THE ASSOCIATION OF ZN-CHROMITE WITH DIAMONDIFEROUS LAMPROPHYRES AND DIAMONDS: UNIQUE COMPOSITIONS AS A GUIDE TO THE DIAMOND POTENTIAL OF NON-TRADITIONAL DIAMOND HOST ROCKS

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INTRODUCTION

Archean amphibole/phlogopite-bearing lamprophyre dykes, locally xenolith-bearing, transect rocks of the Yellowknife Supergroup at Yellowknife, Canada. Dykes and volcanic breccias with lamprophyric affinities occur in the Wawa area of the Michipicoten Greenstone belt in north central Ontario and share similarities to the Yellowknife lamprophyres. Most significant is that some Wawa lamprophyres are known to be diamond bearing and a small outcrop sample of the Jackfish lamprophyre at Yellowknife returned 2 clear yellow microdiamonds.

Lamprophyre Zn-Chromites

Yellowknife and Wawa lamprophyres have similar amphibole and mica compositions, typical of minettes Amphibole from the Yellowknife and Wawa lamprophyres are typically zoned from Mg-hastingsite / pargasite cores to actinolite-tremolite rims (Figure 1).

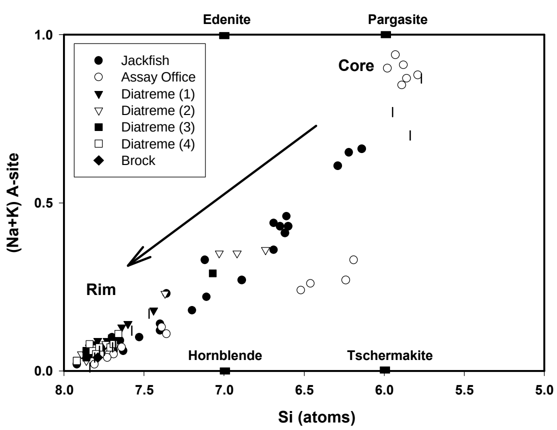


Figure 1. Compositional variation of lamprophyre amphibole in apfu. For Yellowknife lamprophyres, similar trends are observed in Wawa lamprophyres.

Micas from both locations are phlogopite-biotite$_{ss}$ with compositions typical of minettes (Figure 2) with elevated Cr_2O_3 and locally elevated BaO (to 2 wt%). Groundmass spinels in the Yellowknife lamprophyres demonstrate core-rim zonation with zinc-rich cores (to

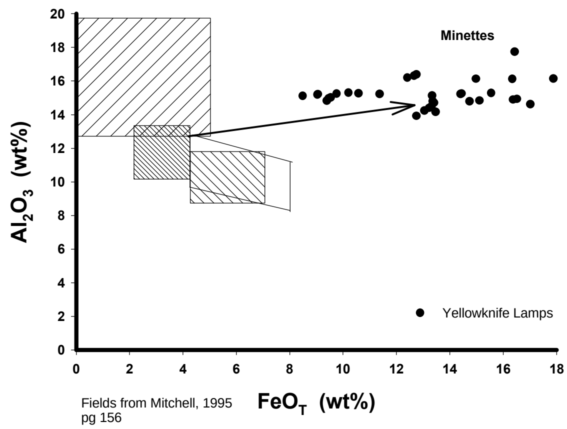


Figure 2. Compositional variation of phlogopite/biotite$_{ss}$, Yellowknife lamprophyres.

7 wt% ZnO) and Cr-magnetite rims. Anhedral groundmass spinels are also Zn-rich to 3wt% ZnO and display evolutionary trends toward Cr-magnetite. In addition to the enriched Zn contents, the chromites are characterized by very low MgO (< 0.5 wt%), elevated MnO (1.5 - 2.1 wt%), low Al_2O_3 (< 10 wt%), low TiO2 (< 1 wt%), and variable Cr_2O_3 (31 to 52 wt%). Grains display a core-rim evolution of increasing Cr, Fe^{3+} with decreasing Al, Zn. Significantly, the diamondiferous Wawa lamprophyres also contain groundmass spinels with elevated ZnO (to >4 wt%), MnO (to > 1.5 wt%), low MgO, low Al_2O_3, and moderate Cr_2O_3. Locally Zn-chromite cores are overgrown by Ti-Cr-magnetite rims and Mg-rich spinels (MgO to>7wt% have been noted) and vice versa. In their systematic core to marginal zonation with Ti-Cr-magnetite rims the lamprophyric Zn-rich chromites demonstrate evolutionary trends akin to magmatic spinels commonly found in kimberlite. Representaive analyses are listed in Table 1

Zn-chromites and Zn-spinels may also occur as accessory minerals within other ultramafic rocks and paleoplacer environments. Some of these Zn-chromites display similarities to those from lamprophyres, while others contain elevated Al2O3 contents, trending toward gahnite, indicative of metamorphic reactions

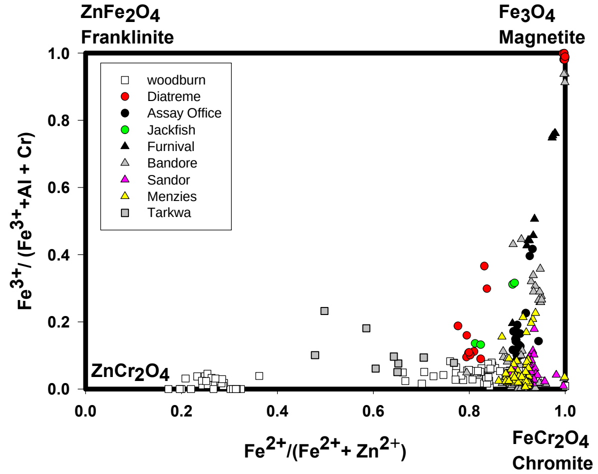


Figure 3. Planes within a modified spinel prism demonstrating magmatic reactions for Zn-spinels from Wawa (Menzies, Sandor, Furnival, Bandore) and Yellowkinfe (Diatreme, Jackfish, Assay Office). Zn-chromites from Archean- Paleoproterozoic paleoplacer environments display both metamorphic and magmatic trends (Woodburn, Tarkwa). Wawa data from Sage, 2000 and this study, Tarkwa data from Weiser and Hirdles (1997); Woodburn data from this study.

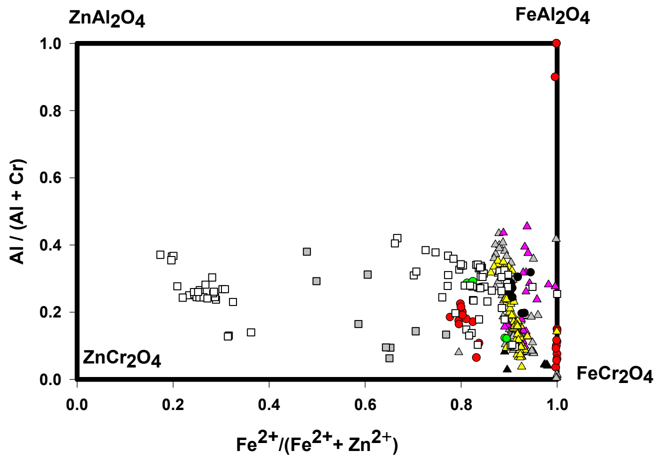
Table 1 Representative Zn-chromite Analyses

	1	2	3	4
SiO2	0.28	0.15	na	0.29
TiO2	0.21	0.49	nd	0.09
Al2O3	4.70	9.37	2.70	3.23
Cr2O3	60.57	48.16	60.54	61.10
Fe2O3	1.31	7.76	3.58	2.68
FeO	27.57	25.30	21.98	28.8
MnO	1.69	1.43	1.41	0.41
MgO	0.38	0.34	nd	0.54
NiO	0.3	0.00	na	na
ZnO	3.31	7.23	9.78	2.38
Total	100.05	100.23	99.99	99.78

1) Wawa-Bandore, 2) Yellowknife Diatreme, 3)Tarkwa(from Weiser and Hirdes,1997), 4) inclusion in diamond from Meyer and Boyd (1972)

Zn-Chromites in diamond

Chromites with elevated zinc have been documented as inclusions in diamonds from Sierra Leone (Meyer and Boyd, 1972) and Brazil (Tappert et al., 2002) and are typified by low to moderate MgO, low Al_2O_3, elevated ZnO approaching 7 wt%, moderate to high Cr_2O_3 and moderate to low total Fe. Tappert et al (2002) implicate epigentic processes for Zn enrichment



DISCUSSION

Collectively, the diamond-affinity Zn-spinel compositions differ from crustally derived or other magmatic spinels in their elevated zinc and consistently low contents of MgO. As such, traditional plots utilized to relate chromites to diamond intergrowth and inclusion compositions are not applicable to Zn-rich chromite compositions.

Given the rather unique nature of the Zn-chromite compositions, a discriminant plot in ternary compositional space has been generated in terms of Fe3/(Fe3+Al)-Fe3/(Fe3+Cr)-Al/(Al+Cr) (Figure 4). Modification of this ternary, incorporating Zn, allows

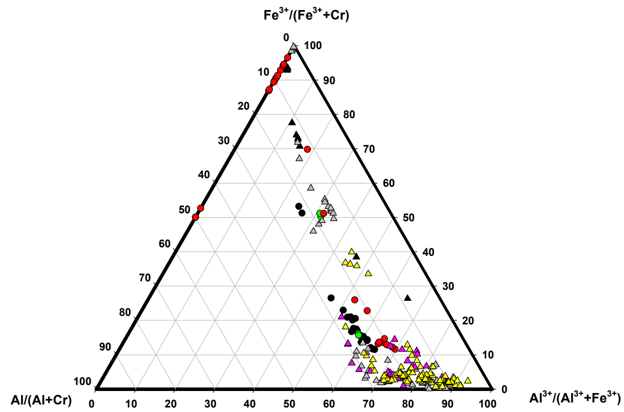
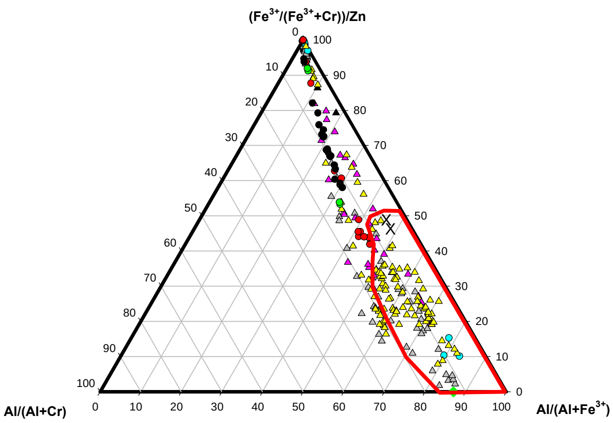


Figure 4. Ternary space for Zn-spinels, symbols same as Figure 2.

discrimination between Zn-chromite from diamond-bearing lamprophyres from those of non-diamond bearing rocks (of crustal or magmatic derivation)(Figure 5). Significantly, the rare Zn-chromites included within diamond also fall within the ‘diamond-affinity Zn-spinel compositional space’ defined for diamondiferous lamprophyres. Some analyses of Zn-chromite grains from Paleoproterozoic paleoplacer environments may overlap with the diamond affinity compositional space. The ultimate source of these chromites is unknown and as such their origin may be indicative of older unrecognised diamond bearing rocks (ie. sourced in ultramafics or lamprophyric rocks).

Figure 5. Modified ternary space incorporating Zn content. Note that Zn-chromites from diamond bearing rocks cluster



within lower right portion of the diagram (red outline). X are Zn-chromite of Meyer and Boyd (1972), green polygon average Brazilian Zn-chromite (Tappert, pers comm) Other symbols same as Figure 2

The evolutionary trends demonstrated for diamond affinity Zn-chromites are consistent with a magmatic origin and the elevated zinc contents are not considered to be the result of later mestasomatic or metamorphic activity. Regardless, the relative oxidation state (as reflected in the spinel ferric iron content) was sufficiently reducing in nature to allow diamond preservation.

REFERENCES

Meyer, H.O.A., Boyd, F.R. 1972. Composition and origin of crystalline inclusions in natural diamonds. Geochemica Cosmochimica Acta, 36, 1255-1273.

Sage, R. 2000. “Sandor” Diamond Occurrence. Michipicoten Greenstone belt, Wawa Ontario. Ontario Geological Survey Open File Report 6016.

Tappert, R., Stachel, T., Harris, J.W., Brey, G.P. 2002. Composition of mineral inclusions from Brazilian diamonds. GAC-MAC abstract volume, Saskatoon 2002. Pg 116

Weiser, T.W., Hirdes, W. 1997. Zince-rich chromite from Paleoproterozoic conglomerates at Tarkwa Gold Mine, Ghana. Canadian Mineralogist, 35, 587-595.

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