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Poikilitic chromite in komatiitic cumulates

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With 5 Figures

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Summary

Chromite is a widespread accessory mineral in olivine-rich cumulates derived from komatiitic lavas. The distribution and crystal habit of chromite is related to the degree of differentiation of the parent magma as reflected in the composition of cumulus olivine. Cumulates with olivine forsterite content greater than 93 mol percent typically contain no chromite at all, while chromite forms clusters of disseminated euhedral grains in cumulates with forsterite less than 91 mol percent. In the forsterite 91–93 interval, chromite may develop lobate interstitial habits. In the Six Mile Well ultramafic complex in the Yakabindie region of the Agnew-Wiluna greenstone belt, and in other olivine-rich komatiitic units within this belt, chromite shows well developed poikilitic textures enclosing olivine.

The absence of intercumulus silicate phases in these rocks and the low normative chromite content of the parent magma make it impossible for these chromite grains to have crystallised from intercumulus trapped liquid. These rocks must be cotectic chromite-olivine adcumulates, owing their unusual texture to differing relative rates of nucleation and growth of chromite and olivine, crystallising together *in-situ*. This observation provides further evidence for a cumulus origin for oikocrysts in layered intrusions, and casts doubt on the usefulness of cumulus terminology.

Zusammenfassung

Poikilitischer Chromit in komatiitischen Kumulaten

Chromit ist in Olivin-reichen Kumulaten, die von komatiitischen Laven abstammen, ein häufiges akzessorisches Mineral. Die Verteilung und der Kristallhabitus von Chromit hängt vom Grad der Differentiation des Stammagmas, der in der Zusammensetzung der Kumulus-Olivine zum Ausdruck kommt, ab. Für Kumulate mit Olivinen mit einem Forsterit-Gehalt von über 93 mol.% ist es charakteristisch, daß sie überhaupt keinen Chromit enthalten, während Chromit in Kumulaten mit Olivinen mit weniger als 90 mol.% Forsterit Cluster aus fein verteilten, idiomorphem Körnern bildet. Im Intervall Forsterit 90–93 kann Chromit lobate, interstitielle Formen ausbilden. Im ultramafischen Komplex Six Mile Well in der Yakabindie-Region des Agnew-Wiluna-Grünsteingürtels und in anderen Olivin-reichen komatiitischen Einheiten in diesem Gürtel zeigen die Chromite gut entwickelte poikilitische Texturen mit eingeschlossenen Olivinen.

Da silikatische Interkumulus-Phasen in diesen Gesteinen fehlen und der normative Chromitgehalt des Stammagmas niedrig ist, können diese Chromitkörner nicht aus einer Interkumulus-Schmelze auskristallisiert sein. Diese Gesteine müssen daher kotektische Chromit-Olivin-Adkumulate sein, die ihre ungewöhnliche Textur den variierenden relativen Keimbildungs- und Wachstumsraten von Chromit und Olivin, die gemeinsam in situ kristallisierten, verdanken. Diese Beobachtung stellt einen weiteren Beweis für die Entstehung von Oikokristallen als Kumulusphase in geschichteten Intrusionen dar und läßt die Zweckmäßigkeit der Kumulus-Terminologie als zweifelhaft erscheinen.

Introduction

Chromite is a widespread accessory phase in komatiites, and shows a variety of crystal habits related to the cooling history of the host rock. It typically shows skeletal morphologies in spinifex-textured komatiites, and occurs as clusters of subhedral to euhedral equant grains in komatiitic rocks containing non-skeletal cumulus olivine (*Zhou* and *Kerrich*, 1992). In this note we describe an occurrence of coarse poikilitic chromite in coarse-grained komatiitic olivine adcumulates from the Yakabindie area of the Western Australian Yilgarn Block.

Geological setting

The komatiites of the Yakabindie area occur in the middle of a 170 km long continuous belt of komatiitic rocks in the Agnew-Wiluna greenstone belt, in the

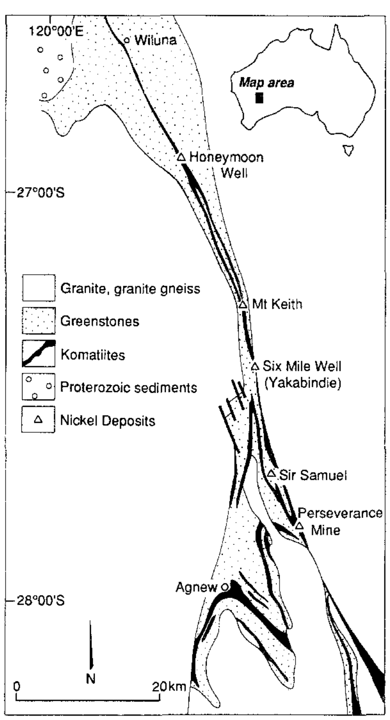

Fig. 1. Location map of the Agnew-Wiluna Greenstone Belt, showing the location of the Yakabindie region and the Six Mile Well deposit

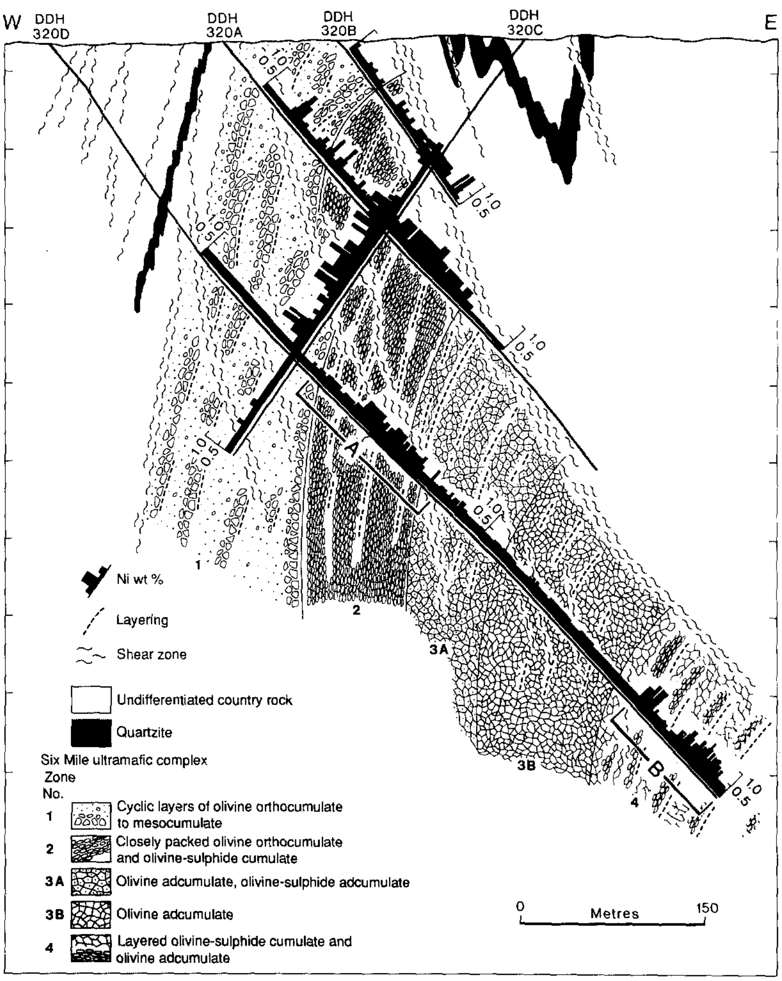

Fig. 2. Cross section through the Six Mile Well ultramafic complex, after *Hill* et al. (1990)

north western part of the Eastern Goldfields province of the Yilgarn Block (Fig. 1). This belt of komatiites is composed primarily of extensive sequences of fine to medium grained, mostly serpentinised, olivine orthocumulates with minor amounts of spinifex textured komatiite. Lenticular bodies of coarse grained olivine mesocumulates and adcumulates within the sequence are interpreted by *Hill* et al. (1989) and *Barnes* et al. (1988) as occupying thermal erosion channels formed by extensive komatiite lava rivers. The Six Mile dunite body (Figs. 1, 2), previously described by *Naldrett* and *Turner* (1977), is one such body.

The core of the Six Mile dunite lens (*Hill* et al., 1990) consists of coarse grained, very pure olivine adcumulates with olivine compositions ranging from $Fo_{93.5}$ to $Fo_{94.5}$, and no chromite. This central core is overlain by a cyclically layered sequence of olivine adcumulates (Fig. 3a), mesocumulates and orthocumulates with disseminated Fe–Ni sulphides, and olivine compositions ranging from Fo_{90} to Fo_{92}. Chromite is a common accessory within this layered unit. Layering is evident on a range of scales, and chromite abundance fluctuates on a scale of 5 to 20 centimetres from layers with no chromite at all to layers with up to 5 modal percent.

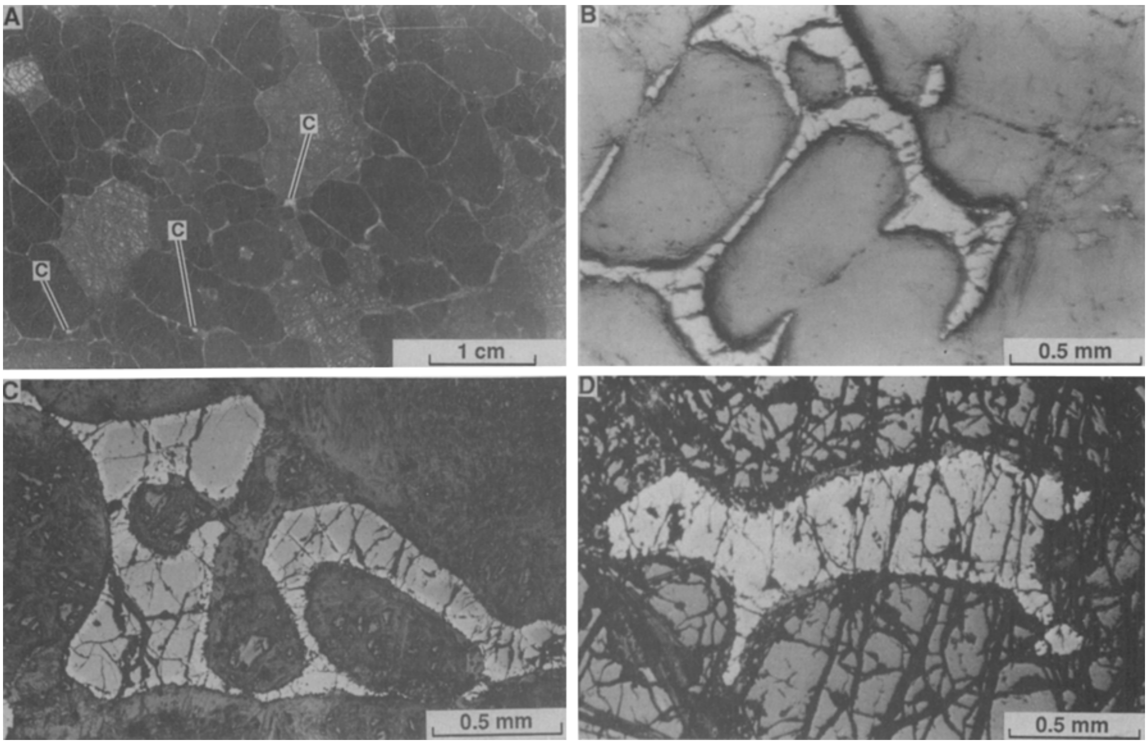

Fig. 3. Photomicrographs (reflected light) showing chromite textures in olivine-chromite adcumulates from the Six Mile Well complex. **A** Olivine adcumulate, partially serpentinised, from zone 3A, with lobate interstitial chromite ("C") partially pseudomorphed by stichtite. **B, C, D** Interstitial and poikilitic chromite grains in serpentinised olivine adcumulate. Rim of secondary ferrichromite, related to serpentinisation of olivine, evident in C and D

Olivine is typically serpentinised through most of the Six Mile ultramafic body, and chromite shows narrow rims of ferrichromite. Locally chromite shows partial to complete marginal alteration to stichtite.

Chromite habit and host rock composition

Chromite abundance and habit within komatiitic olivine rich cumulates in the Yakabindie area and elsewhere shows a clear relationship to olivine composition in the host rock (Fig. 4). The more magnesian dunites, having olivines with greater than 93 mol.% forsterite, usually contain very little or no chromite, while dunites having olivines less magnesian than about Fo_{91} contain relatively abundant chromite as clusters of small euhedral equant grains. Within the range Fo_{91-93}, chromite is relatively coarse grained (1–4 mm), and ranges from lobate to distinctly poikilitic in habit (Fig. 3b,c,d). These poikilitic grains are homogenous and unzoned, except for the development of thin ferrian chromite rims in serpentinised rocks. Over the range of olivine compositions from Fo_{88} to Fo_{93} and over the range of textural types there is very little systematic variation in the relative proportions of Cr, Al and ferric iron in komatiitic chromites (Fig. 4).

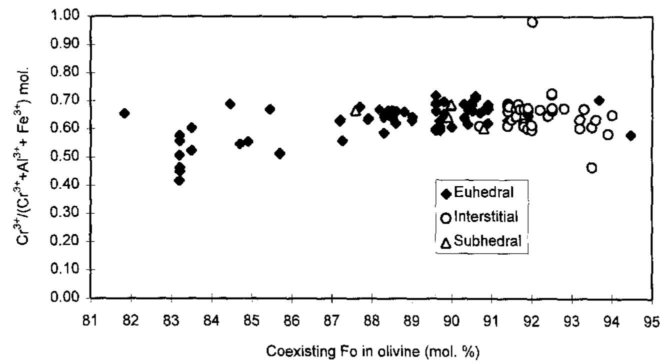

Fig. 4. Plot of chromite composition (trivalent ion components) vs. forsterite content of coexisting olivine in komatiitic cumulates from various localities in the Norseman-Wiluna Greenstone Belt. Symbols refer to chromite habit; "interstitial" incorporates both lobate and poikilitic varieties

Origin of poikilitic chromites

Traditionally, poikilitic textures in cumulate rocks have been interpreted as the result of crystallisation of the poikilitic phase from trapped liquid interstitial to cumulus grains. In most cases of mafic and ultramafic cumulates, the poikilitic phase is plagioclase or pyroxene which would have been a major normative component of the intercumulus liquid. In the present case, however, chromite could only have been a minor normative component. Experimental data of *Murck* and *Campbell* (1986) (Fig. 5) suggest that a typical chromite-saturated komatiitic melt in equilibrium with Fo_{92} olivine would have contained no more than about 0.3% Cr_2O_3, or approximately 0.5 to 1 normative percent chromite. In view of the almost complete absence of intercumulus silicate minerals in these rocks, the poikilitic chromite could not have crystallised from trapped intercumulus liquid.

The only possible explanation of these textures is that these rocks represent cotectic olivine-chromite cumulates, in which chromite and olivine nucleated and grew simultaneously *in situ*. The poikilitic habit of the chromite can be explained if chromite grew relatively rapidly from sparse, widely separated nucleation sites, while olivine was simultaneously growing more slowly from much more abundant nucleation sites. Scattered, rapidly growing chromite grains could therefore have overtaken and trapped small olivine crystals. This mechanism was invoked to explain poikilitic textures in Skaergaard rocks by *McBirney* and *Noyes* (1979), and a more elaborate model involving *in-situ* crystallisation in a thermal boundary layer has been proposed by *Wilson* (1992) for poikilitic pyroxenites in the Great Dyke. This occurrence of poikilitic chromite in the Six Mile dunite, and numerous other dunite bodies of similar composition in the Agnew-Wiluna belt, provides strong supporting evidence for the *in-situ*, crescumulate origin of oikocrysts.

A requirement for the growth of large poikilitic chromite grains is a continuous supply of chromite-supersaturated liquid to the site of crystallisation, and the inhibition of compositional boundary layers around the growing crystals. This could be achieved by rapid turbulent flow of magma past the site of crystallisation. This situation would exist at the floor of a turbulent komatiite lava river, which is the

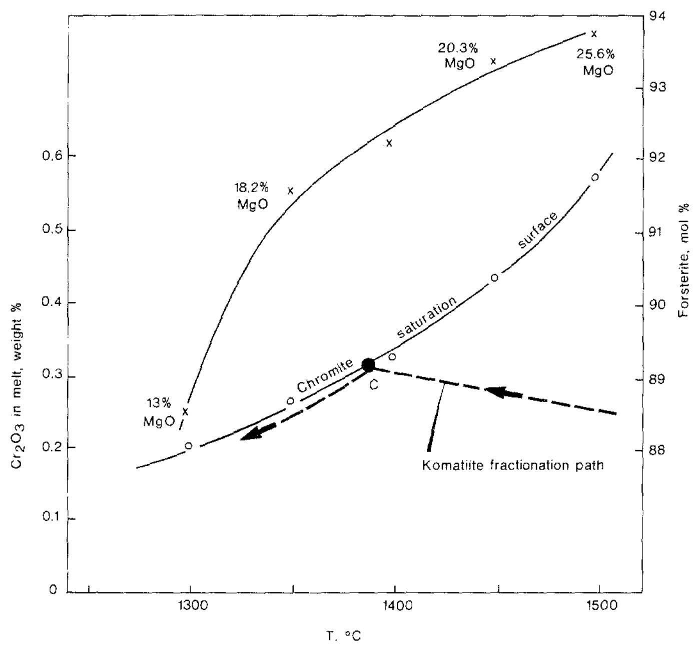

Fig. 5. Experimental data from *Murck* and *Campbell* (1986) on the crystallisation of chromite and olivine from a Kambalda komatiite, as a function of temperature, at the oxygen fugacity of the QFM buffer. The lower curve (values on left hand axis) shows the chromite saturation surface, i.e. the Cr content of the liquid at which chromite begins to crystallise. The upper curve (right hand axis) shows the equilibrium composition of olivine crystallising from the liquid. Data points on this curve are labelled with the corresponding MgO content of the komatiite liquid. The heavy dashed curve shows a hypothetical trend for variation in Cr in a fractionating komatiite liquid. Chromite appears on the liquidus at point C, corresponding to an olivine composition of about 92 mol. % forsterite

environment of formation of the komatiitic dunite lenses postulated by *Hill* et al. (1989).

The appearance of chromite in komatiite cumulates with Fo_{92-93} olivine is consistent with experimental data of *Murck* and *Campbell* (1986) on chromite solubility in komatiites (Fig. 5). Chromite solubility, i.e. the Cr content of the melt at which chromite begins to crystallise, is a strong negative function of temperature. This accounts for the commonly observed absence of chromite in the most magnesian komatiitic dunites, as indicated by the dashed "komatiite fractionation path" in Fig. 5. Most primitive komatiite melts start out undersaturated in chromite. Cr therefore behaves as an incompatible element, and increases during olivine fractionation until the melt intersects the chromite saturation surface, at a composition corresponding to approximately Fo_{92} olivine. The poikilitic textures correspond to crystallisation close to the temperature where chromite first appears on the liquidus.

Implications

Poikilitic chromite has not been reported from any other environment, and is probably peculiar to primitive komatiite magmas where the chromite solubility is high compared with lower temperature magmas. It is probably also peculiar to the unique environment of turbulent lava flow and very low degrees of supercooling found at the base of major komatiite lava rivers.

The textures described here have broader implications as evidence of the *in-situ*, cumulus origin of oikocrysts. Poikilitic textures may be expected in multi-phase cotectic adcumulates where the relative rates of nucleation and growth of the different cumulus phases are significantly different. This may account for the common occurrence in large major intrusions such as the Bushveld, Stillwater and Great Dyke of pyroxene heteradcumulates with poikilitic plagioclase. By analogy with the poikilitic chromite-bearing rocks, these cumulates may have crystallised from magmas on the plagioclase-pyroxene cotectic. Given that plagioclase is more difficult to nucleate than ferromagnesian minerals (*Lofgren*, 1980), pyroxene would tend to nucleate more readily producing local constitutional supersaturation with plagioclase. Once the degree of supersaturation became critical, plagioclase would nucleate and subsequently grow rapidly to form scattered oikocrysts enclosing more slowly growing euhedral pyroxenes.

Plagioclase oikocrysts in pyroxenites in the Stillwater Complex and in the Great Dyke are most strongly developed in the stratigraphic interval just below the horizon of first appearance of true "cumulus" plagioclase. Correspondingly, as noted above, poikilitic chromite in komatiitic cumulates occurs in the temperature range where chromite has just begun to crystallise. Poikilitic textures in both cases correspond to the arrival of the new phase on the liquidus.

The poikilitic chromite textures described here, and the emerging view of oikocrysts as liquidus or near-liquidus phases, expose the limitations of cumulus terminology. Strict application of cumulus terminology to these rocks would classify them as olivine cumulates with intercumulus chromite, whereas in fact they are obviously olivine chromite cumulates in the sense that both olivine and chromite must have been on the liquidus of the parent magma. Cumulus terminology may have become more confusing than enlightening.

Acknowledgements

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