this study). Although stronger single crystal patterns may show additional weak reflections, it appears unlikely that the 002 and 004 reflections are correctly indexed on the powder pattern, since they would never become stronger than the 003 reflection, present in the precession photograph, but not observed in the powder photograph. The intensity of the 00*l* reflections in the powder photograph may be weakened by preferred orientation of the fibers, parallel or at small angles to the spindle axis. The very weak 8.00 and 4.02 Å reflections on the stronger powder photograph may correspond to possible (110) and (200) reflections, missing on the weaker precession photographs, but the 3.173 Å reflection cannot be indexed as an FeKα reflection. All three reflections, as well as other reflections known to be beta reflections, are enhanced in white radiation; therefore, the d-spacings of the three reflections have been recalculated from the measured 2θ using λ, FeK$\beta = 1.7568$ (Table 2).

References

LINDBERG, MARIE L. (1958) Beryllium content of roscherite from the Sapucaia pegmatite mine, Minas Gerais, Brazil, and from other localities. *Am. Mineral.* **43,** 824–838.

——— AND K. J. MURATA (1953) Faheyite, a new phosphate mineral from the Sapucaia pegmatite mine, Minas Gerais, Brazil. *Am. Mineral.* **38,** 263–270.

THE AMERICAN MINERALOGIST, VOL. 49, MARCH–APRIL, 1964

LITHIAN HUREAULITE FROM THE BLACK HILLS

D. JEROME FISHER, *Rosenwald Hall, University of Chicago, Chicago, Illinois.*

In 1946 the writer published an abstract describing what was thought to be a new pegmatite "phosphate of lithium, with iron and manganese" which was given the name *bastinite.* On the basis of work with the Universal stage it was decided the mineral was triclinic. At this time the mineral had not been examined with *x*-rays. Weissenberg pictures taken late in 1947 indicated that the mineral was monoclinic and powder pictures (Table 1) taken a few months later confirmed that it was a variety of hureaulite. At this time I was too busy with other things to finish the study of this mineral, and unfortunately the name got preserved by Chudoba (in Hintze) and in Strunz's tables, although later communications to these gentlemen corrected the matter.

A few samples of hureaulite were discovered in 1825 by the ceramist Alluaud in the pegmatite quarry of Huréaux at St. Sylvestre, according to LaCroix (1962). After the original discovery no more samples were found here. LaCroix states that from 1849–52 samples now in museum collec-

TABLE 1. DATA FROM POWDER PHOTOS OF HUREAULITE[1]

(h k l)[2]	Computed[3] d	Bauldaufite (Strunz) Int.	d	Wenzelite (Strunz) Int.	d	Wenzelite P37 Int.	d	La Vilate (Strunz) Int.	d	Limoges P88 Int.	d	Palaite P49 Int.	d	Branchville P90 Int.	d	Black Hills P46 Int.	d
200	8.71	m	8.415	m	8.415	6	8.690	m	8.786	6	8.623	7	8.758	6	8.690	4	8.734
110	8.08	m	7.777	m	7.729	8	8.063	m	7.977	7	8.005	9	8.063	7	8.005	5	8.005
$\bar{1}11$	6.325					2	6.332			2	6.296	3	6.296	3	6.261	½	6.368
111	6.00					2	5.994			2	5.946	3	5.994	3	5.962	1	5.931
(310)	4.87					¾	4.901					1	4.943	½	4.901		
002	4.75	s	4.633	s	4.610	2	4.717	s	4.674	2	4.678	3	4.717	3	4.698	1	4.698
$\bar{3}11$	4.48	s	4.468	s	4.465	3	4.529	s	4.489	4	4.502	4	4.547	5	4.511	2	4.511
311, 400	4.35–.18					1	4.372			2	4.347	4	4.339	2	4.355	½	4.339
021, 220	4.08–.04	s	4.002	s	4.025	2	4.061	s	4.031	3	4.054	3	4.046	3	4.054	1	4.061
$\bar{2}21$	3.76	ss	3.718	ss	3.715	1	3.792	ss	3.780	2	3.773	3	3.792	2	3.767	¾	3.767
221	3.64	ss	3.592	ss	3.599	2	3.648	ss	3.602	3	3.636	4	3.648	3	3.636	1	3.625
$\bar{3}12$	3.57											4	3.558			½	3.493
$\bar{4}02$	3.41	nicht messbar				1	3.351	sss	3.382	1	3.400	1	3.400	1	3.390	½	3.391
022, 312	3.29–.25					3	3.257			4	3.253	5	3.257	5	3.261	3	3.257
$\bar{5}11$	3.19									6	3.177			6	3.186	5	3.186
$\bar{2}22$	3.16	st	3.112	st	3.126	10	3.152	st	3.128	10	3.135	10	3.143	10	3.135	10	3.139
$\bar{4}21$, 402	3.07–.04									3	3.061	5	3.053	2	3.069	2	3.053
222	3.00	s	3.010	s	3.006	2	3.069	s	3.015	3	3.013					2	3.021
511	2.98	m	2.950	m	2.954	7	2.990	m	2.970	7	2.983	7	2.983	8	2.983	7	2.975
600	2.90									3	2.902	2	2.916	2	2.902	2	2.902

[1] All photos taken with filtered iron radiation, the Chicago ones with Straumanis (Philips) 114 mm. diameter cameras. The Chicago pictures were measured ($\lambda = 1.9373$ A.) by Leon Atlas in 1948–49. *P37* is Harvard 81242. *P88* is Yale (Brush 3159), presumably from "La Vilate." *P49* from the Stewart Mine (Pala, Calif.) is from W. T. Schaller. *P90* is Yale (Brush 3162). *P46* is from the Custer Mt. Lode, SE of Custer, South Dakota.

[2] All indices represent planes confirmed from the study of single crystal (precession and Weissenberg) photos. Those given in parentheses furnished weak reflections, the others medium to strong ones.

[3] Spacings to ($\bar{5}11$) of d = 3.19 mostly computed graphically in 1949 by F. D. Bloss (*Am. Mineral.* **37**, 588–599, 1952) using 17.42:9.12:9.50 with β of 96°40′.

TABLE 1—(*continued*)

(h k l)[2]	Computed[3] d	Bauldaufite (Strunz) Int.	d	Wenzelite (Strunz) Int.	d	Wenzelite P37 Int.	d	La Vilate (Strunz) Int.	d	Limoges P88 Int.	d	Palaite P49 Int.	d	Branchville P90 Int.	d	Black Hills P46 Int.	d
113	2.896	sss	2.851	sss	2.834	4	2.880	sss	2.862	5	2.860	5	2.866	5	2.874	4	2.860
$\bar{5}12$	2.83											1	2.805	1	2.832		
$\bar{3}13$	2.79									1	2.766			1	2.766		
$\bar{4}22$	2.73	sss	2.720	sss	2.716			sss	2.712	1	2.722	1	2.722	1	2.728	½	2.728
330	2.69									1	2.691	1	2.691	1	2.691	½	2.691
$\bar{3}31, 023, \bar{6}02$	2.65–.60	s-m	2.591	s-m	2.588	4	2.631	s-m	2.605	5	2.620	6	2.626	6	2.626	5	2.620
$\bar{1}32, 512$	2.56					2	2.564			1	2.580			2	2.586	1	2.586
331,	2.55	s	2.526	s	2.523			s	2.529	4	2.553	6	2.547	4	2.553	4	2.553
132	2.51											1	2.489				
$\bar{6}21, 223$	2.43					2	2.439			4	2.429	4	2.429	4	2.429	3	2.429
$\bar{5}13, \bar{7}11, 004$	2.40–.38	s	2.397	s	2.408	2	2.400	s	2.403	3	2.391	4	2.396	4	2.391	3	2.391
602	2.35					1	2.358			2	2.354	1	2.358	2	2.354	1	2.363
$621, \bar{2}04$	2.34–.32	sss	2.328	sss	2.312	1	2.322	sss	2.321	2	2.318	2	2.322	3	2.322	2	2.318
530	2.29									1	2.288	3	2.292	2	2.292	2	2.288
711	2.27									3	2.267	3	2.271	3	2.266	2	2.267
$\bar{6}22, 114, \bar{7}12$	2.25–.24	ss	2.252	ss	2.249			ss	2.244	¾	2.242			½	2.242	½	2.242
$800, \bar{1}33, \bar{4}04$	2.20–.18	ss	2.169	s-m	2.167	6	2.186	s-m	2.170	6	2.186	6	2.186	6	2.182	6	2.186
423	2.145	ss	2.132	ss	2.126	1	2.141	ss	2.129	2	2.141	3	2.148	3	2.141	2	2.145
$133, \bar{3}33$	2.11													1	2.126		
$622, \bar{2}24$	2.09–.08	sss	2.072	sss	2.067	1	2.094	sss	2.077	1	2.098	2	2.098	2	2.098	1	2.098
314	2.06													1	2.080		
$\bar{6}23, 042,$	2.04	ss	2.033	ss	2.034	1	2.050	ss	2.036	3	2.050	3	2.050	3	2.050	2	2.050
333, 440	2.02–.00					1	2.024			3	2.024	3	2.024	3	2.024	2	2.024
$\bar{4}24, 404$	1.99–.96	s	1.964	s	1.962	1	1.979	s	1.970	2	1.979	2	1.982	2	1.979	2	1.982

TABLE 1—(*continued*)

(h k l)[2]	Computed[3] d	Baldaufite (Strunz) Int.	d	Wenzelite (Strunz) Int.	d	Wenzelite P37 Int.	d	La Vilate (Strunz) Int.	d	Limoges P88 Int.	d	Palaite P49 Int.	d	Branchville P90 Int.	d	Black Hills[5] P46 Int.	d
730, 820	1.94–.93	ss	1.920	ss	1.915	1	1.931	ss	1.917	3	1.926	3	1.926	3	1.926	2	1.926
821, 802, $\bar{1}15$	1.88–.87					¾	1.894			2	1.894	1	1.897	1	1.897	½	1.892
(134), (623)	1.85–.84	sss	1.852	sss	1.849	1	1.859	sss	1.846	2	1.856	2	1.859	2	1.859	1	1.859
(115)	1.828					1	1.828			1	1.833	2	1.833	1	1.833	½	1.833
424	1.814	sss	1.809	sss	1.806			sss	1.811	1	1.818	2	1.820	1	1.818	½	1.818
$\bar{1}51$	1.786	sss	1.772	sss	1.770	1	1.788	sss	1.777	2	1.788	1	1.786	2	1.788	1	1.788
$\bar{2}25$	1.756											4	1.755			2	1.757
604, 822, 10·0·0, 350	1.74–.73	s	1.738	s	1.736	2	1.746	s	1.733	4	1.741	4	1.737	3	1.744	2	1.741
$\bar{1}52$, $\bar{8}04$	1.705	s	1.696	s	1.693	2	1.710	s	1.694	4	1.706	3	1.706	3	1.708	2	1.706
152	1.688											1	1.687	1	1.687		
044	1.645	m	1.628	m	1.629	5	1.640	m	1.629	6	1.640	6	1.638	6	1.640	6	1.640
$\bar{1}35$,	1.62	sss	1.604	sss	1.598	¾	1.610	sss	1.605	2	1.610	1	1.610	2	1.610	1	1.613
$\bar{1}0\cdot2\cdot2$, $\bar{2}06$, 135	1.590									2	1.595	1	1.597	2	1.595	1	1.599
10·2·1, 10·0·2, $\bar{1}53$, 425	1.58–.57	s-m	1.573	s-m	1.570	5	1.582	s-m	1.574	6	1.582	6	1.580	6	1.580	6	1.584
(153)	1.566									1	1.566	1	1.563	1	1.566		
206, 060, 116	1.54–.52	s	1.522	s	1.516			s	1.516			2	1.523	2	1.529		
061, $\bar{2}26$	1.502					1	1.510					2	1.510	2	1.510		
10·2·2	1.49	s	1.487	s	1.485			s	1.485	2	1.494	3	1.493	3	1.494	2	1.495
226, 12·0·0	1.45	s	1.453	s	1.449	2	1.456	s	1.449	4	1.459	4	1.456	4	1.459	4	1.459
154	1.433	ss	1.431	ss	1.428	1	1.436	ss	1.429	2	1.436	2	1.436	2	1.436	1	1.437
$\bar{1}36$	1.411	ss	1.408	ss	1.406	1	1.419	ss	1.408	2	1.418	2	1.415	2	1.416	1	1.418
		s	1.382	s	1.379	1	1.388	s	1.382	3	1.391	3	1.388	3	1.391		

tions were taken from the pegmatite of La Vilate (just east of Route N20 close to Barost creek, and also known as Les eaux vertes) about one mile north of Chanteloube (the latter is 26 km north and a bit east of Limoges, and 7 km north of St. Sylvestre), but this deposit has now long been abandoned.

The results obtained from x-ray powder pictures are given in Table 1. The spacings and intensities of the stronger lines for hureaulite are thus 3.16 (10), 8.08 (7), 2.98 (7), 8.71 (6), 2.18 (6), 1.64 (6), 1.58 (6), 2.62 (5). The indexing in this table is based on the study of both precession and Weissenberg photographs made on samples from the Custer Mountain Lode in the Black Hills (Fisher, 1945) and from a crystal from the Stewart Mine, Pala, California, kindly sent me by Professor Joseph Murdoch. The results from the crystals from these two localities are in full agreement. Both J. D. McCullough (in Murdoch, 1943) and H. Strunz (1954), on the basis of study of rotation pictures, concluded the space group to be #13-C_{2h}^4, although McCullough gave the orientation $P2/c$, whereas Strunz used $P2/n$. My pictures show the limitations on reflections to be $hkl-h+k=2n$; $h0l-h=2n$, $l=2n$; and $0k0-k=2n$. In short the space group is either #9-C_s^4-Cc or #15-C^6_{2h}-$C2/c$, presumably the latter. The cell dimension obtained from precession photos of the Black Hills material are 17.64 Å $\pm$ .04; 9.13 $\pm$ .02; 9.49 $\pm$ .02; $\beta = 96°30' \pm .02'$. As noted by Strunz the mineral becomes colored after bombardment by x-rays for a few hours; the Black Hills sample turned dark pink.

The results obtained from chemical analyses of hureaulite are shown in Table 2, which omits a number of apparently less-reliable efforts. The analysis of the Black Hills material was made on a sample of 40 mg. by Brynjolf Bruun for Fe, Mn and P. The determinations of Li, Ca and Mg were made spectroscopically by Oiva Joensuu. In the spring of 1948 Edward D. Goldberg ran a neutron-activation analysis for P on the Black Hills sample at the Argonne Laboratory. His results showed that 14.69 g of hureaulite carried 2.13 g of P; his standard was $(NH_4)H_2PO_4$. Goldberg thought his result (14.5% P, or 33.22% P_2O_5) had a probable error of 10%, but apparently it was closer to 20%.

The optical properties that have been determined for hureaulites are summarized in Table 3. All are in agreement that the crystals are (−) and the orientation has $\alpha \rightarrow [b]$, with γ lying in (obtuse) angle β. My results on the Black Hills sample for the dispersion of γ in this position are not however in agreement with what is given in LaCroix. The value of β varies from 1.653 at λ of 6200 to 1.660 at λ of 5360. In general as is to be expected the Fe-rich members show higher n-values than the Fe-poor ones; however the results given for wenzelite in column (5) are an excep-

TABLE 2. CHEMICAL ANALYSES OF HUREAULITE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Li_2O				tr			2.1±0.3
CaO				1.77	2.02	1.33	not>0.7
MgO					0.26	0.40	not>1.7
FeO		7.87	4.56	7.48	10.57	11.34	6.
Fe_2O_3				0.16			
MnO	48.66	41.66	42.29	40.87	36.01	36.16	37.
P_2O_5	38.98	38.00	38.36	39.02	38.83	38.91	43. ±3.
H_2O	12.36	11.98	12.20	10.43	12.42	12.37	n.d.
Insol.		0.38	2.70	0.89			
Total	100.00	99.89	100.11	100.62	100.11	100.51	
G	3.23	3.191	3.149	3.17± .03	3.196	3.194	3.21

(1) Computed for $Mn_5H_2(PO_4)_4 \cdot 4H_2O$.
(2) La Vilate, France. Average of three (Damour 1858)
(3) Branchville, Conn. Average of two (Wells 1890)
(4) Palaite (Schaller 1912). Note Murdoch found only 0.1% Fe.
(5) Baldaufite (Strunz 1954)
(6) Wenzelite (Strunz 1954)
(7) Black Hills (new)

tion. It also seems likely that the value given for α in column (3) is a bit too high.

The morphology of hureaulite is described in some detail by Strunz (1954). Most of the Black Hills crystals are much like those of Fig. 1 of Strunz, except that $\{\bar{2}01\}$ is so large that it tends to eliminate $\{\bar{1}11\}$ or reduce it to a "line" face between $(\bar{2}01)$ and the prism.

TABLE 3. OPTICAL PROPERTIES OF HUREAULITE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
α	—	1.647	1.652	1.652	1.646	1.652	1.649	1.637
β	1.66	1.654	1.656	1.657	1.655	1.658	1.655	1.645
γ	—	1.660	1.660	1.662	1.657	1.663	1.659	1.649
2V	73½ red 74 yel	74	—	—	—	85 (cpd)	76 red 77 green	76°03′(λ=578) 76°14′(λ=546)
$\gamma \wedge [C]$	75 red 76 blue	75	—	—	—	66	57 red 52 green	66 red 64 green
$\gamma - \alpha$	—	.013	.008	.010	.011	.011	.010	.0119

(1) La Vilate, France, LaCroix.
(2) Branchville, Conn. Schaller.
(3) Palaite. Schaller.
(4) Baldaufite.
(5) Wenzelite.
} Larsen and Berman.
(6) Wenzelite. Strunz, 1954.
(7) Black Hills. Fisher.
(8) Mangualde, Portugal.

A grain of Black Hills hureaulite held on a small loop of Pt wire above a candle flame fuses readily to a brown glass. The fusibility is closer to 1, rather than 3 as given in Winchell (1951). The hardness is very close to 4. The color varies from colorless to rose pink.

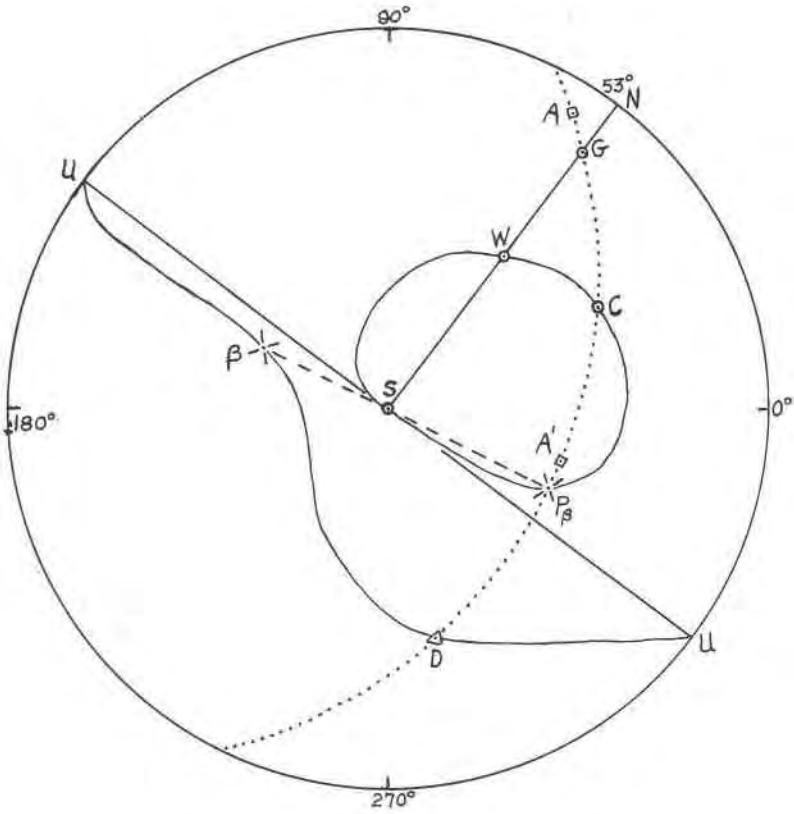

FIG. 1. Stereogram showing extinction curves given by the Mangualde hureaulite on the spindle stage.

Along the cracks (fracture surfaces) cutting the lithiophilite of the Custer Mt. Lode are found lilypad-shaped films of sicklerite or its alteration products; the hureaulite occurs as drusy aggregates fringing but not overlapping these, and is thought to be of very late hydrothermal origin. The paragenesis is discussed in detail in an earlier report (Fisher, 1945).

It is a pleasure to acknowledge the receipt of specimens used in this study from Professors Frondel, Murdoch and Winchell, and from Dr. Schaller.

Addendum

After the above paper had been completed, I received a hureaulite sample from Professor Joseph Murdoch of the University of California (Los Angeles) which he had collected from the Mesquitela pegmatite, Mangualde, Beira, Portugal in 1955. One crystal was mounted on the Umrig (Fisher, D. J., 1960, *Zeit. Krist.*, **113,** 77) where it was determined that the optical orientation was as stated earlier, with $\gamma-\beta = .0042$ and $\beta-\alpha=.0077$ and that other data were as given in rows 4 and 5 of column (8) of Table 3. Paul Moore and Paul Ribbe of this department are studying the crystal structure of hureaulite; their work should be completed shortly.

Another crystal was mounted on the spindle stage to determine the indices of refraction ($\pm .002$) as given in Table 3. The extinction curves obtained using Na light appear in Fig. 1, with the principal indices located at C (on the polar curve), and D and β on the equatorial curve. Particular care was taken in determining the spindle readings of 53 and 233, when extinction occurred as the analyzer vibration direction was parallel to the spindle axis. This permitted the plotting of the diameter UU with high accuracy. The radius SN drawn normal to UU served to locate point G where it cuts the optic plane. Then the formula (20) of Garacochea and Wittke (*Acta Cryst.* **17,** 183–189, 1964) after locating P_β (the polar point of β, where a diameter through β cuts the optic plane):

$$\cos 2V_C = \frac{\sin(CP_\beta - CG)}{\sin(CP_\beta + CG)}$$

gave the result of 75°19′ (with $CP_\beta = 45\frac{1}{4}°$ and $CG = 31°$), which is quite satisfactory; the optic axes A, A′ were then added to the figure, assuming $C=\alpha$ to be the acute bisectrix.

References

Chudoba, K. F. (1960) *Handbuch der Mineralogie von C. Hintze. Erg.* **II,** 33, 460, 499, 639.

Fisher, D. J. (1945) Mineralogy of some pegmatites near Custer. *South Dakota Geol. Surv. Rept. Invest.* **50,** IV, 45.

——— (1946) Bastinite, a new pegmatite phosphate (abs.). *Am. Mineral.* **31,** 192.

Jasker, G. (1956) Neue Beobachtungen am Wentzelit von Hagendorf. *Hamburger Beitr. angew. Mineral. Kristallphysik,* **1,** 183–87. (This reference is to a paper presented in 1953, the contents of which became obsolete with the appearance of the 1954 paper of Strunz.)

LaCroix, A. (1962) *Mineralogie de la France. Vol.* **4,** 501–06.

Larsen, E. S. (1921) Microscopic determination of non-opaque minerals. *U. S. Geol. Surv. Bull.* **679,** 88. (See also the second ed. by Larsen and Berman, *Bull.* **848,** 1934).

Murdoch, J. (1932) Crystallography of hureaulite. *Am. Mineral.* **28,** 19–24.

Palache, Charles *et al.* (1951) *Dana's System of Mineralogy. Vol.* **2,** John Wiley & Sons, New York, 701.

SCHALLER, W. T. (1912) New manganese phosphates from S. Calif. *Jour. Wash. Acad. Sci.* **2**, 144. (Also see p. 57 of App. III of Dana's System of Mineralogy, 1915).

STRUNZ, H. (1954) Identität von Wenzelit und Baldaufit mit Hureaulith. *Neues Jahr. Mineral., Mtsh.* 166–77.

——— (1957) *Mineralogische Tabellen*, 3d ed. 237, 357.

WINCHELL, A. N. WITH H. WINCHELL (1951) *Elements of Optical Mineralogy, Pt.* **II**, John Wiley & Sons, Inc., New York, 215.

THE AMERICAN MINERALOGIST, VOL. 49, MARCH–APRIL, 1964

USE OF THE NAKAMURA PLATE IN UNIVERSAL STAGE ORIENTATIONS

THOMAS A. VOGEL, *Department of Geology, University of Wisconsin, Madison, Wisconsin*[1]

The Nakamura plate is a refined biquartz wedge and can be used to determine accurately the optical orientation with the universal stage. It consists of two halves of equal thickness, one a right-handed quartz, the other a left-handed quartz which rotate the plane of polarization in opposite directions. The Nakamura plate divides the field into two halves and if the polarizer and analyzer are exactly crossed and the crystal is at extinction, the two halves of the plate will be exactly equally illuminated. Its use is similar to that of the biquartz wedge and has been described by Wright (1908).

The Nakamura plate is designed to be used at the focal plane of the ocular, between the polarizer and the analyzer, and the ocular must be adapted so as to permit its insertion. The Wright slotted ocular enables one to focus on the accessory plate and on the normal orthoscopic image at the same time. The slotted ocular used by this author is an improved Wright slotted ocular designed by Hallimond and Taylor (1948) which contains a rotatable internal sliding analyzer above the accessory slot. With wide tube microscopes it is necessary to construct a special joint in order to place the slot at the normal focal plane of the instrument.

Extinction positions with the Nakamura plate are more easily determined than with the normal orthoscopic image. When the mineral is at extinction both halves of the Nakamura plate are exactly equally illuminated, and if the crystal is rotated from extinction, the intensity of illumination in the two halves of the plate is rendered unequal. Extinction positions can be determined to 0.10 degree (Hallimond, 1953).

[1] Present address: Department of Geology, Rutgers—The State University, New Brunswick, New Jersey.