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CHROMITE GRAINS SHOWING ALTERED BORDERS FROM THE BASAL REEF, WITWATERSRAND SYSTEM

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ABSTRACT

Chromite grains possessing different reflectivities and higher reflecting borders have been observed in the Basal Reef of the Witwatersrand System. The electron microprobe revealed the increase in reflectivity to be caused by an increase in the iron and, possibly, the chromium content, and a decrease in the magnesium and aluminum content of the chromite. It is suggested that this alteration took place to a great extent *in situ*, and has been intensified by radioactive emanation, which facilitated the destruction of the crystal lattice and thus promoted subsequent replacement.

INTRODUCTION

Chromite grains that exhibit rims of higher reflectivity have been described by Horninger (1941), Spangenberg (1943), de Wijkerslooth (1943), Augusthithis (1960), Panagos and Ottemann (1966), and in great detail by Weiser (1967).

An ore-microscopic study of sediments belonging to the Basal Reef of the Witwatersrand System in the locality of Welkom, in the Orange Free State Goldfield, showed a large proportion of the chromite grains, which form a common constituent of the heavy mineral suite, to be rimmed by such a marginal area showing higher reflectivity.

Horninger (1941) designated the alteration product forming high reflecting marginal areas in chromite as 'grey magnetite.' He suggested that the alteration takes place by substitution of material with the country rock, *i.e.*, by either the removal of Al and Mg from, or the addition of Fe to, the chromite.

Spangenberg (1943) ascribed the high reflecting margins to serpentinization and chloritization of the country rock. He suggested an exchange between the $MgAl_2O_4$ component of the chromite and the Fe_3O_4 component of the country rock. During the process the Cr_2O_3 content of the chromite is supposed to remain constant.

De Wijkerslooth (1943) believed marginal zones originate at a hydrothermal-metamorphic period that is later than serpentinization and chloritization and involves selective resorption, during which certain components (FeO-Fe_3O_4, Cr_2O_3) are more slowly removed than others (Al_2O_3, MgO). The higher reflecting margins therefore represent areas which contain relatively higher concentrations of Fe and Cr.

According to Ramdohr (1950), the altered rims result from weathering and hydrothermal decomposition and are composed of pure magnetite in extreme cases.

The marginal area in chromites from the Belledonne Massif was thought by Den Tex (1955) to be enriched in magnetite.

Qualitative determinations with an electron microprobe by Panagos and Ottemann (1966) on the marginal phase of chromites from Rodiani, Greece, showed not only an increase in the iron and chromium content, but also a decrease in the magnesium and aluminum content.

Chromite grains from various localities have been investigated by Weiser (1967). He found no consistent composition for the marginal areas, but a consistent compositional trend towards a more iron-rich spinel. He distinguished two groups of marginal higher reflecting areas. In one group, an increase in the Fe and Cr concentration is formed at the expense of Al and Mg. This leads to solid solutions that are rich in ferrochromite. In the other group, considerably higher contents of Fe and lower concentrations of Al, Mg, and Cr occur and a magnetite-rich solid solution is formed.

The authors cited above, with the exception of Ramdohr (1950), mention the higher reflecting rims formed in the primary environment of the chromites. In this paper, higher reflecting rims on detrital grains are described, and it is suggested that they are formed, at least partly, in a sedimentary environment.

On the composition of the marginal phase, the present authors have not much new to offer. However, they have noted some unusual environmental relationships of some of the chromites in the Witwatersrand sediments that may bear on the genesis of the marginal zones exhibited by these grains.

Optical Investigation of Polished Sections

An optical examination of more than two hundred polished sections revealed a slight variation in the reflectivity of the chromite grains, most readily detected when grains could be directly compared (Fig. 1A). In addition to this variation, a large proportion of grains exhibited borders of higher reflectance, this being especially noticeable using oil immersion (Fig. 3A). These marginal areas are generally fairly narrow. They follow the outline of the grains and also border cracks and fractures. Where a chromite grain abuts a grain of uraninite or other radioactive mineral, the side of the chromite nearest to the radioactive source displayed a noticeable widening of the marginal area (Fig. 2A). Similar features have been noted by Ramdohr and Schidlowski (1965) in connection with radioactive corrosion of chromite. This juxtaposition of chromite to a radio-

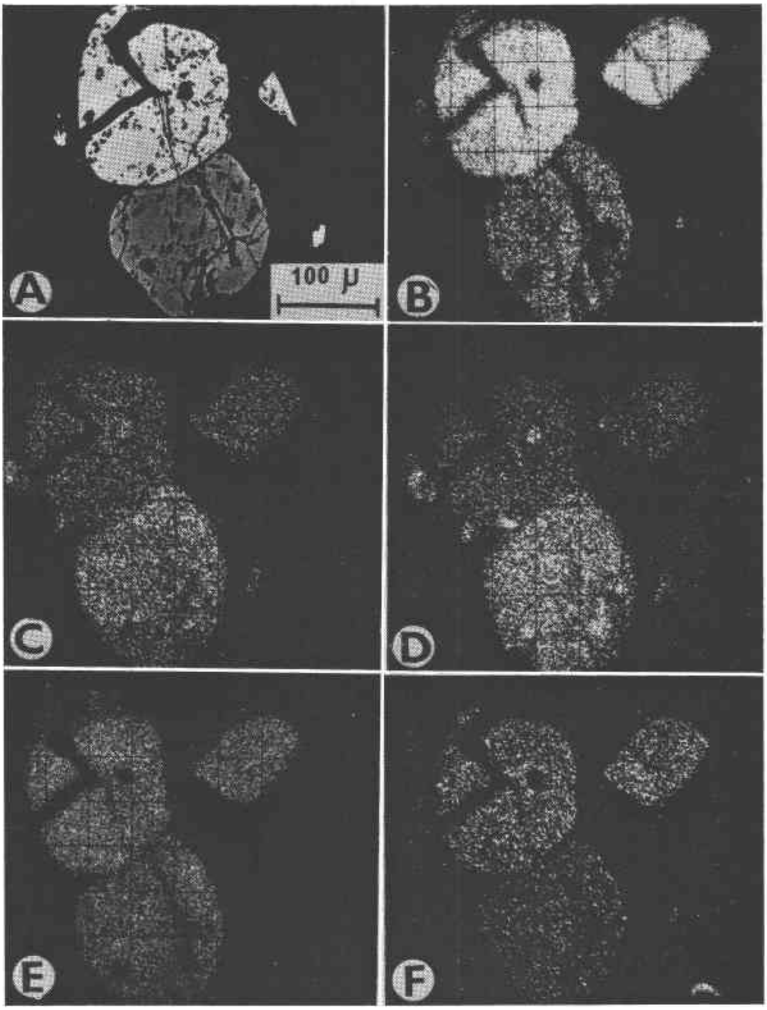

FIG. 1. (A) Optical photomicrograph showing two chromite grains differing considerably in reflectivity. Basal Reef. Oil immersion. (B) Electron-backscatter image. (C-F) X-ray distribution images of Al, Mg, Cr, and Fe Kα radiations respectively.

active mineral is naturally rare. Among the limited cases observed, a few exceptions to the rule of marginal widening were noticed.

REFLECTIVITY DETERMINATIONS

Reflectivities were determined with a Leitz Dialux-Pol microscope, fitted with an MPE Leitz-photometer and photomultiplier tube (type VFS9A, Fernseh GMBH; for its spectral sensitivity see Saagar and Mihá-

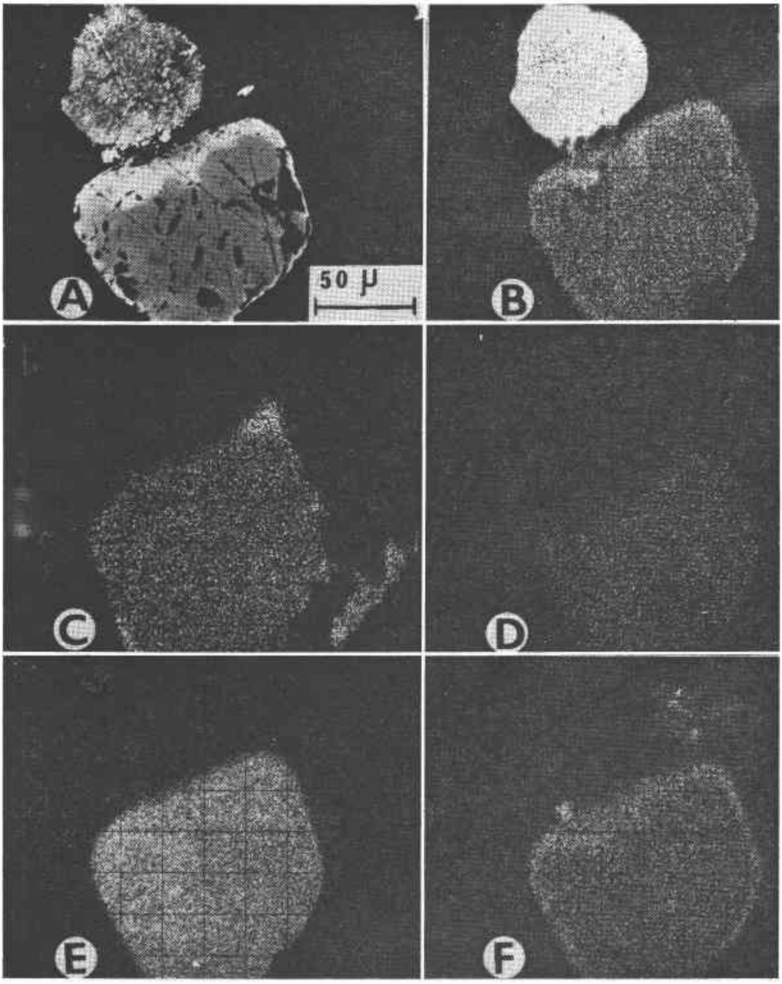

FIG. 2. (A) Optical photomicrograph showing a grain of uraninite lying in juxtaposition with a chromite grain. Basal Reef. Oil immersion. (B) Electron-back, scatter image. (C-F) X-ray distribution images of Al, Mg, Cr, and Fe Kα radiations, respectively.

lik (1967), Fig. 3). The results obtained on the grains pictured in Figures 1, 2, and 3, are shown in Table 1. Each of the reflectivity values given is the mean of 6 measurements and related to the (111) plane of pyrite from Rio Marina, Elba, which was standardized at 54.6 percent at a wavelength of 590nm, according to the value obtained by Singh (1965) on pyrite from the same locality.

The reflectivity of both the cores and the rims of various chromite grains shows considerable variation.

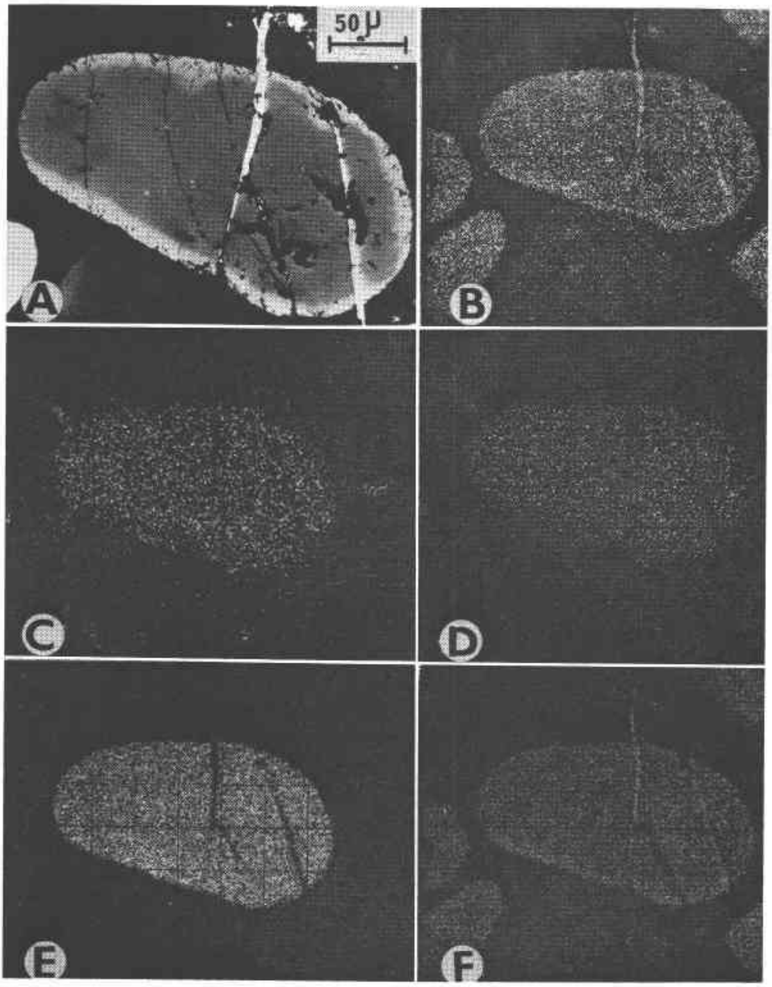

FIG. 3. (A) Optical photomicrograph showing a chromite grain with a higher reflecting border traversed by two pyrite veinlets. (B) Electron-backscatter image. (C–F) X-ray distribution images of Al, Mg, Cr, and Fe Kα radiations respectively.

MICROHARDNESS MEASUREMENTS

Microhardness determinations carried out on a Leitz Durimet Vickers Hardness Tester with a load of 200 grams and a contact time of 25 seconds, are given in Table 1. The differences obtained on the various types of chromite lie within the margin of error of measurement.

ELECTRON-MICROPROBE ANALYSIS

Qualitative determinations were carried out with an Applied Research

TABLE 1. REFLECTIVITY AND HARDNESS OF CHROMITES FROM THE BASAL REEF

Chromite phase	Reflectivity value %	Hardness value HV
Darker grain, Figure 1A	9.3±0.4	1226
Lighter grain, Figure 1A	11.0±0.4	1206
Marginal phase, Figure 2A	11.5±0.4	1206
Core of grain, Figure 2A	10.3±0.4	1192
Marginal phase, Figure 3A	13.2±0.4	1183
Core of grain, Figure 3A	11.8±0.4	1183

Laboratories Model EMX electron microprobe. Figure 1A shows two chromite grains, one moulded against the other, and each possessing different reflectivities. Figure 1B shows the electron-backscatter image indicating the grain of higher reflectivity to have a higher mean atomic weight. Figures 1C to 1F show the X-ray-distribution images of Al, Mg, Cr, and Fe Kα radiations, respectively. The higher Mg and Al content of the darker chromite grain is apparent.

Figure 2A shows the optical photomicrograph of a chromite grain adjoining a grain of uraninite containing numerous inclusions of radiogenic galena. Figure 2B shows the electron-backscatter image. Note the clearly higher mean atomic weight of the marginal area, which is noticeably wider in the neighbourhood of the uraninite. Figures 2C to 2F show the X-ray-distribution images of Al, Mg, Cr, and Fe Kα radiations, respectively. The markedly lower Mg and higher Fe content of the marginal area is evident. Here it seems that MgO has been replaced by FeO, whereas Al and Cr are little affected.

Figure 3A shows the optical photomicrograph of a chromite grain traversed by two younger pyrite veins and possessing a higher reflecting rim. Figure 3B is the electron-backscatter image, which again shows the higher mean atomic weight of the marginal area. Figures 3C to 3F show the X-ray-distribution images of Al, Mg, Cr, and Fe Kα radiation respectively. The Al and Mg are present in lower concentration in the marginal areas, whereas again Fe is higher, and in this instance, possibly also chromium.

The higher iron and chromium content and the lower magnesium and aluminum content of the more intensely reflecting chromite phase is clearly demonstrated. It appears that, in the samples investigated, the reflectance intensity of chromite is a measure of the degree of leaching of the magnesium and aluminum from the lattice.

CONCLUSIONS

The rounded form of the Witwatersrand chromite grains and the lack of adherent source-rock material suggested to Davidson and Bowie (1951) that the grains had been transported over a considerable distance. Ramdohr (1955), however, pointed out that chromite, even in primary deposits, occurs mostly as rounded grains and that even limited transport will liberate the chromite from its source-rock and that any serpentine attachments could also be dissolved by pseudohydrothermal solutions circulating during the consolidation and metamorphism of the conglomerates. Ramdohr (1955) further considered the higher reflecting rims of many Witwatersrand chromite grains as evidence of limited transport, because such borders are present in chromites in their primary environment and would be abraded during long transport. This seems to the present authors to contradict Ramdohr's earlier statement (Ramdohr, 1950) that chromite alteration results from weathering and decomposition.

The present investigation revealed that at least part of the higher reflecting borders in Witwatersrand chromites were formed *in situ* and therefore cannot serve as a criterion of limited transport.

The two groups of marginal areas described by Weiser (1967) were not observed in this investigation, and this may be due to chemical changes during transport and incorporation of the grains in the Witwatersrand Sediments. Subsequent alteration is also indicated by the presence of a marginal phase adjoining open cracks and fissures, and by the widening of the marginal areas where chromite grains abut grains of uraninite. Both these conditions were induced within the Witwatersrand sediments.

The physical damage caused to surrounding minerals by radioactive grains is not unknown, and has been described by Liebenberg (1955), and others. The proximity of a radioactive mineral to some of the chromite grains in the Witwatersrand sediments is believed to have caused a certain amount of lattice destruction, which in turn facilitated the leaching of MgO from the lattice and its replacement by FeO. There is no apparent change in the Cr and Al content in this particular instance. In other cases, however, a decrease of Mg and Al, together with a marked increase in Fe and a possible increase of Cr, has been found.

The presence of juxtaposed chromite grains, the cores of which differ in composition, points to considerable primary differences between the various grains at the time of deposition.

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