lines $n_\parallel$ and $n_\perp$ show the preferred hypothesis.

and a pair of variation curves that cross somewhere in the range $0.5 < x < 0.8$, with (b) the fit obtained using curves that do not cross. This is attempted without decisive results in Fig. 1 and in the following:

Hurlbut's data (1950, Table 2, p. 803) appear to be by far the best available describing the variations of physical with chemical properties. His independent variable was the weight percentage of FeO in the analyses; for convenience these weight percentages were divided by 31.26, the percentage by weight of FeO in the childrenite end-member, $FeAl(PO_4)(OH)_2(H_2O)$, giving a number $x'(0 \leq x' \leq 1)$ that differs from the atomic proportion x by less than 0.005, well within the probable limits of chemical-analytical uncertainty. Considering x [or x'] as the independent

variable, linear regression formulas were computed by the method of least squares for each of the physical properties G, n_x, n_y, n_z as given by Hurlbut, and also for $n_\perp$ and $n_\parallel$. The equation for linear variation is

$$y_i = a_i + b_i x + s_i \tag{1}$$

where y_i is the measure of one of the physical properties, considered as the dependent variable; a_i and b_i are parameters to be determined; x is the independent variable defined above; i refers in turn to each of the physical properties G, n_x, n_y, n_z, $n_\parallel$, $n_\perp$; and s_i is the root-mean-square deviation of the observations from the calculated values. Least-squares evaluations of the several a's, b's, and s's give

$$
\begin{aligned}
G &= 3.071 + 0.127x \pm 0.010 \\
n_x &= 1.6317 + 0.0160x \pm 0.0025 \\
\left. \begin{aligned}
n_y &= 1.6500 + 0.0332x \pm 0.0015 \\
n_z &= 1.6574 + 0.0312x \pm 0.0013
\end{aligned} \right\} &(2a) \\
\left. \begin{aligned}
n_\parallel &= 1.6592 + 0.0233x \pm 0.0011 \\
n_\perp &= 1.6482 + 0.0411x \pm 0.0019
\end{aligned} \right\} &(2b)
\end{aligned}
\right\} \quad (2)
$$

There is no significant difference in the s-values in equations ($2a$) as compared with equations ($2b$). A careful plot of the data (Fig. 1) tends to confirm the same conclusion, and also shows that the hypothesis of linear regression is satisfactory for G, n_y, n_z, $n_\parallel$, and $n_\perp$, but perhaps not for n_x.

Strunz and Fischer (1957) provide further data that are shown in Fig. 1 by small triangles, but are not included in the above calculation. Their values for a specimen from Hagendorf with $FeO = 14.86\%$ (wt.) and unusually high CaO (3.587% wt.), are $n_x = 1.644$, $n_y = 1.662$, $n_z = 1.671$, $2V = (-)25°$, $Y\|c$ and $G = 3.11$ to 3.15, agreeing essentially with Hurlbut's data for material from Red Hill, Rumford, Maine (14.62% FeO, $n_x = 1.640$, $n_y = 1.664$, $n_z = 1.670$, $2V = (-)45°$, $Z \wedge c = 4°$, $r < v$, $G = 3.14$). Strunz and Fischer's value of n_x also helps suggest that n_x does not vary linearly. They discuss the x-ray data so far published and conclude that the mineral is orthorhombic, and that the small extinction angles generally observed are anomalous. The change of optic orientation discussed here is probably due to intersection of the curves for $n_\parallel$ and $n_\perp$ regardless of the question of orthorhombic or lower symmetry.

Equations ($2b$) show that the uniaxial composition (if one exists) is near $x = .62$. The change in optic orientation and the reversal of the dispersion of 2V strongly favor the existence of such a composition. A sample of eosphorite-childrenite with x near .62 would probably afford the data needed to settle the question. The alternative hypothesis that childrenite-eosphorite is not in fact a continuous isomorphous series seems improbable on the basis of known data.

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HURLBUT, C. S., JR., (1950) Childrenite-Eosphorite Series: *Am. Mineral.*, **35**, 793–805.
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ADDITIONAL DATA ON BIKITAITE

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A new mineral, *bikitaite*, $LiAl_2O_6 \cdot H_2O$, was described in the November-December, 1957 *American Mineralogist.** The description was made on fine grained material interstitial to granular eucryptite and quartz. The largest fragments of single crystals were measured in tenths of millimeters.

Shortly after the manuscript on bikitaite was submitted for publication, Mr. George H. Nolan sent the writer another specimen from his mine in Southern Rhodesia. This specimen, measuring $25 \times 15 \times 15$ centimeters is largely granular eucryptite and quartz as in the original material. However, one surface is covered by bikitaite with individual crystals measuring up to six centimeters in length, and one centimeter across (Fig. 1). In addition, massive bikitaite forms a layer beneath the crystals two to five centimeters thick.

The bikitaite crystals are coated with a thin crust of stilbite so that, although the crystal habit is well displayed, there are no faces visible. Two other minerals, formed later than the stilbite, are present on the specimen. These are calcite, in scalenohedral crystals; and allophane, filling voids between some of the bikitaite crystals.

When the stilbite crust is removed, the bikitaite crystals are seen to be colorless and transparent. They are elongated on [010] (Fig. 2); and the faces in this zone are of high quality. The faces of the [001] zone, that terminate the elongated crystals, are deeply etched and thus give poor measurements on the reflecting goniometer. At the end of some crystals etching has produced slots several millimeters deep parallel to (100).

All the crystals are of the same habit with $c\{001\}$ and $t\{\bar{1}01\}$ the dominant forms in the [010] zone. Because these two forms have nearly equal development and similar rho angles, the crystals have a pseudo-orthorhombic appearance. Three etched forms, $b\{010\}$, $m\{110\}$ and $n\{210\}$, terminate the crystals. Of these, the faces of $\{210\}$ are the largest and also the most deeply etched. $o\{\bar{1}12\}$ was noted on only one

* C. S. Hurlbut, Jr., Bikitaite, $LiAlSi_2O_6 \cdot H_2O$, a new mineral from southern Rhodesia. *Am. Mineral.*, **42**, p. 792–797, 1957.