

## Otwayite, a new nickel mineral from Western Australia

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### Abstract

Otwayite, found in the Nullagine region of Western Australia, occurs as fibrous veinlets in a nickel-rich assemblage. The composition of otwayite corresponds to  $(\text{Ni,Mg})_2(\text{OH})_2\text{CO}_3 \cdot \text{H}_2\text{O}$ . Fiber-rotation and powder X-ray diffraction patterns can be indexed on an orthorhombic unit cell with  $a = 10.18$   $b = 27.4$ , and  $c = 3.22\text{Å}$ . Measured  $G$  is 3.41; calculated  $G$ , assuming  $Z = 8$ , is 3.346. Otwayite is green in hand specimen, pale green and weakly pleochroic in transmitted light, has parallel extinction, is length-fast, and has  $\gamma = 1.72$ ,  $\alpha = 1.65$ .

### Introduction

The mineral described in this paper was found in three samples from the Otway prospect (lat.  $21^\circ 39'S$ ; long.  $120^\circ 06'$ ) in the Nullagine region of Western Australia, 23 km north of the town of Nullagine. An ultramafic body is cut by numerous shears that contain an unusual mineral assemblage including apatite, chlorite, magnesite, gaspeite, pecoraite, millerite, polydymite, and another new basic nickel carbonate that will be described elsewhere. A brief description of the gaspeite and pecoraite has been published (Nickel, 1973), and a more complete description of the entire occurrence is currently in preparation.

The mineral is named after Mr. Charles Otway, Gosnells, Western Australia, who has been very helpful in providing access to, and samples from, his mineral lease. Both mineral and name have been approved by the IMA Commission on New Minerals and Mineral Names. Type specimens are preserved in the mineral collection of the Division of Mineralogy, CSIRO, Perth, Western Australia under catalogue numbers 10016, 10027, and 10740.

### Occurrence

Otwayite has so far been found only in narrow veinlets between 0.5 and 1 mm in width. The veinlets appear to represent late-stage fracture filling, and

transect nickeloan serpentine, millerite, polydymite, and apatite. Associated with the otwayite in the veinlets are magnesite, gaspeite, and pecoraite.

The otwayite has a pronounced fibrous habit, with the fibers usually arranged in rosette-like aggregates (Fig. 1) more or less normal to the veinlet walls. Electron transmission micrographs (Fig. 2) indicate that individual fibers are about  $0.05\mu\text{m}$  in width. Fiber bundles, as observed under electron-scanning and optical microscopes, are seen to be several hundred microns in length.

### Chemical composition

A sample weighing 23 mg was hand-picked from one of the veinlets in sample 10027. A chemical analysis, in which NiO, MgO, and  $\text{SiO}_2$  were determined by atomic absorption and colorimetric procedures, and  $\text{CO}_2$  and  $\text{H}_2\text{O}$  were determined as C and H by a microanalytical procedure (MacDonald, 1974), gave the results shown in Table 1, col. 2. No elements other than Ni, Mg, and Si were detected by electron-microprobe analyses. Assuming that the 0.28 percent  $\text{SiO}_2$  is due to admixed pecoraite, the analysis was recalculated as shown in column 3. The atomic proportions (col. 6) are close to whole numbers if their sum is taken as 6. Recalculation of the analysis on this basis gives  $\text{Ni}_{1.904}\text{Mg}_{0.064}(\text{OH})_{1.924}(\text{CO}_3)_{1.006} \cdot 1.102\text{H}_2\text{O}$ , or nearly  $\text{Ni}_2(\text{OH})_2\text{CO}_3 \cdot \text{H}_2\text{O}$ .

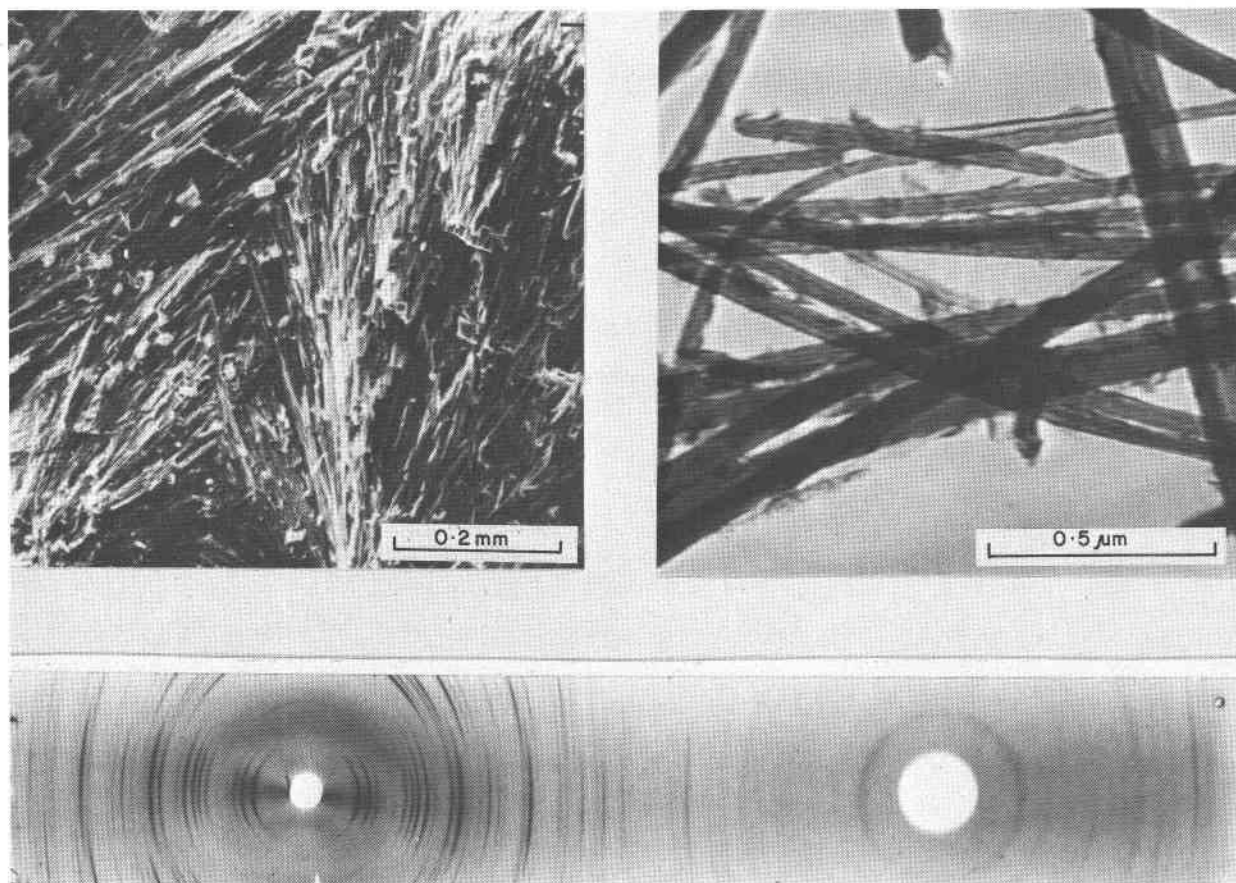


Fig. 1 (top left). Electron scanning micrograph of a broken surface, showing typical otwayite morphology.  
 Fig. 2 (top right). Electron transmission micrograph, showing dispersed otwayite fibers.  
 Fig. 3 (bottom). Fiber-rotation X-ray diffraction pattern of otwayite.

Table 1. Chemical composition of otwayite

	Weight Percent			Atomic Proportions		
	Analysis	Recalc.	Ideal $\text{Ni}_2(\text{OH})_2\text{CO}_3 \cdot \text{H}_2\text{O}$		Otwayite	Ideal $\text{Ni}_2(\text{OH})_2\text{CO}_3 \cdot \text{H}_2\text{O}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
NiO	62.20	62.87	65.12	Ni	1.904	2
MgO	1.12	1.14	-	Mg	0.064	-
$\text{SiO}_2$	0.28	-	-	OH	1.924	2
$\text{CO}_2^*$	19.24	19.57	19.18	$\text{CO}_3$	1.006	1
$\text{H}_2\text{O}^{**}$	16.17	16.42	15.70	$\text{H}_2\text{O}$	1.102	1
	99.01	100.00	100.00		6.000	6

\* Determined as C.

\*\* Determined as H.

### Optical and physical properties

Otwayite is bright green with a silky luster in hand specimen. In transmitted light it is pale green and weakly pleochroic, with the deepest color normal to the fiber axis. Extinction is parallel. Refractive indices are 1.65 parallel to the fiber length, and 1.72 normal to it; the mineral is therefore length-fast. The mean refractive index  $\bar{n}$  is  $[2(1.72) + 1.65]/3 = 1.70$ . Calculated  $\bar{n}$ , using the Gladstone-Date relationship and the values for specific refractive energies recently proposed by Mandarino (1976), is 1.719.

Specific gravity, determined by suspension in Clerici solution, is 3.41. Calculated density, using the corrected analysis in Table 1, col. 3, a unit-cell volume of  $898.2\text{A}^3$  (see below), and assuming  $Z = 8$ , is 3.346. The theoretical density for  $\text{Ni}_2(\text{OH})_2\text{CO}_3 \cdot \text{H}_2\text{O}$ , using the same cell volume, is 3.393.

Indentation hardness, using a 5-gram load, was found to be VHN 247, with a standard deviation of 114 for ten determinations.

Otwayite dissolves slowly in cold 1:1 HCl; at  $100^\circ\text{C}$  it dissolves rapidly, with visible evolution of  $\text{CO}_2$  bubbles.

### X-ray diffraction analysis

The X-ray powder diffraction data for otwayite are given in Table 2. Unfortunately it was not possible to isolate single crystals for X-ray diffraction, and thereby to index the powder pattern unequivocally. However, the parallel optical extinction suggests that the mineral has orthorhombic or higher symmetry. Fiber-rotation patterns (Fig. 3) provided some additional information that assisted the indexing. The fiber axis was arbitrarily taken as the  $c$  axis, which therefore makes all the equatorial reflections  $hk0$ . The lowest-angle line (6.8A) was taken as an  $0h0$  reflection, and it was necessary to designate it as 040 to enable some of the higher-angle lines to be indexed. Complete indexing of the powder pattern on an orthorhombic cell was possible when  $a$  was given a value of 10.2A. The final cell parameters, refined by least-squares calculations, are  $a = 10.18$ ,  $b = 27.4$ , and  $c = 3.22\text{A}$ . The calculated  $d$ -values (Table 2) show reasonable agreement with the measured ones. The cell parameters give a unit-cell volume of  $898.2\text{A}^3$ , which can accommodate 8 formula units when the formula weight and measured density are taken into account.

### Discussion

No mineral of otwayite composition appears in Isaac's (1963) review of nickel carbonates, and we

Table 2. X-ray powder diffraction pattern of otwayite

hkl	$d_{\text{obs}}^*$	$d_{\text{calc}}^\dagger$	$I_{\text{est}}^*$	hkl	$d_{\text{obs}}^*$	$d_{\text{calc}}^\dagger$	$I_{\text{est}}^*$
040	6.84	6.850	10	440	2.370	2.386	4
140	5.67	5.680	8	321	2.297	2.302	<1
200	5.04	[5.090] [5.004]	2	2·11·0	2.242	2.237	5
210				191	2.166	2.162	2
060	4.588	4.567	1	0·10·1	2.097	2.087	2
240	4.087	4.086	1	510	2.031	2.030	3
170	3.651	3.653	1	2·13·0	1.940	1.947	1
080	3.410	[3.425] [3.399]	2	3·12·0	1.898	1.894	2
260				391	1.851	1.853	1
001	3.227	3.220	2	570	1.813	1.806	<1
021	3.122	[3.135] [3.103]	1	1·13·1	1.732	1.738	4
270				590	1.692	1.692	4
031	3.022	3.037	5	640	1.648	1.647	3
190	2.922	2.917	<1	650	1.619	1.621	<1
280	2.835	2.842	<1	3·13·1	1.562	1.565	4
0·10·0	2.737	2.740	6	222	1.523	1.525	2
221	2.664	2.669	2	4·15·0	1.485	1.484	4
370	2.562	2.564	<1	710	1.452	1.452	1
241	2.529	2.529	5	730	1.434	1.436	1
071	2.481	2.487	3	5·11·1	1.415	1.416	1
380	2.402	2.411	2	5·13·1	1.333	1.333	2

\*  $d_{\text{obs}}$  in Å and  $I_{\text{est}}$  (visually estimated) are from 114.6mm Debye-Scherrer patterns made with  $\text{CoK}\alpha$  rad. ( $\lambda = 1.780\text{Å}$ ); out-off  $18\lambda$ .

†  $d_{\text{calc}}$  in Å are from  $a = 10.18$ ,  $b = 27.4$ ,  $c = 3.22$ .

have not found an existing mineral group to which otwayite might belong. Furthermore, no chemical compound of this sort seems to have been reported in the literature. The otwayite unit cell appears to be geometrically related to that of aurichalcite,  $(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6$ , which has  $a = 27.1$ ,  $b = 6.40$ , and  $c = 5.29\text{A}$  (Jambor and Pouliot, 1965), and of gerhardtite,  $\text{Cu}_2(\text{NO}_3)(\text{OH})_3$ , which has  $a = 5.59$ ,  $b = 6.07$ , and  $c = 13.81\text{A}$  (Oswald, 1961). However, both these minerals have quite different chemical compositions from otwayite, and the diffraction patterns are also dissimilar, except for the positions of the strong low-angle reflections (6.8–6.9A).

Not much can safely be said about the stability relations or mode of formation of otwayite, since it has not yet been synthesized. Its paragenesis, as indicated by its occurrence as late veinlets cutting across virtually all other minerals in the assemblage, and its association with gaspeite and pecoraite, suggests a late-stage, relatively low-temperature origin, possibly at ambient temperatures. The preferential alignment of fibers approximately normal to the veinlet walls suggests that directional pressure may be a significant factor in the formation of otwayite.

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