THE AMERICAN MINERALOGIST, VOL. 54, JULY–AUGUST, 1969

NICKEL MINERALS FROM BARBERTON, SOUTH AFRICA: I. FERROAN TREVORITE

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Abstract

The reinvestigation of the alleged nepouite-trevorite deposit near the Scotia Talc Mine, Barberton, revealed the presence of a series of nickel minerals, *viz.* violarite, millerite, ferroan trevorite, nickel-rich talc, nickel-rich chlorite, and reevesite.

The ferroan trevorite has 4.2 nickel ions per 32 oxygen atoms in the unit cell, a cell edge of 8.367 ± 0.003 Å, a reflectivity of 21 percent, a Vickers hardness of 798 to 773 kg/mm^2, and a specific gravity of 5.212 ± 0.007 (measured).

The term 'ferroan trevorite', as used in this paper, is suggested for all the members in the magnetite-trevorite series containing between 4 and 6 nickel ions per 32 oxygen atoms.

Introduction

As part of a study of the distribution of nickel in serpentinites and related rocks, a sample of trevorite and associated silicate minerals from the well-known occurrence about two miles west of the Scotia Talc Mine in the Bon Accord area, Barberton, South Africa, was reinvestigated, mainly to ascertain the nature of the associated silicate minerals that are reported to be nepouite (South Africa Geological Survey, 1959). During this investigation, four nickel minerals, *viz*, ferroan trevorite, a nickel-rich talc, a nickel-rich chlorite, and reevesite, as well as violarite and millerite, were encountered. This paper is the first in a series in which these nickel minerals are described in detail. The name 'ferroan trevorite' has been used to indicate a mineral in the magnetite-trevorite series containing between four and six nickel ions per 32 oxygen atoms.

A review of the field relations as well as a description of the petrography of the nickel ore are also presented.

Field Relations of the Nickel Ore

The nickel ore under discussion was first reported by Trevor (1920). According to the South African Geological Survey (1959), the ore constitutes a tabular body two feet thick and about twenty-feet long and is probably a contact deposit along the junction of the Moodies quartzite and the Jamestown Igneous Suite. It is further stated that the major minerals are trevorite and nepouite.

Experimental Methods

Microscopy, using both transmitted and reflected light, formed the basis of the approach.

All colors allotted macroscopically are in accordance with the Rock-Color Chart, issued by the Geological Society of America (1963).

The very fine grain of the purified ferroan trevorite powder made it impossible to use normal techniques for determinations of the specific gravity. For this purpose, the weight of a small glass bucket with a diameter of 2 cm and a depth of 1 cm was determined in air and in toluene. The bucket was then half filled with the powder and weighed in air. Just enough toluene to fill the bucket to the brim was introduced in the bucket, and trapped air was removed in vacuum. The weight of the bucket with the powder was determined in toluene. From these measurements, the specific gravity of the ferroan trevorite could be determined. Corrections were made for variations in the density of the toluene with varying temperature.

The specific gravity of the ferroan trevorite was also calculated from its chemical analysis, cell edge, and Avogadro's number (6.0228×10^{23}).

A Leitz Miniload Hardness Tester was used for the Vickers microhardness determinations. From these values the macrohardness was derived from the hardness correlation graph given by Young and Millman (1964).

Reflectivity measurements were made on a freshly polished surface of the ferroan trevorite with a Leitz microphotometer. The Leitz standards, calibrated at 548 nm and 589 nm, were used as the reference materials.

The X-ray-diffraction analysis was done with a Debye-Scherrer camera with a diameter of 114.6 mm and with Co Kα radiation. Corrections for shrinkage were taken into consideration, and the cell edge was determined by extrapolation of the curve obtained by plotting the cell edge against $f(\theta)$, given by

$$f(\theta) = \frac{1}{2}\left(\frac{\cos^2\theta}{\sin\theta} + \frac{\cos^2\theta}{\theta}\right)$$

The ferroan trevorite was purified for chemical analysis by the use of its strong magnetic character and its relatively high hardness value combined with that of the associated silicate minerals. By successive grinding in a mechanical agate mortar, and magnetic separation with a hand magnet, both done in alcohol, a high degree of purity was finally obtained. The total amount of talc and chlorite present as impurities in the purified ferroan trevorite sample was calculated by the formula

$$100D_TD_2 - D_TD_2M_2 + D_TD_1M_2 = 100D_1D_2$$

where

D_T = sp. gr. of purified ferroan trevorite sample (measured),
D_1 = mean sp. gr. of the talc and chlorite impurities,
D_2 = sp. gr. of the ferroan trevorite as calculated from chemical analysis and cell edge.
M_2 = weight percentage of ferroan trevorite in purified sample.

It was assumed that the volume of the talc equals that of the chlorite.

RESULTS

Petrography of the nickel ore. The nickel-rich ore, in which the ferroan trevorite is found, has a greenish-gray (5 G 6/1) appearance on a fresh surface. The color, however, tends to be somewhat mottled owing to the patchy distribution of the ferroan trevorite in the green silicates. This latter phenomenon strongly simulates brecciation.

In thin section, the rock consists of clusters of minute opaque grains embedded in the nickel-rich talc. The nickel-rich chlorite forms irregular veins in the talc and opaque ore.

In the polished section, the ferroan trevorite forms the major component of the ore. The grain size of the ferroan trevorite varies considerably from about 0.5 mm to less than 10 μm in diameter. Polished sections further revealed the presence of violarite and millerite. The violarite is intergranular to the ferroan trevorite whereas the other sulphide forms minute inclusions in the ferroan trevorite. The amount of sulphide varies markedly from one hand specimen to another.

Secondary alteration of the ore is manifested by the formation of opal and moderate greenish-yellow (10 Y 7/4) reevesite in druses. These minerals have been mildly stained by iron oxide and small amounts of goethite are present.

Mineralogy of the Trevorite. The general physical and optical properties of the ferroan trevorite are presented in Table 1. The results of the etch

TABLE 1. PROPERTIES OF FERROAN TREVORITE

Property	Ferroan trevorite	Trevorite
Color and lustre	Black, metallic; dark grey (N3) in powder concentrate	Black, metallic
Specific gravity	5.212±0.007 (measured) 5.227 (calculated)	5.165 (Walker, 1923, p. 53)
Hardness	Vickers microhardness (HV): 798 kg/mm^2 with 50 g load 773 kg/mm^2 with 100 g load Macrohardness (Mohs): $5\frac{1}{2}$–6 (derived from HV)	Macrohardness (Mohs): 5+(Partridge, 1944, p. 123)
Reflectivity	21.0% at 548 nm and 20.8% at 589 nm	
Cell edge	8.367±0.003 Å	
Miscellaneous	Strongly magnetic; crystals often show octahedral habit but are usually well rounded; resembles magnetite in polished section but rosy tinge less pronounced; weekly anistropic	Etch tests (Partridge 1944, p 123): Negative: HNO_3, HCl, KCN, $FeCl_3$, KOH, $HgCl_2$ aqua regia, H_2O_2, $HClO_4$, $K_4FeC_6N_6$. KCNS, conc. $SnCl_2$, KI, conc, $H_2SO_4+KMnO_4$, hot conc. conc. HCl at 100°C

TABLE 2. CHEMICAL DATA FOR FERROAN TREVORITE, TREVORITE, AND MAGNETITE

Chemical Analyses

	1	2	3	4
SiO_2	0.66	1.40	0.03	0.47
Al_2O_3	0.03	—	0.19	0.00
Fe_2O_3	68.51	66.24	68.95	68.49
FeO	13.00	1.96	30.82	12.99
MnO	0.00	—	—	0.00
MgO	0.07	0.24	—	0.03
NiO	16.75	29.71	—	16.60
CoO	0.32	—	—	0.32
CaO	0.04	—	0.02	0.04
H_2O	n.d.	0.36	0.04	n.d.

Number of ions on the basis of 32 Oxygen atoms

	1		2		3		4	
Si	0.204	16.16	0.433	15.85	0.009	16.04	0.146	16.19
Al	0.011		—		0.070		—	
Fe^{3+}	15.947		15.414		15.961		16.042	
Mg	0.032	7.65	0.111	8.01	—	7.94	0.014	7.64
Ni	4.167		7.396		—		4.156	
Fe^{2+}	3.363		0.505		7.929		3.381	
Mn	0.000		—		—		0.000	
Ca	0.013		—		0.007		0.013	
Co	0.079		—		—		0.080	

1. Ferroan trevorite (present investigation), no corrections made; n.d. = not determined.
2. Trevorite after Walker as quoted by Deer, Howie, and Zussman (1962).
3. Magnetite after Takeuchi and Nambu as quoted by Deer, Howie, and Zussman (1962).
4. Ferroan trevorite (present investigation) corrected for 0.48 percent impurities of talc and chlorite; n.d. = not determined.

test carried out by Partridge (1944) on trevorite from the same locality are also included. A plot of the cell edges of magnetite, ferroan trevorite, and nickel ferrite against their respective numbers of nickel ions per 32 oxygen atoms indicates that there is a linear relation between these parameters.

In Table 2, the chemical analyses of trevorite, ferroan trevorite, and magnetite are compared. The ferroan trevorite has a nickel content that falls about halfway between the magnetite and the trevorite described by Dear, Howie, and Zussman (1962).

Discussion

Nomenclature. The magnetite series of minerals are well described in the literature, and the present findings once more verify the existing data. One main issue, brought forward with the present work, is that seemingly there exists a full isomorphous series between trevorite and magnetite. This phenomenon poses the problem of when a mineral should be called trevorite and when magnetite. To clarify matters it is suggested that the series should be subdivided as follows: magnetite—0 to 2 nickel ions per 32 oxygen atoms; nickeloan magnetite—2 to 4 nickel ions per 32 oxygen atoms; ferroan trevorite—4 to 6 nickel ions per 32 oxygen atoms; and trevorite—6 to 8 nickel ions per 32 oxygen atoms.

Chemical Composition. The fact that the ferroan trevorite (Table 2) has a total of $16.16+7.65=23.81$ cations per 32 oxygen atoms indicates that the mineral is very slightly altered to maghemite, a phenomenon that was not observed under the microscope.

Acknowledgments

The writer is indebted to Dr. R. E. Robinson, Director, and Dr. W. R. Liebenberg, Deputy Director, of the National Institute for Metallurgy for the opportunity to investigate the ferroan trevorite and for various suggestions to improve the script. Thanks are also due to Dr. S. A. Hiemstra, Head of the Mineralogy Division, for critical comments, and to colleagues for assistance at various stages during the investigation.

References

Deer, W. A., R. A. Howie, and J. Zussman (1962) *Rock Forming Minerals, vol. 5. Non-silicates. 1st ed.* London, William Clowes and Sons, Ltd., 371.

Partridge, F. E., (1944) Trevorite and a suggested new nickel-bearing silicate from Bon Accord, Sheba Siding, Barberton District. *Trans. Geol. Soc. S. Afr.*, **46,** 119–136.

Rock-Color Chart Committee. (1963) *Rock-Color Chart.* Geological Society of America, New York.

South Africa Geological Survey. (1959) *The mineral resources of South Africa. 4th ed.* Pretoria, Government Printer, 622 p.

Walker, T. L. (1923) Trevorite, a distinct mineral species. *Toronto Univ. Studies, Geol. Ser.*, **16,** 53–54.

Young, B. B., and A. P. Millman (1964) Microhardness and deformation characteristics of ore minerals. *Trans. Inst. Min. Metall.*, **73,** 437–466.