10IKC-136

CHEMICAL AND TEXTURAL CHARACTERISATION OF NON-KIMBERLITIC CHROMIAN SPINEL POPULATIONS FROM DIAMOND EXPLORATION PROGRAMMES

Macdonald AI[1] and Napier S[2]

[1]*De Beers Group Services, Group Exploration, Johannesburg, South Africa*
[2]*Napier Exploration cc, Johannesburg, South Africa.*

INTRODUCTION

Chromian spinel is an important indicator or pathfinder mineral in the early stages of exploration for primary diamond deposits, such as described in Muggeridge (1995), but is also present in a variety of other rock types. The focus in such exploration is on the chemical and other characteristics of the spinel xenocrysts derived from the mantle, as well as the spinel phenocrysts and overgrowths derived from the magma of kimberlites and related rocks. However, if surficial sediment sampling is to be used in the early stages of diamond exploration, it is also useful to consider the potential sources and likely characteristics of non-kimberlitic spinels in a target area, to anticipate the potential complications of using such exploration methods. Many studies of spinel extracted directly from other rock types have been published, providing a reference for comparison, but the datasets from any one source considered in these studies are quite small. In addition the spinels extracted directly from such source rocks have not been subject to modification in the surface environment, as is the case with those recovered during exploration sampling programmes.

This study has utilised many thousands of electron microprobe analyses and surface feature classifications of chromian spinels from historical soil and stream sediment samples, spread across southern and central Africa, to characterise some of the non-kimberlitic sources found within this cratonic environment and adjacent metamorphic belts.

DATA AND METHODOLOGY

Chemical data from electron microprobe analyses of exploration samples from historical soil and stream samples from various localities across southern and central Africa were utilised. Based on the collection and treatment methods employed, the size range of material collected falls between 0.15 and 1 mm in diameter, with the 0.3 to 0.5 mm fraction being the most common size range utilised. Wherever possible, the visual classifications of the analysed spinels were incorporated with the chemical data. The exploration samples evaluated in this study were processed and analysed at facilities that utilise industry accepted analytical methods as well as common standards for the analysis of kimberlitic indicator minerals. Analyses of chromian spinel extracted directly from various rock types, compiled by Barnes & Roeder (2001), were used to provide a reference for comparative purposes. The analyses were plotted on discriminant diagrams as utilised by Fipke et al (1995), including the diamond inclusion (DI) field, which has since been validated through the compilation of DI data by Stachel and Harris (2008). Some examples are presented here for illustrative purposes.

OBSERVATIONS

Mineral Chemistry

Spinels recovered from samples associated with mafic intrusions, such as the Molopo Farms Complex of southern Botswana, typically display a rapid increase in TiO_2 with decreasing Cr_2O_3, compared to the fairly constant TiO_2 content usually seen in spinel xenocrysts derived from kimberlites (Figures 1a and b). Their overall composition range is usually tightly constrained. Once a few tens of spinels from such a source have been recovered, these populations can easily be distinguished from the typical kimberlitic spinel trends. Similar trends are also displayed in the northern, western and eastern limbs of the Bushveld Igneous Complex of South Africa. This observation also applies to spinels derived from intrusions which have undergone regional metamorphism. Note that although the composition of such spinels commonly overlaps with the DI field in Cr_2O_3 – TiO_2 space, this is not the case in Cr_2O_3 - MgO space.

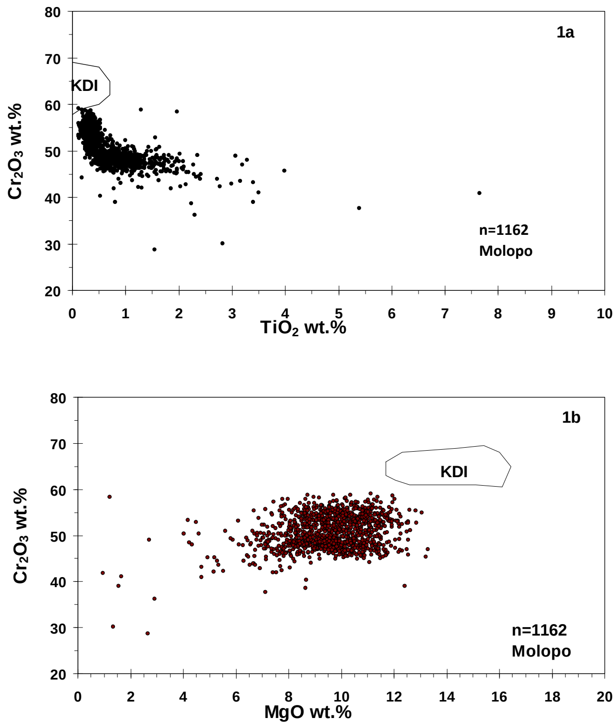


Figure 1: Major element mineral chemistry plots of spinels recovered from soil samples in the vicinity of one part of the Molopo Farms Complex, Southern Botswana; **a:** Cr_2O_3 vs. TiO_2 showing typical trend of spinels from mafic intrusions and **b:** Cr_2O_3 vs. MgO showing restricted compositional range. KDI indicates kimberlitic diamond inclusion field, modified after Fipke et al. (1995).

Complications arise when looking at smaller populations of spinels derived from greenstone terrains, where spinel with high Cr_2O_3 and MgO contents may occur. Single grains recovered in exploration could be problematic, due to the overlap with the DI field. However, when looking at larger populations collected from specific areas, well defined trends become apparent. In the Barberton area of South Africa, spinels commonly display low TiO_2, almost constant, high Cr_2O_3, but highly variable MgO contents (Figure 2a and b). It is notable that the range of MgO and maximum Cr_2O_3 observed from this example exceeds that of the general "komatiite" category, which includes a variety of specific rock types typically found in greenstone belt settings, from the Barnes and Roeder (2001) compilation (Figures 2c and d).

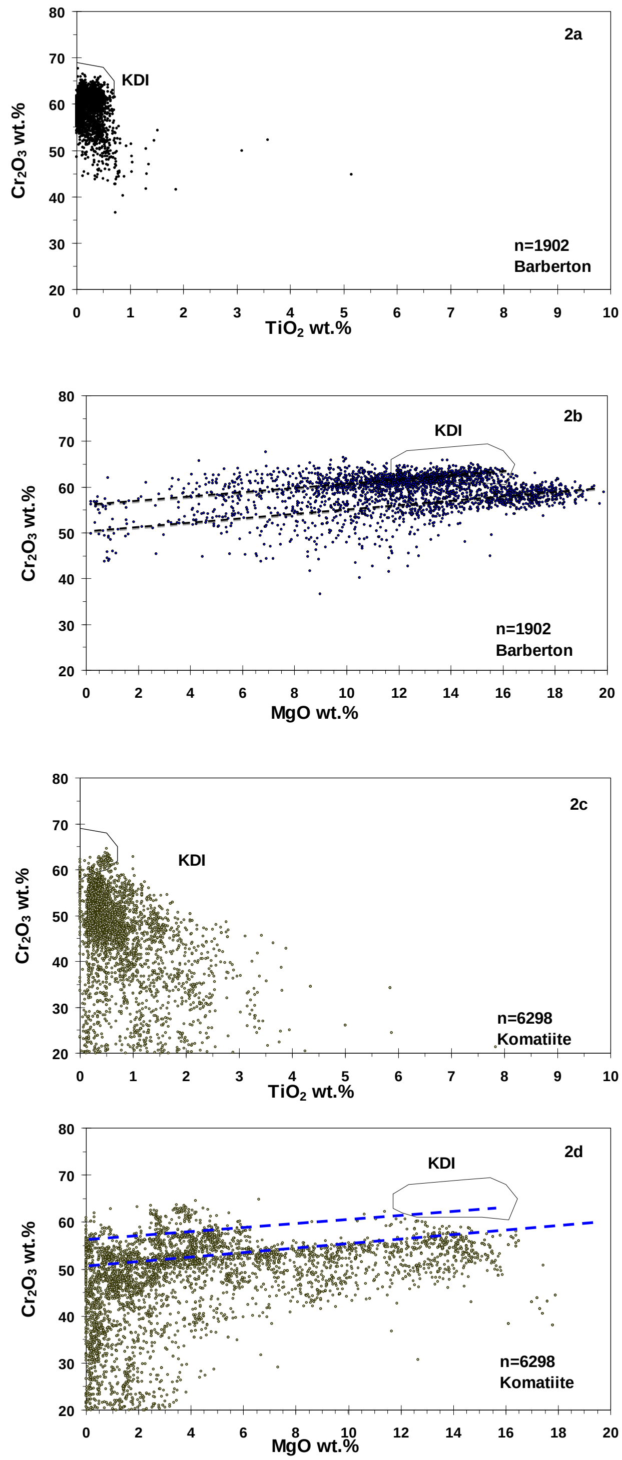
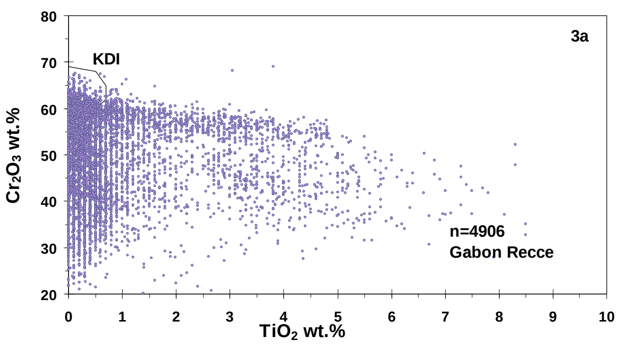


Figure 2: Major element mineral chemistry plots of spinels recovered from stream sediment samples in the Barberton Greenstone Belt, South Africa; **a:** Cr_2O_3 vs. TiO_2 showing overlap with KDI field; **b:** Cr_2O_3 vs. MgO showing well developed trends; **c** and **d**: all worldwide komatiite data compiled by Barnes and Roeder (2001) for comparison, with Barberton spinel population trends shown as dashed blue lines on **d**.

Spinels from samples collected from other greenstone terranes in the region (the Giyani and Pietersburg belts in South Africa; the Kraaipan and Tati belts in Botswana) do not show such extreme chemistries and fall within the range of the Barnes and Roeder (2001) data. Similar compositional trends, at lower Cr_2O_3 to those from Barberton, are also noted from these populations.

In southern Gabon, spinels recovered from exploration samples on a Precambrian metamorphic terrrane of mixed rock types show a more complex pattern, including trends similar to those from both kimberlites and greenstones, albeit with slightly lower Cr_2O_3 content than is the case in Barberton (Figures 3a and b). The integration of the visual characterisation with the mineral chemistry data, allowed a distinction to be made between the two parageneses. The field of kimberlitic spinels as determined by this approach is indicated on Figure 3b. Similar complexities have been encountered in parts of the Limpopo Mobile Belt of Southern Africa.



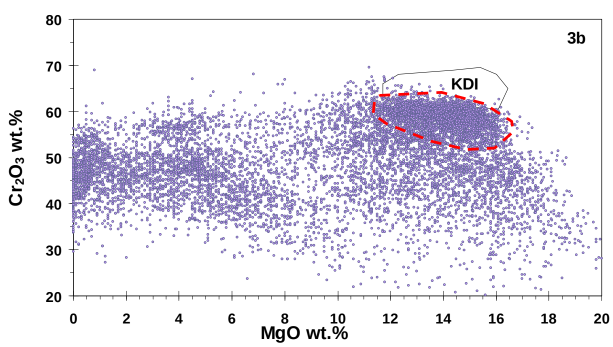


Figure 3: Major element mineral chemistry plots of all spinels recovered from reconnaissance level soil and stream sediment samples collected in southern Gabon; **a:** Cr_2O_3 vs. TiO_2 showing mixed kimberlitic and non-kimberlitic compositions; **b:** Cr_2O_3 vs. MgO with field of kimberlitic spinels based on a combined chemical and visual classification outlined in dashed red line.

Visual Characteristics

In many areas of Africa, chromian spinels are the dominant indicator mineral to survive the weathering and transportation processes occurring in the surface environment. Surface features observed on kimberlitic spinels have been well documented (Fipke et al, 1995) as have metasomatic alteration features and resultant elemental zonation (Menzies et al, 2003). The latter alteration seen on kimberlitic spinel xenocrysts is unique to these rocks and an important feature for observation during visual identification. The morphology of kimberlitic spinels is another useful criteria, as described by Lee et al (2003). Because spinels derived from non-kimberlitic sources such as komatiites, serpentinites and chromitites can have chemical compositions that overlap the mantle derived kimberlitic chromites, visual observation of morphology, size, abundance and surface textures becomes an important tool.

Indicator minerals recovered during exploration programmes are often broken and abraded to varying degrees, and practical methods of distinguishing these features becomes important. Common observations of non-kimberlitic spinel include distinct features such as subhedral to euhedral shapes with sharp edges, constrained size ranges, and coarse-grained alteration textures.

Visual classifications of the spinels recovered from exploration samples collected on or near mafic intrusions were virtually always correctly classified, prior to confirmation using chemical analysis. The situation with spinels derived from greenstone belts and other metamorphic terranes is more complex and requires careful cross-checking between visual and chemical classifications.

DISCUSSION

The complication of overlapping compositional fields of spinels with high Cr_2O_3, low TiO_2 and high MgO contents between kimberlitic and non-kimberlitic sources is well known (e.g. Afanasiev et al, 1998) and is also demonstrated in examples considered in this study. However, this difficulty can be somewhat overcome in the exploration context by considering in combination the typical chemical trends and visual characteristics observed in the most common non-kimberlitic source populations. Whilst compositional differences between specific non-kimberlitic sources of the same broad rock type occur, some common chemical trends can be identified which are found in association with the same types of sources in different geographical locations. Recognition of these chemical trends as well as being able to identify the morphology and surface texture of these spinels may thus assist with diamond exploration.

Visual classification of spinel textures requires specialised training and experience, but whilst time consuming, may reduce the need to analyse every spinel grain once the populations within a specific geological terrane have been characterised.

REFERENCES

Afanasiev, V.P., Pokhilenko, N.P., Logvinova, A.M. and Yefimova, E.S. (1998). Problem of false indicators for kimberlites and lamproites (on the example of chromites). Proc. 7th International Kimberlite Conference, Cape Town, South Africa, Extended Abstracts.

Barnes, S.J. and Roeder, P.L. (2001). The Range of Spinel Compositions in Terrestrial Mafic and Ultramafic Rocks. Journal of Petrology 42, 2279-2302.

Fipke, C.E., Gurney, J.J., Moore, R.O., (1995). Diamond exploration techniques emphasising indicator mineral geochemistry and Canadian examples. Geol. Surv. Can., Bull. 423 (86 pp.).

Lee, D.C., Maddren, J. and Griffin, B.J. (2003). The importance of chromites morphology in diamond exploration. International Kimberlite Conference (8th: Jun 22-27 2003: Victoria, BC, Canada) - Extended Abstracts.

Menzies, A., Frazenburg, M., Baumgartner, M., Gurney, J.J. and Moore, R. (2003). Evaluation of chromites derived from kimberlites, and implications for diamond exploration programs. International Kimberlite Conference (8th: Jun 22-27 2003: Victoria, BC, Canada) - Extended Abstracts.

Muggeridge, M.T. (1995). Pathfinder sampling techniques for locating primary sources of diamond: recovery of indicator minerals, diamonds and geochemical signatures. In: Griffin, W.L. (Ed.), Diamond Exploration: Into the 21st Century. J. Geochem. Explor., vol. 53, pp. 183– 204.

Stachel, T. and Harris, J.W. (2008). The origin of cratonic diamonds – Constraints from mineral inclusions. Ore Geology Reviews 34, 5-32.