SIGNIFICANCE OF CHROMITE, G5 Mg-ALMANDINE GARNET, ZIRCON AND TOURMALINE IN HEAVY MINERAL DETECTION OF DIAMOND BEARING LAMPROITE

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A project, with the objective of identifying heavy minerals that could be utilized in heavy mineral prospecting programs to detect diamondiferous lamproite, was completed by the Geological Survey of Canada and C.F. Mineral Research Ltd. consultants in 1990.

The project involved ball milling, heavy mineral concentrating and S.E.M. micro analysing of all heavy mineral species from large (30 – 180 kg) rock samples from the Argyle (AT) Australia, the Prairie Creek (PC) Arkansas, and the Jack (JK) B.C., Canada, diamondiferous lamproites.

Potential abrasion resistant heavy indicator minerals identified in the foregoing samples were similarly concentrated and analyzed using bulk rock samples from the following diatremes: the Ellendale 4 (EL4) diamondiferous lamproite, Australia; the Smoky Butte (SB) lamproite, Montana, U.S.A.; the Sloan 1 (SL) diamondiferous kimberlite, Colorado, U.S.A.; the Presidente Olegario (PO2, PO3) and satellite (PO1) possible lamproitic diatremes, Brazil; the Sover (SV) and the New Elands kimberlites, South Africa; and from Canada – the Larry (LR), the Mark (MR) and the Mike (MK) lamproitic diatremes, B.C.; the Batty (BT), N.W.T., the Crossing Creek (CC), B.C., the Joff (JF), B.C., the Kirkland Lake (KL), Ont., the Sturgeon Lake (SK), Sask., barren and diamondiferous kimberlites; the Blackfoot (BF), B.C., the HP (HP), B.C., the Ile Bizard (IB), Que., alkaline lamprophyres; and the Mountain (MD) olivine melilitic diatreme, N.W.T.

The indicator minerals recovered and analyzed from the foregoing diatremes as well as world wide diamond inclusion mineral compositions were computer classified. The classifications used were adapted from Dawson and Stephens (1975&1977) and R. Moore's (1990) methods of classifying garnets and clinopyroxenes ("Cpx") so that J. Gurney's (1985) method of classifying G10 composition garnets was included and minerals of regional "R" compositions excluded.

Table 1 illustrates that only three "E" eclogitic and three "P" peridotitic garnets were recovered from 32 kg. of the most diamondiferous sandy tuff phase of Argyle (AT); similarly, only two "E" and three "P" garnets were recovered from 42 kg. of the most diamondiferous phase of Prairie Creek (PC). Low counts were similar for the Jack (JK) but substantially higher for the Ellendale 4 (EL4) diamondiferous lamproite. Although significant quantities of Cpx were recovered from (PC) and (EL4) only three Cpx (classified according to Dawson's methods) were recovered from the (AT) sample and four Cpx from the (JK) sample. It is thus probable that the Argyle and Jack lamproites would be bypassed by prospecting surveys based only on results of "P" and "E" garnets and Cpx.

Table 1 illustrates that chromites, G5 garnets, zircons and tourmaline are the most abundant abrasion resistant heavy minerals present in concentrates from all diamondiferous lamproites sampled – (AT, EL4, PC, JK). A summary of characteristics of these minerals is as follows:

CHROMITES from diamondiferous lamproite tend to be euhedral to slightly rounded and/or broken, opaque black to translucent brown colored grains that commonly exhibit grey alteration frosting of outer rims. Table 1 illustrates that between 1.5% (for PC) and 12% (for AT) of the chromites analyzed have >60% Cr_2O_3. Most of these plot within the diamond inclusion and intergrowth fields of MgO–Cr_2O_3, Al_2O_3–Cr_2O_3, and Cr_2O_3–TiO_2 (figure 1). Figure 1 illustrates that non-diamond inclusion chromites from diamondiferous lamproites (and kimberlites) have enriched Cr_2O_3 and TiO_2 compared to a file of 821 chromite analyses from volcanic, ophiolite,

alpine and layered ultramafic sources. Some chromites from the PO1 diatreme situated near Presidente Olegario, Brazil, plot within the enriched Cr203–TiO2 field.

G5 Mg–ALMANDINE GARNETS recovered from diamondiferous lamproite exhibit pink to purple or pale brown coloration and tend to exhibit broken or anhedral form, thought to be a result from milling of megacrystic forms. Although these garnets typically classify as "R" regional garnets by R. Moore parameters, a search of publications did not identify any regional rocks as sources for these G5 garnets of FeO <29.94% other than kimberlite or lamproite. Table 1 (bottom) demonstrates that seven garnets, included in diamond, classified as G5. While such G5 garnets could be useful in some regional heavy mineral prospecting programs to locate lamproite and kimberlite they are non discriminating between barren and diamondiferous as illustrated in table 1 (note barren SB count).

DIATREME ZIRCONS appear to differ from round xenocystic zircons from sandstone wallrocks by the presence of glassy to frosted textures typical of "E" and "P" garnets and by the absence of abrasion textures characteristic of clastic rounded zircons. These tiny (<0.5mm) mostly round to spherical, purple to brown colored, non fluorescent zircons and pink to honey colored orange fluorescent (to UV) zircons were recovered from 22 of the 23 diatremes tested. Such zircons, in some cases, contain concentric overgrowths of dark purple or pink zircon on round light zircon cores. Lead isotopes dates to 1856 MY have been obtained from round zircons from the Prairie Creek and to 2685 MY from the Jack lamproites. Levels of up to 0.16 K20 and 1.7% MgO have been detected in zircons recovered from diamondiferous lamproite.

DIATREME TOURMALINES are characteristically unzoned, exhibit glassy to frosted textures typical of "E" and "P" garnets and typically lack abrasion surface textures. Minor to abundant quantities of round to rounded, light translucent brown to opaque brown dravitic tourmaline was recovered from all diamondiferous lamproite tested (AT, EL4, PC and JK) but was significantly absent from the Smoky Butte (SB) barren lamproite and most other diatremes tested (Table 1). Fifty four out of fifty nine (92%) diatreme tourmalines microprobe analyzed to date contain (33.7–37.4 %) SiO2, (28.1–35.3 %) Al203, ,<0.15% Cr203, <0.22% MnO, (2.9–13.0%) FeO, (>1.0–8.8%) Al203, <0.15% TiO2, (1.3–2.3%) Na20, (>0.05–2.0%) CaO, <10.7% B203, <0.55%F and <0.3% Cl. Thirty nine out of a file of 164 regional tourmalines (from world wide literature sources) also classify within the foregoing compositional limits of diatreme tourmalines. Figure 2, a TiO2 – K20 compositional plot of the 54 diatreme and 39 regional tourmalines, demonstrates that 30 of 39 total tourmalines from diamondiferous lamproite (77%) and 7 of 164 total regional tourmalines (4%) plot in a field of elevated TiO2 – K20. None of the diatreme tourmalines, from non-diamondiferous pipes, plot within the elevated TiO2 – K20 field.

The presence of dravitic tourmaline of elevated TiO2 – K20 in diamondiferous lamproite (and kimberlite(SK)), as well as the common presence of CP8 jadetic diopside included in worldwide diamond inclusions but absence of CP8 clinopyroxene in worldwide diamondiferous lamproite and kimberlite (refer to table 1) can be explained by a reaction similar to the following:

$$\underset{\text{olivine}}{Mg(Mg,Fe)SiO_4} + B^{+3}{}_2(H^{+1})Cl^{-1} + F^{-1} + (OH)^{-1} + B_2O_4^{-2} + 3\underset{\left[\begin{array}{c}\text{kyanite}\\ \text{or}\\ \text{SiO2+corun}\end{array}\right]}{[SiO_2+Al_2O_3]} + \underset{\text{D.I.(CP8)jadetic diopside}}{(K,Na,Ca)(Mg,Fe,Ti)(Si,Al)_2O_6} = \underset{\text{dravitic tourmaline}}{(Na,K)(Mg,Fe,Ca,Ti)_3Al_6B_3Si_6O_{27}(OH,F,Cl)_4}$$

The above reaction would necessitate olivine–rich kimberlitic or lamproitic magmas charged with boron and weak acid gases to react on intrusive contact with jadetic diopside and kyanite or corundum (with excess SiO2) constitutes of diamond

bearing Group I eclogite to form dravitic tourmaline. Boron is a minor constitute of some kimberlite and lamproite matrixes as well as a trace constitute of blue colored diamonds (Fipke et al,1990).

R. Moore (1986) has demonstrated that the arithmetic mean of K20 and of TiO2 in Group I eclogitic clinopyroxenes is 0.08 and 0.58 respectively ,compared with 0.02 and 0.33 for Group II eclogitic clinopyroxenes not associated with diamond formation. The above reaction does not necessitate the presence of K in Cpx, therefore it is possible that a similar reaction with low (K20–TiO2) Cpx from non diamond bearing Group II eclogite may have produced the low (K20–TiO2) dravitic tourmalines detected from pipes not known to contain diamond. The absence of tourmaline could perhaps be related to low activities of magmatic boron. The elevated K20–TiO2 levels preserved in dravitic tourmaline from diamondiferous lamproite would be enhanced by buffering effects of high activities of K and Ti present in lamproite magmas.

Regardless of paragenesis, round tourmalines and zircons have been utilized to detect lamproites in the southeast Rocky Mountains of British Columbia, because such minerals are absent from stream sediments derived from the regional stratigraphy.

Table 1 – Classified Amounts of Indicator Minerals Recovered from Diatreme Rock Samples Compared with Diamond Inclusion Minerals from Worldwide Sources.

ID	Dia Mac %	Dia Mic	RK Ty	RK pe	OR RK VI kg	ZIR CON	TOU RHA LIN	TOU sat	CHROMITE CR 60	CHROMITE CR 60	ILMENITE PIL	ILMENITE IL	GARNETS CPM MODIF. OF DAWSON CLASSIFICATIONS. G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	R.MOORE CLASS E	P	R	CLINO-PYROXENES DAWSON CP1	CP2	CP3	CP4	CP5	CP6	CP8	CP9	CP10	R.MOORE CE	CP	CPM CV
AT	Vab	L	32	ab	ood	+13	+100	8	13	–	2	2	–	23	–	–	–	–	1	–	3	3	+52	1	2	–	–	–	–	–	–	15	4	2
EL4	ood	L	46	ab	Vab	10	+69	1	+3	–	–	34	1	30	–	–	–	16	8	6	–	+53	+29	+29	–	–	–	–	35	1	–	–	–	–	–	–	+37	+1
JKM	tr	L	180	ab	ab	2	12	48	11	6	3	–	–	–	–	–	–	4	1	20	–	–	34	–	–	–	–	–	–	–	–	–	–	–	–	7	7	7
JK2	tr	L	90	ood	ood	–	+21	2	13	1	–	1	–	10	–	–	–	2	4	5	–	3	12	43	–	–	–	–	–	–	–	–	–	–	–	–	2	–	3
JK3	nil	L	63	oin	oin	–	+41	–	8	–	–	–	–	4	–	–	–	–	–	1	–	–	1	17	–	3	–	–	1	–	–	–	–	–	–	19	5	9
PC64	oin	L	21	ab	oin	1	+116	5	4	–	–	1	–	44	–	–	–	1	–	–	–	3	.1	47	–	6	–	–	26	3	–	–	–	–	–	–	+1	+32	+6
PC65	ood	L	21	ab	nod	2	+79	15	–	–	–	1	–	.23	–	–	–	–	–	–	1	6	1	32	1	7	1	–	36	1	–	–	–	–	–	–	+15	+37	+39
SB	nil	L	65	tr	nil	3	20	+75	7	30	6	6		17				21	1	35		46	69	28		1			5	7							8	19	2
LRO	nil	PL	31	oin	nil	–	+91	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
LRB	nil	PL	46	tr	nil	–	+99	–	–	–	–	–	–	4	–	–	–	–	–	–	–	1	–	10	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
MR	nil	PL	34	oin	tr	–	+66	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
MF	tr	PL	30	oin	tr	–	+114	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
PC23	nil	PL	42	nil	nil	–	1	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	7	–	–
PO1	nil	PL	17	oin	oin	1	11	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	2	–	–
BT	oin	K	74	oin	nil	2	39	+17	1	13	–	–	–	4	–	–	–	28	–	17	–	+14	+45	+12	–	3	1	–	8	4	–	–	–	–	–	–	+5	+17	+1
CC	nil	K	63	tr	nil	1	+139	1	1	10	–	–	–	–	–	–	–	43	3	30	–	+13	+73	+12	–	1	2	–	17	1	–	–	–	–	–	–	–	+7	+14
JF	nil	K	64	oin	tr	–	+82	–	1	–	–	1	–	–	–	–	–	1	–	–	–	3	–	9	–	6	2	–	15	–	–	–	–	–	–	–	2	9	+20
EL1	tr	K	23	oin	nil	–	32	+28	–	1	–	5	–	–	–	–	–	14	7	17	–	5	+39	–	–	2	–	–	7	22	–	–	–	–	–	–	1	34	–
EL5	nil	K	5	tr	nil	3	+92	+54	–	1	2	1	–	1	–	–	–	32	17	47	–	2	+99	–	–	8	1	1	16	3	–	–	–	–	–	–	13	29	1
AC	ab	K	21	oin	nil	40	+79	1	5	2	–	7	–	–	–	–	–	26	77	30	3	+18	+127	–	–	1	–	–	12	26	–	–	–	–	–	–	+1	+42	–
SK	tr	K	36	oin	oin	1	47	+40	–	28	6	16	1	–	1	–	–	28	1	24	–	+35	+69	–	–	–	–	–	16	1	–	–	–	–	–	–	–	+18	+1
SL	ood	K	44	oin	nil	1	+65	+36	–	9	2	41	–	–	1	–	–	22	11	80	–	+57	+111	4	–	7	–	–	32	2	–	–	–	–	–	–	–	+42	–
SV	ab	K	10	tr	nil	28	+70	2	1	4	–	8	–	1	–	–	–	3	33	4	–	+12	+40	1	–	–	–	–	6	34	–	–	–	–	–	–	–	41	+1
BF	nil	AL	71	oin	nil	–	+180	0	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	9	–	52	2	–	–	–	–	–	–	1	8	+75
HP	nil	AL	60	tr	nil	–	+85	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	3	–	34	2	–	–	–	–	–	–	3	4	+49
IB	nil	AL	65	tr	nil	–	44	+25	–	–	–	–	–	–	–	–	–	36	–	–	–	+36	–	–	–	11	7	8	11	1	–	–	–	–	–	–	+25	+28	+45
HD	nil	OH	100	ood	nil	–	32	10	9	–	1	–	–	–	–	–	–	1	–	–	–	–	2	11	6	3	–	–	–	–	–	–	–	–	–	9	2	2
DIAMOND INCLUSIONS																																						
South Africa						132	6	3	–	3	1	75	62	4	7	2	–	5	57	8	1	144	117	5	–	5	–	–	5	4	48	10	6	132	17	–
North America						1	–	2	2	–	–	28	5	3	–	–	–	–	3	1	–	31	4	5	–	–	–	–	2	–	15	3	1	21	4	–
AUSTRALIA						1	–	–	1	1	–	6	93	–	34	–	–	–	2	–	–	134	3	–	–	–	–	–	1	2	–	16	4	6	43	3	–
USSR						8	–	1	–	3	–	6	4	–	–	–	–	–	26	4	–	11	32	–	–	2	–	–	6	2	3	1	–	4	10	–

Vab: very abundant ab: abundant ood: moderate oin: minor tr: trace +: additional present

L: lamproite PL: possibly lamproite? K: kimberlite AL: alkaline lamprophyre CM olivine melilite

Diamond Inclusion Compositions Provided By Dr. John Gurney & Dr. Rory Moore 1989

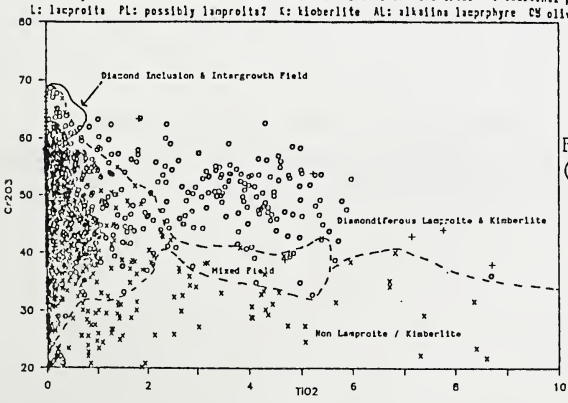

FIGURE 1: PLOT OF CHROMITES FROM (AT,EL4,PC,JK):o PO1:+ NonKim:x

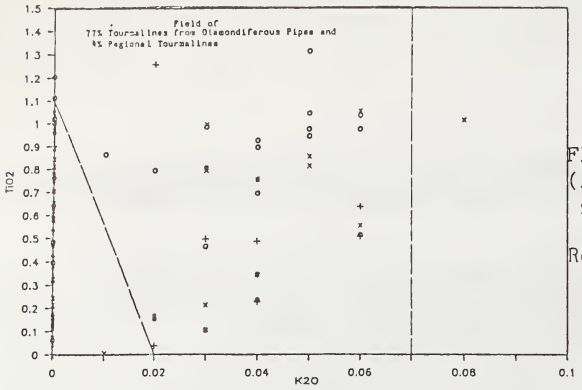

FIGURE 2: ALL TOURMALINES (AT,EL4,PC,):o JK:+ SK:s analyzed by U. of Saskatchewan

Reg:x from many literature sources

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