

## Nickel-hexahydrate from Tasmania, Australia

IN April 1968 small amounts of a pale-green mineral were observed among mineral exploration samples from Noddy's Creek, Tasmania. The mineral formed thin efflorescent crusts on rocks mainly composed of talc, pyrite, and quartz. A partial chemical analysis, performed by Mr. K. Kinson on a small amount of the isolated mineral, showed major quantities of Ni (NiO over 15 % by weight) plus minor amounts of Mg, Zn, Co, and Fe<sup>2+</sup>. These results were supported by emission spectrographic and X-ray fluorescence examination. The refractive index of the mineral was in the range 1.47 to 1.49 and optically it was found to be biaxial negative. An indexed X-ray diffraction powder pattern of the mineral is listed in table I. The monoclinic unit-cell data,  $a$  9.97,  $b$  7.24,  $c$  24.23 Å, and  $\beta$  98.5°, differ slightly from Sutor's (1959) data on

TABLE I. X-ray powder diffraction data for nickel-hexahydrate

<i>hkl</i>	$d_{\text{calc}}$	$d_{\text{obs}}$	$I/I_0$	<i>hkl</i>	$d_{\text{calc}}$	$d_{\text{obs}}$	$I/I_0$	$d_{\text{obs}}$	$I/I_0$
004	5.990 Å	5.985 Å	10	222	2.780 Å	2.778 Å	10	1.962 Å	10
110	5.836	5.829	13	026	2.682	2.683	13	1.947	11
$\bar{1}11$	5.789	—	—	223	2.667	2.667	10	1.927	8
111	5.560	5.570	5	$\bar{2}25$	2.595	2.592	8	1.922	10
$\bar{1}12$	5.438	5.434	19	118	2.573	2.571	11	1.905	8
112	5.075	5.072	21	224	2.537	2.535	6	1.898	8
200	4.931	—	—	$\bar{1}19$	2.506	2.511	10	1.878	14
$\bar{1}13$	4.922	4.924	25	$\bar{4}02$	2.489	4.488	14	1.861	22
$\bar{2}02$	4.818	4.818	22	$\bar{2}26$	2.461	2.458	16	1.844	9
$\bar{1}14$	4.376	4.373	100	$\bar{3}17$	2.421	2.425	6	1.827	10
202	4.340	4.340	14	208	2.406	2.407	10	1.818	13
$\bar{2}04$	4.118	4.120	19	315	2.398	2.398	5	1.767	9
114	4.008	4.004	61	402	2.348	2.350	10	1.759	17
006	3.993	—	—	028	2.308	2.310	8	1.753	8
$\bar{1}15$	3.873	3.870	9	$\bar{3}18$	2.276	2.277	17	1.720	9
020	3.620	3.616	24	226	2.263	2.259	17	1.706	8
204	3.558	3.562	24	$\bar{1}34$	2.209	2.207	10	1.701	9
$\bar{1}16$	3.439	3.440	16	$\bar{2}28$	2.188	2.191	9	1.699	9
$\bar{2}06$	3.355	3.359	29	404	2.170	2.172	10	1.677	8
116	3.169	3.175	13	134	2.157	2.156	8	1.656	8
$\bar{1}17$	3.072	3.069	8	$\bar{1}111$	2.101	2.098	7	1.649	5
$\bar{3}11$	3.021	3.048	5	$\bar{4}08$	2.054	2.054	10	1.642	6
$\bar{3}12$	3.001	2.998	18	$\bar{1}36$	2.053	—	—	1.607	13
311	2.922	2.922	25	$\bar{4}23$	2.035	2.035	6	1.588	5
206	2.901	2.903	35	—	—	2.019	8	1.565	9
$\bar{2}22$	2.894	2.894	37	—	—	2.006	13	1.489	12
$\bar{2}23$	2.822	2.824	13	—	—	1.992	21	—	—

Diffraction data, Cu-K $\alpha$  radiation: monoclinic cell  $a$  9.97,  $b$  7.24,  $c$  24.23 Å,  $\beta$  98.5°, indices consistent with space group  $C2/c$ .

synthetic crystals of  $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ , for which he determined the space group  $C2/c$ , and  $Z = 8$ . Oleinikov *et al.* (1965) first discovered the mineral from the Severnaya mine of the Norilsk sulphide deposit and described it under the name of nickel-hexahydrate. The mineral formed bluish-green crusts on unweathered gabbro. They list two chemical analyses with variable nickel content and their powder patterns slightly vary with composition. In chemical composition and strong  $d$ -spacings the Tasmanian mineral is similar to the one with lower nickel content. The artificial nickel sulphate hexahydrate is dimorphic, a blue, tetragonal form, stable under ordinary conditions, inverting to the green, monoclinic form at  $53.4^\circ\text{C}$  (Mellor, 1936). The tetragonal compound occurs in nature as the mineral retgersite (Frondel and Palache, 1949) and, contrary to expectation, the monoclinic nickel-hexahydrate is also stable at room temperature. Metastable condition for the Tasmanian mineral is discounted on the grounds that its formation at or above the transition temperature requires too high concentrations of  $\text{NiSO}_4$  (solubility approx. 52% at  $53^\circ\text{C}$ ) for crystallization to occur in nature. It seems likely, although there is no experimental proof for it, that the monoclinic structure is stabilized due to a certain critical percentage of the substituent cation(s). This is to be expected, for all of the observed substituents, zinc, magnesium, iron, and cobalt form stable monoclinic minerals or compounds and their tetragonal counterparts exist only as unstable artificial compounds. An example of substitution-controlled structure is siderotil  $(\text{Fe,Cu})\text{SO}_4 \cdot 5\text{H}_2\text{O}$ , which requires at least 1.3 wt %  $\text{CuO}$  to stabilize its triclinic structure (Jambor and Traill, 1963) in preference to monoclinic rozenite. The Tasmanian mineral was probably formed under ordinary conditions by the oxidation of pyrite which was the source of nickel, iron, and sulphur. Oleinikov *et al.* (1965) propose a similar origin from waters containing free  $\text{H}_2\text{SO}_4$ .

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