THE AMERICAN MINERALOGIST, VOL. 54, JANUARY–FEBRUARY, 1969

NEW DATA ON TYCHITE

KENNETH L. KEESTER, GERALD G. JOHNSON, JR.[1] AND VLADIMIR VAND,[2] *Materials Research Laboratory, The Pennsylvania State University, University Park, Pennsylvania 16802.*

ABSTRACT

X-ray diffraction powder data for tychite from Searles Lake, California: strongest lines are {511}, 2.67$_4$ Å, (100); {311}, 4.18 Å, (76); {440}, 2.459 Å (40); Least-squares gave $a = 13.898 \pm 0.001$ Å; X-ray density 2.586 g/cm^3 at 24°C. Refractive index $n_D = 1.510$ at 25.8°C.

Tychite, $Na_6Mg_2(SO_4)(CO_3)_4$, for this study came from Searles Lake, San Bernardino County, California. It was collected from a drill hole at about 250 feet, near the top of the Mixed Layer (Smith, 1949, p. C-66), sometime during 1949–51.

Since the original description of the mineral from Searles Lake[3] by Penfield and Jamieson (1905), it has been reported by many others. The only other reported locality is in the Green River Formation (Fahey and Mrose, 1962, p. 18).

X-ray powder diffraction data were obtained from 0.5 to 1.5 mm crystals. The crystals are colorless, transparent, unmodified octahedrons. Some of the largest octahedrons have clay inclusions and were not used. The sample was ground to a fine powder under CCl_4, but was not sized. The data (shown in Table 1) were collected on a Norelco Diffractometer with Geiger counter detector, using Cu radiation and Ni filter. Intensities were measured as relative peak heights on a strip chart. Our 1/4° 2θ/min. pattern includes reflections between 10° and 90° 2θ. Quartz was used as an internal standard.

Thirty Kα ($\lambda = 1.54178$ Å), Kα_1 ($\lambda = 1.54051$ Å), and Kα_2 ($\lambda = 1.54433$ Å) reflections, *i.e.* all those not obscured by the standard, were processed by a least squares refinement program (Appleman *et al.*, 1963), giving the cubic cell parameter $a = 13.898 \pm 0.001$ Å, in excellent agreement with the value $a = 13.90$ Å, given by Shiba and Watanabé (1931, p. 1422), for pure synthetic material.

Confusion has resulted over Shiba and Watanabé's cell parameter. Palache *et al.* (1951, p. 294) correctly state the value as 13.87 kX, having recalculated it from the Å value first reported. Later Watanabé (1933, p.

[1] Also Computer Science Department.

[2] Deceased April 4, 1968.

[3] Originally described as "Borax Lake," San Bernardino Co., not to be confused with Borax Lake, Lake County, California, another saline evaporite locality.

TABLE 1. X-RAY POWDER DIFFRACTION DATA FOR TYCHITE

hkl	*d* (calc), Å, $a=13.898$	Searles Lake This Study		Synthetic (Watanabé, 1933)	
		d (meas), Å	I/I_0	*d* (meas), Å	I/I_0
111	8.024			8.07	2
200	6.949				
220	4.914	4.92_5	7	4.94	15
311	4.190	4.18_7	76	4.09	72
222	4.012				
400	3.475			3.48	5
331	3.188	3.19_0	24	3.20_1	26
420	3.108				
422	2.837	2.83_0	4	2.84_0	3
511, 333	2.675	2.67_4	100	2.67_3	100
440	2.457	2.459	40	2.45_4	59
531	2.349	2.349	20	2.351	18
600, 442	2.316	2.320	3	2.319	5
620	2.197	2.198	6	2.200	13
533	2.119				
622	2.095	2.096	2	2.093	5
444	2.006	2.006	17	2.002	23
711, 551	1.946	1.946	15	1.945	28
640	1.927				
642	1.857	1.859	4	1.857	10
731, 553	1.809	1.810	2	1.805	5
800	1.737	1.736	17	1.737	36
733	1.698	1.698	6	1.697	10
820, 644	1.685			1.682	2
660, 822	1.638	1.638	7	1.634	13
751, 555	1.605	1.605	24	1.616	36
662	1.594	1.594	8		
840	1.554	1.555	2		
911, 753	1.526				
842	1.516	1.518	2		
664	1.482				
931	1.457				
844	1.418	1.418	6		
771, 933, 755, 10.0.0, 860	1.397				
10.2.0, 862	1.363				
951, 773	1.344	1.344	6		
10.2.2, 666	1.337				
953	1.296				
10.4.0, 864	1.290				
10.4.2	1.269				
11.1.1, 775	1.253				
880	1.228	1.228	4		
11.3.1, 971, 955	1.214				
882, 10.4.4	1.210				
10.6.0, 866	1.192				
11.3.3, 973	1.179	1.178	4		
10.6.2	1.175				
12.0.0, 884	1.158				
11.5.1, 777	1.146				
12.2.0	1.142				
12.2.2, 10.6.4	1.127	1.127	3		
11.5.3, 975	1.116				
12.4.0	1.099	1.099	2		

53) gave $a = 13.87$ Å, published with his powder data. *Mineral. Abstr.* 5, 451 (1933) reports this value. Donnay *et al.* (1963, p. 1013) abstracted their value from *Strukturbericht* (1933, II, p. 98)[1], but since this value, 13.90, had no units, they erroneously assumed it to be in kX units and recalculating obtained $a = 13.93$ Å. In addition, the later Watanabé value, 13.87 Å, seems to be in error. Inspection of Table 1 reveals that Watanabé's data show equal positive and negative deviation from our lines, hence the parameter should be the same, or 13.90 Å.

There is similar confusion over the space group of this mineral and of isostructural northupite. Gossner and Koch (1931, p. 458) correctly describe $2/m\bar{3}$ as the crystal class and $Fd3$ for the space group of northupite. Shiba and Watanabé (1931, p. 1422) first reported a structure based on $Fd3m$. Later, after consulatation with Gossner, Tokunosuke Watanabé (1933, p. 53) redetermined these structures using $Fd3$. Therefore, one sees the space group variously reported or abstracted as $Fd3$ (correct) and $Fd3m$ (incorrect).

Palache *et al.* (1951, p. 294–295) also incorrectly report Shiba and Watanabé's density values. They give "2.490 for artificial crystals," when the original paper (1931, p. 1422) actually states 2.549 (meas.), 2.569 (calc.). They actually are referring to Watanabé (1933, p. 36), but give no such reference. Although it appears Shiba and Watanabé incorrectly calculated their density (their 13.90 Å value calculates to 2.585 g/cm), the discrepancy is probably due to old atomic weights and a less accurate Avogadro number. The calculated density for our sample at 24°C is 2.586 g/cm^3 using 1961 $^{12}C = 12$ atomic weights and 1.6602 for a combined Avogadro and units-conversion factor.

The refractive index of our sample, as measured by oil immersion techniques at 25.8°C, is $n_D = 1.510$, in exact coincidence with the value for pure, synthetic tychite given by Penfield and Jamieson (1905, p. 219) and Shiba and Watanabé (1931, p. 1422).

Shiba and Watanabé (1931) presented no powder data. Only after preparation of our data did the published pattern by Watanabé (1933, p. 59) come to our attention. Table 1 includes this pattern converted to Å and maximum significant figures. In addition, diagramatic powder data have been reported by Neumann and Bryn (1958, pl. IV, #64). Spacings (second column, Table 1) were calculated with the computer program of Smith (1963).

In the interest of providing a more complete and accurate X-ray Powder Data File for mineralogists, this and other work is sponsored by the American Society for Testing and Materials, Grant No. 2212. We would

[1] Cites incorrect formula for this mineral. There should be four carbonate radicals, not two.

like to thank Mr. Ralph E. Merrill of Minerals Unlimited, Berkeley, California, for generously providing tychite for this study and information as to its occurrence.

References

Appleman, D. E., D. S. Handwerker, and H. T. Evans, Jr. (1963) The least-squares refinement of crystal unit cells with powder diffraction data by an automatic computer indexing method. (abstr.) *Prog. Ann. Meet., Amer. Crystallogr. Ass., Cambridge, Mass.*, p. 42–43.

Donnay, J. D. H., Gabrielle Donnay, E. G. Cox, Olga Kennard, and M. W. King (1963) Crystal data. *Amer. Crystallogr. Ass. Mongr.*, **5,** 1302 pp.

Fahey, Joseph, and Mary Mrose (1962) Saline minerals of the Green River Formation. *U.S. Geol. Surv. Prof. Pap.*, **405,** 50 pp.

Gossner, B., and I. Koch (1931) Über das Kristallgitter von Langbeinit, Northupit, und Hanksite. *Z. Kristallogr.*, **80,** 455–464.

Neumann, Heinrich, and K. O. Bryn (1958) X-ray powder patterns for mineral identification. IV. Carbonates. *Norkse Vidensk.-Akad. Oslo, I. Math.-Naturw. Kl. Adhandl.* **1958,** 6 p.

Palache, Charles, Harry Berman, and Clifford Frondel (1951) *System of Mineralogy · · · (7th ed.), Vol. 2,* John Wiley and Sons, Inc, New York, 1124 pp.

Penfield, S. L., and G. S. Jamieson (1905) On tychite, a new mineral from Borax Lake, California, and on its artificial production and its relations to northupite. *Amer. J. Sci., (4th ser.)* **20,** 217–224.

Shiba, Hikoichi, and Tokunosuke Watanabé (1931) Les structures de cristaux de northupite, de northupite bromee et de tychite. *C. R. Acad. Sci. Paris* **193,** 1421–1423.

Smith, Dean K. (1963) A FORTRAN program for calculating X-ray powder diffraction patterns. *Univ. Calif. Lawrence Rad. Lab.* [*U.S. Clearinghouse Fed. Sci. Tech. Info.*] *Rep. UCRL* **7196.**

Smith, G. I. (1952) Subsurface stratigraphy of late quaternary deposits, Searles Lake, California—A summary. *U.S. Geol. Surv. Prof. Pap.* **450-C,** p. C65–C69.

Wantanabé, Tokunosuke (1933) Synthese de la northupite, de la tychite et de nouveaux mineraux artificiels du meme groupe. *Tokyo Inst. Phys. Chem. Res., Sci. Pap.*, **21,** 35–39.

——— (1933) Les structures cristallines de la northupite $2MgCO_3 2Na_2CO_3 2NaCl$ et de la tychite $2MgCO_3 2Na_2CO_3 Na_2SO_4$. *Tokyo Inst. Phys. Chem. Res., Sci. Pap.*, **21,** 40–63.