British Columbia
Ministry of Energy, Mines and Petroleum Resources

Kimberlite and Diamond Indicator Minerals in Northeast British Columbia, Canada - A Reconnaissance Survey

By G.J. Simandl, T. Ferbey, V.M. Levson, N.D. Robinson,
R. Lane, R. Smith, T.E. Demchuk, I.M. Raudsepp and A.S. Hickin

British Columbia Geological Survey

GeoFile 2005-25

Suggested reference:

Simandl, G.J., Ferbey, T., Levson, V.M., Robinson, N.D., Lane, R., Smith, R., Demchuk, T.E., Raudsepp, I.M., and Hickin, A.S. (2005): Kimberlite and Diamond Indicator Minerals in Northeast British Columbia, Canada - A Reconnaissance Survey, *British Columbia Ministry of Energy, Mines Petroleum Resources* GeoFile 2005-25, 25 pages.

Kimberlite and Diamond Indicator Minerals in Northeast British Columbia, Canada – A Reconnaissance Survey

By G.J. Simandl[1], T. Ferbey[2], V.M. Levson[2], N.D. Robinson[1], R. Lane[3], R. Smith[4], T.E. Demchuk[2], I. M. Raudsepp[5] and A.S. Hickin[2]

[1]British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey, Victoria, BC
[2]British Columbia Ministry of Energy, Mines and Petroleum Resources, Resource Development and Geoscience Branch, Victoria, BC
[3]British Columbia Ministry of Energy, Mines and Petroleum Resources, Mining and Minerals Division, Prince George, BC
[4]Geological Survey of Canada, Calgary, Alberta
[5]Dept of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC.

Keywords: Diamond, kimberlite, lamproite, indicator minerals, exploration potential, G10, G12, G11, garnet, Cr-spinel, Cr-diopside, ilmenite, olivine.

Executive Summary

Northeast British Columbia is underlain by Precambrian basement that belongs to the North American craton (Figure 1). It has diamond exploration potential, particularly if the modified "diamondiferous mantle root model" is considered (Simandl, 2004). This heavy mineral reconnaissance project expands on an earlier study, which was restricted to kimberlite indicator minerals (KIMs) present in Late Pleistocene glaciofluvial sands and gravels sampled in the Fort Nelson region (Levson *et al.*, 2004; Simandl *et al.*, 2005). A variety of media were sampled and tested during this study, including bedrock and regolith of partially consolidated conglomerates of the Dunvegan Formation, active river/stream sediments, and glaciofluvial or glaciolacustrine deposits. Of the 58 samples processed, 38 contain KIMs, such as purple pyrope garnet, Cr-diopside, olivine, ilmenite, or spinel. In contrast with the earlier study, no eclogitic garnets were recovered. At least a portion of the KIMs recovered from these samples may be derived from a local igneous sources, or from secondary or tertiary sources that originated by weathering, transportation and natural preconcentration of protolith-derived constituents. The fact that the Dunvegan Formation contains Cr-spinel, but no other indicator minerals, is noteworthy. The chemical composition of some of these spinels is suggestive of a lamproite/kimberlite provenance.

Concentrations of KIMs located east of Mathews' (1980) Line, which approximates the maximum extent of the Laurentide glaciation (Figure 2), may have been locally derived and reworked or brought into the region from the Northwest Territories and Alberta by Late Pleistocene glacial and/or glaciofluvial systems. Samples from the Etsho Plateau area yield a wide spectrum and relatively high concentration of potential kimberlite indicator minerals. Follow-up sampling in this area is warranted.

Samples NEBC-1, NEBC-7, NEBC-23, NEBC-43 and NEBC-44 are noteworthy because of their high concentrations of Cr-spinels (chromites). Some of these spinels have the same chemical characteristics as chromites that plot within the diamond inclusion field. Samples NEBC-1 and NEBC-7 are active river sediments, and upstream prospecting is justified.

An intriguing, but problematic, aspect of this study is the recovery of a diamond during the processing of sample NEBC-11, which did not contain any indicator minerals. This stone is a clear diamond nearly 0.8 millimetres in size (Plates 1a and 1b). Because of its size and colourless nature, the diamond may have been lodged within the screen during the processing for an unspecified number of samples without being detected by the laboratory personnel. If the diamond did not belong to sample NEBC-11, as suggested by a lack of associated KIMs, it may have come from any of the samples that were processed prior to it, including samples belonging to the previous client. Ten BC Geological Survey samples numbered NEBC-1 to NEBC-10 were processed before sample NEBC-11. Samples from several of these sites are shown here to contain KIMs.

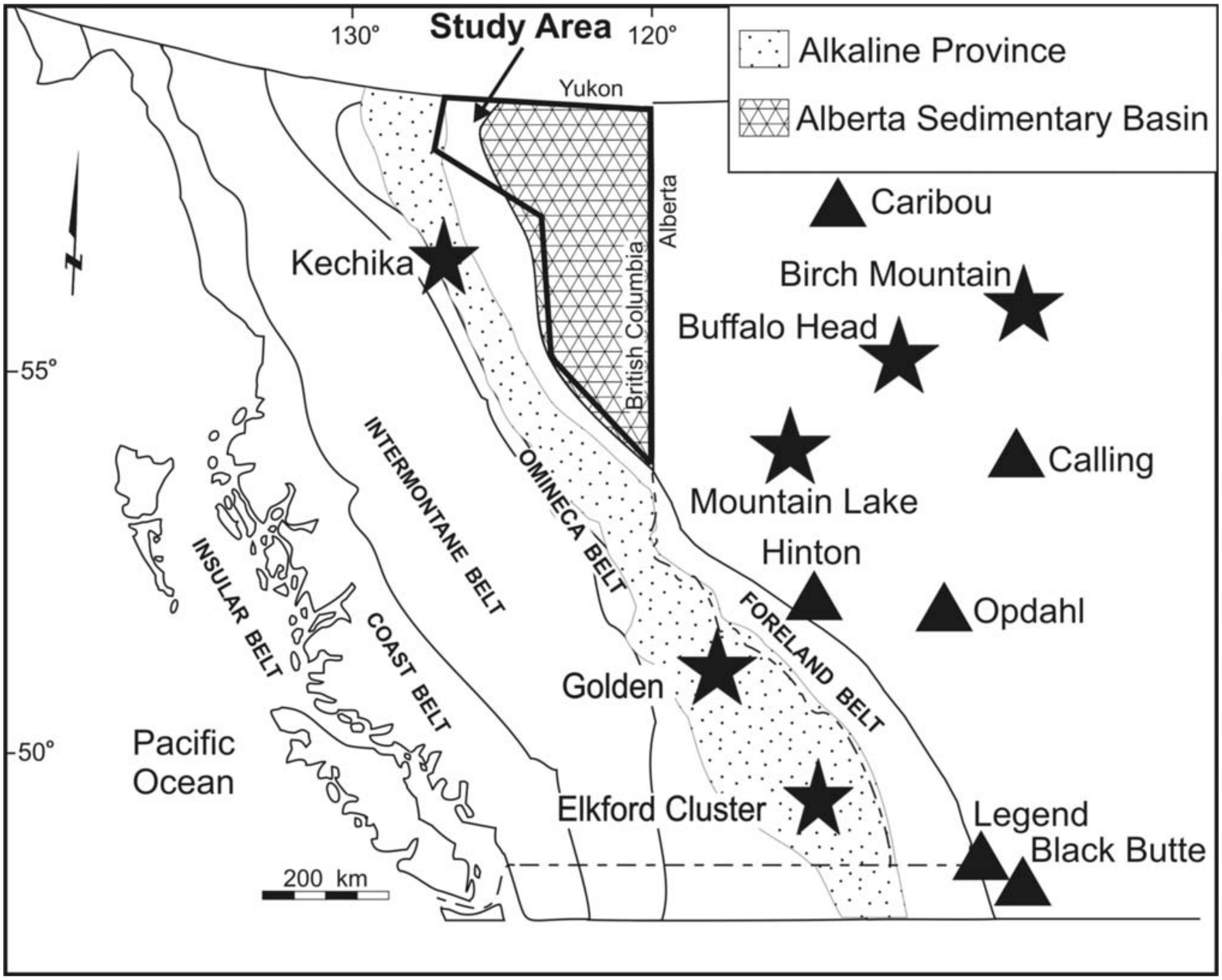


Figure 1. Location of the study area; corresponds approximately to British Columbia's portion of the Western Canada Basin. Known primary (star) and secondary (triangle) diamond occurrences in British Columbia and Alberta are also shown. The Crossing Creek diatreme, within the Elkford Cluster, is the only confirmed kimberlite in British Columbia (modified from Simandl, 2004).

BACKGROUND

Northeast British Columbia is an under-explored portion of the North American continent with respect to diamonds, other gemstones, and non-energy minerals. It is characterized by low relief and has a rapidly developing infrastructure that supports of the oil and gas industry. High-quality diamonds are presently mined within the Slave Craton of the Northwest Territories (Carlson *et al.*, 1999 and Lockhart *et al.*, 2004), approximately 600 kilometres northeast of Fort Nelson. Diamond deposits have also been discovered in the Buffalo Head Terrane in neighbouring Alberta (Eccles, 2004; Hood and McCandless, 2004), approximately 400 kilometres southeast of the Fort Nelson area. Several alluvial diamond occurrences have also been reported in the Northwest Territories and in Alberta (Simandl, 2004). There are reports of diamond occurrences within the British Columbia Alkaline Province (Allan, 1999, 2002; Anonymous, 1994; McCallum, 1994; Northcote, 1983a, b; Pell 1994; and Roberts, 2002). Recent age dating (Simandl and Davis, 2005) indicates that Precambrian crystalline basement similar in age to the Buffalo Head Terrane extends farther west than previously expected, supporting the hypothesis that northeast British Columbia may have been underlain by a thick cold lithosphere prior to rifting of the Rodinia Supercontinent. The "diamondiferous root", as described by Haggerty (1986), and Mitchell (1991), may have been destroyed after the diamonds were brought to the surface by kimberlites, lamproites, or other diamond elevators (Simandl, 2004). The results of this heavy mineral reconnaissance/orientation survey, when considered in conjunction with the findings of a previous KIM study (Simandl *et al.*, 2005), provide support for the use of the diamondiferous mantle root exploration model in Northeast British Columbia.

BEDROCK GEOLOGY, POTENTIAL DIAMOND ELEVATORS AND THEIR AGE

Northeast British Columbia is underlain by a Precambrian basement that belongs to the North American craton (Hoffman, 1988, 1989, 1991; Villeneuve *et al.*, 1993; Ross *et al.*, 1991 and 1995; and Simandl and Davis, 2005). Traditionally, northeast British Columbia was regarded as being "too close to the edge" of the continent to apply the diamondiferous mantle root concept; however, recent age dating indicates that Precambrian crystalline basement of similar age as the Buffalo Head Terrane extends farther west than was previously thought (Simandl and Davis, 2005).

The Precambrian basement in northeast British Columbia is overlain by a thick sedimentary sequence. Outcropping in the study area are major stratigraphic elements of this sedimentary package: the Toad and Grayling Formations (Triassic, 208-245 Ma) the Wapiti Formation (Upper Cretaceous, 65-97 Ma), the Fort St. John Group or Smokey Group (Cretaceous, 65-145.6 Ma), the Dunvegan Formation (Upper Cretaceous, 65-97 Ma), the Sikanni Formation of the Fort St. John Group (Cretaceous, 65-145.6 Ma) and Kotaneelee Formation (Upper Cretaceous, 65-97 Ma), in a compilation map by Massey *et al.* (2005). The Fort Nelson area is underlain predominantly by marine shales of the Shaftsbury Formation, part of the Lower Cretaceous Fort St. John Group. These shales are interpreted to have been deposited in a prodelta or shelf environment during a transgression of an embayment in the Cretaceous (Thompson, 1977).

Directly overlying the Fort St. John Group and forming the resistive cap of the Etsho Plateau are sandstones of the Dunvegan Formation of the Upper Cretaceous Smokey Group. These sandstones are part of an assemblage of clastic rocks that range texturally from clay-rich shales and mudstones to boulder conglomerates. The contact between the Dunvegan and Shaftsbury formations is gradational and consists of sandy siltstones and fine-grained sandstones interbedded with silty shales (Thompson, 1977; Stott, 1982). The stratigraphy and sedimentology of the Dunvegan Formation have been discussed in detail by Plint *et al.* (2001), Plint (2002), and Plint and Wadsworth (2003).

There are no known kimberlite or lamproite occurrences in the study area. The closest examples of extensive alkaline volcanic activity are in the Lac de Gras area (Northwest Territories), the Buffalo Head Hills area (Alberta), and British Columbia's Alkaline Province. Most kimberlite pipes in the Northwest Territories were emplaced between 45 and 75 Ma (Lockhart *et al.*, 2004). In northern Alberta, the radiometric ages of kimberlite emplacement range from 70.3±1.6 to 88±5 Ma (Eccles *et al.*, 2004). The known radiometric ages of lamprophyres, lamproites and kimberlites within British Columbia's Alkaline Province vary from 391±12 My for the HP pipe to 240 to 250 My for the Cross kimberlite (Smith *et al.*, 1988; Pell, 1994) and are older than sedimentary rocks that outcrop in northeast British Columbia. It is possible that pipes of similar ages to those of the Lac de Gras and Buffalo Head Hills areas cut sedimentary units of comparable or older ages in northeast British Columbia. It is also possible that the pyroclastic material ejected from craters or eroded from the pipes was incorporated into the sedimentary sequence.

This is the first report substantiating that indicator minerals may occur in the sedimentary rocks of northeast British Columbia. The presence of indicator minerals within the outcropping sedimentary sequence may complicate the interpretation of KIM anomalies in surficial materials; however, if confirmed, this report will provides invaluable information in the exploration for possible secondary (placer) diamond targets.

SURFICIAL GEOLOGY

Quaternary History

A recent account of the glacial history of the North American continent is provided by Dyke (2004). For detailed information regarding the Quaternary geology of portions of northeast British Columbia and the surrounding areas, the reader is referred to Smith *et al.* (1998), Bednarski (1999, 2000 and 2001), Levson *et al.* (2004), and Plouffe *et al.* (2004). The text that follows is a simplified glacial history of northeast British Columbia, with emphasis on aspects directly related to diamond exploration using glacial or glaciofluvial deposits.

According to Mathews (1980), three glacial systems (*i.e.*, the Laurentide, Rocky Mountain and Cordilleran) coexisted in northeast British Columbia during the last glaciation. During the Late Pleistocene, the Laurentide ice sheet advanced westward up the regional slope into northeast British Columbia. Its western boundary with the Rocky Mountain and Cordilleran glacial systems is approximated on Figure 2. Most, if not all, of the region was covered by ice during the last glacial maximum. The configuration of late glacial ice fronts and lobes is indicated by cross-cutting relationships observed in large-scale landforms (*e.g.* flutes, crag and tails, recessional moraines, etc.). Although the Laurentide ice sheet generally moved into

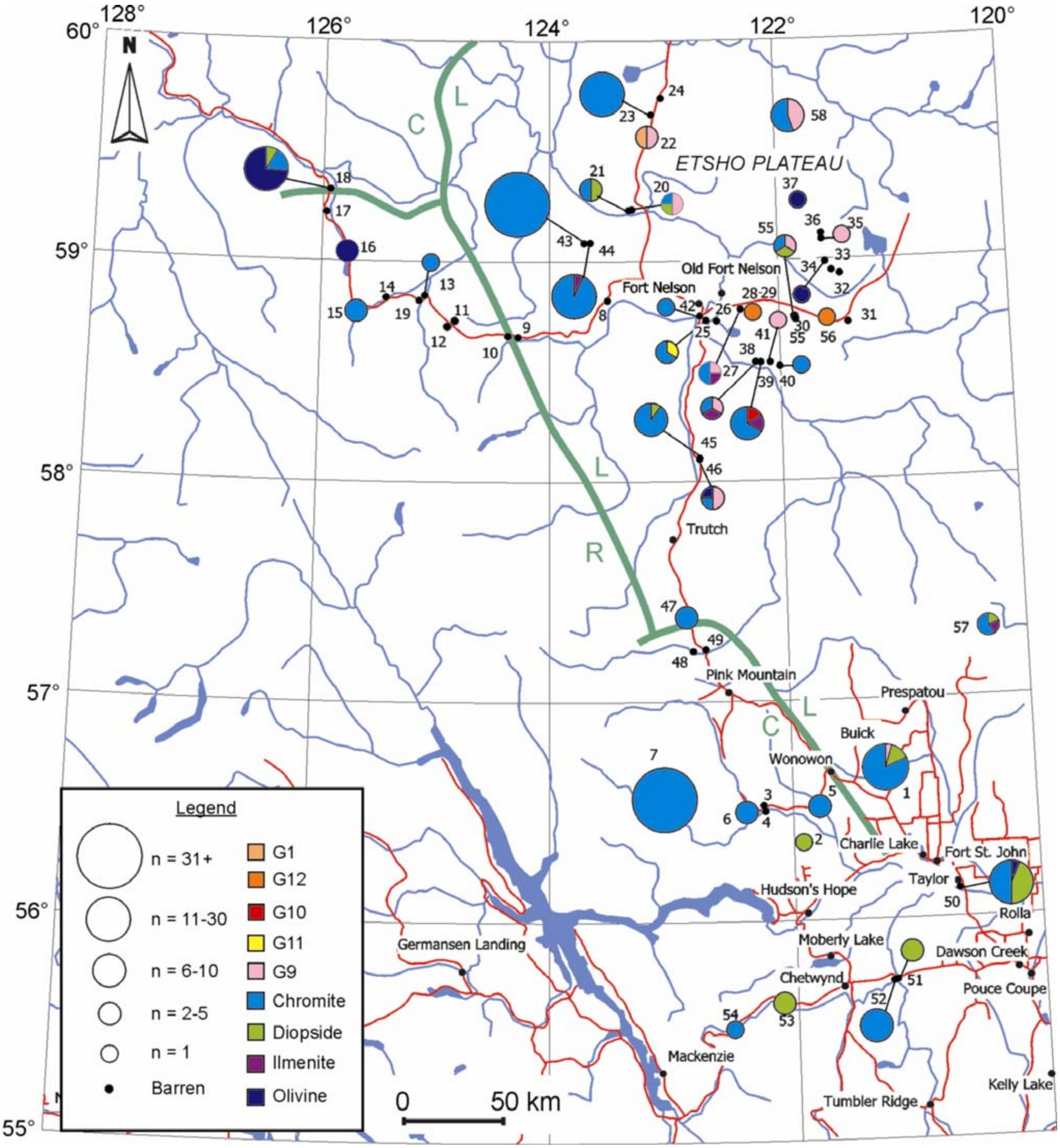


Figure 2. Location of glaciofluvial, stream sediment and bedrock samples. The circle diameter is proportional to the number of indicator mineral grains. Colours correspond to specific indicator minerals (KIMs). The green line separates the glacial systems: L - Laurentide glacial system; C - Cordilleran glacial system; R - Rocky Mountain glacial system.

the region from the east and northeast, its advance was not uniform. Differing orientations of these landforms suggest that multiple ice-flow events occurred in the region during the Late Wisconsinan and that ice lobes were active during the later stages of glaciation. During the eastward retreat of the Laurentide ice sheet, numerous meltwater channels flowing towards the west incised the landscape. Glacial lakes commonly developed along the ice margin, as drainage down the regional slope to the east was blocked by ice (Mathews, 1980).

Based on clast lithologies, glacial deposits within the study area can be divided into three groups: Those affected by the *Laurentide system* during the last glacial advance, east of Mathews' line (Figure 2), contain a variety of lithologies and are characterized by the presence of pink granitic and gneissic clasts that originated within the Canadian Shield. Deposits affected by the *Cordilleran system,* are characterized by grey granite fragments, quartzite/sandstone pebbles and boulders, and schist and slate clasts. This area that was affected by the *Rocky Mountain system* is characterized by fragments and pebbles of locally-derived sedimentary rocks including chert, quartzite, limestone, dolomite, shale and minor diabase. These areas are devoid of pebbles of either Cordilleran or shield-derived plutonic rocks (Mathews, 1980).

SAMPLE LOCATION AND COLLECTION

The study area is shown in Figure 1. The 58 samples analyzed and reported in this study were collected across northeast British Columbia, from as far as 200 kilometres west of Muncho Lake Park to 350 kilometres south of Dawson Creek (Figure 2). These samples were collected during the 2004 field season and correspond to a variety of sample media including modern stream and river deposits, and glaciofluvial sand and gravel.

The spatial distribution of the glaciofluvial samples was affected by the scarcity of glaciofluvial material in the region and accessibility constraints. This material was collected from vertical exposures in gravel pits, trenches, and roadcuts. Samples of modern stream or river sediments were, in most cases, collected upstream from bridges or where river valleys were easily accessed from nearby roads. Sample weights typically ranged from 15 to 30 kilograms, but some samples were over 40 kilograms. The samples were sieved in the field to exclude clasts greater than 4 millimetres. Sample depth was typically 20 to 50 centimetres below surface and samples were collected from undisturbed material.

Samples from modern river and stream sediments were collected from fluvial systems that drain significant basins. These systems may have incorporated indicator minerals from primary diamond deposits, till, glaciofluvial and glaciolacustrine deposits, or sedimentary bedrock. In samples where KIM grains are present, it is expected that those from river and stream deposits will have higher counts relative to till, as flowing water will tend to naturally pre-concentrate heavy minerals. Modern stream or river sediments are particularly useful sample media for assessing the potential of inaccessible areas within well-defined topography and catchment areas.

Information on the samples collected for this study is summarized in Table 1. Clast lithologies are provided for samples that contained pebble and cobble-sized clasts only. This information is important to establish the provenance of the sediments that host KIMs. The clasts were invariably well-rounded with the exception of samples that contained shales or locally derived sediments. Samples that did not contain any clasts are described as sand-sized or clay-rich material. The table also lists the type and frequency of grains that were confirmed to be potential KIMs based on their chemical composition.

Samples NEBC-23 and NEBC-43 must be considered separately. The former was sampled from a regolith derived from a conglomerate facies of the Dunvegan Formation, whereas the latter was sampled from lithified Dunvegan conglomerate.

Figure 3 summarizes the sample processing procedure. A 500 gram sample split was taken from the original sample and archived prior to processing by Lakefield Research Laboratory. Each sample was then wet-screened at 20 and 60 mesh. The +20 mesh material and approximately 500 grams of the -60 mesh material were dried and stored. The -20+60 mesh fraction was further concentrated using the Wilfley table and the tail fractions were dried and stored. The concentrates were subjected to heavy liquid separation (Methylene iodide @ 3.1 g/cm^3) followed by dry screening (35 mesh) and magnetic separation by hand-magnet and Frantz electromagnetic separator.

Using a binocular microscope, the mineral concentrates were picked for diamond indicator mineral species. All picked indicator minerals were put into standard 1-inch polished grain mounts and returned to the BC Ministry of Energy, Mines and Petroleum Resources. Microprobe analyses were then conducted on these mounts by M. Raudsepp at the University of British Columbia to determine the major element composition of the visually picked mineral grains. Chemical composition of mineral grains is required to determine if a mineral is a diamond or kimberlite indicator.

In total, 381 mineral grains were subjected to microprobe analyses. Of these, 315 grains were identified as potential KIMs. All samples, including those with KIMs, are shown on Figure 2. Samples containing potential KIMs based on the interpretation of microprobe analysis are listed in Tables 2 to 5 and Appendix 1. The locations of sample sites and number of KIM grains at each site are provided in Figure 2 and Table 1.

Table 1. Sample description, location and kimberlite indicator mineral summary. Key: gn = gneiss, gr = granite, sh = shale, ls = limestone, ss = sandstone, cl = clay, congl = conglomerate, umf = ultramafic, cb = crystalline basement sed = sedimentary, qtz = quartzite, ch = chert, si = siltstone, is = ironstone, maf = mafic, (p) = pink, (g) = grey, > = greater than, >> = much greater than, commas indicate similar abundances

					KIMs									
Sample Number	UTM - Northing	UTM - Easting	Composition of clasts	Sample type	G10	G9	G11	G1	G12	Cr Diop	Ilm	Chr	Ol	Total
NEBC-01	6282870	608712	ss/si > gr (p), gn (p), ls, is	River		1				3		18		22
NEBC-02	6264810	575052	ss > sh > gr > gr gn > umf > ch > maf	River						1				1
NEBC-03	6262791	546990	sand-sized material	River										0
NEBC-04	6262536	547022	ss > ls > sh > is	River										0
NEBC-05	6265576	573653	ss >> ls, sh > is > gr	Stream								4		4
NEBC-06	6297889	522801	mainly sed	Stream								2		2
NEBC-07	6304336	520920	ss >> sh, ls > ch, congl	River								71		71
NEBC-08	6520367	471424	ss, si > gr > sh > ch, gn	Pit										0
NEBC-09	6502598	426083	ss >> ls > congl	River										0
NEBC-10	6503318	420959	ss >> ls > sh, ch	Pit										0
NEBC-11	6508859	390131	ls > ss > ch > sh	Pit										0
NEBC-12	6501947	400528	ls > ss > ch	Pit										0
NEBC-13	6524807	379408	ls, ss, sh > qtz > ch > maf	Pit								1		1
NEBC-14	6524322	359904	ls >> sh, ch, ss > congl, qtz	Flood Plain										0
NEBC-15	6518192	344777	ls >> maf, ss, sh, (g)	Pit								2		2
NEBC-16	6548532	340361	ls >> ss, qtz, ch	Pit									5	5
NEBC-17	6568296	330650	cl (clay-rich)	River										0
NEBC-18	6579659	332851	ls >> ss, si, sh > gr	River						2		4	17	23
NEBC-19	6522313	376458	ls > qtz > sh, gn > ch > maf	Flood Plain (River)										0
NEBC-20	6566238	484386	gn >> maf > qtz, sh	Pit		2				1		1		4
NEBC-21	6565844	482724	gr gn >> qtz, ss > is	Pit						1		1		2
NEBC-22	6603120	492464	qtz, ss, gn	Pit		1		1						2
NEBC-23	6614075	494595	congl, ls, ss, sh >> qtz > gn	pit, Dunvegan Fm, regolith								25		25
NEBC-24	6622371	499465	ss, sh > gr gn > qtz	Pit										0
NEBC-25	6510030	520870	gn (p) > qtz > gr > ch	Pit			1					2		3
NEBC-26	6509616	526229	gr gn >> qtz > sh	Stream										0
NEBC-27	6515567	538244	gn > qtz > sh, ss	Roadcut		1					1	2		4
NEBC-28	6514501	544774	ss, cb (p)	Pit					1					1
NEBC-29	6514501	544774	ss, cb (p)	Pit										0
NEBC-30	6512127	565471	gn (p), qtz > maf, umf	Pit										0
NEBC-31	6509051	592514	cb (p)	Trench										0
NEBC-32	6533569	588526	gr gn >> qtz	Pit										0
NEBC-33	6535231	584300	cl (clay-rich)	Surface										0
NEBC-34	6539551	581206	cb (p) > sh	Pit									1	1
NEBC-35	6551005	579502	sand-sized material	Stream		1								1
NEBC-36	6553888	578755	cb (p)	Stream										0
NEBC-37	6570249	567872	cb (p)	Small Pit									1	1
NEBC-38	6489088	545698	gr (p) > qtz > maf	Pit		1					1	1		3
NEBC-39	6488921	548332	cb (p)	Esker	1						1	4		6
NEBC-40	6486881	557911	sand-sized material	Pit								1		1
NEBC-41	6488850	553059	cb (p)	Pit		1								1
NEBC-42	6512245	517785	cb (p)	Pit								1		1
NEBC-43	6549892	460825	ch, congl, ss > qtz	pit, Dunvegan Fm, hard rock								37		37
NEBC-44	6549887	461981	congl, sh > 70% >> cb (p)	Stream							2	25		27
NEBC-45	6440574	516839	gn (p) > gn (g) > ss > maf, sh > is, congl	Stream						1		9		10
NEBC-46	6439810	516735	cb (p) > ss	Pit		2						1	1	4
NEBC-47	6360037	509264	ss, ls > sh > gr gn >> maf	River								3		3
NEBC-48	6342957	512200	ls+sh > 97%	Pit										0
NEBC-49	6343737	518469	ss >> is	River										0
NEBC-50	6222613	645018	ss > sh > qtz > is > gr gn (p)	Stream						7		8	1	16
NEBC-51	6176752	613163	qtz/ss >> 70% > congl, is > gr	Pit						2				2
NEBC-52	6176129	611299	ss, sh > is > maf >> gr (p)	River								8		8
NEBC-53	6165753	556133	ss > sh > ls, congl >> is	River						2				2
NEBC-54	6152653	530479	qtz > ls >> sh, is, maf	Stream								1		1
NEBC-55	6510906	565930	gr (p), qtz	Pit		1				1	1			3
NEBC-56	6539487	581232	gr (p), qtz	Pit					1					1
NEBC-57	6354768	661877	gr (p), qtz	Pit						1	1	3		5
NEBC-58	6612910	564017	gr (p), qtz	Pit		4						5		9
Total Indicators					1	15	1	1	2	22	7	240	26	315

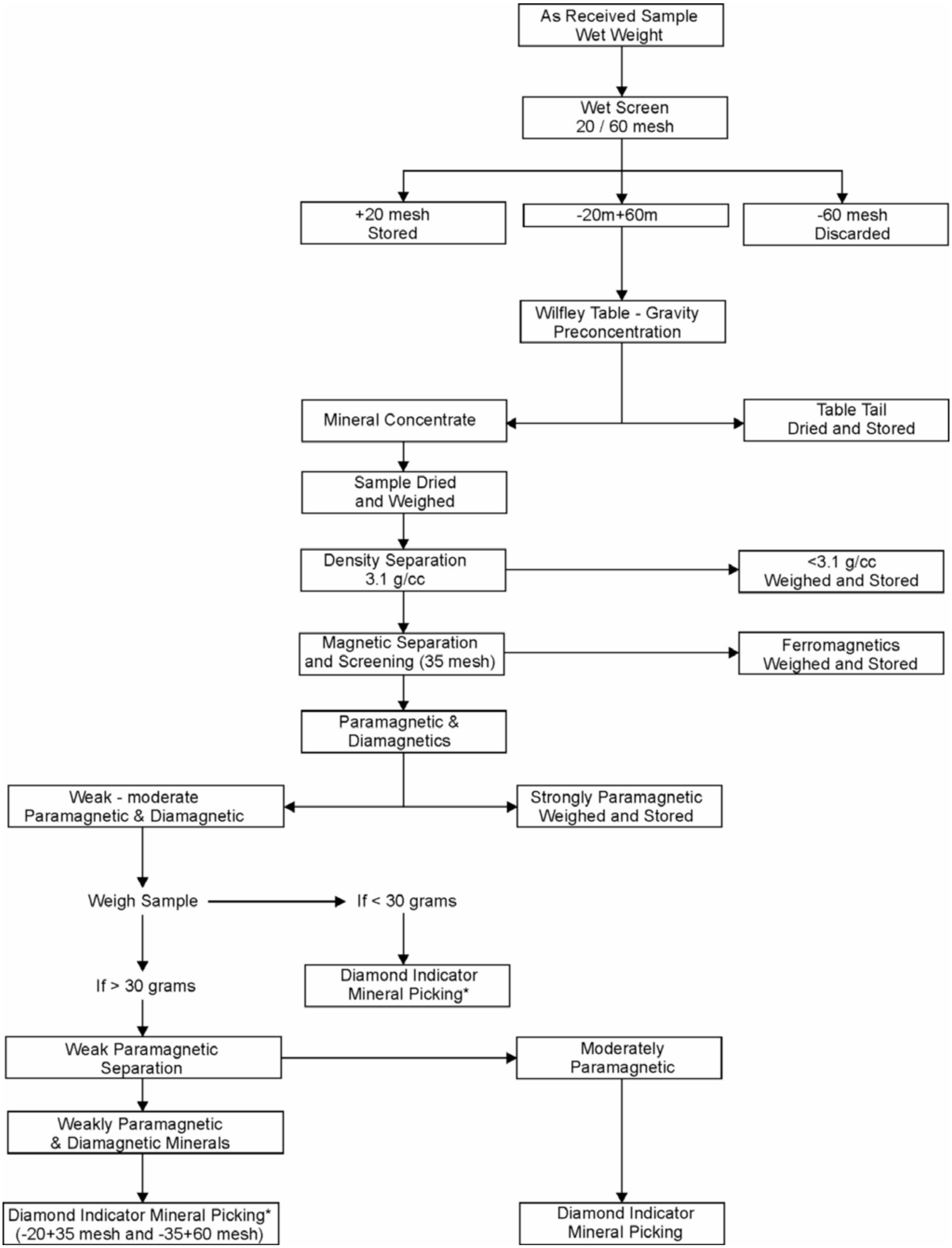


Figure 3. Diamond indicator mineral extraction flow sheet. * indicates primary diamond indicator mineral fraction. Source: SGS Lakefield Research Limited.

INTERPRETATION OF MICROPROBE ANALYSES

Interpretation of the data from northeast British Columbia is more complex than from areas such as Lac de Gras (NWT) or Buffalo Head Hills because sediments in northeast British Columbia contain clinopyroxenes, olivines and chromites with chemical compositions which may not be unique to kimberlites or lamproites. For example Cr-spinel can be also derived from Alaskan intrusions, ophiolites, boninites, xenoliths within alkali basalts, or from other lithologies typical of British Columbia's alkaline province. Of the 58 samples collected for this study, 39 contain potential KIMs. Of these, 28 contain more than one indicator mineral variety and often more than one grain of each. The following section presents microprobe data on visually picked minerals and includes a discussion of the KIMs identified in this study.

Garnet

Mantle-derived garnet is considered to be the most important kimberlite and diamond indicator mineral. The two most recent studies on garnet classification and interpretation are those of Schulze (2003) and Grütter *et al.* (2004). Methods presented in these studies are very effective in distinguishing pyrope, eclogitic and crustal garnets. The key elements used to identify and interpret mantle-derived garnets, and to estimate the diamond potential of an area or individual pipe are Cr, Ca, Mg, Fe, Ti and Na.

In this paper, different garnet species are classified in accordance with the method described by Grütter *et al*. (2004). This scheme divides garnets into 12 categories (G1 to G12). Of these, harzburgitic (G10), lherzolitic (G9), pyroxenitic, websteritic and eclogitic garnets (G4, G5 and G3) are commonly associated with diamonds. Wehrlitic garnets are referred to as G12, low-Cr megacrysts as G1, and Ti-rich peridotitic varieties as G11. The garnets that do not fit any of the twelve categories, including crustal garnets, are referred to as G0. The scheme is in part empirical; it was tested on a large data set and is robust.

Microprobe analyses of hand-picked garnets, and results of classification using the method outlined by Grütter *et al.* (2004), are provided in Table 2. The locations of garnet-bearing samples identified in this study are presented in Figure 2. Of the 21 garnets visually picked and analyzed, at least 20 can be considered as KIMs. There is one G10 garnet (Sample NEBC- 39). Fifteen of the mantle-derived garnets are lherzolitic (G9), two are wehrlitic (G12), one is a G11 and one is a G1 garnet (Figure 4). Eclogitic (G3) garnets were previously reported from this area by Simandl *et al.* (2005); however, no eclogitic garnets were picked in this study. Follow-up picking is required to confirm the lack of eclogitic garnets. Kelyphitic rims were not observed on any of the visually picked garnets, and some garnets did have an orange peel texture, suggesting that they were subject to some degree of transport, or at least local reworking, after being liberated from their host rock.

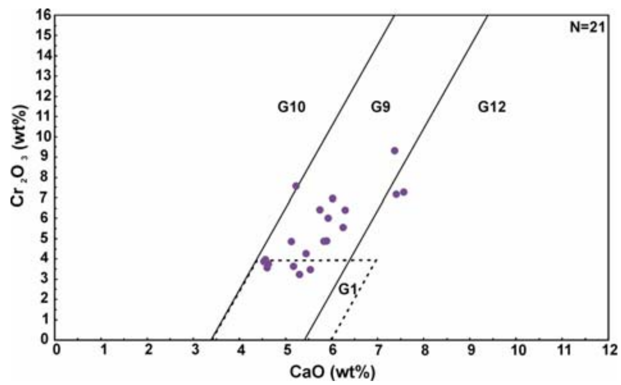


Figure 4. Garnet Cr_2O_3-CaO discrimination plot. One grain plots in the G10 field, and 15 plot within the G9 field. Fields from Gurney and Moore (1994) and Grütter et al. (2004).

Clinopyroxene

Chrome-bearing, green to bright green clinopyroxenes are typically easy to visually identify in heavy mineral concentrates, and can be associated with diamonds. For these reasons, clinopyroxenes are considered effective KIMs. Unfortunately, clinopyroxenes with similar characteristics to those present in kimberlitic rocks are also found in variety of ultramafic rocks such as ophiolitic layered intrusions, Alaskan-type intrusions, and basalt hosted xenoliths. Consequently, microprobe analyses are required to differentiate kimberlite-related clinopyroxene grains from those associated with other lithologies, and clinopyroxene is therefore considered a less significant KIM than garnet or ilmenite. The chemical compositions of the 24 clinopyroxene grains that were visually picked from concentrates are provided in Table 3.

All the clinopyroxenes except one (a clinoenstatite) plot within the kimberlite indicator field on the Quirt (2004) Wo-En-Fs diagram. The Mg numbers (100Mg / (Mg+Fe)) of these clinopyroxenes vary from

Table 2. Chemical composition of garnets; for sample locations see Table 1 and Figure 2.

Sample ID	UTM Northing	UTM Easting	Na_2O	MgO	Al_2O_3	SiO_2	CaO	TiO_2	Cr_2O_3	MnO	FeO	Total	Garnet Type
NEBC-1	6282870	608712	0.01	19.10	19.59	41.10	6.29	0.02	6.41	0.44	7.58	100.55	G9
NEBC-20	6566238	484386	0.02	19.50	20.49	41.05	5.87	0.00	4.89	0.43	8.29	100.55	G9
NEBC-20	6566238	484386	0.02	20.01	20.83	41.10	5.45	0.05	4.26	0.41	8.51	100.65	G9
NEBC-22	6603120	492464	0.07	20.83	19.38	41.73	5.16	1.00	3.64	0.29	8.04	100.14	G1
NEBC-22	6603120	492464	0.04	19.70	20.65	41.36	5.13	0.11	4.85	0.38	8.66	100.90	G9
NEBC-25	6510030	520870	0.05	20.45	18.23	41.63	5.74	0.63	6.44	0.23	7.03	100.43	G11
NEBC-27	6515567	538244	0.02	19.62	19.81	41.09	6.26	0.05	5.56	0.35	8.00	100.74	G9
NEBC-28	6514501	544774	0.00	18.38	18.32	40.57	7.40	0.00	7.18	0.41	8.27	100.53	G12
NEBC-35	6551005	579502	0.04	20.32	20.72	41.62	5.86	0.01	4.88	0.38	7.09	100.89	G9
NEBC-38	6489088	545698	0.03	20.23	21.42	41.19	5.55	0.01	3.47	0.41	8.07	100.39	G9
NEBC-39	6488921	548332	0.05	20.10	18.42	40.74	5.24	0.30	7.57	0.39	7.58	100.39	G10
NEBC-41	6488850	553059	0.03	19.87	18.77	41.10	6.01	0.09	6.96	0.35	8.37	101.55	G9
NEBC-46	6439810	516735	0.02	19.50	19.05	41.38	5.92	0.16	6.01	0.32	7.79	100.14	G9
NEBC-46	6439810	516735	0.01	19.85	21.82	40.87	5.30	0.03	3.25	0.33	8.03	99.50	G9
NEBC-55	6510906	565930	0.02	17.74	16.62	40.04	7.36	0.06	9.32	0.42	7.47	99.06	G9
NEBC-56	6539487	581232	0.01	16.94	18.62	40.94	7.57	0.01	7.28	0.57	8.50	100.44	G12
NEBC-58	6612910	564017	0.06	20.74	20.98	41.53	4.56	0.28	3.96	0.29	7.84	100.24	G9
NEBC-58	6612910	564017	0.06	20.66	21.15	41.64	4.60	0.29	3.58	0.39	7.93	100.30	G9
NEBC-58	6612910	564017	0.05	20.85	21.10	41.29	4.54	0.26	3.85	0.30	7.58	99.82	G9
NEBC-58	6612910	564017	0.06	20.78	21.01	42.15	4.62	0.31	3.77	0.36	7.54	100.60	G9

Table 3. Composition and Mg # of clinopyroxenes (Cr-diopsides); for sample locations, see Table 1 and Figure 2.

Sample ID	UTM Northing	UTM Easting	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Cr_2O_3	MnO	FeO	Total	Mg #
NEBC-1	6282870	608712	1.21	15.80	6.17	51.31	0.00	20.91	0.30	0.83	0.03	2.79	99.36	0.909978
NEBC-1	6282870	608712	1.85	15.16	7.29	51.70	0.01	19.74	0.43	0.71	0.06	3.01	99.96	0.89966
NEBC-1	6282870	608712	1.41	15.68	6.17	51.34	0.00	20.74	0.26	1.05	0.07	2.74	99.45	0.910806
NEBC-2	6264810	575052	0.16	17.83	1.16	53.32	0.02	23.22	0.10	0.92	0.14	2.90	99.76	0.916483
NEBC-18	6579659	332851	1.44	15.78	6.45	51.27	0.00	19.57	0.42	1.10	0.10	2.71	98.85	0.912209
NEBC-18	6579659	332851	0.16	18.04	0.84	53.55	0.00	22.89	0.13	0.45	0.07	2.89	99.01	0.917638
NEBC-20	6566238	484386	0.70	16.79	1.11	53.13	0.00	22.13	0.03	0.74	0.20	3.55	98.38	0.893889
NEBC-21	6565844	482724	0.70	16.31	1.54	53.56	0.00	22.50	0.06	0.51	0.08	3.91	99.18	0.881399
NEBC-45	6440574	516839	0.45	15.94	2.80	51.96	0.00	22.37	0.16	0.77	0.13	4.85	99.43	0.854281
NEBC-45	6440574	516839	1.44	16.08	6.63	51.17	0.00	19.50	0.38	1.04	0.13	3.19	99.57	0.899722
NEBC-50	6222613	645018	0.16	17.74	1.48	53.24	0.00	23.19	0.12	0.65	0.09	3.03	99.70	0.912654
NEBC-50	6222613	645018	1.64	15.65	6.71	50.99	0.00	19.53	0.46	0.64	0.09	3.10	98.81	0.900126
NEBC-50	6222613	645018	0.47	17.31	3.43	52.52	0.01	21.98	0.01	1.11	0.02	2.21	99.06	0.93332
NEBC-50	6222613	645018	1.50	15.11	7.00	50.95	0.00	20.42	0.35	1.00	0.10	2.61	99.04	0.911777
NEBC-50	6222613	645018	1.24	15.82	5.79	51.91	0.00	21.37	0.36	0.96	0.09	2.79	100.33	0.910081
NEBC-50	6222613	645018	1.18	16.91	4.91	52.43	0.01	20.25	0.13	1.36	0.05	2.74	99.97	0.916749
NEBC-50	6222613	645018	1.55	15.55	6.20	51.41	0.00	20.65	0.30	1.07	0.12	2.48	99.32	0.917881
NEBC-51	6176752	613163	1.47	16.30	7.13	50.98	0.01	18.68	0.37	0.84	0.05	3.36	99.18	0.896459
NEBC-51	6176752	613163	1.38	15.85	5.89	51.72	0.01	20.81	0.26	1.22	0.09	2.56	99.80	0.91698
NEBC-52	6176129	611299	0.11	33.40	4.80	54.15	0.01	0.64	0.09	0.31	0.14	6.50	100.15	0.901617
NEBC-53	6165753	556133	1.29	15.87	6.79	50.79	0.00	19.54	0.42	0.77	0.13	3.19	98.79	0.898615
NEBC-53	6165753	556133	1.65	15.17	6.98	51.02	0.00	19.87	0.62	0.94	0.09	2.73	99.08	0.908319
NEBC-56	6539487	581232	0.31	17.36	2.03	51.55	0.00	21.81	0.30	0.85	0.14	4.47	98.82	0.873772
NEBC-57	6354768	661877	0.69	16.87	1.90	53.36	0.00	22.63	0.15	0.92	0.07	3.10	99.70	0.906524

85.42 to 93.33 with an average higher than 90 (Table 3). Cr-diopside grains with an Mg number greater than 88 are likely to be from mantle peridotite, particularly if they have elevated Cr_2O_3 (> 0.5 wt %) as do most of the grains analyzed.

The Cr_2O_3-Al_2O_3 discrimination plot of Ramsey and Tompkins (1994) and Cr_2O_3-CaO plot of Fipke *et al.* (1989) were used to further refine this interpretation. Globally, most clinopyroxene found as solid inclusions or intergrowths in and/or with diamond, plot into the 'on-craton' garnet-peridotite field seen in Figure 5, but clinopyroxenes plotting in the "off craton" garnet peridotite and spinel peridotite field are also recovered from kimberlite concentrates. On the Cr_2O_3 – CaO plot (Figure 6), with the exception of three grains, all the clinopyroxenes visually picked from heavy mineral concentrates plot within the field representative of diopsides found as inclusions in diamonds. If we consider the Cr-Al-Na ternary diagram of Morris *et al.* (2002), only one of the clinopyroxenes plot within the Cr-diopside field for kimberlite xenoliths and xenocrysts; however, when this discrimination plot is applied to parts of the world other than Ontario, it achieves only limited success (Figure 10B in Quirt, 2004). If we consider the Na-Ca-Cr-Fe diagram of Thorleifson *et al.* (1994) and Quirt (2004), depending on the plot, about half of the diopsides from Northeast

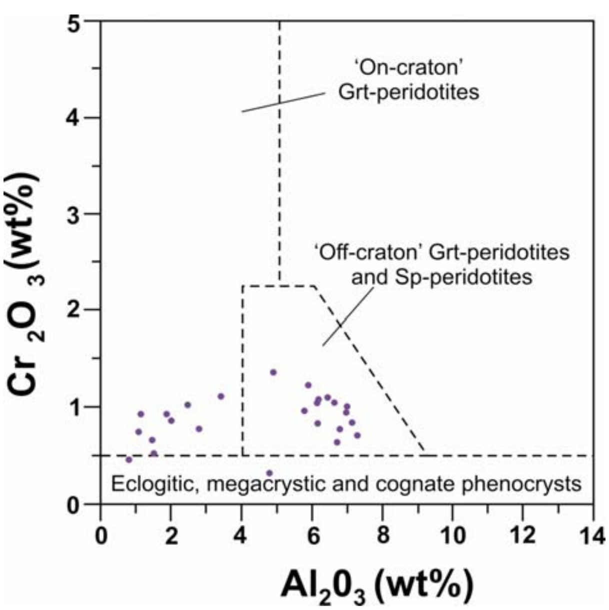


Figure 5. Clinopyroxene Cr_2O_3-Al_2O_3 discrimination plot (after Ramsey and Tompkins, 1994). Eight of the grains from this study plot within the 'on-craton' field, further refining interpretations based on the Mg-number. Fourteen grains plot within the spinel peridotite and "off -craton" garnet peridotite fields. Two grains has Cr_2O_3 content below 0.5 wt% and plot within the field of "eclogitic, megacrystic, and cognate phenocrysts."

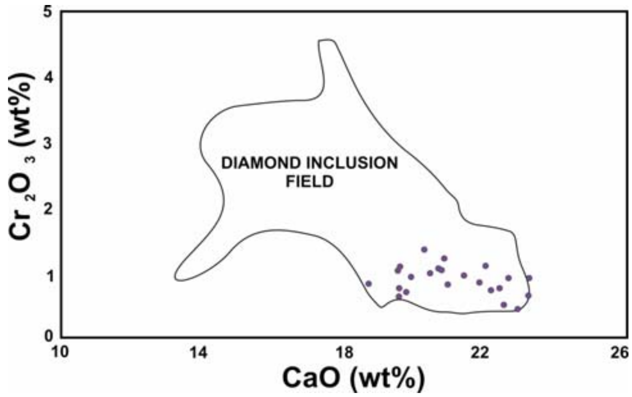


Figure 6. Clinopyroxene; Cr_2O_3 – CaO plot. The outlined field represents the composition of clinopyroxenes found as inclusions in diamonds (Fipke *et al.*, 1998)

British Columbia would be peridotitic. Normally, Cr-diopsides do not carry as much weight as garnets during the interpretation of heavy mineral data; however, if clinopyroxene of appropriate chemical composition occurs in the same sample with other indicators such as pyrope or ilmenite (or at least in the same geographic area as G9 or G10), it is appropriate to consider it as a full-fledged KIM. A detailed investigation that leads to the Cr-diopside interpretation is underway and it will be published as separate document. For the purpose of this study, all the samples listed in Table 3 are considered KIMs.

Spinel

As with Cr-diopside, the distinction of kimberlite-related spinels from spinels derived from other sources is not straightforward. Spinels are found in a variety of settings, including layered intrusions, Alaskan type intrusions, ophiolites, xenoliths within alkali basalts, and boninites. Of the 275 Cr-spinels (chromite) grains picked, 240 grains, can be considered as potential KIMs based on their chemical composition. These chromite grains consist mainly of Al_2O_3 (4.70 to 36.26%), Cr_2O_3 (29.15 to 62.91%), FeO (13.22 to 44.45%), and MgO (3.91 to 19.77%). Smaller constituents are TiO_2 (<4.89%), MnO (<1.74%), NiO (<0.47%), and SiO_2 (<0.30%). The chemical analyses of potential KIM chromite grains can be found in Appendix 1.

The majority of these grains appear to follow the peridotite trend (Figure 7). Five of the grains have high chrome content (>60% Cr_2O_3) and an appropriate MgO content to fit the compositional fields of chromite inclusions in diamonds. On the TiO_2 vs. 100Cr / (Cr+Al) diagram (Figure 8), the majority of the chromites plot within the garnet peridotite field and at least 16 grains have compositions compatible with chromites found as inclusions in diamonds. To further improve discrimination between kimberlite-related spinels and spinels from a variety of other sources, additional criteria were selected based on the database of spinels published by Barnes and Roeder (2001, 2004) and other factors, such as the grain-size of spinels from a variety of non-kimberlite/lamproite environments (Grütter and Apter, 1998; McCandless and Dummett, 2003). Details of this enhanced interpretation method will be published as a separate paper, but the results are already incorporated into our current interpretation

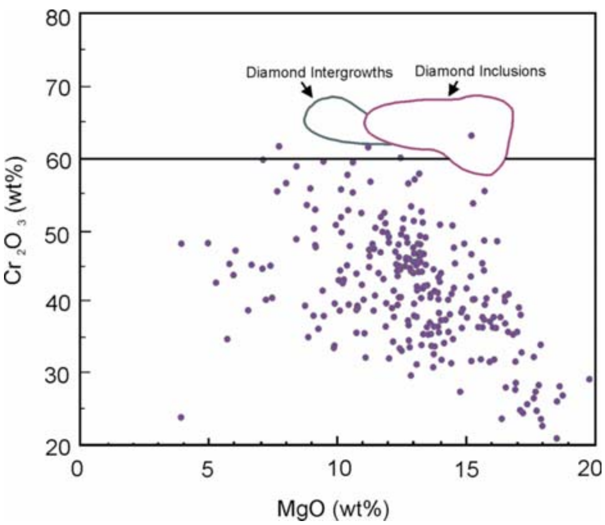


Figure 7. Cr-spinels, Cr_2O_3 – MgO diagram. Most of the grains appear to follow the peridotite trend and 5 of these grains have Cr_2O_3 content of 60 wt% or more. Compositions of spinels found as intergrowths with or inclusions in diamonds from Fipke et al. (1998)

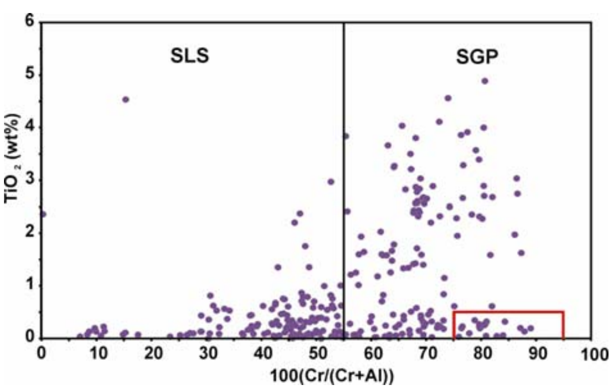


Figure 8. Cr-spinel TiO_2 - 100Cr / (Cr+Al) diagram. The majority of the chromites plot within the garnet peridotite field. At least 16 grains have compositions compatible with chromites found as inclusions in diamonds, indicated by a rectangle. SLS – spinels from spinel peridotites, SGP – spinels from garnet peridotites, fields from Ramsey and Tompkins (1998).

(Figure 2). Samples NEBC-1, NEBC-7, NEBC-23, NEBC-43, and NEBC-44 contain 18, 71, 25, 37, and 25 chromites, respectively. Sample NEBC-1 also contains Cr-diopside and a G9 garnet, and sample NEBC-44 contains ilmenite that has an appropriate chemical composition to be interpreted as kimberlite-related. A substantial portion of spinels from these samples have the characteristics of lamproite-derived spinel; however, it is possible that some of the spinel from NEBC-7 originated from lamprophyre dikes or diatremes related to the Aley Carbonatite complex (also referred to as the Ospika pipe), which is located less than 100 kilometres from the sample site. At this stage, we have no microprobe analyses of spinels from this complex.

Ilmenite

Ilmenite is one of the most widely used kimberlite indicator minerals. It is a common member of the megacryst suite, and the major compounds TiO_2, MgO, CrO_2, MnO_2 and Fe_2O_3 are used to distinguish kimberlitic ilmenites from those that are non-kimberlitic (Wyatt *et al.*, 2004). Seven grains of ilmenite were picked and analyzed, and are given in Table 4. Based on

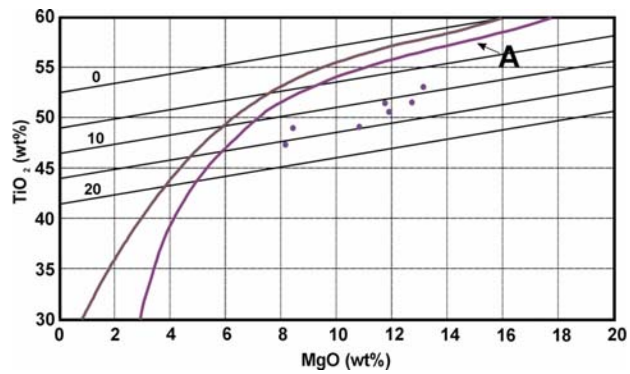


Figure 9. Ilmenite TiO_2 - MgO discrimination plot (after Wyatt *et al.*, 2004). Seven grains plot within the kimberlite field, which is located to the right of the curve marked 'A'.

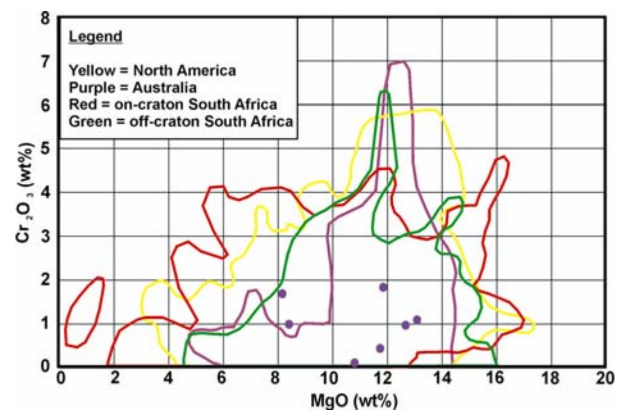


Figure 10. Ilmenite Cr_2O_3 - MgO discrimination plot (after Haggerty, 1991). Simplified fields representing North American, Australian and South African (on- and off-craton) kimberlitic ilmenites derived from plots by Wyatt et al. (2004). All seven ilmenite grains from northeast British Columbia plot within the fields representing South African and North American kimberlitic ilmenites. Five of the seven grains also fall within the field of Australian kimberlitic ilmenites.

the TiO_2 - MgO plot (Figure 9), all the ilmenite indicator grains analysed plot within the kimberlite field (*i.e.* to the right of the curve marked 'A').

As shown in Figure 10, the Cr_2O_3-MgO plot also suggests that the same seven grains identified in Figure 9 are associated with kimberlite. The fields of typical North American, South African (on- and off- craton), and Australian kimberlitic ilmenites are provided in Figure 10 for reference, and are based on data from Wyatt *et al.* (2004). Six of these ilmenites come from samples collected in the Etsho Plateau region east of Fort Nelson and one originates from a sample collected approximately 110 kilometres north of Fort St. John near the BC-Alberta border (Figure 2).

Table 4. Chemical composition of ilmenites; for sample locations, see Table 1 and Figure 2.

Sample ID	UTM Northing	UTM Easting	MgO	Al_2O_3	SiO_2	CaO	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	NiO	Nb_2O_5	Ta_2O_5	Total
NEBC-27	6515567	538244	8.16	0.10	0.00	0.02	47.39	0.00	1.68	0.26	41.06	0.06	0.16	0.00	98.89
NEBC-38	6489088	545698	11.87	0.55	0.05	0.03	50.60	0.00	1.81	0.26	33.07	0.11	0.22	0.02	98.59
NEBC-39	6488921	548332	12.70	0.58	0.05	0.01	51.54	0.00	0.95	0.19	32.01	0.07	0.15	0.00	98.25
NEBC-44	6549887	461981	8.42	0.16	0.04	0.00	48.97	0.00	0.97	0.27	40.09	0.10	0.31	0.01	99.35
NEBC-44	6549887	461981	13.11	0.37	0.05	0.04	53.05	0.00	1.07	0.24	30.73	0.12	0.16	0.03	98.97
NEBC-55	6510906	565930	10.82	0.48	0.00	0.05	49.09	0.00	0.10	0.28	36.87	0.03	0.15	0.02	97.89
NEBC-57	6354768	661877	11.75	0.61	0.06	0.01	51.48	0.00	0.42	0.26	33.93	0.00	0.13	0.00	98.64

Olivine

Olivine is considered a useful KIM in cold climates. Olivine is the most common rock-forming mineral in kimberlites; however, it is also present in a variety of other ultramafic rocks, basalts, and mantle xenoliths in British Columbia (Voormeij and Simandl, 2004a, b). Due to its occurrence in diverse lithologies, olivine is less diagnostic and it does not provide as much information regarding the diamond potential of northeast British Columbia as garnet, ilmenite, spinel or Cr-diopside. Nevertheless, in association with other indicator minerals, olivine may play an important role in the evaluation of indicator mineral anomalies. Olivine from kimberlites and peridotites is MgO-rich (close to the forsterite end-member of the olivine solid solution series) and is colourless to pale yellow or pale green. Its chemistry is characterized by Mg-numbers (100Mg / (Mg+Fe)) between 84 and 95 and notable traces of NiO. Most of the olivines from our study area fall within that range (Table 5 and Figure 11). Olivines that are found as inclusions in diamonds commonly plot in an irregularly shaped field on Fipke's (1989) Cr_2O_3 - Fo diagram (Figure 11).

The Mg-rich variety of olivine identified in samples from northeast British Columbia is commonly pale yellow-green in colour, equidimensional, subrounded to rounded, and has a fresh appearance. Microprobe data on 47 olivine grains recovered from collected samples are presented in Table 5 and plotted on the Cr_2O_3 - Fo diagram (Figure 11). None of the olivine grains collected during this study fall within the compositional field of olivines found as inclusions in diamonds.

The concentrations of olivine in samples NEBC-16 and NEBC-18 suggest that these olivines may be derived from known ultramafic rocks west of the study area, that are part of the Cache Creek and Slide Mountain terranes, or from alkaline pipes or dikes in the Kechika River area, which is consistent with Mathew's (1980) inference of the glacial history of the area..

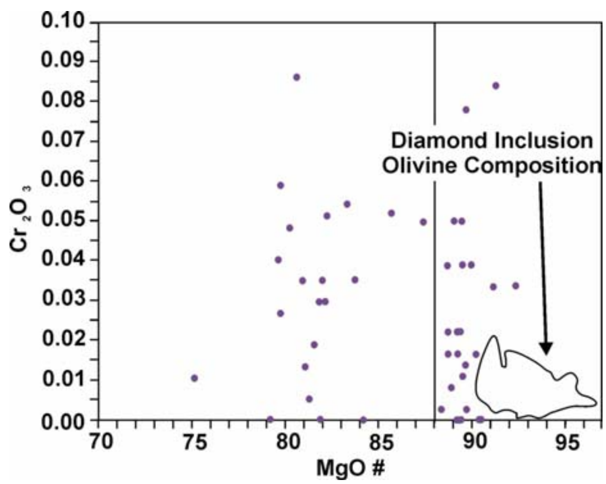


Figure 11. Olivine Cr_2O_3 - Mg# discrimination plot. Olivines with the Mg# greater than 88 are commonly, but not uniquely, associated with kimberlites. Twenty six grains from this study have Mg# greater than 88. The outline of olivine compositions found as solid inclusions in diamonds is from Fipke *et al.* (1995). None of the grains recovered during the current study from this study fit that profile.

Table 5. Chemical composition and Mg# of olivines; for sample locations, see Table 1 and Figure 2.

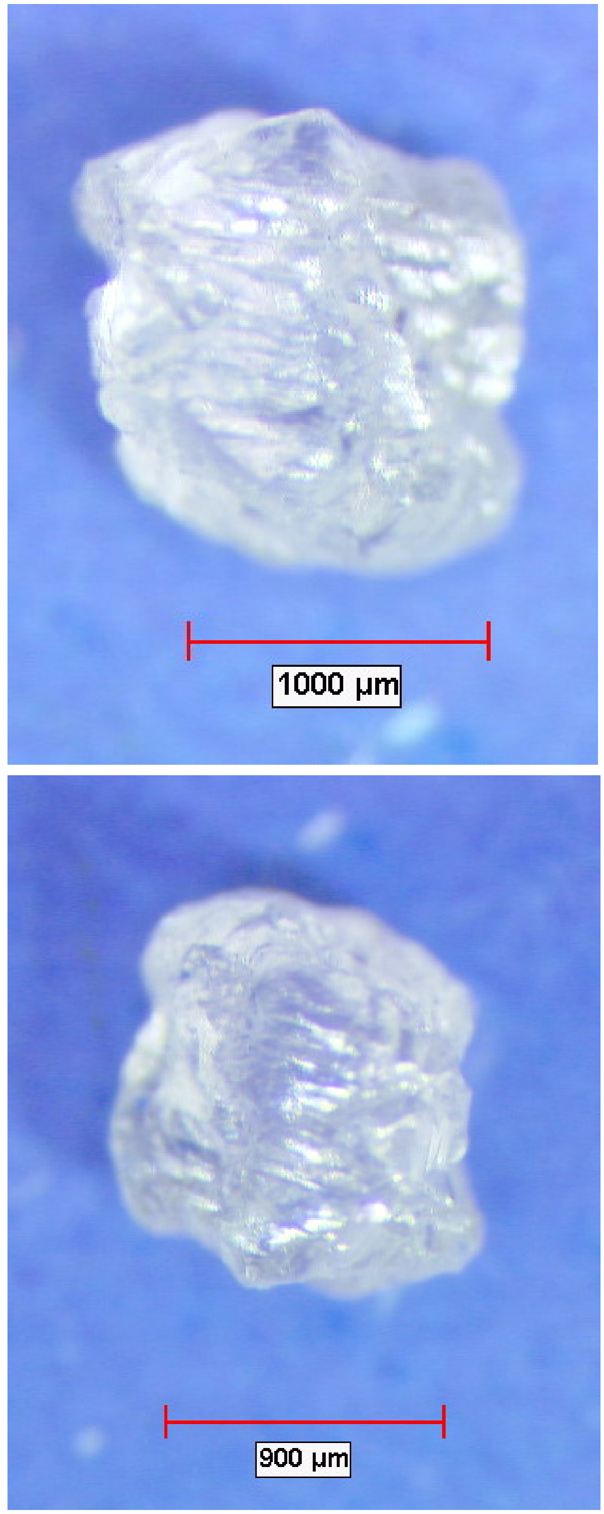
Sample ID	UTM Northing	UTM Easting	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Cr_2O_3	MnO	FeO	Total	Mg #
NEBC-16	6548532	340361	0.02	49.91	0.00	40.08	0.01	0.06	0.02	0.00	0.14	10.19	100.44	0.897277
NEBC-16	6548532	340361	0.02	41.66	0.03	38.44	0.00	0.28	0.01	0.00	0.19	19.48	100.11	0.792167
NEBC-16	6548532	340361	0.03	50.06	0.03	40.05	0.00	0.05	0.02	0.00	0.12	9.44	99.79	0.904375
NEBC-16	6548532	340361	0.00	50.00	0.00	40.72	0.00	0.05	0.00	0.02	0.14	9.66	100.59	0.902232
NEBC-16	6548532	340361	0.01	50.56	0.16	40.52	0.00	0.13	0.00	0.08	0.09	8.60	100.16	0.912901
NEBC-16	6548532	340361	0.00	48.76	0.02	39.92	0.01	0.11	0.00	0.00	0.14	11.42	100.39	0.883907
NEBC-17	6568296	330650	0.03	39.01	0.04	37.16	0.00	0.24	0.03	0.01	0.22	23.02	99.76	0.751308
NEBC-18	6579659	332851	0.00	49.16	0.04	40.27	0.02	0.07	0.01	0.01	0.15	10.90	100.62	0.889382
NEBC-18	6579659	332851	0.02	48.79	0.04	39.74	0.01	0.11	0.02	0.04	0.10	11.07	99.95	0.887063
NEBC-18	6579659	332851	0.00	49.71	0.01	40.53	0.00	0.04	0.03	0.04	0.13	10.37	100.86	0.895222
NEBC-18	6579659	332851	0.00	48.84	0.03	40.02	0.00	0.06	0.00	0.02	0.18	11.04	100.20	0.887438
NEBC-18	6579659	332851	0.00	48.98	0.03	40.15	0.00	0.05	0.00	0.00	0.18	10.50	99.88	0.892655
NEBC-18	6579659	332851	0.00	44.09	0.02	38.25	0.01	0.22	0.04	0.03	0.19	17.05	99.89	0.821757
NEBC-18	6579659	332851	0.03	43.75	0.04	38.96	0.00	0.24	0.00	0.00	0.17	17.21	100.40	0.819269
NEBC-18	6579659	332851	0.01	49.19	0.02	39.89	0.00	0.07	0.01	0.00	0.16	10.50	99.85	0.893045
NEBC-18	6579659	332851	0.02	49.11	0.04	40.21	0.00	0.07	0.00	0.02	0.11	10.54	100.12	0.892556
NEBC-18	6579659	332851	0.01	49.09	0.01	39.82	0.00	0.06	0.02	0.00	0.21	10.55	99.78	0.892382
NEBC-18	6579659	332851	0.01	43.59	0.05	38.51	0.02	0.21	0.02	0.01	0.19	18.13	100.76	0.810865
NEBC-18	6579659	332851	0.00	48.90	0.05	39.72	0.01	0.11	0.01	0.05	0.18	10.69	99.71	0.890754
NEBC-18	6579659	332851	0.04	49.03	0.05	40.23	0.01	0.09	0.03	0.00	0.19	10.33	99.99	0.894319
NEBC-18	6579659	332851	0.02	42.46	0.04	38.19	0.00	0.21	0.00	0.05	0.24	18.59	99.80	0.802768
NEBC-18	6579659	332851	0.05	43.16	0.03	38.80	0.01	0.24	0.02	0.04	0.27	18.08	100.70	0.809689
NEBC-18	6579659	332851	0.01	45.25	0.06	38.96	0.00	0.22	0.00	0.04	0.21	15.63	100.37	0.837704
NEBC-18	6579659	332851	0.02	43.51	0.04	38.91	0.01	0.20	0.02	0.02	0.20	17.51	100.43	0.815819
NEBC-18	6579659	332851	0.03	41.85	0.05	38.24	0.00	0.22	0.05	0.06	0.27	18.94	99.72	0.797514
NEBC-18	6579659	332851	0.02	46.55	0.04	39.47	0.00	0.09	0.01	0.05	0.21	13.86	100.30	0.856847
NEBC-18	6579659	332851	0.02	45.39	0.03	38.78	0.00	0.08	0.02	0.00	0.17	15.18	99.66	0.842061
NEBC-18	6579659	332851	0.03	49.35	0.06	40.58	0.00	0.09	0.03	0.02	0.14	10.60	100.90	0.892413
NEBC-18	6579659	332851	0.01	43.65	0.05	38.79	0.00	0.24	0.01	0.03	0.18	17.26	100.21	0.818504
NEBC-18	6579659	332851	0.00	45.09	0.03	39.13	0.02	0.22	0.02	0.05	0.21	16.06	100.83	0.8335
NEBC-18	6579659	332851	0.02	49.48	0.03	40.00	0.02	0.08	0.00	0.08	0.12	10.12	99.94	0.897045
NEBC-18	6579659	332851	0.01	49.73	0.03	40.28	0.00	0.11	0.00	0.05	0.13	10.44	100.78	0.894647
NEBC-18	6579659	332851	0.00	43.65	0.04	38.59	0.00	0.21	0.00	0.01	0.25	17.89	100.63	0.813043
NEBC-18	6579659	332851	0.00	43.70	0.05	38.79	0.00	0.24	0.00	0.04	0.20	17.10	100.11	0.819992
NEBC-18	6579659	332851	0.01	42.87	0.07	38.11	0.00	0.26	0.05	0.09	0.22	18.31	99.99	0.806683
NEBC-18	6579659	332851	0.00	47.65	0.05	39.73	0.01	0.07	0.04	0.05	0.13	12.23	99.96	0.874144
NEBC-18	6579659	332851	0.00	49.38	0.02	40.00	0.00	0.07	0.00	0.02	0.15	10.44	100.09	0.893975
NEBC-18	6579659	332851	0.00	42.61	0.08	38.64	0.00	0.24	0.00	0.03	0.19	19.26	101.06	0.797694
NEBC-18	6579659	332851	0.00	50.25	0.02	40.55	0.01	0.05	0.00	0.00	0.14	9.41	100.42	0.904946
NEBC-18	6579659	332851	0.00	49.28	0.02	40.28	0.01	0.08	0.04	0.01	0.15	10.28	100.13	0.895255
NEBC-18	6579659	332851	0.02	49.09	0.02	39.94	0.01	0.08	0.00	0.02	0.15	11.10	100.43	0.887456
NEBC-34	6539551	581206	0.02	49.82	0.04	40.58	0.02	0.06	0.01	0.04	0.21	9.88	100.68	0.899919
NEBC-37	6570249	567872	0.02	51.57	0.00	41.06	0.00	0.04	0.00	0.03	0.13	7.61	100.46	0.923568
NEBC-46	6439810	516735	0.01	50.61	0.00	40.63	0.00	0.00	0.00	0.03	0.08	8.76	100.14	0.911497
NEBC-50	6222613	645018	0.00	49.18	0.02	39.99	0.00	0.06	0.01	0.01	0.15	10.12	99.54	0.896521
NEBC-50	6222613	645018	0.00	44.25	0.04	38.82	0.00	0.22	0.00	0.05	0.25	17.01	100.64	0.822623
NEBC-52	6176129	611299	0.01	42.31	0.02	38.37	0.01	0.21	0.02	0.04	0.23	19.24	100.47	0.79672

DIAMOND AND FLUORITE

One of the most intriguing aspects of this study is a recovery of a clear diamond that cannot be attributed to a specific sample. It was recovered from the -1.18/+0.85 millimetres fraction of heavy mineral concentrate derived from the sample NEBC-11. The stone is a transparent diamond (Plates 1a and 1b) with crystal faces measuring 1.05 × 1.03 × 0.73 millimetres and weighing 1.34 mg (0.0067 carat). Apparently, because of its size and colourless nature, this diamond may have been sitting on the screen (or lodged within the screen) for an unspecified length of time without being detected and before making its way through the screen. If this explanation is correct, the diamond may have come from any of the ten samples numbered from NEBC-1 to NEBC-10 were processed before sample NEBC-11 entered the system. This diamond may have also come from samples belonging to a previous client (contamination). Therefore, the sample from which this diamond was recovered cannot be established.

Besides the above described diamond, the heavy mineral fraction of sample NEBC-11 also contained abundant fluorite. Fluorite (CaF_2) is a relatively soft (4 on Moh's hardness scale), brittle mineral with well-developed cleavage. Fluorite is commonly found as an ore or gangue mineral in Mississippi Valley-type Pb-Zn deposits (Leach and Sangster, 1993), Vein-type fluorite, fluorite-barite veins (Hora, 1996a, 1996b), and carbonatite deposits (Birkett and Simandl, 1999). It is relatively common in samples from northeast British Columbia, and it is particularly abundant in concentrates from samples NEBC-11 and NEBC-12, where it is the most abundant non-magnetic heavy mineral. The fluorite is most likely derived from local sources such as the known fluorite occurrences of Mile 397, Stone, Rep 6, Ctv T-7, and Hope H-3 (Figure 12).

There is no established association between diamonds and fluorite in classical kimberlite- or lamproite-hosted diamond deposits; however, both of these minerals have similar density (3.52 and 3.13 g/cm^3 respectively) and are non-magnetic. The lack of obvious association genetic association between diamond and fluorite in primary diamond deposits is probably the main reason why the Lakefield laboratory interpreted this diamond as probable contamination. The diamond does not show visible signs that are characteristic of alluvial diamonds, such as scuffing and scratching concentrated at the edges of the crystals, percussion marks and green or brown spots which are related to radiation damage. The lack of these signs prevent us from speculating if this diamond was derived directly from a primary diamond deposit (with little glacial or glaciofluvial or fluvial transport) or if it was transported for long distances from its primary source.



Plates 1a and 1b: Colourless diamond identified in the heavy mineral concentrate of the sample NEBC-11. There is a distinct possibility that this diamond was derived from samples processed prior to sample NEBC-11 or may have come from samples belonging to a previous client (contamination). See sections "Diamond and Fluorite" and "Discussion & Recommendations" for possible implications of this find on diamond exploration in Northeastern British Columbia.

DISCUSSION & RECOMMENDATIONS

The geology of the Precambrian basement in northeast British Columbia is poorly understood, but there are indications that it could be more favourable for diamond exploration than previously reported (Simandl, 2004; Simandl and Davis, 2005). Therefore, the results of this study are important, particularly if the modified diamondiferous mantle root exploration model is applied to northeast British Columbia (Simandl, 2004).

There are several areas with anomalous counts of kimberlite indicator minerals (Figure 2). These minerals may not have the same source, as indicated in the text, and supported by the glacial history of the area. Areas close to the Etsho Plateau are of particular interest because they contain a variety of indicator minerals, including pyrope garnets, Cr-spinel, olivine, ilmenite and Cr-diopside.

Sample NEBC-50, from south of Taylor (Figure 2), contains 16 indicator grains consisting of Cr-spinel, Cr-diopside and olivine. Sample NEBC-7, from about 100 km northwest of Hudson Hope, is unique because it contains 71 Cr-spinel grains. A direct correlation between the number of indicator mineral grains and proximity to their source is unlikely, as different sampling media were used. As expected, some of the highest indicator mineral counts come from active river sediments, where natural concentration was anticipated.

In the following discussion, we will consider the distribution of anomalous glaciofluvial samples in relation to the maximum extent of Laurentide, Cordilleran, and Rocky Mountain glacial systems, which is approximated by "Mathews' line" on Figure 2 (Mathews, 1980).

The first important observation is that all the samples that contain pyrope garnets are located east of Mathews' line, mostly between Fort Nelson and the Etsho Plateau. The samples from this region are characterized by a variety of indicator minerals. They contain G9, G10, G12, and G1 garnets, ilmenite, Cr-spinel and Cr-diopside as well as G3 garnets recovered during the previous field season (Levson *et al.*, 2004; Simandl *et al.*, 2005). Possible sources for these garnets are known diatremes located northeast of the study area within the Slave Craton, diatremes of the Buffalo Head Terrane, or undiscovered pipes cutting the Mesozoic- to Paleozoic-aged sedimentary rocks in the Etsho Plateau region. Some of these grains may have been previously reworked and incorporated into the sedimentary sequence itself. There is a rapid decline in KIM concentrations in stream sediments with increasing distance from pipes in the Buffalo Head Hills area (Friske *et al*., 2003). This suggests that these kimberlites are unlikely sources for high concentrations of indicator minerals reported in this study and in Simandl *et al.* (2005). Currently, there are no high concentrations of KIMs reported along the BC-Northwest Territories border. This makes the local origin of the garnets a viable hypothesis. The northern portion of British Columbia's Alkaline Province is not known to contain primary lithologies such as those described by Canil *et al.* (2005); therefore it is an unlikely source of these garnets.

If we examine the samples with the highest KIM content west of Mathews' line, Cr-spinel and olivine with some Cr-diopside are the potential indicator minerals. The source of these minerals is more difficult to interpret than pyrope garnets or ilmenites because the distinction between Cr-spinels associated with kimberlites and lamproites from those associated with other ultramafic rocks such as layered intrusions, ophiolites, Alaskan complexes, boninites and minerals from xenoliths in basalt is a complex procedure. Ultramafic rocks are common in the Cache Creek and the Slide Mountain terranes (Voormeij and Simandl, 2004a, b), but these terrains occur well to the west of the study area.

The details of our interpretation will be the subject of a related paper; however, results of our discrimination procedure are incorporated into Figure 2. The results of our study indicate that a number of Cr-diopsides and Cr-spinels may be related to alkaline intrusions located within the northern portion of the Alkaline Province, as described in Pell (1994) and Simandl (2004).

Based on a combination of discrimination methods (Simandl and Robinson, in preparation), it is possible that some of the Cr-spinels from samples NEBC-1, NEBC-7, NEBC-23, NEBC-44, NEBC-50, NEBC-52, and NEBC-58 are lamproite-related. A more detailed study of chromite morphology, as described by Lee *et al.* (2004) and some trace element analyses are required to corroborate this.

Samples from the Fort St. John area are characterized by dominant Cr-spinels and Cr-diopside kimberlite indicators. Sample NEBC-1, from northeast of Fort St. John, is an exception. It contains 22 indicator grains consisting of Cr-spinel, Cr-diopside and one G9 garnet. Sample NEBC-23 is regolith and sample NEBC-43 is bedrock, both corresponding to the Dunvegan conglomerate and containing numerous Cr-spinel grains. This finding is extremely significant because it demonstrates that at least some of the Cr-spinels were incorporated into the Upper Cretaceous Dunvegan Formation before being incorporated into surficial deposits. If these Cr-spinel grains are indeed related to kimberlites or lamproites, then the age of primary alkaline rocks from which they were derived is

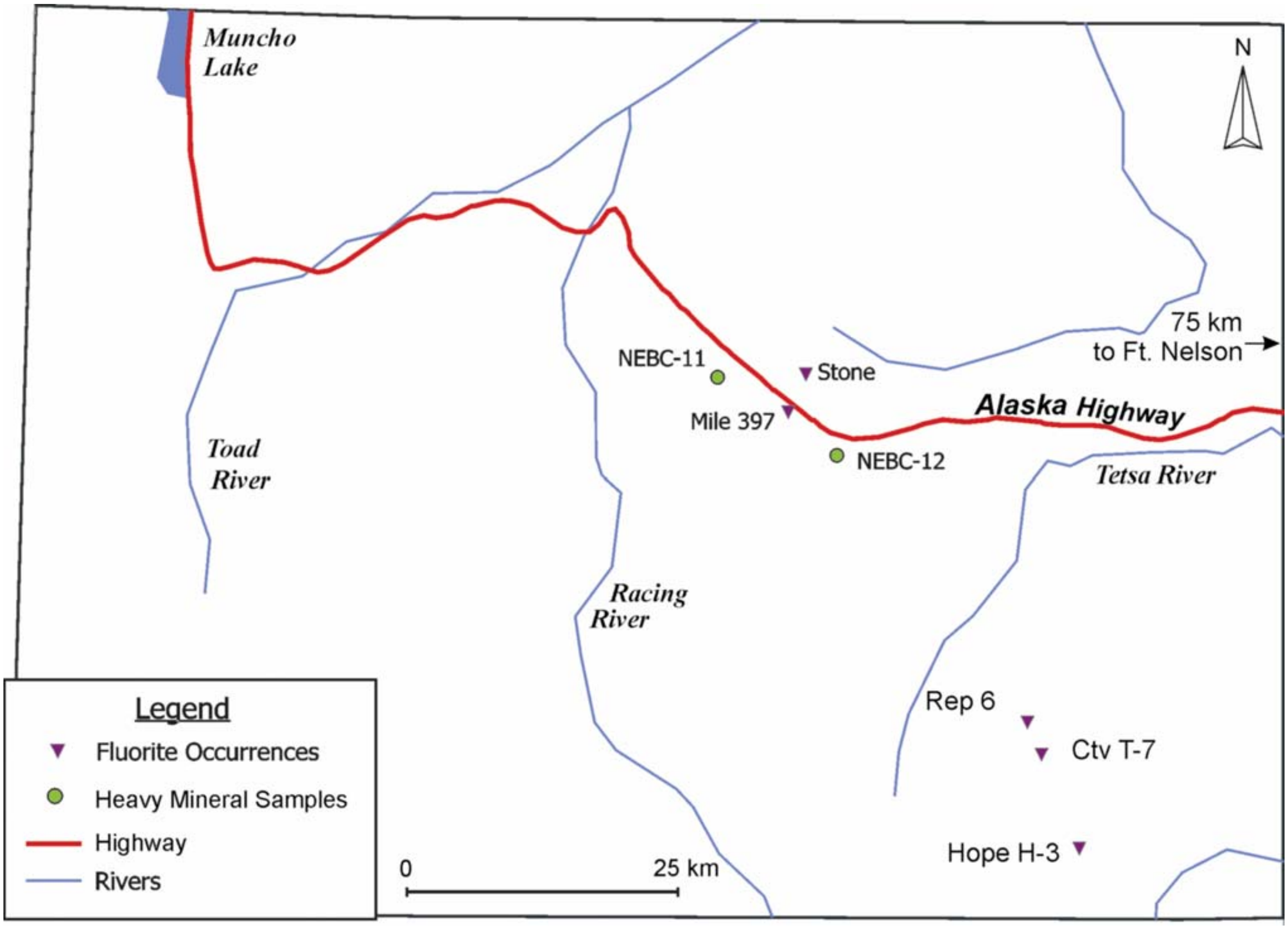


Figure 12. Detailed map showing the location of samples NEBC-11 and NEBC-12 which contain the highest concentrations of fluorite grains. Sample NEBC-11 was originally reported to contain a diamond. The known fluorite occurrences are shown as triangles. Their descriptions are available through the Ministry of Energy, Mines and Petroleum Resources website at: http://www.em.gov.bc.ca/mining/geolsurv/minfile/search/

upper Cretaceous or older. Under those circumstances, detailed studies of the Dunvegan Formation may reveal potential heavy mineral traps favourable for formation of paleoplacer diamond deposits. Deep incisions into the Dunvegan Formation described by Plint and Wadsworth (2003) may represent invaluable information that can help to "zero in" exploration on potential diamond paleoplacer targets.

The following is a series of other important points and recommendations:

- The Etsho Plateau region contains several samples that are worth following up. This region is particularly interesting because of the wide range of KIMs. Before designing a follow-up exploration program, samples from Simandl *et al.* (2005) should be incorporated into this database. There are also high concentrations of non-garnet indicators in the southern part of the study area worth following up.
- Because of uncertainty regarding the provenance of diamond, it is recommended to resample and reanalyze sites NEBC-1 to NEBC-11. The diamond recovered from sample NEBC-11 may have been derived from any of these samples. Samples containing high concentrations of potential kimberlite/diamond indicator minerals are particularly worthy of follow-up. However, the possibility remains that the diamond was derived from one of the samples submitted by the previous client.
- Further studies should pay close attention to the indicator mineral content of sedimentary bedrock. Such information is invaluable in establishing the provenance of Cr-spinel and potentially other indicators in surficial materials commonly sampled by exploration companies and to assigning an age on the potential primary sources of diamonds (including possibly yet undiscovered kimberlite or lamproite pipes). It is therefore recommended to sample material from the strategically located,

large-diameter boreholes that are drilled for oil and gas in the Fort Nelson and Fort St. John areas and study recovered heavy minerals.

- Heavy mineral samples should also be examined for the presence of fluorite, barite, sulphides (base metals) and gold and platinum. Mississippi Valley type (MVT) deposits and sedimentary exhalative (SEDEX) type mineralization have been reported in a number of boreholes drilled for oil and gas and a number of known fluorite and barite deposits were reported in this area.
- Many samples are worthy of follow-up. Of particular interest are the samples in the Fort Nelson area that contain several indicator minerals (pyrope garnets, including G10, ± Cr-spinels, ± Cr-diopside ± olivine ± ilmenite). Samples NEBC-38 and NEBC-39 are good examples in spite of their low total indicator grain content. The final interpretation should also incorporate the data of Simandl *et al*. (2005).
- A number of samples, such as NEBC-1 and NEBC-7, contain high concentrations of Cr-spinel. Preliminary interpretation indicates that these Cr-spinels may be lamproite-derived, but this interpretation should be tested using international databases. Where a potential source is identified, the composition of Cr-spinels from this source should be compared with that of spinels from anomalous samples. For example, it would be worth comparing the compositions of spinels from the Ospika pipe with those of spinels recovered from sample NEBC-7.
- Available geophysical data obtained during oil and gas exploration, particularly in the Etsho Plateau region, should be re-examined to locate anomalies that may correspond to diatremes and/or dykes.
- There is a major gap in sample coverage in the central portion of the study area, on both sides of the Mathews' line, and in the Trutch and Pink Mountain areas. At least 15 helicopter-supported samples would be required to complete reconnaissance scale coverage in this region, east of Mathews' line. There may not be a need for helicopter support west of this line. Samples from this area may contain indicator minerals as well.
- If the Dunvegan Formation is confirmed to contain indicator minerals, as indicated by samples NEBC-23 and 43, then paleogeomorphology could be used to focus exploration on paleoplacer deposits.

SUMMARY

Kimberlite indicator minerals including peridotitic garnets, ilmenite, Cr-diopside, spinel (chromite) and olivine were recovered from -0.5+0.25mm size fraction of heavy mineral concentrates from northeast British Columbia. The same indicator minerals, plus corundum and eclogitic garnets, were previously recovered from the Fort Nelson area (Simandl *et al.*, 2005). The concentrates in this study were produced from glaciofluvial sands and gravels and stream sediments. Thirty-four of the 58 samples collected contain potential KIMs, some with more than one mineral type. Most of the indicator grains appear fresh and subrounded or subangular, but several have sharp edges. Garnets do not appear to have kelyphitic rims, but a few may have an orange peel texture, suggesting that they were subject to some degree of transportation or at least local reworking.

Indicator minerals present in some samples proximal to, or on, the Etsho Plateau, occur in small-scale, low-energy glaciofluvial systems, and may have a local source perhaps somewhere on the Plateau itself, as described by Simandl *et al.* (2005). A number of these samples have several types of kimberlite and diamond indicators. Other samples, particularly those occurring in large-scale, high-energy glaciofluvial systems may not contain locally derived KIMs. Ongoing studies east of the British Columbia-Alberta border by the Alberta Geological Survey and the Geological Survey of Canada will aid in determining if an eastern provenance of the KIMs in the Etsho Plateau area is a viable hypothesis. The Northwest Territories are another potential source of these indicators. It remains to be established to what degree the till and regional stream sediment sampling will constrain these reconnaissance scale anomalies.

For anomalies located west of Mathews' line, the indicator minerals could be local or derived from diatremes located within the Alkaline Province as reviewed by Simandl (2004). If there are no anomalies upstream and within tributaries of rivers that were sampled, then the indicator minerals are most likely local. More work is required to determine the source of these anomalies and to confirm if these Cr-spinels are lamproite/kimberlite-derived.

The Dunvegan Formation in the Fort Nelson area contains Cr-spinels (*e.g.*, samples NEBC-23 and NEBC-43). Systematic sampling and analyses of cuttings from oil and gas wells for heavy minerals is recommended to gain better background information about potential sources of these KIMs.

If the glaciofluvial and fluvial sampling in neighbouring regions of Alberta and the Northwest Territories do not reveal high concentrations of indicator minerals, then the significance of the indicator anomalies presented on Figure 2 will be further enhanced, pointing to a local provenance.

CONCLUSION

The results of this reconnaissance kimberlite/diamond indicator mineral study, in combination with the tectonic setting of northeast British Columbia and most recent basement age dates, suggests that northeast British Columbia has potential to contain kimberlite/lamproite-hosted diamonds.

The presence of potential indicator minerals (Cr-spinels) within the Dunvegan Formation supports the hypothesis that paleoplacer diamond deposits may be present. However, this also opens the possibility that some of the KIMs in glaciofluvial or fluvial sediments may have been derived from sedimentary bedrock, rather than directly from kimberlite or lamproite pipes. Cr-spinel is particularly resistant to weathering and to transport-induced abrasion; it is a mineral that is relatively prone to recycling. Most pyrope garnets (mainly G9 and one G10), encountered in this study, come from glaciofluvial samples that are located in the Etsho Plateau region. These pyropes are associated with a variety of other KIMs, including Cr-diopside, suggesting a more proximal source. As expected, active river sediments have a high, largely Cr-spinel indicator mineral content.

The diamond reported from sample NEBC-11 may have been derived from any of the samples in the NEBC-1 to NEBC-11 series. Another possibility is that it came from samples submitted by a previous client (*i.e.* contamination). Follow-up geological, geochemical, and geophysical studies related to KIMs and diamond targets are justified in northeast British Columbia.

ACKNOWLEDGMENTS

The document benefited from constructive comments of Dr. Suzanne Paradis of Geological Survey of Canada, at the Pacific Geoscience Center, Sidney, BC, and Brian Grant of the British Columbia Ministry of Energy, Mines and Petroleum Resources, Victoria, BC. Enriching discussions with Dr. Herman Grütter, Mineral Services Canada and Dr. John Gurney from Mineral Services Laboratories, South Africa, are gratefully acknowledged. Jan Bednarski, Geological Survey of Canada, Sidney, BC, is thanked for his insights into the Quaternary history of the region. Laura Simandl from St. Margaret's School, Victoria, BC is thanked for photographic documentation of the fieldwork and meticulous sampling.

This study was possible due to financial support from the Rock to Riches program of the BC and Yukon Chamber of Mines and support from the British Columbia Geological Survey and Resource Development and Geoscience branches, of the Ministry of Energy, Mines and Petroleum Resources, Victoria, BC.

REFERENCES

Allan, R.J. (1999): Micro-diamond results from Ice Claim project, B.C.; *Skeena Resources Limited*, News release, August 20, 1999.

Allan, R.J. (2002): Diamond exploration corporate up-date; *Skeena Resources Limited*, News release, March 22, 2002.

Anonymous (1994): BC Diamonds discovered; *in* George Cross News Letter, *Consolidated Ramrod Gold Corporation*, No. 225.

Barnes and Roeder (2001): The range of spinel compositions in terrestrial mafic and ultramafic rocks, *Journal of Petrology*, vol. 42, pages 2279-2302.

Barnes and Roeder (2004): Database available at the following website on July 1.2005:, http://www.em.csiro.au/terrain_studies/aboutus/people/stephen_barnes/BR_spinel_database_dec04.zip.

Bednarski, J. (1999): Preliminary report on mapping surficial geology of Trutch (94G), northeastern British Columbia. *Geological Survey of Canada*, Current Research 1999A, pages 35-43.

Bednarski, J. M. (2000): Surficial geology Trutch, British Columbia. *Geological Survey of Canada*, Open File 3885, scale 1: 250 000.

Bednarski J. M. (2001): Drift composition and surficial geology of the Trutch map area (94G) northeastern British Columbia. *Geological Survey of Canada*, Open File D3815, CD-ROM.

Birkett, T.C. and Simandl, G.J. (1999): Carbonatite-associated deposits: magmatic, replacement and residual; *in* Selected British Columbia Mineral Deposit Profiles, Volume 3, Industrial Minerals, G.J. Simandl, Z.D. Hora and D.V. Lefebure, Editors, *British Columbia Ministry of Energy, Mines and Petroleum Resources*, Open File 1999-10, pages 73-76.

Canil, D., Mihalynuk, M.G. and Charnell, C. (2005): Heavy mineral sampling and provenance studies for potentially diamond-bearing source rocks in the Jurassic Laberge Group, Atlin-Nakina area, Northwestern British Columbia (104N), *in* Geological Fieldwork 2004, *British Columbia Energy and Mines*, pages 83-92.

Carlson, S.M., Hillier, W.D., Hood, C.T., Pryde, R.P. and Skelton, D.N. (1999): The Buffalo Hills kimberlites: a newly-discovered diamondiferous kimberlite province in North-Central Alberta, Canada; *in* Proceedings of the VIIth International Kimberlite Conference, Gurney, J.J., Gurney J.L., Pascoe, M.D., Richardson, S.H., Editors, 1, pages 109-116.

Dyke, A. (2004): An outline of North American deglaciation with emphasis on central and northern Canada; *in* Quaternary Glaciations-extent and Chronology, Part II, (eds.) J. Ehlers and P.L. Gibbard; Elsevier, Amsterdam, *Developments in Quaternary Science*, v. 2b, p. 373-424.

Eccles, D.R., Heaman, L.M., Luth, R.W. and Creaser, R.A. (2004): Petrogenesis of the Late Cretaceous northern Alberta kimberlite province; *Lithos*, 76, pages 435-459.

Fipke, C.E., Gurney, J.J., Moore, R.O., and Nassichuk, W.W. (1989): The development of advanced technology to distinguish between diamondiferous and barren diatremes, *Geological Survey of Canada*, Open File 2124, 1175 pages.

Fipke, C.E., Gurney, J.J., Moore, R.O. and Nassichuk, W.W. (1989): The development of advanced technology to distinguish between diamondiferous and barren diatremes; *Geological Survey of Canada*; Open File 2124, 1175 pages.

Fipke, C.E., Gurney, J.J. and Moore (1995): Diamond exploration techniques emphasising indicator mineral geochemistry and Canadian examples; *Geological Survey of Canada*, Bulletin 423, 86 pages.

Friske, P.W.B., Prior, G.J., McNeil, R.J., McCurdy, M.W., Day, S.J.A. (2003): Relative proportion of kimberlite indicator minerals in stream sediment bulk samples (parts of NTS 84B, 84C, 84F, 84G); *Alberta Geological Survey* Special Report 66 / *Geological Survey of Canada*, Open File 1790.

Grütter, H.S. and Apter, D.B. (1998): Kimberlite and lamproite-borne chromite phenocrysts with "diamond-inclusion"-type chemistries; Extended Abstract; 7th International Kimberlite Conference, South Africa, pages 280-288.

Grütter, H.S., Gurney, J.J., Menzies, A.H. and Winter, F. (2004): An updated classification scheme for mantle-derived garnet, for use by diamond explorers; *Lithos*, 77, pages 841-857.

Gurney, J.J and Moore R.O. (1994): Geochemical correlation between kimberlitic indicator minerals and diamonds as applied to exploration; *in* 5th International Kimberlite Conference, Araxa, Brazil, *Companhia de Pesquisa de Recursos Minerais - CPRM*, 1, page 125.

Haggerty, S.E. (1986): Diamond genesis in a multiply constrained model; *Nature*, 320, pages 34-38.

Haggerty, S.E. (1991): Oxide mineralogy of the upper mantle. Oxide Minerals. *In* Mineralogical Society of America Short Course Notes, 3, pages Hg 101 – Hg 300.

Hoffman, P.F. (1988): United plates of America: the birth of a craton; *Annual Reviews in Earth and Planetary Sciences*, 16, pages 543-603.

Hoffman, P.F. (1989): Speculations on Laurentia's first gigayear (2.0-1.0 Ga); *Geology*, 17, pages 135-138.

Hoffman, P.F. (1991): Did the breakout of Laurentia turn Gondwanaland inside-out?; *Science*, 252, pages 1409-1412.

Hood, C.T.S. and McCandless, T.E. (2004): Systematic variations in xenocryst mineral composition at the province scale, Buffalo Hills kimberlites, Alberta, Canada; *Lithos*, 77, pages 733-747.

Hora, Z.D. (1996): Vein Barite, *in* Selected British Columbia Mineral Deposit Profiles, Volume 2 - Metallic Deposits, Lefebure, D.V. and Hõy, T, Editors, *British Columbia Ministry of Employment and Investment*, Open File 1996-13, pages 81-84.

Hora, Z.D. (1996): Vein Fluorite-barite; *in* Selected British Columbia Mineral Deposit Profiles, Volume 2 - Metallic Deposits, Lefebure, D.V. and Hõy, T, Editors, *British Columbia Ministry of Employment and Investment*, Open File 1996-13, pages 85-88.

Leach, D.L. and Sangster, D.F. (1993): Mississippi Valley-type Lead-Zinc Deposits; *in* Mineral Deposit Modeling, R.V. Kirkham, W.D. Sinclair, R.I. Thorpe and J.M. Duke, editors, *Geological Association of Canada* Special Paper 40, pages 289-314.

Lee, D.C., Maddren, J. and Griffin, B.J. (2004): The importance of chromite morphology in diamond exploration. 8th International Kimberlite Conference; Long Abstract, Victoria, Canada. 5 pages.

Levson, V.M., Ferbey, T., Kerr, B., Johnsen, T., Bednarski, J., Smith, I.R., Blackwell, J. and Jonnes, S. (2004): Quaternary geology and aggregate mapping in northeast British Columbia: applications for oil and gas exploration and development; *in* Summary of Activities 2004, *British Columbia Ministry of Energy and Mines*, pages 29-40.

Lockhart, G., Grütter, H. and Carlson, J. (2004): Temporal, geomagnetic and related attributes of kimberlite magmatism at Ekati, Northwest Territories, Canada; *Lithos*, 77, pages 665-682.

McCallum, M.E. (1994): Lamproitic (?) diatremes in the Golden area of the Rocky Mountain Fold and Thrust Belt, British Columbia, Canada; *in* Kimberlites, Related rocks and mantle xenoliths, Proceedings of the 5th International Kimberlite Conference, Araxa, Brazil, *Companhia de Pesquisa de Recursos Minerais - CPRM*, 1, pages 195-209

Massey, N.W.D, MacIntyre, D.G., Desjardins, P.J. and Cooney, T. (2005): Digital geology map of British Columbia; DVD documentation utilities; *British Columbia Ministry of Energy and Mines*; Open File 2005-2.

Mathews, W.H. (1980): Retreat of the last ice sheets in northeastern British Columbia and adjacent Alberta; *Geological Survey of Canada*, Bulletin 331, 22 pages.

McCandless, T.E and H.T. Dummett (2003): Some aspects of chromian spinel (chromite) chemistry in relation to diamond exploration. GAC-MAC Meeting in Vancouver, Special Session 13: Canadian diamond deposits: History and techniques of their discovery – A Tribute to Hugo Dummett (abstract).

Mitchell, R.H. (1991): Kimberlites and lamproites: primary sources of diamonds; *Geoscience Canada*, 18, pages 1-16.

Morris, T.F., Sage, R.P., Ayer, J.A., Crabtree D.C. (2002): A study in clinopyroxene composition: implications for kimberlite exploration, *Geochemistry: Exploration, Environment, Analysis*, 2, pages 321-331.

Northcote, K.E., (1983a): Report on Mark property, Pangman Peek (82N/15W); Assessment Report 13596. *British Columbia Ministry of Energy, Mines and Petroleum Resources.*

Northcote, K.E., (1983b): Report on Jack Claims Lens Mountain (82N/14E); Assessment Report 13597. *British Columbia Ministry of Energy, Mines and Petroleum Resources.*

Pell, J. (1994): Carbonatites, nepheline syenites, kimberlites and related rocks in British Columbia; *British Columbia Ministry of Energy and Mines*, Bulletin 88, 136 pages.

Plint, A.G., McCarthy, P.J. and Faccini, U.F. (2001): Nonmarine sequence stratigraphy; updip expression of sequence boundaries and systems tracts in a high-resolution framework, Cenomanian Dunvegan Formation, Alberta foreland basin, Canada; *AAPG Bulletin*, 85, pages 1967-2001.

Plint, A.G. (2002): Paleovalley systems in the Upper Cretaceous Dunvegan Formation, Alberta and British Columbia; *Bulletin of Canadian Petroleum Geology*, 50, pages 277-296.

Plint, A.G. and Wadsworth, J.A. (2003): Sedimentology and palaeogeomorphology of four large valley systems incising delta plains, Western Canada foreland basin; implications for Mid-Cretaceous sea-level changes; *Sedimentology*, 50, pages 1147-1186.

Plouffe, A., Smith, I.R., Paulen, R.C., Fenton, M.M. and Pawlowicz, J.G. (2004): Surficial geology, Bassett Lake, Alberta (NTS 84L/SE); *Geological Survey of Canada*, Open File 4637, scale 1:100 000.

Quirt, D.H. (2004): Cr-diopside (clinopyroxene) as a kimberlite indicator mineral for diamond exploration in glaciated terrains; *in* Summary of Investigations 2004, Volume 2, *Saskatchewan Geological Survey*, Sask. Industry Resources, Misc. Rep. 2004-4.2, CD-ROM, Paper A-10, 14 pages.

Ramsey, R.R. and Tompkins, L.A. (1994): The geology, heavy mineral concentrate mineralogy, and diamond prospectivity of Boa Esperanca and Cana Verde pipes, Corrego D'anta, Minas Gerais, Brazil; *in* Kimberlites, Related Rocks and Mantle Xenoliths, Proceedings of the 5th International Kimberlite Conference, *Companhia de Pesquisa de Recursos Minerais - CPRM*, 2, pages 329-345.

Roberts, W.J. (2002): Diamond discovery at Xeno; *Pacific Ridge Exploration Limited.*, News Release, March 13, 2002.

Ross, G.M., Parish, R.R., Villeneuve, M.E. and Bowring, S.A. (1991): Geophysics and geochronology of the crystalline basement of the Alberta Basin, Western Canada; *Canadian Journal of Earth Sciences*, 28, pages 512-522.

Ross, G.M., Milkerreit, B., Eaton, D., White, D. Kanasewich; E.R. and Buryanyk, M.J.A. (1995): Paleoproterozoic collisional orogen beneath Western Canada Sedimentary Basin imaged by Lithoprobe crustal seismic reflection data; *Geology*, 23, pages 195-199.

Schulze, D. J. (2003): A classification scheme for mantle-derived garnets in kimberlite: a tool for investigating the mantle and exploring for diamonds, *Lithos*, 71, pages 195-213.

Simandl, G.J. (2004): Concepts for diamond exploration in "on/off craton" areas - British Columbia, Canada; *Lithos*, 77, pages 749-764.

Simandl, G.J., Davis, W. (2005): Cratonic basement in northeastern British Columbia, new age dates and their significance for diamond exploration; *in* Geological Fieldwork 2004; *British Columbia Ministry of Energy and Mines*, pages 337-346.

Simandl, G.J., Ferbey, T., Levson, V.M., Demchuk, T.E., Smith, I.R. and Kjarsgaard, I. (2005): Kimberlite indicator minerals in the Fort Nelson area, northeastern British Columbia, *in* Geological Fieldwork 2004, *British Columbia Ministry of Energy and Mines,* pages 325-336.

Smith, C.B., Colgan, E.A., Hawthorne, J.B. and Hutchinson G. (1988): Emplacement age of the Cross kimberlite, Southeastern British Columbia, by Rb-Sr phlogopite method; *Canadian Journal of Earth Sciences*, 25, pages 790-792.

Stott, D.F. (1982): Lower Cretaceous Fort St John group and upper Cretaceous Dunvegan formation of the foothills and plains of Alberta, British Columbia, District of MacKenzie and Yukon Territory; *Geological Survey of Canada*, Bulletin 328, 124 pages.

Thompson, R.I. (1977): Geology of Beatton River, Fontas River and Petitot River Map-Areas, Northeastern British Columbia; *Geological Survey of Canada*, Paper 75-11, 8 pages.

Villeneuve, M.E., Ross, G.M. Thérialt, R.J., Miles, W. Parrish, R.R. and Broome, J. (1993): Tectonic subdivision and U-Pb geochronology of the crystalline basement of the Alberta basin, Western Canada; *Geological Survey of Canada*, Bulletin 447, 93 pages.

Voormeij, D.A. and Simandl, G.J. (2004a): A Map of Ultramafic Rocks in British Columbia: Applications in CO_2 Sequestration and Mineral Exploration, *BC Ministry of Energy and Mines*, Geofile 2004-1.

Voormeij, D.A. and Simandl, G.J. (2004b): Ultramafic Rocks in British Columbia: Delineating Targets for Mineral Sequestration of CO_2; *in* Summary of Activities, *BC Ministry of Energy and Mines*, pages 157-167.

Wyatt, B.A., Baumgartner, M., Ancar, E. and Grütter, H. (2004): Compositional classification of "kimberlitic" and "non-kimberlitic" ilmenite; *Lithos*, 77, pages 819-840.

Appendix 1. Chemical composition of Cr-spinels (Chromites); for sample locations, see Table 1 and Figure 2.

Sample ID	UTM Northing	UTM Easting	MgO	Al_2O_3	SiO_2	CaO	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	NiO	Nb_2O_5	Ta_2O_5	Total
NEBC-1	6282870	608712	12.48	30.72	0.06	0.00	0.56	0.12	33.15	0.09	21.70	0.10	0.05	0.00	99.03
NEBC-1	6282870	608712	9.10	19.06	0.10	0.00	0.25	0.08	47.76	0.00	20.72	0.11	0.00	0.00	97.18
NEBC-1	6282870	608712	14.29	30.05	0.03	0.01	0.12	0.15	35.70	0.03	18.59	0.20	0.02	0.00	99.18
NEBC-1	6282870	608712	19.77	29.97	0.10	0.00	0.27	0.11	29.15	0.15	19.21	0.25	0.00	0.00	98.97
NEBC-1	6282870	608712	12.34	13.07	0.17	0.01	2.65	0.00	46.01	0.03	24.68	0.16	0.00	0.00	99.13
NEBC-1	6282870	608712	7.11	8.24	0.06	0.00	0.04	0.30	59.60	0.16	22.93	0.00	0.00	0.00	98.44
NEBC-1	6282870	608712	8.80	10.11	0.07	0.01	0.10	0.15	53.27	0.04	25.93	0.10	0.00	0.00	98.57
NEBC-1	6282870	608712	9.87	19.45	0.09	0.00	1.02	0.27	39.62	0.19	27.81	0.23	0.04	0.00	98.58
NEBC-1	6282870	608712	9.43	9.35	0.07	0.02	0.04	0.19	59.32	0.01	20.48	0.03	0.05	0.00	98.98
NEBC-1	6282870	608712	15.54	35.36	0.09	0.02	0.16	0.19	31.93	0.04	16.51	0.21	0.03	0.00	100.08
NEBC-1	6282870	608712	5.26	19.11	0.04	0.00	0.32	0.14	42.54	0.04	30.83	0.10	0.08	0.00	98.46
NEBC-1	6282870	608712	11.67	15.16	0.06	0.02	0.07	0.20	51.67	0.00	20.44	0.15	0.00	0.00	99.45
NEBC-1	6282870	608712	3.91	16.75	0.09	0.00	0.09	0.24	47.91	0.00	29.73	0.02	0.00	0.00	98.73
NEBC-1	6282870	608712	15.76	25.98	0.11	0.01	0.60	0.17	40.30	0.00	16.28	0.24	0.03	0.00	99.47
NEBC-1	6282870	608712	10.72	24.24	0.04	0.01	0.70	0.16	35.58	0.09	27.11	0.23	0.00	0.00	98.88
NEBC-1	6282870	608712	12.91	24.67	0.06	0.01	0.13	0.17	43.84	0.00	18.04	0.04	0.09	0.00	99.96
NEBC-1	6282870	608712	10.06	20.08	0.05	0.00	1.22	0.21	38.64	0.00	28.11	0.20	0.00	0.00	98.57
NEBC-1	6282870	608712	13.93	23.93	0.03	0.00	0.04	0.22	43.43	0.03	17.58	0.16	0.00	0.00	99.35
NEBC-5	6265576	573653	13.86	24.51	0.21	0.00	0.75	0.08	41.12	0.11	19.37	0.22	0.06	0.00	100.30
NEBC-5	6265576	573653	13.03	26.59	0.05	0.00	0.31	0.20	37.81	0.04	21.04	0.09	0.00	0.00	99.17
NEBC-5	6265576	573653	13.23	30.65	0.05	0.03	0.65	0.15	33.91	0.11	21.27	0.19	0.00	0.00	100.23
NEBC-5	6265576	573653	13.72	30.39	0.03	0.00	0.29	0.10	32.70	0.07	21.83	0.13	0.07	0.00	99.32
NEBC-6	6297889	522801	13.40	9.88	0.15	0.00	2.67	0.00	48.74	0.00	23.68	0.11	0.02	0.00	98.65
NEBC-6	6297889	522801	13.19	9.68	0.10	0.03	3.29	0.00	47.83	0.03	25.30	0.26	0.00	0.00	99.72
NEBC-7	6304336	520920	16.06	34.79	0.11	0.00	0.43	0.07	31.77	0.05	16.15	0.32	0.08	0.00	99.84
NEBC-7	6304336	520920	7.65	5.67	0.11	0.00	2.75	0.00	55.18	0.00	25.57	0.19	0.00	0.00	97.11
NEBC-7	6304336	520920	15.70	26.96	0.14	0.00	0.59	0.06	39.44	0.00	16.29	0.30	0.03	0.00	99.51
NEBC-7	6304336	520920	12.10	15.29	0.11	0.00	3.67	0.00	39.02	0.05	28.29	0.17	0.02	0.00	98.72
NEBC-7	6304336	520920	16.30	27.74	0.19	0.00	0.78	0.07	37.75	0.00	16.48	0.20	0.00	0.00	99.53
NEBC-7	6304336	520920	12.41	13.45	0.13	0.00	2.84	0.00	44.46	0.00	25.00	0.15	0.00	0.00	98.44
NEBC-7	6304336	520920	15.14	23.33	0.10	0.00	0.07	0.17	43.35	0.00	17.38	0.17	0.06	0.00	99.79
NEBC-7	6304336	520920	17.01	29.47	0.09	0.02	0.19	0.12	39.10	0.04	13.22	0.24	0.05	0.00	99.55
NEBC-7	6304336	520920	12.61	13.85	0.16	0.01	2.61	0.00	44.89	0.06	24.62	0.17	0.00	0.00	98.98
NEBC-7	6304336	520920	7.98	14.56	0.13	0.00	0.25	0.11	56.38	0.03	19.86	0.11	0.00	0.00	99.40
NEBC-7	6304336	520920	12.31	13.08	0.15	0.00	3.04	0.00	43.57	0.00	25.99	0.11	0.04	0.00	98.29
NEBC-7	6304336	520920	11.26	6.06	0.11	0.00	1.98	0.00	56.47	0.00	20.57	0.15	0.00	0.00	96.59
NEBC-7	6304336	520920	12.94	14.17	0.14	0.02	2.58	0.00	45.33	0.00	23.41	0.18	0.00	0.00	98.77
NEBC-7	6304336	520920	11.38	12.58	0.13	0.02	3.22	0.00	38.65	0.17	32.40	0.20	0.02	0.00	98.76
NEBC-7	6304336	520920	12.62	13.29	0.16	0.01	2.57	0.00	45.62	0.05	24.43	0.17	0.00	0.00	98.92
NEBC-7	6304336	520920	12.62	12.39	0.11	0.00	2.90	0.00	45.78	0.03	24.90	0.15	0.00	0.00	98.88
NEBC-7	6304336	520920	16.94	30.17	0.18	0.00	0.75	0.10	35.72	0.00	16.34	0.26	0.00	0.00	100.45
NEBC-7	6304336	520920	17.13	32.37	0.21	0.01	0.62	0.11	32.80	0.00	15.70	0.19	0.00	0.00	99.13
NEBC-7	6304336	520920	11.87	13.90	0.11	0.00	4.04	0.00	39.68	0.12	29.29	0.16	0.07	0.00	99.24
NEBC-7	6304336	520920	10.73	7.49	0.11	0.02	3.40	0.00	43.80	0.10	32.26	0.12	0.00	0.00	98.03
NEBC-7	6304336	520920	10.03	8.88	0.06	0.00	3.87	0.00	42.90	0.21	32.15	0.08	0.00	0.00	98.18
NEBC-7	6304336	520920	12.41	13.24	0.13	0.00	2.66	0.00	44.85	0.03	25.00	0.15	0.03	0.00	98.50
NEBC-7	6304336	520920	16.17	19.81	0.19	0.00	0.71	0.05	48.24	0.00	13.70	0.15	0.00	0.00	99.03
NEBC-7	6304336	520920	13.19	14.36	0.14	0.02	2.44	0.00	45.30	0.14	22.97	0.16	0.01	0.00	98.72
NEBC-7	6304336	520920	13.28	8.22	0.16	0.00	2.90	0.00	50.91	0.02	23.28	0.23	0.01	0.00	99.01
NEBC-7	6304336	520920	13.10	14.97	0.08	0.00	2.83	0.00	43.95	0.05	23.85	0.19	0.06	0.00	99.08
NEBC-7	6304336	520920	12.80	7.84	0.10	0.00	3.58	0.00	44.33	0.09	29.62	0.10	0.00	0.00	98.45
NEBC-7	6304336	520920	15.92	27.67	0.18	0.00	0.87	0.11	37.22	0.00	16.80	0.25	0.04	0.00	99.06
NEBC-7	6304336	520920	17.08	28.27	0.16	0.01	0.71	0.12	38.04	0.00	14.99	0.20	0.03	0.00	99.61
NEBC-7	6304336	520920	12.71	12.17	0.08	0.00	2.33	0.00	48.08	0.01	22.95	0.18	0.11	0.00	98.62
NEBC-7	6304336	520920	13.15	14.07	0.17	0.00	2.44	0.00	46.25	0.00	22.58	0.13	0.00	0.00	98.80
NEBC-7	6304336	520920	13.06	13.99	0.15	0.00	2.60	0.00	45.38	0.00	23.81	0.17	0.02	0.00	99.18
NEBC-7	6304336	520920	12.52	8.26	0.12	0.00	2.70	0.00	51.32	0.06	23.36	0.30	0.00	0.00	98.64
NEBC-7	6304336	520920	16.45	25.58	0.21	0.00	1.00	0.03	40.52	0.00	15.36	0.34	0.01	0.00	99.51
NEBC-7	6304336	520920	9.23	8.51	0.11	0.00	4.57	0.00	36.27	0.29	38.83	0.13	0.06	0.00	98.01
NEBC-7	6304336	520920	13.29	8.10	0.12	0.02	3.92	0.00	41.79	0.05	30.94	0.22	0.00	0.00	98.46

Appendix 1. Chemical composition of Cr-spinels (Chromites); for sample locations, see Table 1 and Figure 2.

Sample ID	UTM Northing	UTM Easting	MgO	Al_2O_3	SiO_2	CaO	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	NiO	Nb_2O_5	Ta_2O_5	Total
NEBC-7	6304336	520920	12.32	13.65	0.17	0.01	2.78	0.00	44.14	0.11	24.94	0.19	0.01	0.00	98.30
NEBC-7	6304336	520920	12.30	13.17	0.15	0.02	2.67	0.00	45.04	0.00	24.98	0.16	0.00	0.00	98.49
NEBC-7	6304336	520920	15.60	22.83	0.07	0.00	0.08	0.14	45.29	0.00	15.42	0.11	0.00	0.00	99.56
NEBC-7	6304336	520920	16.61	30.55	0.14	0.00	0.76	0.08	35.79	0.00	15.14	0.24	0.00	0.00	99.30
NEBC-7	6304336	520920	14.97	24.89	0.09	0.00	0.63	0.13	41.68	0.00	17.09	0.12	0.00	0.00	99.60
NEBC-7	6304336	520920	13.03	14.34	0.16	0.00	2.39	0.00	45.03	0.02	22.98	0.15	0.04	0.00	98.14
NEBC-7	6304336	520920	11.21	7.36	0.09	0.00	4.89	0.00	46.17	0.00	28.85	0.25	0.00	0.00	98.83
NEBC-7	6304336	520920	13.24	14.21	0.16	0.01	2.32	0.00	46.43	0.00	22.92	0.17	0.00	0.00	99.48
NEBC-7	6304336	520920	12.16	12.98	0.13	0.02	3.81	0.00	41.46	0.02	28.41	0.23	0.00	0.00	99.22
NEBC-7	6304336	520920	12.36	15.15	0.12	0.00	3.26	0.00	40.50	0.14	27.27	0.20	0.08	0.00	99.08
NEBC-7	6304336	520920	13.15	14.06	0.17	0.01	2.41	0.00	46.46	0.00	22.75	0.16	0.00	0.00	99.17
NEBC-7	6304336	520920	16.04	28.35	0.09	0.01	0.47	0.08	37.65	0.05	15.87	0.20	0.00	0.00	98.80
NEBC-7	6304336	520920	13.18	14.23	0.15	0.01	2.38	0.00	45.37	0.00	22.89	0.21	0.00	0.00	98.41
NEBC-7	6304336	520920	13.70	16.34	0.12	0.00	1.43	0.01	44.38	0.04	22.63	0.18	0.00	0.00	98.84
NEBC-7	6304336	520920	10.11	15.12	0.18	0.00	0.21	0.10	51.55	0.09	21.79	0.13	0.00	0.00	99.30
NEBC-7	6304336	520920	14.84	23.36	0.20	0.02	1.40	0.03	38.89	0.08	19.60	0.25	0.00	0.00	98.66
NEBC-7	6304336	520920	13.15	7.35	0.12	0.01	2.98	0.00	49.03	0.02	25.93	0.27	0.00	0.00	98.85
NEBC-7	6304336	520920	13.08	11.67	0.13	0.01	1.59	0.00	48.00	0.05	24.01	0.24	0.00	0.00	98.78
NEBC-7	6304336	520920	14.44	16.44	0.08	0.04	1.15	0.04	50.49	0.00	15.92	0.09	0.00	0.00	98.70
NEBC-7	6304336	520920	16.48	28.88	0.23	0.01	0.51	0.07	36.89	0.00	15.39	0.14	0.00	0.00	98.61
NEBC-7	6304336	520920	12.72	5.86	0.15	0.01	2.21	0.00	56.31	0.00	21.55	0.09	0.00	0.00	98.90
NEBC-7	6304336	520920	11.19	9.60	0.07	0.01	3.04	0.00	44.71	0.00	29.62	0.19	0.00	0.00	98.43
NEBC-7	6304336	520920	14.89	17.82	0.09	0.01	1.96	0.00	47.89	0.02	16.68	0.16	0.00	0.00	99.50
NEBC-7	6304336	520920	11.32	7.77	0.11	0.00	3.28	0.00	47.29	0.05	28.13	0.09	0.00	0.00	98.04
NEBC-7	6304336	520920	12.59	14.65	0.19	0.01	2.28	0.00	44.83	0.06	23.63	0.16	0.00	0.00	98.40
NEBC-7	6304336	520920	10.44	8.11	0.09	0.00	3.51	0.00	47.63	0.03	28.55	0.08	0.00	0.00	98.42
NEBC-7	6304336	520920	12.66	11.26	0.13	0.00	2.32	0.00	48.79	0.04	23.58	0.17	0.02	0.00	98.98
NEBC-7	6304336	520920	12.51	8.98	0.13	0.01	2.50	0.00	50.10	0.00	23.61	0.13	0.00	0.00	97.97
NEBC-7	6304336	520920	15.21	25.62	0.22	0.00	0.35	0.16	40.08	0.07	17.07	0.20	0.02	0.00	99.00
NEBC-7	6304336	520920	16.48	28.98	0.11	0.01	0.15	0.12	39.95	0.02	13.77	0.19	0.00	0.00	99.76
NEBC-7	6304336	520920	12.91	9.45	0.12	0.00	1.76	0.00	51.04	0.00	23.02	0.12	0.00	0.00	98.43
NEBC-7	6304336	520920	12.85	7.76	0.14	0.03	2.36	0.00	53.08	0.00	22.91	0.17	0.02	0.00	99.33
NEBC-7	6304336	520920	12.78	13.93	0.13	0.00	2.68	0.00	44.57	0.00	23.77	0.20	0.00	0.00	98.05
NEBC-7	6304336	520920	12.72	12.88	0.14	0.00	2.87	0.00	45.79	0.00	24.95	0.20	0.00	0.00	99.56
NEBC-7 float QC	6304336	520920	12.46	10.16	0.10	0.00	2.36	0.00	49.32	0.01	23.27	0.09	0.03	0.00	97.80
NEBC-13	6524807	379408	15.65	27.54	0.15	0.02	0.67	0.10	37.43	0.00	17.79	0.25	0.09	0.00	99.67
NEBC-15	6518192	344777	11.64	7.57	0.15	0.07	4.00	0.00	46.76	0.00	27.86	0.13	0.00	0.00	98.19
NEBC-15	6518192	344777	13.91	25.04	0.08	0.00	1.36	0.02	35.57	0.07	22.86	0.21	0.02	0.00	99.13
NEBC-18	6579659	332851	10.91	15.00	0.07	0.01	0.28	0.18	52.17	0.08	20.81	0.03	0.00	0.00	99.55
NEBC-18	6579659	332851	14.00	29.87	0.03	0.00	0.06	0.16	37.35	0.00	18.35	0.07	0.04	0.00	99.92
NEBC-18	6579659	332851	10.35	9.49	0.07	0.00	0.24	0.08	57.45	0.13	21.69	0.06	0.06	0.00	99.64
NEBC-18	6579659	332851	16.62	27.49	0.09	0.00	0.15	0.13	40.89	0.00	14.68	0.26	0.02	0.00	100.32
NEBC-20	6566238	484386	15.24	14.64	0.13	0.00	0.32	0.11	53.56	0.00	15.32	0.32	0.00	0.00	99.64
NEBC-21	6565844	482724	7.07	15.35	0.08	0.00	0.43	0.10	44.46	0.16	30.68	0.05	0.00	0.00	98.39
NEBC-23	6614075	494595	8.86	23.07	0.08	0.01	0.38	0.14	35.00	0.05	31.20	0.28	0.05	0.00	99.12
NEBC-23	6614075	494595	5.70	10.36	0.07	0.00	1.60	0.12	34.73	0.11	44.45	0.13	0.00	0.00	97.27
NEBC-23	6614075	494595	12.30	24.53	0.04	0.00	0.36	0.14	39.47	0.08	22.06	0.15	0.03	0.00	99.17
NEBC-23	6614075	494595	15.19	34.28	0.04	0.00	0.24	0.18	31.71	0.04	17.38	0.12	0.00	0.00	99.19
NEBC-23	6614075	494595	11.98	20.85	0.07	0.00	0.03	0.28	48.09	0.00	18.57	0.03	0.00	0.00	99.90
NEBC-23	6614075	494595	15.88	36.26	0.03	0.03	0.07	0.15	31.54	0.06	15.32	0.21	0.00	0.00	99.56
NEBC-23	6614075	494595	10.14	17.73	0.08	0.02	0.27	0.09	49.54	0.10	21.64	0.09	0.06	0.00	99.75
NEBC-23	6614075	494595	10.19	21.62	0.08	0.03	0.07	0.24	42.51	0.16	23.93	0.15	0.06	0.00	99.03
NEBC-23	6614075	494595	9.91	15.39	0.09	0.00	0.14	0.17	50.51	0.03	22.48	0.10	0.04	0.00	98.86
NEBC-23	6614075	494595	8.73	24.29	0.14	0.00	0.55	0.04	39.31	0.19	26.05	0.11	0.00	0.00	99.40
NEBC-23	6614075	494595	12.93	18.98	0.09	0.00	0.05	0.28	47.42	0.00	19.04	0.16	0.00	0.00	98.94
NEBC-23	6614075	494595	11.87	19.09	0.08	0.00	0.08	0.20	49.38	0.00	19.13	0.09	0.07	0.00	99.98
NEBC-23	6614075	494595	13.30	28.45	0.06	0.00	0.31	0.18	35.42	0.08	20.69	0.10	0.02	0.00	98.61
NEBC-23	6614075	494595	13.24	13.51	0.15	0.02	0.22	0.23	52.38	0.00	18.92	0.12	0.03	0.00	98.80
NEBC-23	6614075	494595	13.91	26.46	0.06	0.00	0.39	0.11	38.33	0.10	19.97	0.27	0.02	0.00	99.62

Appendix 1. Chemical composition of Cr-spinels (Chromites); for sample locations, see Table 1 and Figure 2.

Sample ID	UTM Northing	UTM Easting	MgO	Al_2O_3	SiO_2	CaO	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	NiO	Nb_2O_5	Ta_2O_5	Total
NEBC-23	6614075	494595	10.76	21.98	0.04	0.02	1.01	0.21	39.29	0.18	25.93	0.22	0.00	0.00	99.65
NEBC-23	6614075	494595	14.48	30.03	0.06	0.00	0.46	0.16	34.77	0.08	19.62	0.18	0.00	0.00	99.85
NEBC-23	6614075	494595	15.61	26.89	0.09	0.00	0.79	0.10	37.66	0.02	17.83	0.20	0.00	0.00	99.20
NEBC-23	6614075	494595	13.96	24.38	0.09	0.00	0.25	0.21	42.68	0.01	17.85	0.14	0.02	0.00	99.60
NEBC-23	6614075	494595	15.17	20.23	0.10	0.00	0.18	0.11	46.43	0.03	16.95	0.20	0.00	0.00	99.40
NEBC-23	6614075	494595	7.72	5.62	0.11	0.00	0.13	0.14	61.40	0.20	23.51	0.04	0.01	0.00	98.88
NEBC-23	6614075	494595	13.88	23.90	0.05	0.00	0.03	0.25	43.24	0.04	18.42	0.20	0.00	0.00	100.01
NEBC-23	6614075	494595	13.33	14.87	0.11	0.00	1.42	0.00	46.57	0.00	22.08	0.19	0.00	0.00	98.57
NEBC-23	6614075	494595	12.82	34.61	0.04	0.00	0.10	0.15	29.66	0.10	21.65	0.08	0.01	0.00	99.24
NEBC-25	6510030	520870	5.94	14.31	0.03	0.00	0.09	0.09	43.53	0.17	35.02	0.13	0.00	0.00	99.31
NEBC-25	6510030	520870	10.12	8.13	0.07	0.02	0.61	0.17	55.48	0.01	23.23	0.04	0.00	0.00	97.88
NEBC-27	6515567	538244	11.32	10.35	0.09	0.00	2.29	0.00	47.82	0.07	27.23	0.21	0.05	0.00	99.43
NEBC-27	6515567	538244	16.11	31.88	0.08	0.03	0.06	0.10	36.27	0.00	16.10	0.32	0.00	0.00	100.95
NEBC-38	6489088	545698	9.82	26.04	0.01	0.00	0.24	0.18	33.48	0.16	29.45	0.18	0.04	0.00	99.62
NEBC-39	6488921	548332	6.52	23.31	0.10	0.00	0.82	0.05	38.63	0.16	29.55	0.10	0.00	0.00	99.25
NEBC-39	6488921	548332	9.44	9.68	0.12	0.00	4.12	0.00	37.89	0.23	36.32	0.04	0.00	0.00	97.83
NEBC-39	6488921	548332	11.07	30.71	0.07	0.00	0.11	0.11	32.16	0.12	25.08	0.17	0.00	0.00	99.60
NEBC-39	6488921	548332	6.02	11.52	0.06	0.00	0.18	0.13	46.99	0.13	32.82	0.08	0.00	0.00	97.93
NEBC-40	6486881	557911	11.95	14.60	0.08	0.00	0.38	0.11	48.91	0.04	22.01	0.10	0.05	0.00	98.24
NEBC-42	6512245	517785	7.19	15.17	0.07	0.00	0.45	0.08	40.21	0.23	34.98	0.17	0.02	0.00	98.58
NEBC-43	6549892	460825	13.73	31.05	0.06	0.00	0.26	0.18	33.72	0.10	20.72	0.16	0.02	0.00	99.98
NEBC-43	6549892	460825	13.25	16.77	0.11	0.01	1.48	0.02	44.14	0.00	23.41	0.20	0.00	0.00	99.37
NEBC-43	6549892	460825	14.40	33.32	0.04	0.00	0.08	0.22	31.32	0.06	20.58	0.17	0.04	0.00	100.24
NEBC-43	6549892	460825	12.34	21.18	0.07	0.01	0.42	0.09	47.79	0.00	18.15	0.02	0.00	0.00	100.08
NEBC-43	6549892	460825	17.60	34.79	0.15	0.00	0.45	0.11	32.21	0.00	14.63	0.13	0.00	0.00	100.08
NEBC-43	6549892	460825	15.00	28.82	0.10	0.01	0.03	0.17	37.68	0.03	17.59	0.22	0.00	0.00	99.65
NEBC-43	6549892	460825	13.61	30.49	0.05	0.01	0.67	0.20	33.76	0.07	21.37	0.14	0.03	0.00	100.40
NEBC-43	6549892	460825	12.71	27.47	0.10	0.00	0.23	0.12	37.23	0.07	22.18	0.19	0.00	0.00	100.30
NEBC-43	6549892	460825	13.72	29.13	0.07	0.00	0.32	0.18	36.49	0.04	20.02	0.06	0.03	0.00	100.06
NEBC-43	6549892	460825	15.66	12.20	0.15	0.02	0.61	0.04	55.15	0.00	15.55	0.26	0.08	0.00	99.71
NEBC-43	6549892	460825	15.15	5.14	0.17	0.00	0.19	0.00	62.91	0.00	15.05	0.25	0.01	0.00	98.86
NEBC-43	6549892	460825	13.75	23.13	0.05	0.00	0.62	0.19	41.44	0.00	20.43	0.15	0.01	0.00	99.76
NEBC-43	6549892	460825	13.41	16.86	0.10	0.00	1.78	0.03	45.02	0.07	23.08	0.21	0.00	0.00	100.57
NEBC-43	6549892	460825	10.09	13.72	0.12	0.03	1.72	0.00	44.25	0.09	28.71	0.12	0.12	0.00	98.97
NEBC-43	6549892	460825	10.25	18.20	0.08	0.00	1.18	0.02	42.92	0.09	26.68	0.07	0.00	0.00	99.49
NEBC-43	6549892	460825	9.40	16.99	0.12	0.00	1.61	0.05	41.43	0.02	30.21	0.21	0.00	0.00	100.04
NEBC-43	6549892	460825	12.16	25.35	0.03	0.00	0.10	0.14	37.75	0.07	23.37	0.14	0.05	0.00	99.18
NEBC-43	6549892	460825	12.74	29.54	0.06	0.03	0.04	0.25	36.69	0.07	19.70	0.10	0.00	0.00	99.21
NEBC-43	6549892	460825	10.99	23.46	0.07	0.01	0.13	0.18	40.22	0.13	24.50	0.13	0.01	0.00	99.83
NEBC-43	6549892	460825	12.24	12.86	0.14	0.01	2.21	0.00	46.85	0.00	24.83	0.22	0.01	0.00	99.36
NEBC-43	6549892	460825	15.61	30.27	0.09	0.01	0.19	0.16	36.32	0.07	16.13	0.27	0.00	0.00	99.12
NEBC-43	6549892	460825	13.44	28.49	0.06	0.00	0.27	0.19	36.36	0.07	21.12	0.18	0.03	0.00	100.21
NEBC-43	6549892	460825	7.45	16.44	0.07	0.00	1.59	0.01	40.46	0.13	32.79	0.12	0.00	0.00	99.07
NEBC-43	6549892	460825	13.57	27.14	0.08	0.00	0.11	0.19	40.56	0.04	18.75	0.17	0.05	0.00	100.66
NEBC-43	6549892	460825	12.92	22.50	0.05	0.01	0.14	0.10	46.61	0.03	17.95	0.12	0.00	0.00	100.42
NEBC-43	6549892	460825	13.49	31.93	0.04	0.00	0.01	0.15	35.33	0.00	18.57	0.09	0.03	0.00	99.63
NEBC-43	6549892	460825	13.68	33.26	0.05	0.00	0.24	0.15	30.84	0.00	20.78	0.17	0.03	0.00	99.22
NEBC-43	6549892	460825	14.12	30.68	0.08	0.00	0.34	0.16	34.23	0.09	20.49	0.13	0.03	0.00	100.36
NEBC-43	6549892	460825	9.13	14.26	0.08	0.02	0.43	0.14	47.50	0.08	27.20	0.09	0.00	0.00	98.93
NEBC-43	6549892	460825	10.39	14.36	0.30	0.00	0.02	0.21	52.59	0.10	21.81	0.07	0.09	0.00	99.94
NEBC-43	6549892	460825	14.26	28.30	0.15	0.00	0.10	0.17	40.21	0.06	16.26	0.09	0.02	0.00	99.62
NEBC-43	6549892	460825	13.55	27.96	0.03	0.01	0.08	0.19	37.02	0.10	21.41	0.14	0.00	0.00	100.50
NEBC-43	6549892	460825	13.05	24.51	0.04	0.00	0.04	0.21	42.04	0.03	19.52	0.10	0.00	0.00	99.55
NEBC-43	6549892	460825	15.67	16.11	0.12	0.00	1.35	0.00	48.29	0.00	17.33	0.33	0.08	0.00	99.27
NEBC-43	6549892	460825	11.78	13.23	0.13	0.03	0.22	0.08	52.25	0.06	22.16	0.21	0.02	0.00	100.16
NEBC-43	6549892	460825	11.16	5.98	0.11	0.02	0.20	0.01	61.26	0.11	19.96	0.10	0.10	0.00	99.02
NEBC-43	6549892	460825	13.45	25.24	0.08	0.02	0.04	0.22	42.15	0.00	19.08	0.23	0.00	0.00	100.50
NEBC-44	6549887	461981	10.79	26.39	0.07	0.01	0.34	0.15	39.02	0.06	22.33	0.07	0.00	0.00	99.24
NEBC-44	6549887	461981	12.42	16.79	0.13	0.01	2.03	0.00	40.52	0.09	26.23	0.19	0.03	0.00	98.43
NEBC-44	6549887	461981	12.96	11.66	0.09	0.00	0.23	0.04	56.90	0.00	16.87	0.09	0.00	0.00	98.83

Appendix 1. Chemical composition of Cr-spinels (Chromites); for sample locations, see Table 1 and Figure 2.

Sample ID	UTM Northing	UTM Easting	MgO	Al_2O_3	SiO_2	CaO	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	NiO	Nb_2O_5	Ta_2O_5	Total
NEBC-44	6549887	461981	11.03	25.59	0.07	0.00	0.32	0.15	35.51	0.05	26.09	0.19	0.00	0.00	98.99
NEBC-44	6549887	461981	12.41	10.27	0.07	0.00	0.27	0.03	59.80	0.00	16.76	0.11	0.00	0.00	99.72
NEBC-44	6549887	461981	14.19	29.75	0.07	0.00	0.34	0.13	37.45	0.01	17.36	0.13	0.10	0.00	99.52
NEBC-44	6549887	461981	10.70	27.66	0.14	0.00	0.07	0.20	38.72	0.50	21.51	0.08	0.07	0.00	99.64
NEBC-44	6549887	461981	15.25	28.68	0.05	0.01	0.05	0.22	40.15	0.00	15.39	0.16	0.04	0.00	100.01
NEBC-44	6549887	461981	9.87	28.02	0.03	0.00	0.43	0.20	33.78	0.13	26.52	0.20	0.02	0.00	99.19
NEBC-44	6549887	461981	10.58	10.04	0.07	0.00	0.19	0.05	59.24	0.00	19.14	0.02	0.00	0.00	99.32
NEBC-44	6549887	461981	9.05	18.28	0.05	0.00	1.94	0.05	37.96	0.10	31.60	0.19	0.00	0.00	99.21
NEBC-44	6549887	461981	4.95	8.21	0.06	0.00	0.24	0.12	47.99	0.22	36.59	0.04	0.00	0.00	98.42
NEBC-44	6549887	461981	9.04	14.60	0.05	0.00	0.23	0.08	50.01	0.75	23.70	0.05	0.00	0.00	98.51
NEBC-44	6549887	461981	14.79	30.22	0.04	0.00	0.09	0.20	38.46	0.04	15.58	0.11	0.00	0.00	99.51
NEBC-44	6549887	461981	11.77	16.37	0.13	0.01	1.67	0.02	43.09	0.00	25.74	0.19	0.00	0.00	99.00
NEBC-44	6549887	461981	8.37	4.70	0.11	0.02	1.63	0.00	48.51	0.15	34.13	0.29	0.00	0.00	97.91
NEBC-44	6549887	461981	11.83	27.40	0.07	0.01	0.34	0.22	36.43	0.30	22.57	0.12	0.03	0.00	99.33
NEBC-44	6549887	461981	16.00	30.06	0.09	0.02	0.23	0.08	36.41	0.00	15.48	0.17	0.05	0.00	98.57
NEBC-44	6549887	461981	15.67	23.12	0.16	0.01	0.28	0.09	44.26	0.00	15.27	0.29	0.04	0.00	99.19
NEBC-44	6549887	461981	14.34	30.33	0.09	0.00	0.00	0.16	38.18	0.01	16.54	0.11	0.03	0.00	99.81
NEBC-44	6549887	461981	13.12	9.02	0.13	0.00	0.32	0.04	57.62	0.00	19.14	0.19	0.00	0.00	99.59
NEBC-44	6549887	461981	13.98	17.34	0.13	0.00	1.59	0.00	43.87	0.00	21.69	0.28	0.04	0.00	98.91
NEBC-44	6549887	461981	13.15	12.82	0.12	0.00	0.53	0.06	46.63	0.09	25.19	0.12	0.00	0.00	98.70
NEBC-44	6549887	461981	14.52	24.10	0.10	0.00	0.43	0.17	41.94	0.00	17.79	0.16	0.00	0.00	99.20
NEBC-44	6549887	461981	11.71	18.24	0.05	0.01	0.06	0.24	49.57	0.04	20.98	0.08	0.00	0.00	100.97
NEBC-45	6440574	516839	16.81	32.17	0.12	0.00	0.05	0.18	35.20	0.00	14.98	0.27	0.00	0.00	99.78
NEBC-45	6440574	516839	15.44	29.91	0.11	0.01	0.61	0.19	36.31	0.02	17.15	0.20	0.00	0.00	99.95
NEBC-45	6440574	516839	12.39	29.42	0.07	0.00	0.25	0.22	33.46	0.06	22.84	0.18	0.00	0.00	98.88
NEBC-45	6440574	516839	12.13	27.69	0.03	0.01	0.16	0.18	34.33	0.10	24.88	0.13	0.00	0.00	99.64
NEBC-45	6440574	516839	14.50	16.39	0.14	0.00	1.34	0.00	47.33	0.00	19.21	0.17	0.00	0.00	99.08
NEBC-45	6440574	516839	12.95	28.00	0.06	0.01	0.01	0.19	37.90	0.07	20.67	0.16	0.00	0.00	100.02
NEBC-45	6440574	516839	14.82	32.88	0.04	0.03	0.01	0.21	36.26	0.01	15.77	0.19	0.00	0.00	100.20
NEBC-45	6440574	516839	13.90	27.78	0.05	0.00	0.08	0.16	40.25	0.00	18.08	0.08	0.00	0.00	100.38
NEBC-45	6440574	516839	13.33	27.09	0.08	0.00	0.00	0.26	41.94	0.05	17.31	0.12	0.06	0.00	100.23
NEBC-46	6439810	516735	13.05	33.85	0.02	0.03	0.18	0.25	31.22	0.09	20.48	0.15	0.07	0.00	99.40
NEBC-47	6360037	509264	17.87	33.35	0.18	0.00	0.09	0.13	33.96	0.07	13.23	0.23	0.00	0.00	99.10
NEBC-47	6360037	509264	11.58	16.85	0.10	0.00	1.26	0.00	43.86	0.05	25.25	0.12	0.00	0.00	99.06
NEBC-47	6360037	509264	12.74	28.42	0.08	0.00	0.35	0.17	34.53	0.08	22.06	0.12	0.00	0.00	98.55
NEBC-50	6222613	645018	13.98	19.51	0.13	0.02	0.00	0.14	50.52	0.00	15.26	0.07	0.00	0.00	99.63
NEBC-50	6222613	645018	10.58	6.81	0.12	0.02	0.33	0.06	55.04	0.12	25.13	0.14	0.10	0.00	98.44
NEBC-50	6222613	645018	9.12	8.52	0.06	0.00	0.25	0.00	52.63	0.12	26.50	0.05	0.00	0.00	97.24
NEBC-50	6222613	645018	11.44	20.42	0.06	0.00	1.26	0.24	40.77	0.08	23.75	0.21	0.00	0.00	98.23
NEBC-50	6222613	645018	8.93	11.73	0.08	0.00	0.04	0.21	55.50	0.03	22.52	0.05	0.00	0.00	99.09
NEBC-50	6222613	645018	10.41	9.66	0.12	0.00	0.84	0.11	39.47	0.04	36.83	0.11	0.00	0.00	97.58
NEBC-50	6222613	645018	10.93	24.43	0.07	0.00	0.03	0.21	42.20	0.05	21.05	0.06	0.00	0.00	99.02
NEBC-50	6222613	645018	11.81	8.10	0.10	0.00	0.28	0.00	50.75	0.12	27.17	0.18	0.00	0.00	98.49
NEBC-52	6176129	611299	8.40	7.47	0.12	0.00	0.06	0.23	58.66	0.05	23.42	0.13	0.05	0.00	98.58
NEBC-52	6176129	611299	11.40	20.28	0.08	0.01	0.03	0.21	47.25	0.02	20.64	0.05	0.07	0.00	100.04
NEBC-52	6176129	611299	14.54	18.37	0.13	0.02	0.83	0.10	45.25	0.01	19.88	0.18	0.00	0.00	99.30
NEBC-52	6176129	611299	11.44	16.53	0.09	0.01	0.16	0.16	50.09	0.02	20.95	0.03	0.00	0.00	99.48
NEBC-52	6176129	611299	13.58	26.74	0.06	0.00	0.11	0.19	40.90	0.05	18.51	0.10	0.00	0.00	100.23
NEBC-52	6176129	611299	12.95	18.62	0.12	0.00	1.65	0.02	39.56	0.00	26.03	0.14	0.00	0.00	99.09
NEBC-52	6176129	611299	7.37	13.23	0.08	0.02	0.31	0.26	44.89	0.20	31.74	0.13	0.05	0.00	98.29
NEBC-52	6176129	611299	10.36	21.98	0.08	0.00	0.04	0.19	44.91	0.05	22.04	0.03	0.00	0.00	99.67
NEBC-54	6152653	530479	11.20	14.64	0.08	0.00	0.58	0.09	47.08	0.00	25.65	0.06	0.04	0.00	99.43
NEBC-57	6354768	661877	16.88	32.72	0.13	0.03	0.53	0.08	31.56	0.07	17.14	0.29	0.00	0.00	99.43
NEBC-57	6354768	661877	13.22	26.29	0.09	0.01	0.23	0.29	40.37	0.04	18.68	0.22	0.00	0.00	99.43
NEBC-57	6354768	661877	16.08	26.44	0.15	0.01	0.39	0.15	41.45	0.05	16.23	0.19	0.03	0.00	101.18
NEBC-58	6612910	564017	13.89	29.38	0.07	0.02	0.20	0.18	36.46	0.15	19.78	0.14	0.04	0.00	100.30
NEBC-58	6612910	564017	5.80	11.10	0.07	0.01	0.34	0.12	45.14	0.23	35.90	0.13	0.00	0.00	98.84
NEBC-58	6612910	564017	6.64	15.57	0.07	0.01	0.36	0.13	45.04	0.17	30.52	0.17	0.00	0.00	98.67
NEBC-58	6612910	564017	13.09	24.42	0.14	0.01	0.59	0.13	41.49	0.08	19.08	0.17	0.00	0.00	99.20
NEBC-58	6612910	564017	14.40	20.02	0.16	0.00	1.60	0.05	40.96	0.02	22.17	0.18	0.00	0.00	99.57