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An unusual titanium-rich oxide mineral from the Eastern Bushveld Complex

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Abstract

Grains of a titanium-rich oxide mineral found at four horizons in the Critical Zone of the Eastern Bushveld Complex contain, besides Ti, Cr, Al, Zr, Fe, Mg, Ca, and Mn in various proportions, small amounts of Sc, Y, and rare-earth elements. The mineral is probably a member of either the pseudobrookite series or the senaite–crichtonite–loveringite series.

Trace amounts of a complex titanium-rich oxide mineral have been found at four horizons in the Critical Zone of the Eastern Bushveld Complex, as follows:

(1) chromitic bronzitite, 12.5 m below the Steelpoort chromitite, Jagdlust Mine;

(2) thin chromitite, upper part of E unit (Cameron, 1977, Fig. 1), Farm Annex Grootboom;

(3) chromite-rich anorthosite, upper part of H unit, Farm Jagdlust;

(4) Merensky Reef, on Farm Umkoanes Stad and on Farm Grootboom.

The mineral is in all cases associated with bronzite, plagioclase, chromite, and rutile; trace ilmenite is present in the chromitite from Annex Grootboom. The mineral is erratically distributed. It was found initially in a polished section of chromitite from the Merensky Reef on Umkoanes Stad. Four other sections prepared from the same sample are devoid of the mineral. The largest grains found are respectively 0.15 mm and 0.09 mm in length. The mineral forms anhedra marginal to or between chromite grains (Fig. 1). Properties of the mineral are as follows:

color—pale gray, lighter than chromite, darker than rutile;

reflectivity—17.3 percent at 546 mu;

anisotropism—weak, readily detectable only with oil immersion;

microhardness—indeterminate, owing to small size of grains;

polishing hardness—less than chromite, less than rutile.

Analyses of four grains are given in Table 1. There may be trace amounts of other rare earths. Vanadium was sought but not found. Methods of probe analysis used for Ti, Fe, Mg, Ca, Cr, Al, Mn, and V are those described by Cameron and Glover (1973). For Zr and Sc an analyzed baddeleyite and pure scandium, respectively, were used as standards. For REE, standards used were those prepared by Drake and Weill (1972). In analyzing each grain, counts per 40,000 counts on the beam current were taken, at 15 kV, at each of five spots and the counts averaged. Low summations may be due partly to calculation of Fe entirely as FeO. Fe_2O_3 is probably present; coexisting chromites have ferric/ferrous ratios ranging from 1/4 to 1/2. If half the Fe in analysis No. 1 is calculated as Fe_2O_3, the summation becomes 100.26 percent.

The analyses indicate marked variation in composition and suggest complex substitution in a solid-solution series. Substitution of ZrO_2 for TiO_2 is especially conspicuous. Grains a few millimeters apart in the same polished section (*cf.* analyses 1 and 2) differ markedly. This variation is probably related to formation of the mineral late in the post-cumulus stage, the individual grains forming from isolated tiny volumes of residual liquid. Chromite in the Bushveld Complex characteristically shows a similar variation in rocks in which it is present in amounts below 1 percent (Cameron, 1977).

The grains are too small to be extracted for X-ray study. Their compositions fall within the general range of the pseudobrookite series, and the analyses calculate reasonably well to 5 oxygens if allowance is made for the low summations and for the probable presence of Fe_2O_3. If again, half the Fe in analysis No. 1 is ferric iron, cations per 5 oxygens become 2.9865. In complexity the analyses resemble those of lunar Cr–Zr–REE armalcolite described by Dowty *et al.* (1974) and the Cr–Zr–Ca armalcolites reviewed by Frondel (1975). Armalcolite, however, contains no ferric iron, whereas except in kimberlites, terrestrial pseudobrookites invariably do (Smith, 1965; El Goresy, 1976; Haggerty, 1975, 1976); in fact, they commonly contain much more ferric than ferrous iron. The Bushveld mineral is also similar in composition to loveringite, found in the Jimberlana norite intrusive, Western Australia, and described by Gatehouse *et al.* (1978) as isostructural with senaite and crichtonite (Grey *et al.*, 1976). For analysis No. 1 (Table 1) cations per 38 oxygens calculate at 22.1515 if all iron is ferrous, at 21.1383 if all the iron is ferric; the theoretical value is around 21. Until material suitable for X-ray study can be found, however, it is necessary to defer deciding whether the Bushveld mineral belongs to the pseudobrookite or the senaite–crichtonite–loveringite series.

The occurrences described here are the only ones recognized from study of hundreds of polished sections of chromitic rocks from various horizons of the Critical Zone of the Eastern Bushveld. I anticipate, however, that other occurrences will be found. The mineral is erratically distributed and sufficiently close to rutile in color to be easily overlooked.

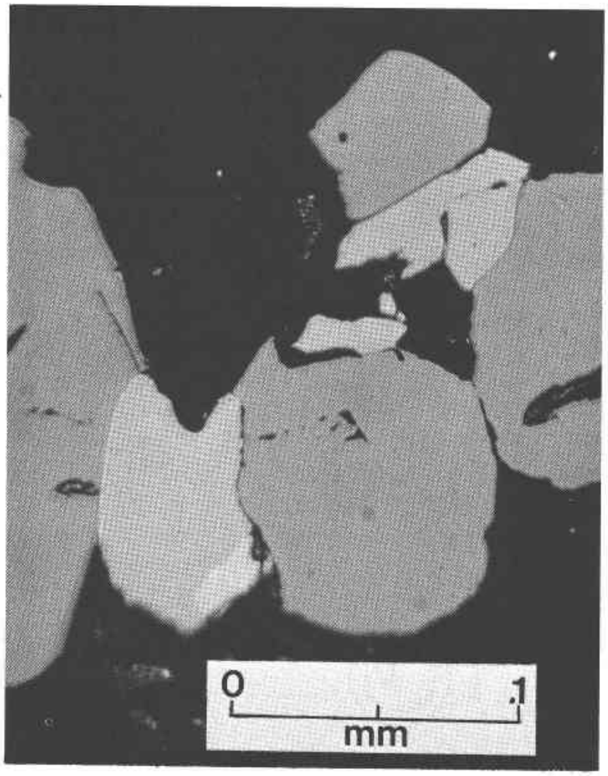

Fig. 1. Two grains (white) of a titanium-rich oxide mineral; one partly plucked during polishing. Rutile (slightly paler) forms the end of the lower grain. Gray chromite. Oil immersion.

Table 1. Analyses of individual grains

	1.	2.	3.	4.
TiO_2	59.72	63.62	62.57	66.03
ZrO_2	4.67	1.08	1.19	0.39
Nd_2O_3	∿0.50	∿0.50	0.47	--
Ce_2O_3	1.77	1.25	1.76	0.65
La_2O_3	0.91	0.33	0.73	0.03
Y_2O_3	0.72	0.97	0.46	Tr.
Sc_2O_3	0.34	0.57	0.29	0.65
Cr_2O_3	10.88	10.28	11.78	9.77
Al_2O_3	1.83	1.49	1.21	0.89
FeO	13.77	13.46	13.87	13.40
MnO	0.15	0.14	0.17	0.70
CaO	2.17	2.66	2.55	3.33
MgO	1.97	2.09	1.79	2.41
	99.50	98.44	98.84	98.25
	Cations per 5 oxygens			
Ti	1.8585	1.9105	1.8985	1.9689
Zr	0.0942	0.0211	0.0235	0.0076
Nd	0.0037	0.0036	0.0000	0.0098
Ce	0.0134	0.0091	0.0131	0.0071
La	0.0070	0.0024	0.0053	0.0002
Y	0.0132	0.0170	0.0082	0.0000
Sc	0.0062	0.0098	0.0051	0.0012
Cr	0.1780	0.1622	0.1879	0.1532
Al	0.0445	0.0350	0.0289	0.0312
Fe	0.4764	0.4494	0.4679	0.4446
Mn	0.0052	0.0048	0.0058	0.0236
Ca	0.0962	0.1137	0.1103	0.1415
Mg	0.1171	0.1238	0.1072	0.1418
	2.9136	2.8624	2.8617	2.9307

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