

corresponding to a stable one-phase crystalline field (Smith and Parsons, 1974; Parsons, 1978).

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Zinc- and manganese-bearing chromites and associated grossular from Zimbabwe

ZINC-RICH chromites have been reported from relatively few localities, and some of these have been discredited in the light of modern analytical techniques. Moore (1977), for example, showed by detailed electron microprobe analysis of Donath's original samples that the supposed zinc-rich (up to 2.6%) chromites from the Helgeland area, Norway (Donath, 1931) contain only up to 0.3% ZnO. Moore suggested, therefore, that the Outokumpu deposit of Finland might be a unique location for zinc-rich chromites, and emphasized that a very unusual geochemical environment must have been necessary for their formation.

We report here the occurrence of chromites with up to 4.3% ZnO in a 'nephrite' sample (BM 1961, 404) from the Mashaba Chromite Mine, Rhodesia, during a routine investigation of the amphibole. The mine, in Archaean Basement rocks, is in a small serpentine body, part of the predominantly ultramafic Mashaba layered complex. The complex is thought to have been formed by multiple intrusion, with the oldest, most ultramafic pulse at the top (Wilson, 1968). The serpentines appear to have been derived almost entirely from the dunites, peridotites, and harzburgites by the action of hydrothermal solutions after consolidation. The 'neph-

rites', however, occur 'as masses enclosed in . . . aplite which appear to have been derived from original xenoliths of serpentinised dunite by interaction with the intruding granitic magma' (Wilson, 1968).

X-ray scanning photographs obtained with the microprobe (fig. 1) show the distribution of some elements in the chromite and the presence of a fringing reaction mineral which is an unusual chromium- and manganese-bearing grossular. The chromites are markedly zoned, and the irregular and diffuse boundaries between areas of different composition suggest that the zoning is a secondary, metasomatic, feature rather than a primary one.

The traverse (fig. 2) shows that magnesium has been replaced by Mn^{2+} , Fe^{2+} , and Zn^{2+} . Each of the 23 points represents a nine-element analysis performed on a Cambridge Instruments wavelength-dispersive Microscan 9 microprobe. From the diagram it can be seen that Mn replacement has penetrated a greater distance into the crystal than Zn replacement, implying different rates of diffusion.

This type of zoning is in marked contrast to that of the Outokumpu chromites, where sharp-bounded, sometimes oscillatory, primary zoning

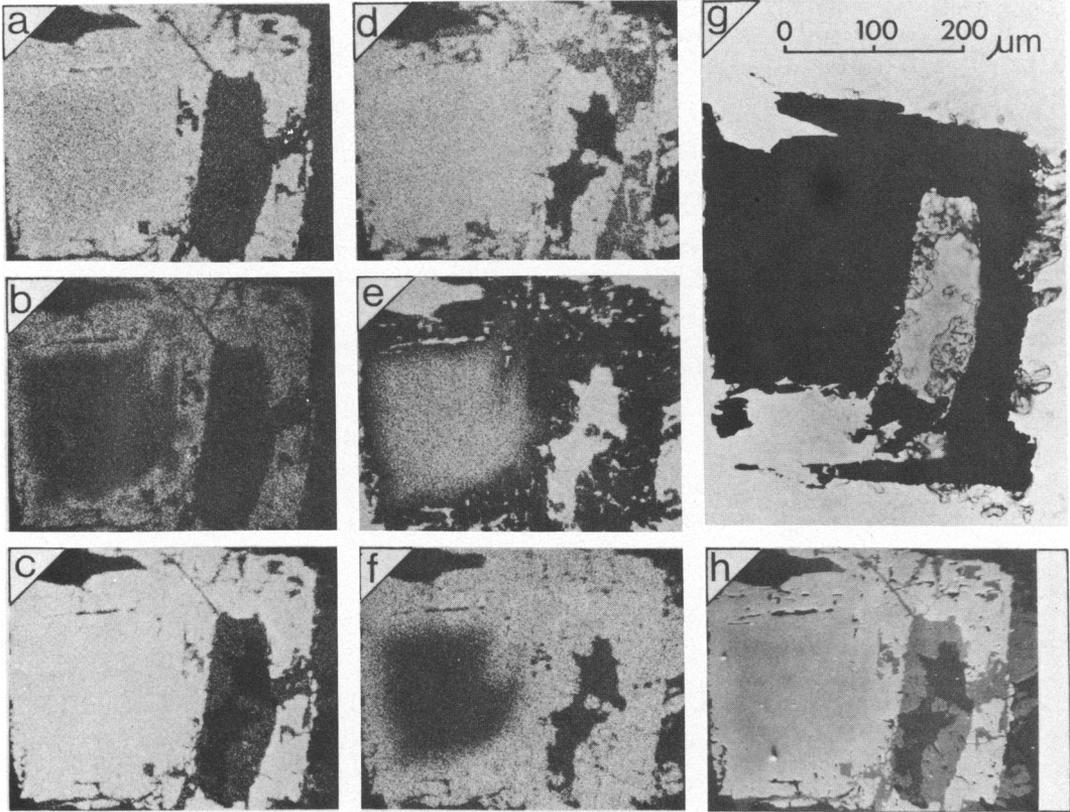


FIG. 1. Photomicrographs of chromite and associated silicates in BM 1961, 404. *a-f*. X-ray scanning photographs of (a) Fe; (b) Zn; (c) Cr; (d) Al; (e) Mg; (f) Mn. *g*. Transmitted light photomicrograph. *h*. Back-scattered and secondary electron image: light grey: chromite; mid-grey: garnet; dark-grey: amphibole.

following crystal outlines is the norm (Weiser, 1967). The Outokumpu chromites are not opaque in transmitted light: the darker zones contain the largest amounts of zinc (up to 12% ZnO) whereas lighter areas have less. Manganese and vanadium are also present in significant amounts (up to 3.1% and 3.0% respectively). These compositional variations must to some extent reflect changes in the supply of the various elements during crystallization or recrystallization. It is suggested that the Outokumpu chromites formed at a late stage by hydrothermal activity involving both chrome-bearing serpentinite and spatially associated zinc-bearing sulphide deposits (Vähätalo, 1953).

However, no sulphide deposits are associated with the Rhodesian zinc-bearing chromites, and although the area is one of serpentinites, the chromites are found in fine-grained tremolite (analysis 6, Table I) rocks ('nephrite'). Compared with analyses of layered chromites from the adjacent

Prince Mine, Mashaba (Wilson, 1968), (e.g. analysis 1, Table I) the chromite core (analysis 2, Table I) has a similar Al and Cr content, and an only slightly higher Mg:Fe²⁺ ratio. Neither Mn nor Zn was reported in any of the previous analyses of chromites from this area. It is thus reasonable to assume that the chromites in the 'nephrite' are relict minerals from an original dunite, and that the zoning was induced during the metasomatic alteration of the dunite xenolith by reaction with the aplite. The cores of the largest chromite grains may be closest to the original composition.

A further result of this metasomatic episode has been the formation of the fringing grossular around the chromite. Zinc was not detected in the garnet, but large amounts of chromium and manganese are present (analysis 5, Table I). In composition and association the garnet is comparable to the uvarovites reported from chromitites of the Bushveld Complex (Frankel, 1959), and to that common in

the Outokumpu deposit (Eskola, 1933), but, unlike these two, carries a significant manganese component of about 17 mole % spessartine.

Conclusions. In the Outokumpu deposits a metamorphic zirconian chromite was formed, according to Moore (1977), under special circumstances involving chrome-bearing serpentinites and spatially associated zinc-bearing sulphide deposits. In the Rhodesian locality, however, an existing igneous chromite from a ultramafic rock took up zinc and

other elements during incorporation as a xenolith in an aplite dyke. The different mechanisms gave rise to spinels with very similar compositions, but with different petrographic features.

Since zinc has not been reported in analyses of the basic and ultrabasic rocks of the Mashaba district (Wilson, 1968), it is probable that the source of the high levels of zinc in these chromites was the aplitic magma. Similarly, it is likely that the manganese was also brought in by the granitic magma, since

TABLE I. *Electron microprobe analyses of chromites and grossular from Rhodesia*

	1	2	3	4		5	6
					SiO ₂	37.3	56.8
TiO ₂	0.18	0.15	0.18	0.27	TiO ₂	n.d.	n.d.
Al ₂ O ₃	14.57	15.2	13.8	3.92	Al ₂ O ₃	17.0	0.38
Cr ₂ O ₃	56.80	54.3	49.3	54.1	Cr ₂ O ₃	5.24	0.42
Fe ₂ O ₃ *	—	1.54	1.80	8.78	Fe ₂ O ₃	2.23	—
FeO	14.23	14.8	21.6	20.3	FeO	1.87	3.31
MnO	n.d.	0.43	8.02	9.46	MnO	7.57	0.20
ZnO	n.d.	n.d.	4.27	2.61	ZnO	n.d.	n.d.
MgO	13.97	12.4	0.70	0.32	MgO	0.32	21.5
					CaO	27.7	13.0
Total	99.77†	99.0‡	99.7§	99.9	Total	99.2	95.6
Numbers of ions on the basis of:							
	32 (O)					24 (O)	23 (O)
Ti	0.03	0.03	0.04	0.06	Si	5.94	7.96
Al	4.34	4.60	4.56	1.36	Al	0.06	0.04
Cr	11.35	11.06	10.93	12.58	Cr	3.14	0.03
Fe ³⁺	0.24	0.28	0.36	1.94	Fe ³⁺	0.66	0.05
Fe ²⁺	2.77	3.18	5.07	4.99	Fe ²⁺	0.27	—
Mn	—	0.09	1.91	2.36	Fe ²⁺	0.25	0.39
Zn	—	—	0.88	0.57	Mn	1.02	0.02
Mg	5.26	4.74	0.29	0.14	Zn	—	—
					Mg	0.07	4.51
					Ca	4.72	1.95
					pyr	1.3	
					alm	4.1	
					spess	16.9	
					uvar	16.3	
					gross	61.5	

1. Chromite from Prince Mine, Mashaba. Sample 19 (Wilson, 1968). Analyst B. J. Radclyffe.

2. Chromite from Mashaba Mine, Mashaba, Rhodesia. Core of grain shown in Fig. 1.

3. Rim of grain shown in Fig. 1.

4. Al-poor chromite ('ferritchromite') forming outer extension of grain in Fig. 1.

5. Grossular fringing chromite. Average of three grains.

6. Tremolite forming matrix of above grains.

* Fe³⁺:Fe²⁺ determined on the basis of charge balance using the structural formulae.

† Analysis recalculated free of serpentine: Fe (total) as FeO.

‡ Total includes 0.12 V₂O₃; 0.06 NiO.

§ Total includes 0.20 V₂O₃.

|| Total includes 0.16 V₂O₃.

Analysis 1: wet chemical; analyses 2-6: by wavelength-dispersive EPMA, analyst J. C. Bevan.

n.d.: not detected.

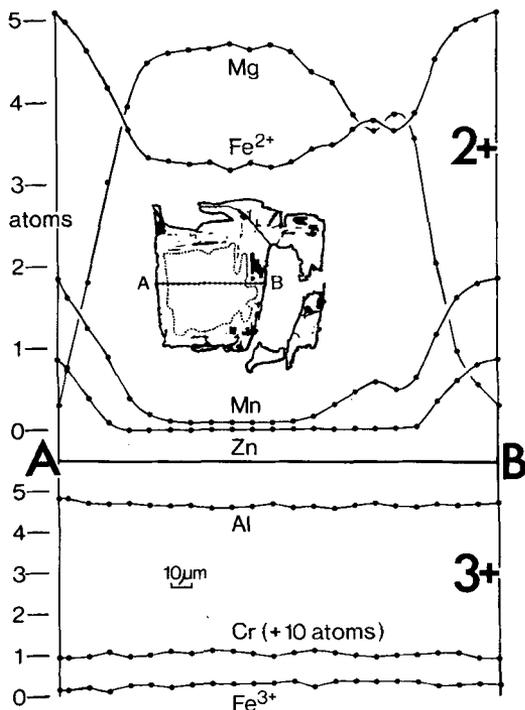


FIG. 2. Traverse of grain shown in Fig. 1. Atoms have been calculated on the basis of 32 oxygens and Fe^{3+} calculated assuming that the mineral is stoichiometric. Analyses 2 and 3 in Table I are points on this traverse at extremes of Mg compositional variation.

manganese levels in the tremolite are virtually the same as those inferred for the pre-existing olivine by comparison with unaltered dunite from the same area. However, the authors believe that the Al

needed for the formation of the garnet was made available by the alteration of the normal chromite to Al-poor 'ferritchromite'. Fig. 1 (d) shows that the extension on the right-hand side of the grain is much lower in Al than the main body of the crystal: analysis 4 in Table I confirms this. It can be seen from Fig. 1 (g) that the garnet is spatially related to this Al-poor material which, although quite different in composition from the main chromite, also contains appreciable amounts of ZnO (2.6%).

Recently Utter (1978) has listed a detrital chromite with 4.71% ZnO from the Klerkdorp Goldfield. He concludes, for a variety of reasons, that this and other chromites came from an Archaean granite-greenstone provenance area. It is possible that this detrital chromite may have obtained its unusual composition by a mechanism similar to that outlined in this paper.

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