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Kimberlite Indicator Mineral Results from Reconnaissance Till Sampling in the East Peace River Region (NTS 84C/East), Alberta

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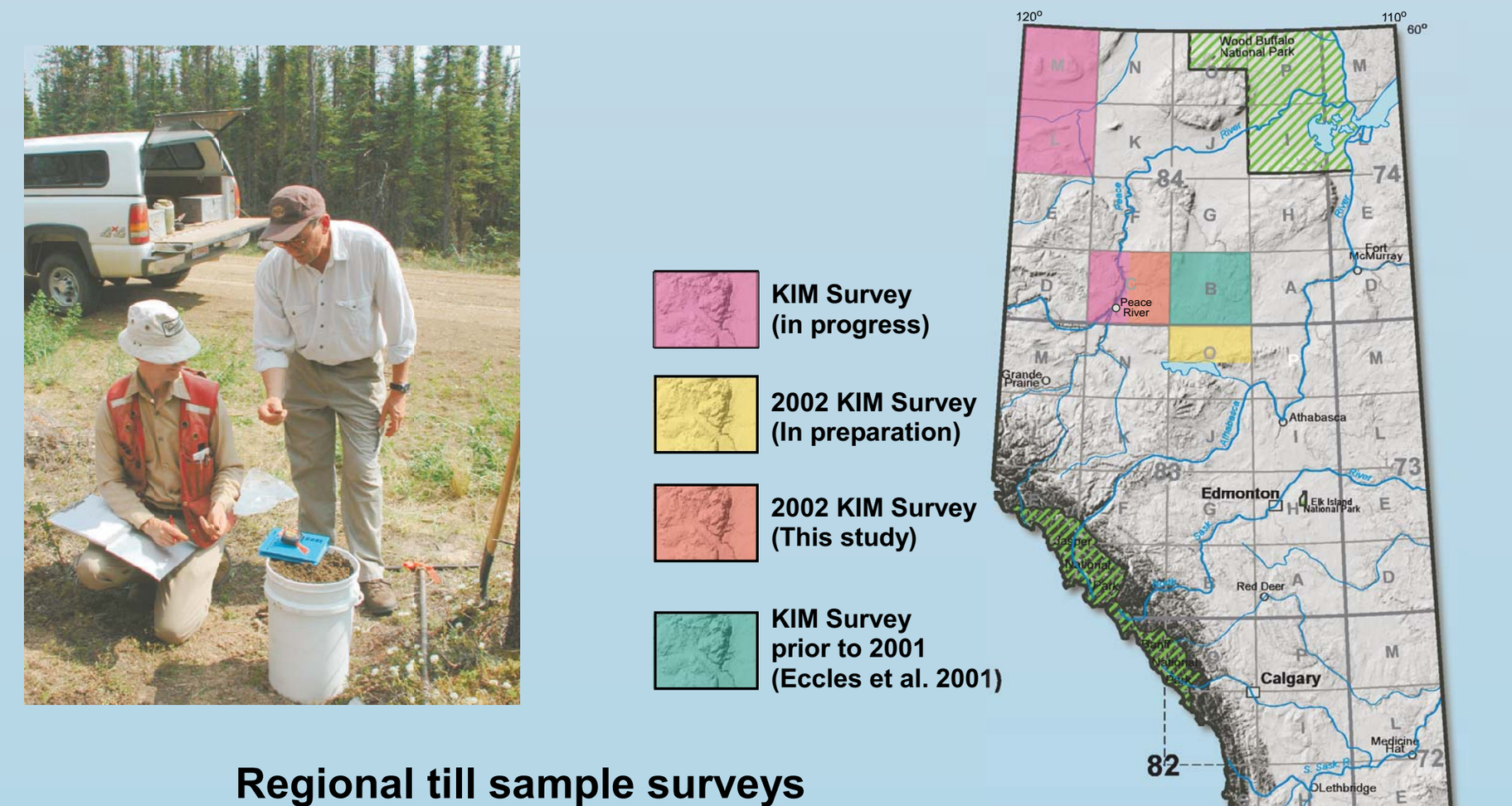
Abstract

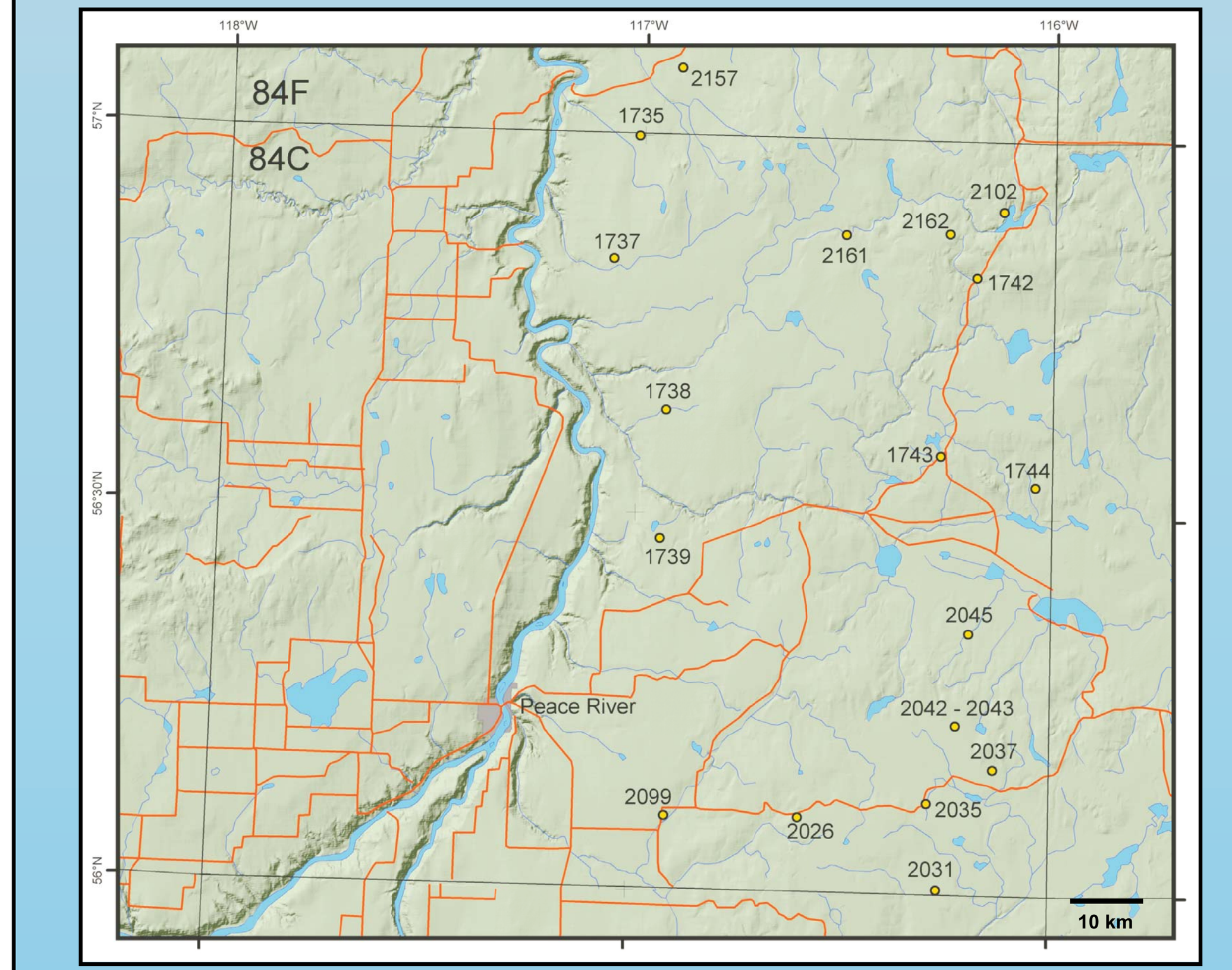
During the summer of 2002, the Alberta Geological Survey (AGS) completed the surficial mapping of the Peace River map area (NTS 84C) as part of a multi-year program initiative under the Alberta Mineral Strategy. During the course of surficial mapping, reconnaissance till samples were collected to document the regional kimberlite indicator mineral (KIM) content of the surface tills and to potentially stimulate exploration in areas not near known kimberlite occurrences. Surficial mapping and ice flow reconstruction studies in the Peace River region provide crucial information that have direct implications for kimberlite exploration using drift prospecting.

Of the 19 samples collected and processed, 14 contain KIMs including pyrope, eclogitic garnet, Cr-diopside, ilmenite, chromite and olivine. KIMs were detected in samples located in excess of 90 km away from known kimberlitic sources. It is possible some of these KIMs were derived from secondary or tertiary sediment sources, or have been glacially transported from known sources (i.e., long distance dispersion). But some of the KIMs are suspected to be from undiscovered sources. At one site in particular, a number of KIMs were recovered from a till with drastic textural, mineralogical and geochemical differences from the ubiquitous regional surface till. This likely reflects a different source provenance of the KIMs than those contained within the overlying younger till.

It is important to understand the complex ice flow history that affected this region before attempting to use drift prospecting methods to explore KIM sources. A reconstruction of Late Wisconsin ice flow is presented for the southern Buffalo Head Hills. The interpretation of erosional ice-flow indicators and clast orientation studies demonstrates there were variable flow directions that could have influenced kimberlite dispersal trains. The lower till was deposited by ice flowing in a southwesterly direction, indicating a source to the northeast. The upper till was initially deposited by late Wisconsin Laurentide ice flowing generally in a southwesterly direction during glacial maximum. Sometime after glacial maximum, southwardly flowing ice in the northern Peace River valley advanced out of the Peace River valley from the northwest and flowed over the southwestern flank of the Buffalo Head Hills. This southeasterly surge was deflected by a large mass of surging ice that was flowing south-southwest down the Loon River Valley. These deflections likely occurred prior to ice stagnation. However, the main erosion and dispersion of kimberlitic debris likely still occurred during glacial maximum (southwestward dispersal), but palimpsest (offset) dispersal trains are suspected in this region from the late southeasterly glacial flow.



Regional till sample surveys conducted by AGS for indicator minerals



Sample locations and numbers of regional bulk till samples collected for the eastern Peace River (NTS 84C) map area.

Introduction & Background

Survey Impetus

During the course of regional surficial mapping, reconnaissance bulk samples (~30 kg) are collected to characterize the regional indicator mineral signature of the surface till. This study documents regional background and elevated indicator mineral content of the surface tills and hopes to stimulate exploration for and discovery of kimberlites in northern Alberta as part of the Alberta Mineral Strategy.

Physiography

The study area straddles the region between the Peace River Lowlands and Russel Lake Uplands (Buffalo Head Hills) physiographic zones (Pettapiece, 1986). Much of the surface morphology in the area is the result of processes associated with the last glacial event (late Wisconsin) and Holocene erosion. The Peace River valley is the dominant geomorphic feature of the region and was developed from incision of the Peace River through the Quaternary sediments and into the Cretaceous bedrock following deglaciation. Elevation ranges from 325 metres at the bottom of the Peace River valley to a maximum of 790 metres in the Buffalo Head Hills.

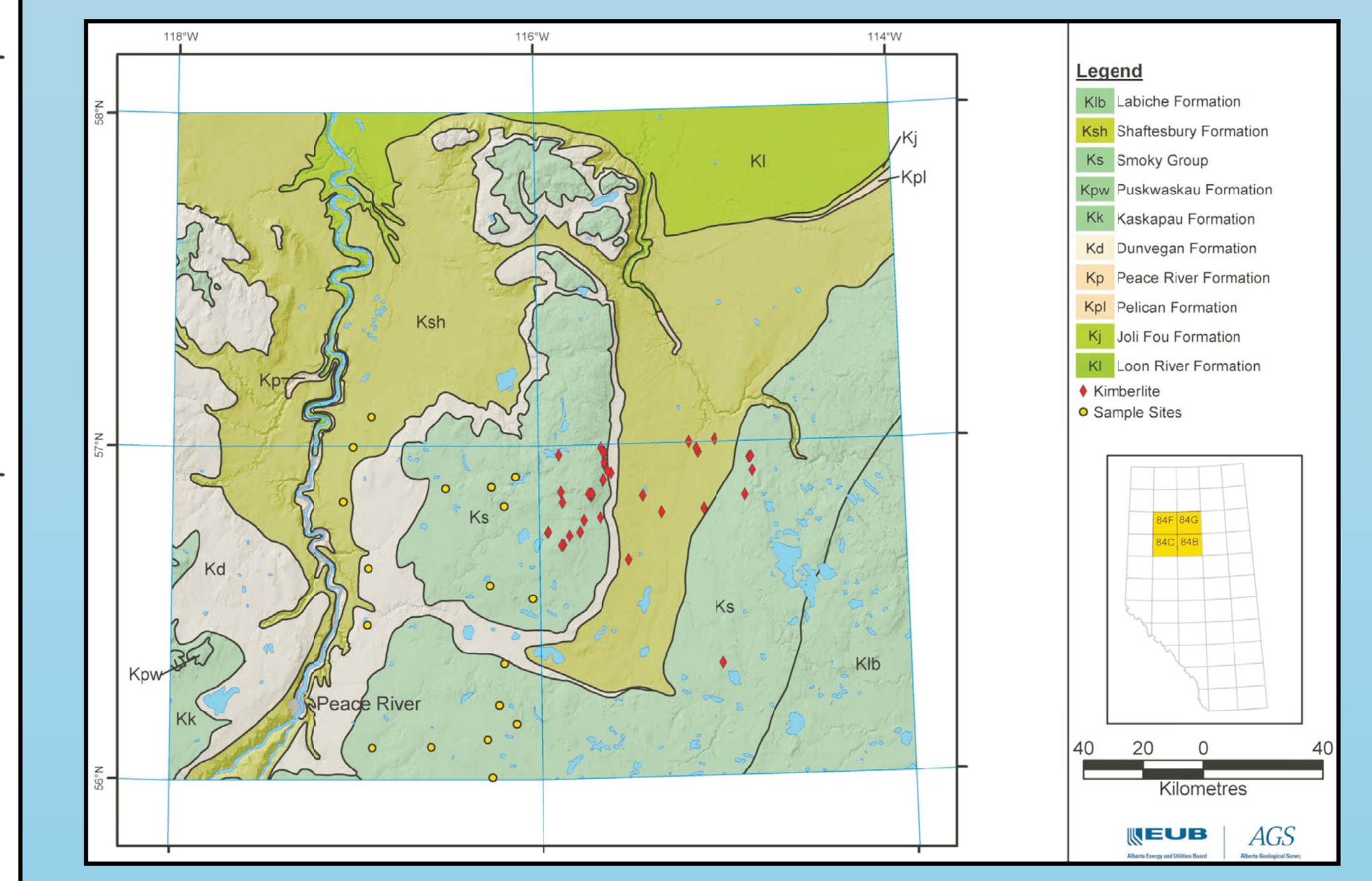
Bedrock Geology

The region is underlain by Cretaceous strata of the Western Canada Sedimentary Basin. The Buffalo Head Hills is underlain by dark grey shale and silty shale of the Upper Cretaceous Smoky Group (Green et al., 1970; Hamilton et al., 1999). The Buffalo Head Hills kimberlite field, which occurs within the southern Buffalo Head Hills and the adjacent Loon River Lowland to the east, contains a minimum of 38 kimberlitic bodies (Hood and McCandless, 2004). These kimberlites are hosted by a Cretaceous succession composed dominantly of marine shales of the Shaftesbury Formation and Smoky Group, which are separated by deltaic to marine sandstones of the Dunvegan Formation (Green et al., 1970; Hamilton et al., 1999). Several of the kimberlites form bedrock highs, which may be accompanied by topographic highs, due to their greater resistance to weathering and glacial erosion relative to the soft Cretaceous sedimentary rocks. According to Hood and McCandless (2003, 2004), indicator mineral assemblages have been assessed for 29 of the Buffalo Hills kimberlites, with forsteritic olivine forming the dominant xenocryst or cryptogenic mineral species. Chromian pyrope garnet and chromite are also important constituents, although some pipes are devoid of these minerals. Eclogitic pyrope-almandine, titanian pyrope, chromian augite/diopside and picroilmenite are also present in lesser amounts, and some bodies contain chromian corundum, zircon, edenitic amphibole and Mg-Cr-Al spinel.

Surficial Geology

Surficial geology of the study area is summarized from 1:100 000 scale maps of Paulen et al. (2004a, b). Above 610 metres above sea level (asl), the dominant sediment is till of varying genesis and thickness. Till is ubiquitous throughout the study area and forms a thick (2 to >25 m) continuous blanket over large parts of the region. It is grey-brown, carbonaceous clayey silt till with 1% to 5% clast content by volume and averages 10% carbonate in the matrix. The till at surface is dissected by numerous meltwater channels and locally capped by veneers of glaciolacustrine silt, eolian sand, alluvium and organic sediments. Below 610 m asl, Glacial Lake Peace silt, clay and minor sand of varying thicknesses blanket the area. These glaciolacustrine sediments commonly consist of a fining upwards sequence of stratified sand, silt and massive clay with lenses of ice-rafted diamicton. Discontinuous deposits of loess, bogs and fluvial sediments cap these deposits. Along the Peace River and its tributaries, slope failure and mass movement have resulted in thick accumulations of colluvium.

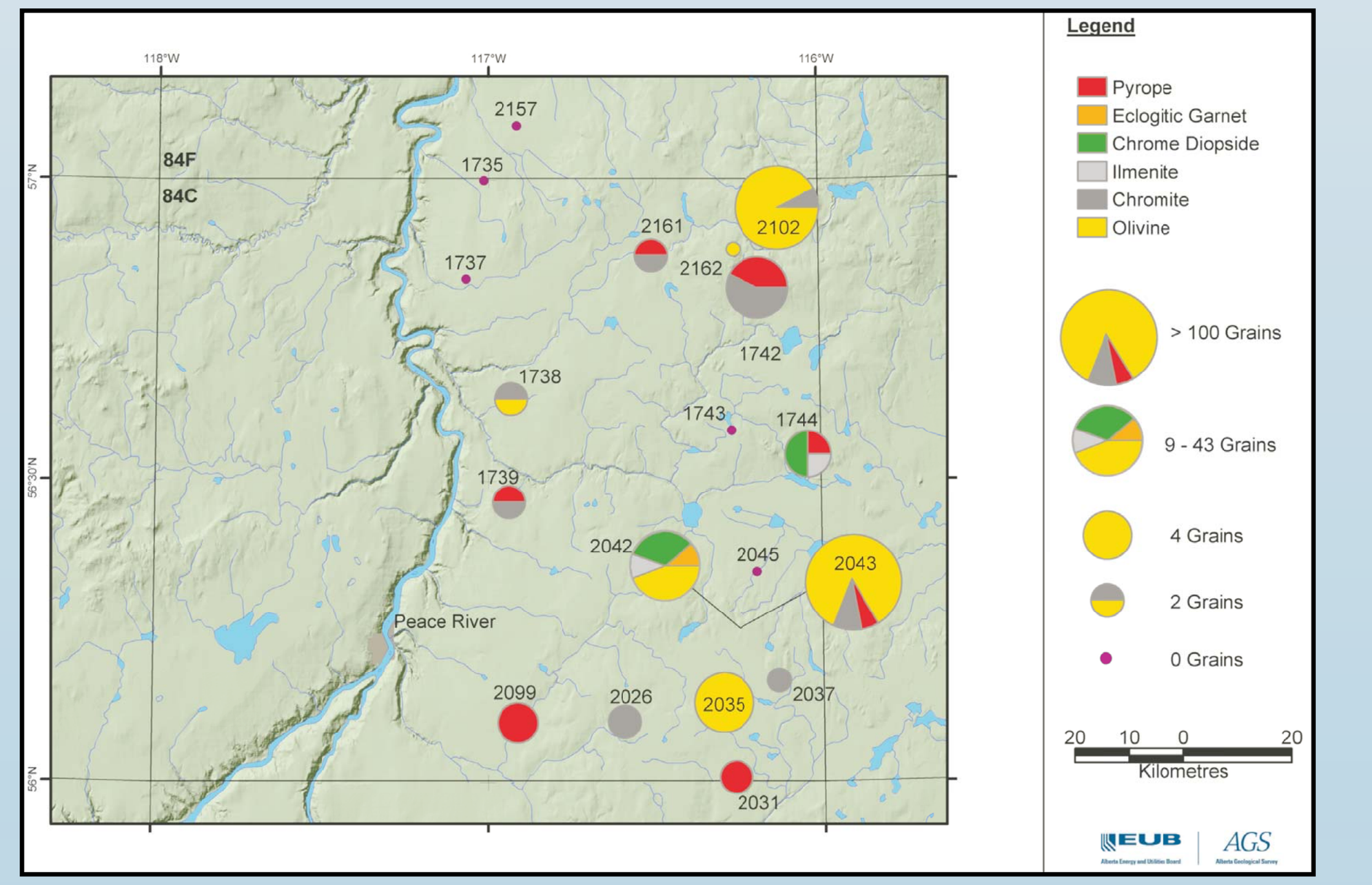
A reconstruction of late Wisconsin ice flow is presented for the southern Buffalo Head Hills (Paulen and McClenaghan, in press). Erosional ice-flow indicators and clast orientation studies demonstrate there were variable ice-flow directions that could have influenced kimberlite dispersal trains. A lower (older?) till was deposited by ice flowing in a southwesterly direction, indicating a source to the northeast. The surface till was initially deposited by Late Wisconsin Laurentide ice flowing generally in a southwesterly direction during glacial maximum. Sometime after glacial maximum, southwardly flowing ice in the northern Peace River valley advanced out of the Peace River valley from the northwest and flowed over the southwestern flank of the Buffalo Head Hills. This southeasterly surge was deflected by a large mass of surging ice flowing south-southwest down the Loon River Valley. These deflections likely occurred prior to ice stagnation. However, the main erosion and dispersion of kimberlitic debris likely still occurred during glacial maximum (southwestward dispersal), but palimpsest (offset) dispersal trains are suspected in this region from the late southeasterly glacial flow.



Bedrock geology (Hamilton et al., 1999) of the Peace River Lowland and Buffalo Head Hills Uplands regions (NTS 84B, C, F, G). Mapped kimberlites are indicated by red diamonds. The yellow dots indicate regional bulk till samples.

Results

Of the 19 samples collected and processed, 14 contained KIMs including pyrope, eclogitic garnet, Cr-diopside, ilmenite, chromite and olivine. KIMs were detected in samples located in excess of 90 km away from known kimberlitic sources. It is possible some of these KIMs were derived from secondary or tertiary sediment sources, or have been glacially transported from known sources (i.e., long distance dispersion); but some of the KIMs are suspected to be from undiscovered sources. At one site in particular (Cadotte Lake), a number of KIMs were recovered from a till (2043) with drastic textural, mineralogical and geochemical differences from the ubiquitous regional surface till (2042). This likely reflects a different source provenance of the KIMs than those contained within the overlying younger till.



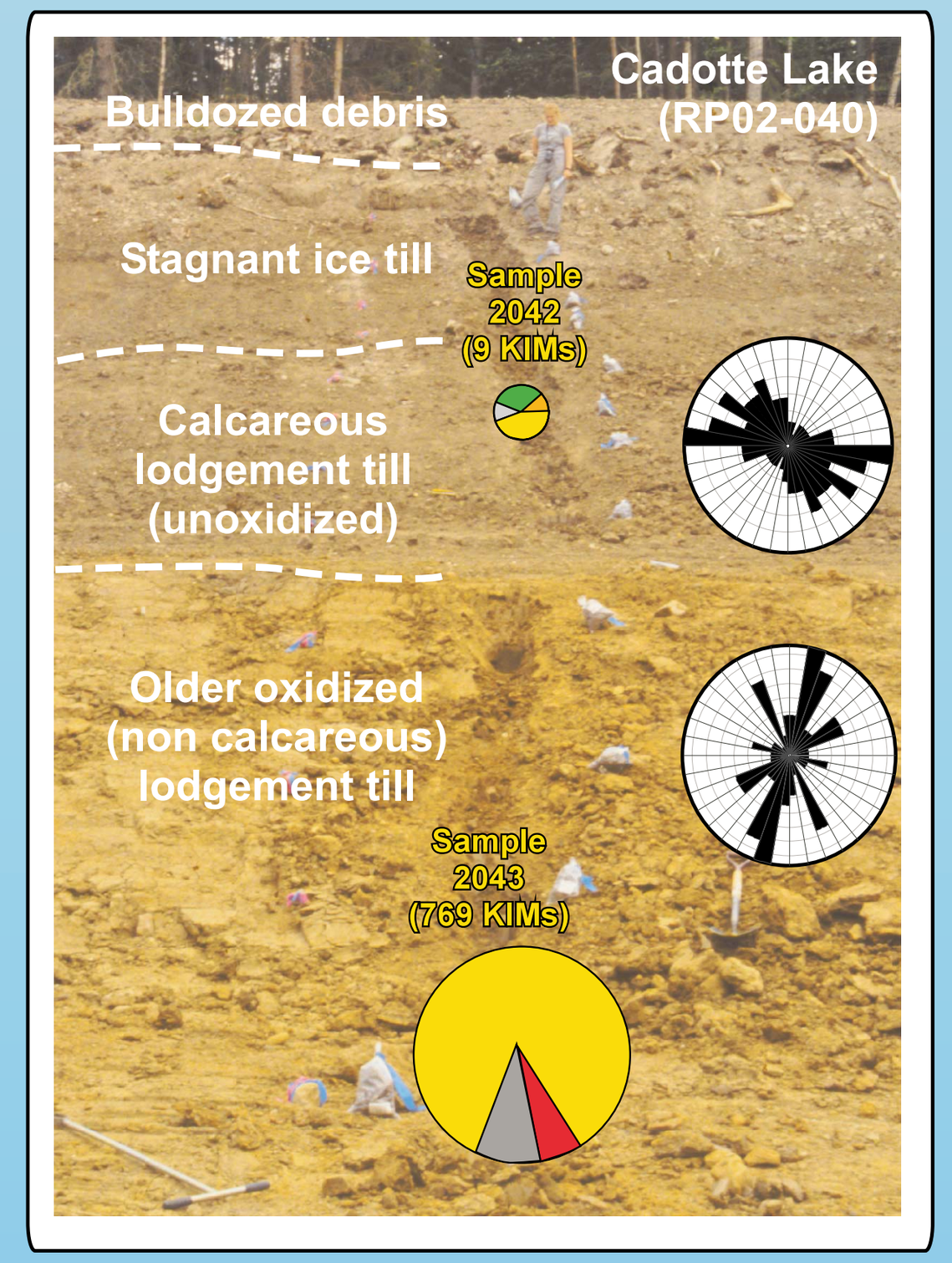
KIM Composition

Mg-ilmenite (picro-ilmenite)

Mg-ilmenite is extremely rare in map area 84C, only two grains were found in this study and only one grain was recovered in a stream sediment study of the same area (Friske et al., 2003). Mg-ilmenite is more common in the map areas to the north (84F and 84G, McCurdy et al., 2004). The compositions of the two grains found in this study are typical of kimberlitic ilmenite megacrysts. One grain is fairly MgO-rich (16 wt.%) and moderately Cr-rich, putting it into the "reduced" limb of Haggerty's (1975) ilmenite parabola, which is usually considered positive for diamond preservation. The other grain, with approximately 10 wt.% MgO and 0.02 wt.% Cr2O3, plotted at the apex of the hypothetical parabola together with grains found in map areas 84F and 84G. The former grain has no compositional equivalent in the stream sediment study of the same quadrant; however, with so few grains, no statement about provenance of ilmenite grains can be made.

Chromite

Chromite is much more numerous than Mg-ilmenite in the survey area. The 18 grains recovered in this study cover the same compositional range of those found during a stream sediment study to the east (Friske et al., 2003), although the latter are more numerous and have therefore a wider compositional range. Chromite compositions are typical of peridotitic chromite from the garnet stability field (data points just below the diamond inclusions and intergrowth fields) and Cr-spinel (typical of peridotitic chromite from shallower depths and crustal rocks), as well as three grains of MgO-poor ferrochromite (close to the y-axis), which might be either from crustal (ultra-) mafic rocks or from metasomatically altered kimberlite. In the absence of any ultramafic lithologies in the vicinity, the majority of the chromites/Cr-spinels analyzed here are interpreted to be from mantle xenoliths carried to the surface by kimberlites.



Garnet

Of the 25 garnets analyzed, 24 were Cr-pyrope that fell well above Gurney's (1984) 85% line in the Ca vs. Cr diagram. This diagram is used to discriminate between fertile lherzolitic garnets and subcalcic (depleted) harzburgitic garnets that fall above and below the diagonal line, respectively. It also separates peridotitic garnets (> 2 wt.% Cr2O3) and low-Cr megacryst and eclogitic garnets (< 2 wt.%). In this study, the 23 Cr-pyropes analyzed were from fertile mantle lherzolite and ranged in composition from 3 wt.% Cr2O3 to 9.5 wt.% Cr2O3; a range also shown by garnets from other till and stream sediment studies in the area. One garnet with high Cr2O3 (10.66 wt.%) was from harzburgite, but it was not subcalcic; that is, not from potentially diamond-bearing assemblages. One other garnet was a Fe-pyrope high in CaO with no Cr2O3. This is most likely an eclogitic garnet; however, unreliable Na (0.00 wt.%) and ambiguous TiO2 (0.24 wt.%) preclude discrimination between group I (potentially diamondiferous) and group II (non-diamondiferous) eclogitic garnet. Garnets of similar composition were not found in the stream sediment study of the area (Friske et al., 2003). However, surveys north of the map area reported a few potentially eclogitic garnets (McCurdy et al., 2004). No megacryst garnets were found in any of the KIM studies in the area.

Cr-diopside

Only five grains of Cr-diopside were recovered in this study. They contained around 1 wt.% Cr2O3 and had Mg-#s (100Mg/(Mg+Fe)) between 91 and 94. This is characteristic of diopside from mantle peridotite (lherzolite), and it can safely be assumed they were transported to the surface by kimberlite. Most Cr-diopside recovered in other studies (Friske et al., 2003; McCurdy et al., 2004) fall into a similar compositional range.

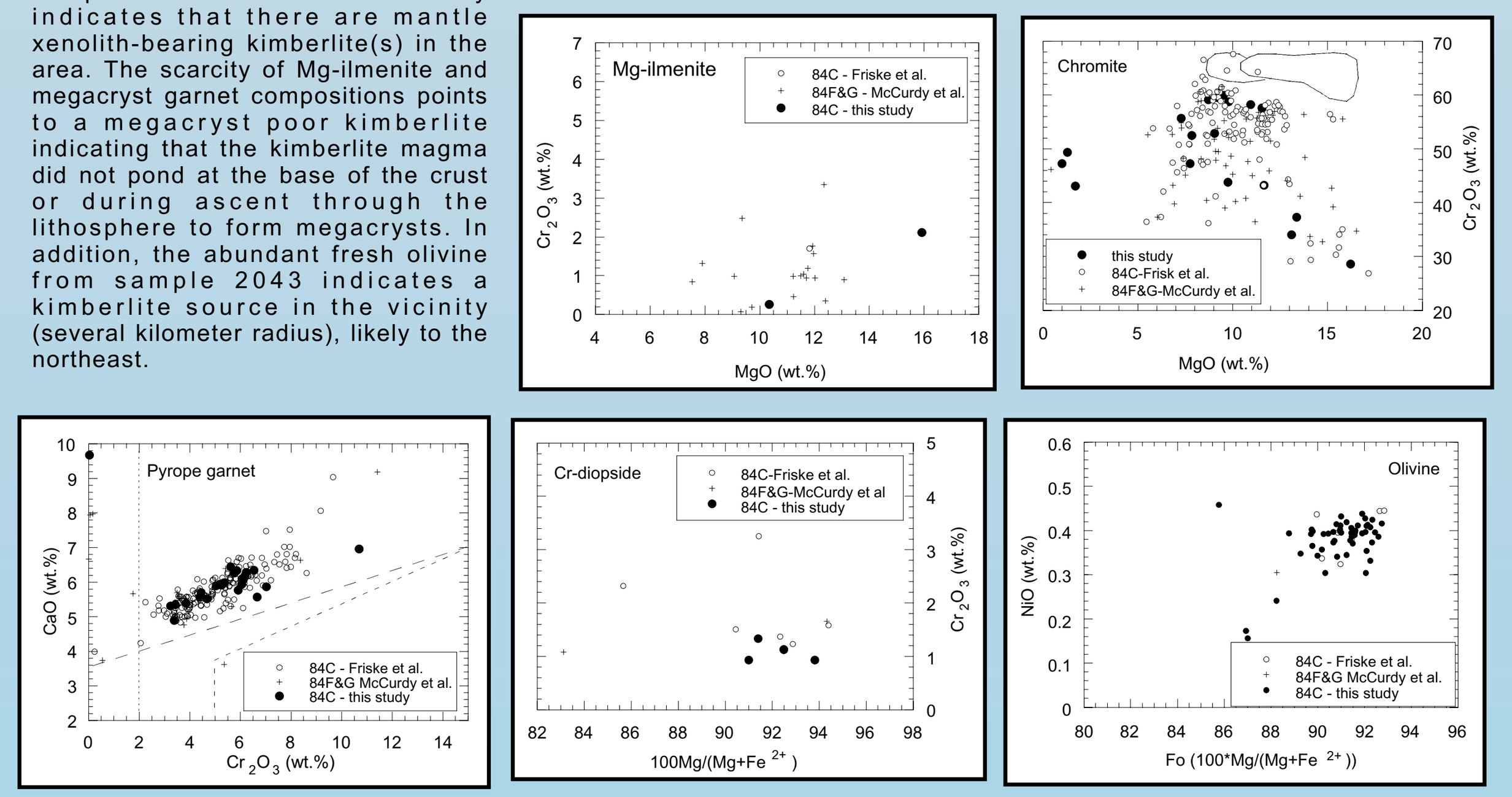
Olivine

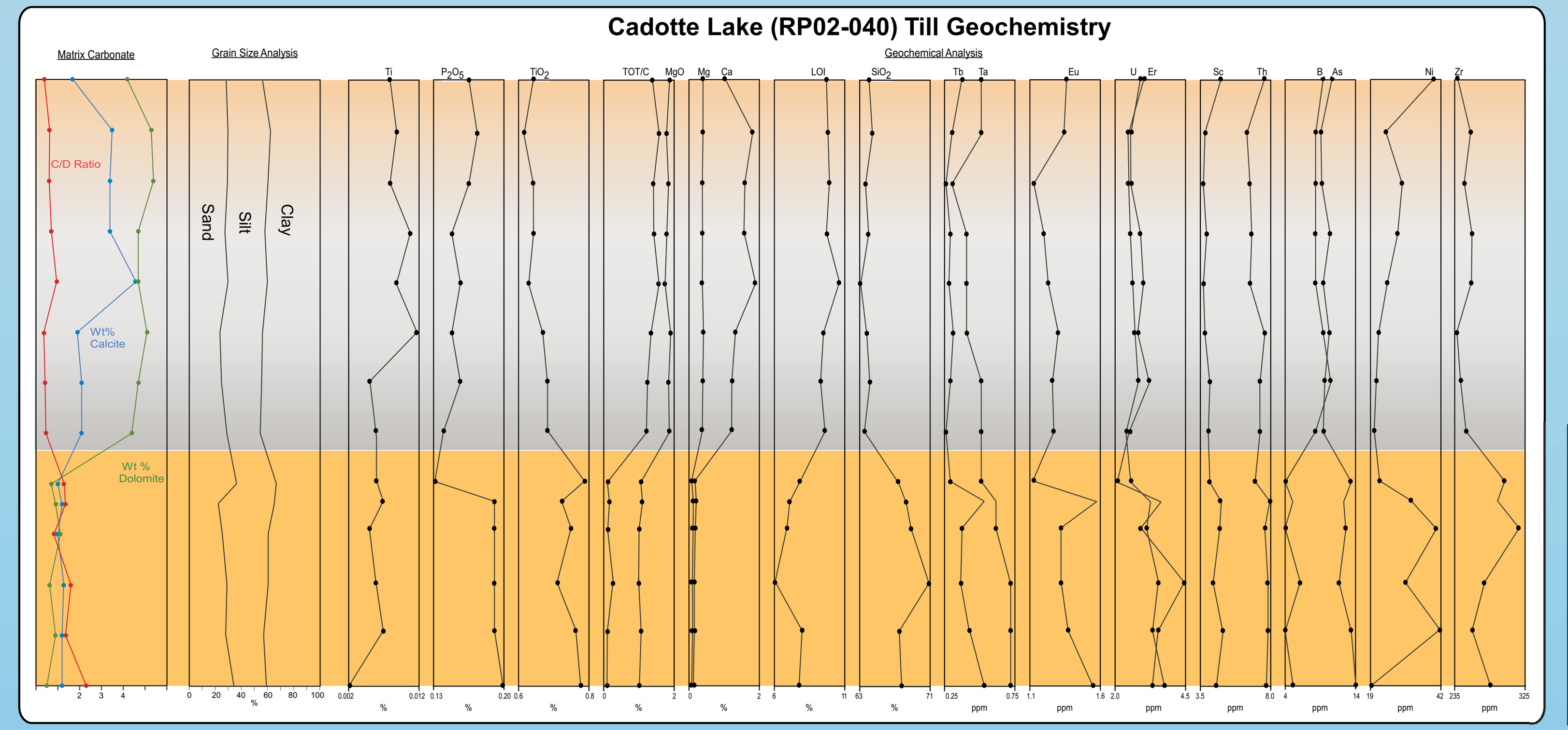
During this study, 52 grains of olivine were probed from till. Their compositions were Mg-rich (forsteritic) with Fo (equal to Mg-#) between 87 and 93 and NiO between 0.15 wt.% and 0.47 wt.%. Their compositions overlapped those of olivines from other studies (Friske et al., 2003). The more Mg and NiO-rich compositions were typical of peridotitic olivine and/or kimberlitic megacryst olivine, which were hard to distinguish compositionally. Two grains with Fo <88 and NiO <0.2 were presumed to be kimberlitic phenocryst olivine, which have slightly lower Fo and NiO than peridotitic olivine.

Regional distribution of indicator minerals

Many samples contain only one or two kimberlite indicator mineral (KIM) grains. The most KIM-rich samples were 2043 (769 grains) and 2102 (43 grains). Sample 2042 is interesting because it contains not only Cr-diopside and olivine but also the only eclogitic garnet and one of the two Mg-ilmenites. The extremely high KIM count at Cadotte Lake (samples 2042/2043) certainly makes it the most prospective in terms of unknown kimberlite occurrences. KIM grains in sample 1744, however, could have been transported from the adjacent Buffalo Head Hill kimberlites.

The presence of these minerals clearly indicates that there are mantle xenolith-bearing kimberlite(s) in the area. The scarcity of Mg-ilmenite and megacryst garnet compositions points to a megacryst poor kimberlite indicating that the kimberlite magma did not pond at the base of the crust or during ascent through the lithosphere to form megacrysts. In addition, the abundant fresh olivine from sample 2043 indicates a kimberlite source in the vicinity (several kilometer radius), likely to the northeast.





Microprobe Analysis

Garnets

Sample	Mineral	mg-#	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
1739-01	Cr-pyrope	80.55	41.651	0.018	19.335	5.862	7.959	0.467	18.485	6.335	0.000	0.002	100.114
1742-01	Cr-pyrope	80.87	41.606	0.064	20.106	4.678	8.196	0.495	19.438	5.517	0.025	0.003	100.128
1742-001	Cr-pyrope	81.55	41.234	0.005	19.565	5.611	7.773	0.505	19.278	6.447	0.000	0.001	100.418
1742-002	Cr-pyrope	83.60	41.793	0.010	21.367	3.390	7.329	0.436	20.959	4.895	0.009	0.000	100.189
1744-001	Cr-pyrope	80.91	41.431	0.010	21.223	3.432	8.264	0.539	19.647	5.348	0.007	0.000	99.902
2031-01	Cr-pyrope	82.89	41.299	0.003	19.602	5.915	7.230	0.397	19.645	5.768	0.026	0.005	99.890
2031-02	Cr-pyrope	83.10	41.590	0.043	19.144	6.047	7.154	0.395	19.733	5.940	0.005	0.004	100.055
2042-002	Fe-Pyrope	59.37	40.685	0.125	22.681	0.034	14.962	0.376	12.265	9.673	0.012	0.000	100.813
2043-01	Cr-pyrope	80.19	41.047	0.010	20.003	5.264	8.213	0.491	18.656	5.913	0.000	0.004	99.601
2043-02	Cr-pyrope	80.05	41.512	0.054	20.991	3.849	8.572	0.482	19.297	5.392	0.000	0.002	100.151
2043-03	Cr-pyrope	80.56	41.035	0.051	19.189	6.221	8.046	0.500	18.709	6.283	0.014	0.003	100.051
2043-04	Cr-pyrope	81.02	41.154	0.007	18.959	6.543	7.795	0.555	18.666	6.349	0.018	0.003	100.049
2043-05	Cr-pyrope	80.49	41.835	0.065	19.023	6.130	8.119	0.479	18.791	6.103	0.014	0.000	100.559
2043-06	Cr-pyrope	80.68	41.488	0.027	19.216	6.168	8.059	0.478	18.876	6.177	0.006	0.000	100.495
2043-07	Cr-pyrope	80.86	41.214	0.080	19.767	5.369	8.116	0.508	19.240	5.986	0.024	0.004	100.308
2043-014	Cr-pyrope	80.79	41.086	0.018	19.248	5.768	8.037	0.513	18.959	6.261	0.009	0.000	99.899
2043-015	Cr-pyrope	81.04	41.050	0.038	19.067	6.062	8.027	0.465	19.250	6.093	0.011	0.000	100.063
2043-016	Cr-pyrope	81.10	41.400	0.013	20.471	4.401	8.147	0.478	19.616	5.570	0.010	0.000	100.106
2043-017	Cr-pyrope	80.85	41.767	0.028	20.135	4.449	8.277	0.509	19.605	5.696	0.007	0.003	100.476
2043-018	Cr-pyrope	80.64	41.163	0.017	19.673	5.182	8.300	0.509	19.395	5.932	0.008	0.000	100.177
2043-019	Cr-pyrope	80.98	41.287	0.018	19.878	5.051	8.181	0.486	19.533	5.899	0.009	0.000	100.342
2099-01	Cr-pyrope	78.95	41.377	0.222	18.674	6.667	8.874	0.561	18.672	5.564	0.041	0.000	100.652
2099-02	Cr-pyrope	81.91	41.076	0.349	17.860	7.022	7.604	0.403	19.318	5.866	0.040	0.000	99.538
2099-03	Cr-pyrope	79.50	41.983	0.032	21.348	3.245	8.891	0.506	19.347	5.307	0.005	0.002	100.666
2161-001	Cr-pyrope	83.68	40.658	0.043	14.761	10.688	6.744	0.337	19.399	6.956	0.006	0.000	99.594

Oxides

Sample	Mineral	Nb2O5	SiO2	TiO2	Al2O3	Cr2O3	V2O5	MnO	FeO*	NiO	MgO	ZnO	Total	Fe2O3	FeO	Total
Chromites																
1738-001	chromite	0.000	0.000	0.114	6.354	47.252	0.204	0.967	42.401	0.047	1.003	0.354	98.697	13.294	30.438	100.029
1739-001	chromite	0.000	0.023	2.643	6.040	47.246	0.499	0.375	33.823	0.190	7.758	0.118	98.715	11.511	23.466	99.869
1742-02	chromite	0.072	0.067	0.165	10.826	52.513	0.264	0.394	26.910	0.051	7.843	0.109	99.214	5.673	21.805	99.782
1742-003	chromite	0.015	0.049	1.497	21.402	37.301	0.191	0.210	24.872	0.199	13.371	0.067	99.172	9.693	16.150	100.143
1742-004	chromite	0.000	0.032	0.248	19.604	43.105	0.300	0.803	30.929	0.021	1.709	2.978	99.729	1.402	29.667	99.869
2026-01	chromite	0.000	0.061	0.063	9.304	55.672	0.214	0.349	25.410	0.037	7.288	0.179	98.577	3.870	21.928	98.965
2026-001	chromite	0.007	0.000	0.150	19.699	34.026	0.144	0.319	30.218	0.240	13.101	0.112	98.016	17.463	14.505	99.766
2037-001	chromite	0.000	0.000	0.272	12.856	49.377	0.184	1.133	33.805	0.044	1.295	0.381	99.348	3.143	30.977	99.663
2043-08	chromite	0.000	0.087	0.421	6.144	59.159	0.294	0.395	22.442	0.105	8.723	0.119	97.889	3.351	19.427	98.225
2043-001	chromite	0.000	0.006	0.123	27.905	28.573	0.053	0.326	25.047	0.225	16.208	0.094	98.560	15.564	11.043	100.119
2043-002	chromite	0.063	0.000	0.143	11.526	57.588	0.305	0.277	18.389	0.074	11.542	0.152	100.058	2.134	16.469	100.272
2043-003	chromite	0.000	0.002	0.410	6.286	59.527	0.282	0.336	22.466	0.099	9.204	0.165	98.777	3.973	18.892	99.175
2043-020	chromite	0.000	0.000	0.022	7.999	58.232	0.266	0.307	21.298	0.097	10.948	0.108	99.277	5.461	16.384	99.824
2043-021	chromite	0.000	0.001	1.389	10.646	43.828	0.138	0.466	32.368	0.234	9.741	0.130	98.941	14.401	19.410	100.384
2043-022	chromite	0.000	0.000	0.438	6.120	58.725	0.243	0.421	23.400	0.101	9.788	0.149	99.386	5.902	18.089	99.977
2102-008	chromite	0.027	0.000	1.224	6.968	52.893	0.292	0.413	27.922	0.158	9.037	0.140	99.074	8.705	20.089	99.946
2102-009	chromite	0.013	0.045	2.201	13.852	43.202	0.229	0.241	27.197	0.223	11.650	0.087	98.939	10.067	18.138	99.947
2161-002	chromite	0.021	0.000	0.485	7.492	59.986	0.187	0.389	21.155	0.080	9.516	0.130	99.442	2.695	18.730	99.712
Picro-ilmenite																
1744-004	Mg-ilmenite	0.278	0.006	54.474	0.996	2.108	0.428	0.273	24.948	0.157	15.916	0.004	99.589	4.192	21.176	100.009
2042-001	Mg-ilmenite	0.375	0.000	51.285	0.376	0.259	0.265	0.262	36.189	0.038	10.344	0.000	99.393	8.869	28.209	100.281

Pyroxenes

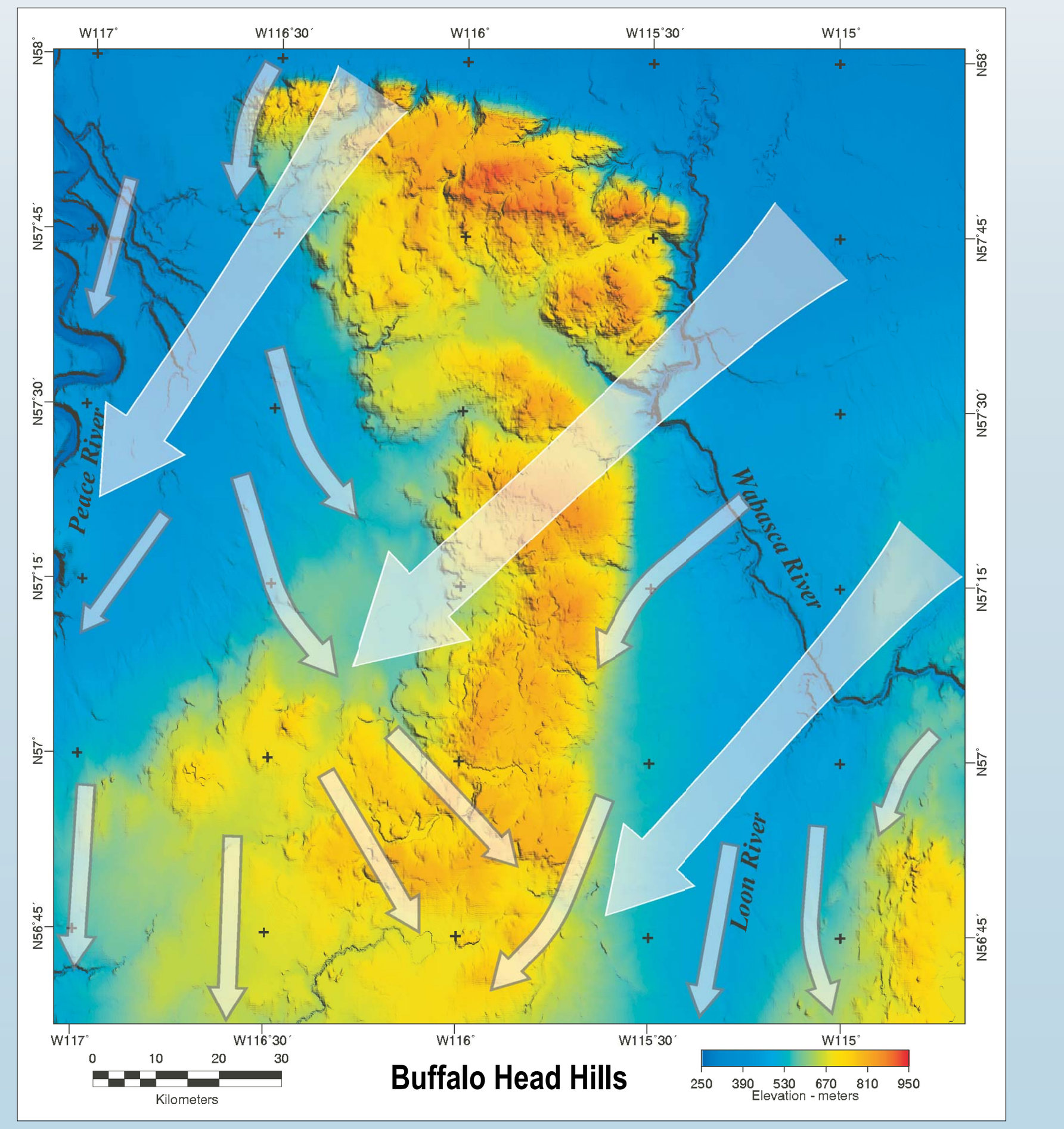
Sample	Mineral	mg-#	SiO2	TiO2	Al2O3	Cr2O3	MgO	CaO	MnO	FeO	Na2O	K2O	Total
1744-002	Cr-diopside	92.50	54.790	0.045	1.667	1.130	16.455	21.560	0.075	2.380	1.557	0.001	99.658
1744-003	Cr-diopside	92.49	54.848	0.049	1.641	1.123	16.383	21.540	0.090	2.370	1.532	0.000	99.577
2042-01	Cr-diopside	93.81	54.318	0.012	1.350	0.934	16.835	22.939	0.071	1.979	1.007	0.001	99.446
2042-02	Cr-diopside	91.00	51.399	0.187	6.827	0.932	15.174	21.070	0.078	2.676	1.337	0.003	99.683
2042-03	Cr-diopside	91.40	50.891	0.507	6.989	1.330	14.747	20.424	0.085	2.472	1.544	0.004	98.993

Olivines

Sample	Mineral	mg-# (Fo)	SiO2	TiO2	Al2O3	Cr2O3	MgO	CaO	MnO	FeO*	CoO	NiO	Total	Ni ppm	Size (mm)
1738-002	olivine	91.23	40.645	0.014	0.004	0.003	49.983	0.028	0.155	8.562	0.014	0.345	99.753	2712	0.25-0.5
2035-001	olivine	89.25	40.136	0.022	0.016	0.026	48.058	0.044	0.117	10.314	0.021	0.348	99.102	2732	0.5-1.0
2035-002	olivine	87.00	40.277	0.024	0.008	0.013	47.032	0.032	0.134	12.527	0.022	0.156	100.225	1227	0.5-1.0
2035-003	olivine	85.76	39.555	0.004	0.000	0.001	45.676	0.000	0.226	13.515	0.028	0.458	99.465	3602	0.25-0.5
2035-004	olivine	90.25	40.928	0.011	0.024	0.037	48.678	0.058	0.110	9.376	0.014	0.392	99.627	3079	0.25-0.5
2035-005	olivine	91.90	40.765	0.000	0.000	0.002	50.101	0.002	0.111	7.874	0.021	0.438	99.315	3441	0.25-0.5
2035-006	olivine	86.93	40.143	0.035	0.008	0.008	46.671	0.036	0.142	12.504	0.028	0.173	99.748	1361	0.25-0.5
2042-003	olivine	91.59	40.857	0.003	0.001	0.009	50.096	0.009	0.123	8.199	0.015	0.396	99.707	3110	0.25-0.5
2042-004	olivine	90.96	41.039	0.012	0.014	0.080	49.575	0.065	0.127	8.785	0.014	0.403	100.113	3168	0.25-0.5
2042-005	olivine	92.44	41.095	0.004	0.000	0.010	50.856	0.007	0.111	7.412	0.015	0.396	99.907	3112	0.25-0.5
2042-006	olivine	88.77	40.415	0.022	0.004	0.010	48.128	0.009	0.164	10.852	0.021	0.394	100.018	3095	0.25-0.5
2043-004	olivine	92.03	41.069	0.000	0.000	0.010	50.242	0.006	0.102	7.755	0.010	0.427	99.622	3357	0.5-1.0
2043-005	olivine	90.45	40.554	0.000	0.000	0.005	49.353	0.001	0.171	9.294	0.026	0.393	99.798	3085	0.5-1.0
2043-006	olivine	92.33	41.305	0.000	0.004	0.011	51.071	0.009	0.097	7.562	0.018	0.425	100.500	3337	0.5-1.0
2043-007	olivine	91.90	41.043	0.011	0.000	0.010	50.825	0.009	0.107	7.987	0.016	0.394	100.402	3095	0.5-1.0
2043-009	olivine	91.58	41.052	0.000	0.000	0.010	50.121	0.011	0.140	8.213	0.010	0.390	99.947	3062	0.5-1.0
2043-010	olivine	90.67	40.715	0.027	0.000	0.006	49.190	0.008	0.141	9.020	0.016	0.373	99.496	2928	0.5-1.0
2043-011	olivine	90.17	41.041	0.025	0.030	0.039	48.700	0.068	0.123	9.464	0.017	0.357	99.862	2802	0.5-1.0
2043-012	olivine	89.98	40.819	0.019	0.001	0.011	48.898	0.011	0.163	9.703	0.026	0.343	99.992	2698	0.5-1.0
2043-013	olivine	89.72	40.068	0.022	0.000	0.002	48.742	0.007	0.125	9.960	0.021	0.392	99.339	3080	0.5-1.0
2043-023	olivine	91.45	40.796	0.001	0.000	0.000	50.179	0.000	0.125	8.364	0.013	0.386	99.864	3034	0.25-0.5
2043-024	olivine	91.72	40.950	0.005	0.000	0.010	50.452	0.009	0.127	8.123	0.014	0.411	100.100	3232	0.25-0.5
2043-025	olivine	89.73	40.454	0.000	0.001	0.007	49.111	0.009	0.152	10.015	0.012	0.402	100.162	3157	0.25-0.5
2043-026	olivine	92.13	41.095	0.000	0.002	0.010	50.466	0.012	0.103	7.687	0.015	0.413	99.805	3244	0.25-0.5
2043-027	olivine	90.71	40.854	0.012	0.000	0.004	49.614	0.014	0.137	9.062	0.021	0.376	100.097	2958	0.25-0.5
2043-028	olivine	91.49	40.734	0.014	0.001	0.013	50.211	0.004	0.134	8.323	0.025	0.371	99.830	2915	0.25-0.5
2043-029	olivine	92.25	41.071	0.001	0.001	0.013	50.588	0.007	0.106	7.578	0.013	0.408	99.785	3205	0.25-0.5
2043-030	olivine	92.04	41.116	0.000	0.003	0.004	50.173	0.008	0.111	7.733	0.013	0.397	99.557	3119	0.25-0.5
2043-031	olivine	91.51	41.075	0.000	0.000	0.010	49.734	0.007	0.138	8.226	0.022	0.391	99.603	3072	0.25-0.5
2043-032	olivine	90.94	40.825	0.009	0.026	0.076	49.624	0.074	0.116	8.808	0.023	0.399	99.979	3136	0.25-0.5
2102-001	olivine	92.59	41.123	0.007	0.006	0.030	51.283	0.019	0.093	7.315	0.020	0.386	100.281	3032	0.5-1.0
2102-002	olivine	90.83	40.544	0.001	0.001	0.020	49.220	0.015	0.158	8.862	0.017	0.341	99.177	2679	0.5-1.0
2102-003	olivine	92.09	41.164	0.002	0.002	0.001	50.351	0.000	0.108	7.706	0.024	0.411	99.770	3228	0.5-1.0
2102-004	olivine	90.99	41.374	0.000	0.002	0.006	49.510	0.012	0.100	8.735	0.016	0.395	100.149	3106	0.5-1.0
2102-005	olivine	92.08	41.273	0.008	0.001	0.007	50.462	0.015	0.139	7.734	0.021	0.354	100.012	2783	0.5-1.0
2102-006	olivine	91.23	40.775	0.009	0.007	0.017	50.060	0.015	0.099	8.576	0.012	0.419	99.990	3295	0.5-1.0
2102-007	olivine	90.32	40.567	0.019	0.003	0.000	49.018	0.020	0.163	9.369	0.014	0.304	99.478	2390	0.5-1.0
2102-010	olivine	92.74	41.199	0.012	0.000	0.008	51.172	0.005	0.096	7.136	0.018	0.416	100.062	3269	0.25-0.5
2102-011	olivine	89.79	40.265	0.015	0.000	0.007	48.583	0.012	0.127	9.850	0.026	0.399	99.285	3132	0.25-0.5
2102-012	olivine	91.01	40.610	0.004	0.026	0.089	49.555	0.080	0.118	8.728	0.015	0.432	99.655	3397	0.25-0.5
2102-013	olivine	91.43	40.681	0.000	0.024	0.089	49.565	0.072	0.109	8.284	0.015	0.394	99.234	3098	0.25-0.5
2102-014	olivine	89.77	40.343	0.027	0.020	0.042	48.371	0.054	0.119	9.831	0.012	0.365	99.184	2871	0.25-0.5
2102-015	olivine	92.24	41.172	0.010	0.000	0.003	50.595	0.015	0.148	7.587	0.012	0.331	99.873	2604	0.25-0.5
2102-016	olivine	91.40	40.724	0.008	0.017	0.079	49.607	0.049	0.113	8.325	0.016	0.378	99.316	2969	0.25-0.5
2102-017	olivine	90.66	40.886	0.020	0.021	0.044	49.183	0.065	0.118	9.029	0.015	0.397	99.778	3118	0.25-0.5
2102-018	olivine	90.98	40.939	0.019	0.009	0.019	49.370	0.025	0.103	8.727	0.018	0.412	99.641	3234	0.25-0.5
2102-019	olivine	91.44	40.753	0.011	0.020	0.082	49.794	0.069	0.113	8.314	0.017	0.406	99.579	3193	0.25-0.5
2102-020	olivine	91.61	41.073	0.000	0.003	0.011	50.121	0.009	0.108	8.180	0.026	0.400	99.932	3142	0.25-0.5
2102-021	olivine	88.24	40.487	0.023	0.014	0.021	47.634	0.044	0.128	11.315	0.026	0.241	99.932	1896	0.25-0.5
2102-022	olivine	92.05	41.172	0.004	0.003	0.000	50.177	0.017	0.142	7.720	0.021	0.304	99.560	2391	0.25-0.5
2102-023	olivine	92.32	41.466	0.007	0.000	0.013	50.605	0.009	0.099	7.500	0.016	0.373	100.089	2934	0.25-0.5
2162-001	olivine	90.80	40.762	0.016	0.028	0.065	49.085	0.072	0.112	8.869	0.024	0.415	99.447	3257	0.25-0.5
Epidote?															
2043-008			38.117	0.082	25.756	0.008	0.018	23.119	0.168	8.736	0.008	0.007	96.017	51	0.5-1.0

Bulk Till Sample Sites

Sample Number	NTS (1:50000)	Datum	Zone	Easting	Northing	Elevation (m)	Material	Weight (kg)	Site Location	Depth (m)	Munsell Colour Code	Munsell Colour Colour	Texture	Clast Content (%)	Comments
1735	84F/03	NAD83	11	499186	6317432	515	lodgment till	32.15	borrow pit	2.00	10YR3/3	dark brown	clayey silt	2 - 8	under 3 - 4m of glacilacustrine sediments
1737	84C/14	NAD83	11	495912	6299198	550	lodgment till	33.70	road cut	1.50	2.5Y4/2	dark greyish brown	clayey silt	2 - 8	under 3 - 4m of glacilacustrine sediments
1738	84C/10	NAD83	11	504218	6277046	550	lodgment till	34.25	creek section	6.00	10YR4/1	dark grey	clayey silt	2 - 8	under 3 - 4m of glacilacustrine sediments
1739	84C/07	NAD83	11	503827	6258065	575	lodgment till	34.10	borrow pit	1.70	10YR3/3	dark brown	sandy silt	2 - 8	good dense blocky till; numerous stones
1742	84C/16	NAD83	11	549609	6297676	730	melt-out till	33.85	road cut	3.00	10YR3/3	dark brown	sandy silt	2 - 8	sample taken 0.5m above lower boulder layer; strongly calcareous
1743	84C/09	NAD83	11	544927	6271276	660	melt-out till	31.70	road cut	1.90	10YR4/1	dark grey	silty clay	2 - 8	
1744	84C/09	NAD83	11	559057	6266948	630	melt-out till	37.70	borrow pit	3.50	2.5Y4/2	dark greyish brown	clayey silt	2 - 8	
2026	84C/02	NAD83	11	525235	6217437	704	melt-out till	24.05	borrow pit	1.40	10YR3/2	very dark greyish brown	silty sand	2 - 4	
2031	84C/01	NAD83	11	545918	6207220	697	melt-out till	27.10	borrow pit	3.00	10YR3/2	very dark greyish brown	clayey silt	2 - 5	
2035	84C/01	NAD83	11	544188	6219938	707	melt-out till	30.30	road cut	0.80	2.5Y4/2	dark greyish brown	clayey silt	3 - 6	
2037	84C/01	NAD83	11	553809	6225108	696	melt-out till	32.35	trench	2.00	2.5Y3/1	very dark grey	clayey silt	3 - 6	
2042	84C/01	NAD83	11	548117	6231507	705	lodgment till	28.45	borrow pit	1.00	2.5Y4/3	olive brown	sandy silt	3 - 6	upper section of 2042 - 2043
2043	84C/01	NAD83	11	548117	6231507	705	lodgment till	32.15	borrow pit	1.00	10YR4/4	dark yellowish brown	sandy silt	5 - 8	lower section of 2042 - 2043 (oxidized)
2045	84C/08	NAD83	11	549756	6245173	625	melt-out till	30.00	borrow pit	4.00	10YR4/2	dark greyish brown	clayey silt	2 - 8	
2099	84C/02	NAD83	11	505504	6217217	610	lodgment till	33.60	trench	3.00	10YR3/1	very dark grey	clayey silt	2 - 8	(Backhoe pit) under 3 - 4m of glacilacustrine sediments
2102	84C/16	NAD83	11	553277	6307511	740	melt-out till	37.55	road cut	2.30	2.5Y4/2	dark greyish brown	clayey silt	2 - 8	
2157	84F/02	NAD83	11	505244	6327593	510	lodgment till	37.50	borrow pit	3.50	2.5Y4/2	dark greyish brown	clayey silt	2 - 8	
2161	84C/15	NAD83	11	530055	6303568	675	melt-out till	33.30	borrow pit	2.30	10YR5/2	brownish grey	clayey silt	2 - 8	
2162	84C/16	NAD83	11	545395	6304118	770	melt-out till	32.20	road cut	2.00	10YR5/2	brownish grey	clayey silt	2 - 8	



Ice flow reconstruction for the Buffalo Head Hills (Paulen and McClenaghan, in press).

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