Nickel Minerals from Barberton, South Africa: VI. Liebenbergite, A Nickel Olivine

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Abstract

Liebenbergite, a nickel olivine from the mineral assemblage trevorite-liebenbergite-nickel serpentine-nickel ludwigite-bunsenite-violarite-millerite-gaspeite-nimite, is described mineralogically. It has $\alpha = 1.820$, $\beta = 1.854$, $\gamma = 1.888$, $2V\alpha = 88°$, specific gravity $= 4.60$, Mohs hardness $= 6$ to 6.5, $a = 4.727$, $b = 10.191$, $c = 5.955$Å, and $Z = 4$. X-ray powder data (48 lines) were indexed according to the space group *Pbnm*. The mean chemical composition, calculated from electron microprobe analyses of eight separate liebenbergite grains, gives the mineral formula:

$$(Ni_{1.52}Mg_{0.33}Co_{0.05}Fe_{0.12})Si_{0.99}O_4$$

The name is for W. R. Liebenberg, Deputy Director-General of the National Institute for Metallurgy, South Africa.

Introduction

A re-investigation of the trevorite deposit at Bon Accord in the Barberton Mountain Land, South Africa, led to the discovery of two peculiar but distinct nickel mineral assemblages. Minerals from the assemblage willemseite-nimite-ferroan trevorite-reevesite-millerite-violarite-goethite have been described in earlier papers in this series (de Waal, 1969, 1970a, 1970b; de Waal and Viljoen, 1971). From the second assemblage trevorite-nickel olivine-nickel serpentine-nickel ludwigite-bunsenite-violarite-millerite-gaspeite-nimite, only the trevorite (de Waal, 1972) has been described to date.

The present paper deals with the nickel olivine, here named liebenbergite. A paper on the nickel serpentine (a nickel-rich lizardite?) and nickel ludwigite is in preparation.

The name liebenbergite is proposed for the pure nickel end member of the olivine group and is applicable to all such minerals that contain nickel as the major cation in octahedral coordination. The name is for W. R. Liebenberg, Deputy Director-General of the National Institute for Metallurgy, South Africa, who has made a major contribution to the advancement of mineralogical science in that country. The name has been approved by the Commission on New Minerals and Mineral Names (IMA).

Experimental Methods

The refractive indices were determined by the conventional liquid immersion method using a sodium lamp as light source. The optical and crystal morphological parameters were studied with the aid of a universal stage. The macrohardness was estimated from the microhardness, which was determined with a Leitz Miniload hardness tester. The curve of Young and Millman (1964) relating microhardness with Mohs hardness was used for this purpose.

The X-ray data were obtained by means of a Debye-Scherrer camera (diameter 114.6 mm) with $CuK\alpha$ radiation. Corrections were made for film shrinkage, and the relative line intensities were estimated visually. By analogy to forsterite and fayalite, the space group *Pbnm* was assumed for the liebenbergite and the powder pattern was indexed accordingly. Cell parameters were refined using the computer program CELFIT (Bracher, 1967).

Microprobe analyses were made with an Applied Research Laboratories model EMX electron microprobe, using a 15 kV excitation potential and a

0.0250 μa specimen current. Wet-chemically analyzed natural silicates were used as standards for Si, Mg, and Fe. Synthetic sulfide standards prepared by Gerald K. Czamanske were used for Ni and Co. Corrections were made for background, instrumental drift, matrix absorption, characteristic fluorescence, and atomic number effects (Beeson, 1967; Beaman and Isasi, 1970).

Occurrence and General Mineralogy

The trevorite-bearing ores at Bon Accord formed a small tabular body approximately 20 feet long and about 2 feet thick at the contact between the Moodies quartzite and serpentinized ultramafite of the Jamestown Igneous Suite. The width of the body is uncertain, but judged from the prospecting trenches it was probably not much more than 10 feet. Unfortunately, most of the ores have been removed during the prospecting and mining activities so that *in situ* investigation of the different assemblages is not possible. This makes the study of the origin and mutual relationship of the two assemblages extremely difficult. The present work was done on samples obtained from the waste dumps.

TABLE 1. Optical and Physical Properties of Liebenbergite

Crystal System:	Orthorhombic
Unit Cell Parameters:	$a = 4.727 \pm 0.001$ Å $b = 10.191 \pm 0.003$ Å $c = 5.955 \pm 0.002$ Å Volume = 286.8 (Å)^3 $Z = 4$ Space group *Pbnm* (assumed)
Optical Properties	
Refractive Indices:	$\alpha = 1.820 \pm 0.003$ $\beta = 1.854$ (calc) $\gamma = 1.888 \pm 0.003$ $(\gamma-\alpha)=0.068$
Optical Orientation:	$\alpha = b$, $\beta = c$, $\gamma = a$ O.A.P. (001)
Optical Axial Angle:	$2V_\alpha = 88° \pm 2°$
Dispersion:	$r > v$
Pleochroism: (in thin section)	$X = Y$ = colorless to pale green Z = greenish yellow
Physical Properties	
ρ (calc):	4.60
Hardness (Mohs):	6 to 6.5 (derived from microhardness)
Cleavage:	{010} weak to moderate {100} weak
Twinning:	None observed
Color:	Yellowish green in grain concentrate

The liebenbergite forms part of the assemblage trevorite-nickel serpentine-nickel ludwigite-bunsenite-violarite-millerite-gaspeite-nimite. The original liebenbergite grains filled the interstices between the trevorite grains and measured up to 1 mm or more in diameter. They are, however, almost completely replaced by the secondary nickel serpentine, with the result that only small irregular grains, few exceeding 150 microns in diameter, are present in the serpentine matrix.

The fine intergrowth between the liebenbergite and the nickel serpentine that replaces it prevented separation of the two phases for bulk chemical or physical studies. Fortunately, as was proved by the microprobe analysis, the liebenbergite is homogeneous in composition within a hand specimen. This imparts greater confidence in the optical and physical properties that were not determined on the same grains as were analyzed.

Optical, Physical and Chemical Properties of the Liebenbergite

The optical and physical parameters of the liebenbergite are listed in Table 1. The crystallography is similar to that of the olivines, but the specific gravity, refractive indices, and optical axial angle of liebenbergite are distinctly different from either forsterite or fayalite.

The indexed X-ray powder pattern of liebenbergite (Table 2) corresponds closely to that of synthetic Ni_2SiO_4 (Pistorius, 1963). Liebenbergite has a $d(130)$-spacing diagnostically smaller than those for forsterite, fayalite, tephroite, and monticellite. Moreover, $d(130)$, in conjunction with either refractive index or specific gravity, can be used to estimate the composition of an olivine within the liebenbergite-forsterite-fayalite compositional triangle.

The chemical composition and mineral formula of liebenbergite are compared in Table 3 with those of Ni_2SiO_4. The results indicate that liebenbergite is homogeneous and is close to ideal Ni_2SiO_4 in composition. Assuming that the deviation from stoichiometry reflects analytical error, the formula may be written:

$$(Ni, Mg, Fe, Co)_2 SiO_4$$

Conclusions

The data presented leave little doubt that liebenbergite belongs to the olivine group of minerals and

TABLE 2. X-Ray Powder Data of Liebenbergite

hkl	I/I_o	d_{obs}	d_{calc}	hkl	I/I_o	d_{obs}	d_{calc}
020	30	5.09	5.10	152	15	1.583	1.585
110	25	4.29	4.29	043	10	1.561	1.566
020	25	3.87	3.87	311	5	1.507	1.506
101	10	3.70	3.70	242	5	1.497	1.498
111	60	3.47	3.48	143	20	1.486	1.487
121	10*	2.986	2.996	062	30	1.473	1.475
130	90	2.759	2.759	330	10	1.429	1.429
022	20*	2.564	2.570	331	20	1.390	1.390
131	80	2.503	2.503	312	10	1.380	1.380
112	100	2.442	2.445	322	15	1.343	1.343
200	10	2.367	2.364	341	15	1.308	1.307
041	10	2.337	2.342	332	5	1.289	1.289
210	5	2.303	2.302	204	5	1.259	1.260
122	30*	2.252	2.259	214	5	1.250	1.250
211	15	2.146	2.147	234	5	1.183	1.181
132	15	2.022	2.024	025	5	1.160	1.160
042	10	1.936	1.936	420	5	1.150	1.151
150	10	1.870	1.872	244	5	1.129	1.129
113	5	1.799	1.801	412	5	1.092	1.092
151	5	1.783	1.785	422	10	1.074	1.074
222	90	1.738	1.740	334	10	1.031	1.031
241	15	1.664	1.663	235	10*	1.015	1.015
061	10	1.631	1.634	384	10*	0.8245	0.8247
133	15	1.609	1.611	295	5*	0.7753	0.7752

* = broad line

that it approaches in composition the ideal nickel end-member of this mineral series.

The liebenbergite- and willemsite-bearing assemblages are unique in mineral composition. Their origin is enigmatic. Neither of the two commonly accepted processes of nickel enrichment, *i.e.*, magmatic segregation of sulfide or superficial enrichment under tropical weathering conditions, produces assemblages anything like those found at Bon Accord.

TABLE 3. Chemical Composition of Liebenbergite

Element oxide	Mean*	Weight percent Estimated standard deviation	Minimum–Maximum values	Stoichiometric Ni_2SiO_4
SiO_2	29.39	0.12	29.22 – 29.56	28.68
NiO	56.32	0.29	55.81 – 56.63	71.32
MgO	6.50	0.25	6.18 – 6.89	–
CoO	1.80	0.05	1.76 – 1.90	–
FeO	4.37	0.20	4.08 – 4.64	–
TOTAL	98.38	0.20	98.14 – 98.72	100.00

Element	Number of cations per 4[O]	
Si	0.99	1.00
Ni	1.52	2.00
Mg	0.33	
Co	0.05	
Fe	0.12	
Σ(Ni, Mg, Co, Fe)	2.02	2.00

*Mean of 8 separate grain analyses from three different sections.
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