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The Diamond Potential of Alberta

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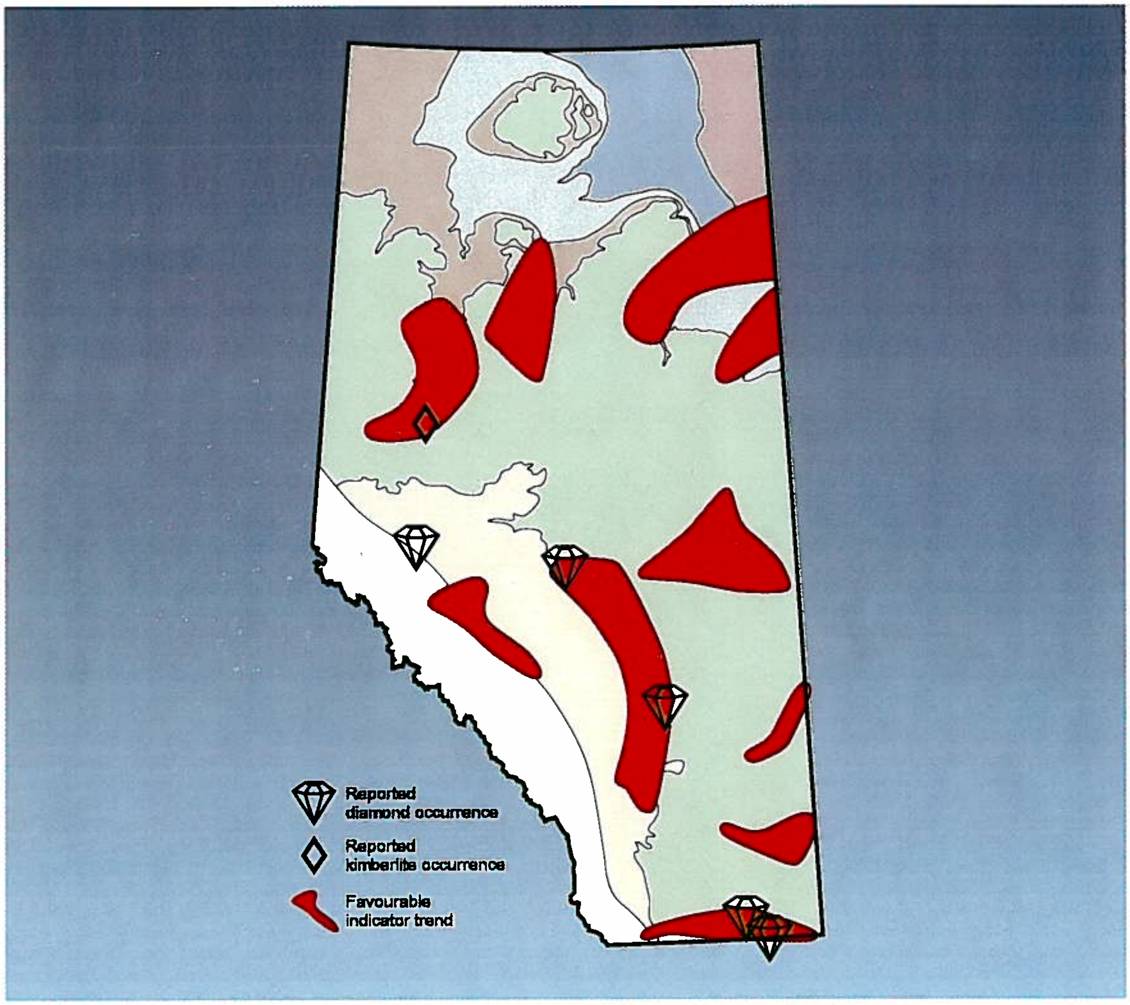

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The Diamond Potential of Alberta

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Cover: Reported diamond and kimberlite occurrences with favourable diamond indicator mineral trends (cf. Figure 33).

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Contents

Figures

Tables

Appendices

Abstract

This study by the Alberta Geological Survey which was funded by the Canada-Alberta Partnership on Minerals, was undertaken in response to the discovery of diamonds in kimberlitic diatremes in the Lac de Gras area of the Northwest Territories and the Fort à la Corne area of Saskatchewan. These discoveries indicate that potential exists for the discovery of diamondiferous diatremes in other areas of Canada, such as Alberta.

The primary objectives of this study were to identify geological anomalies and target areas for diamond exploration, and to provide selected geological, geophysical and geochemical data that would assist industry in its exploration for diamonds in Alberta.

Alberta is favourable for diamondiferous deposits because: (1) the Province is underlain by large areas of thick Precambrian crust that acted as "cool roots"; (2) Alberta contains major faults, arches, grabens and other tectonic features that may have provided conduits for the intrusion of diamond-bearing kimberlitic or lamproitic diatremes; (3) there is evidence of at least four, and possibly five ages of volcanic activity in Alberta, including mid-Cretaceous to Late Cretaceous, which was the most prolific period for diamondiferous kimberlitic volcanism in the world; (4) numerous bentonites and tuffs exist in the Phanerozoic succession in Alberta, and in several places the bentonitic horizons are anomalously thick (up to 11.6 m) and may have resulted from local volcanic venting; and (5) there are a large number of geological, geophysical and geochemical anomalies in Alberta that may have been, or are related, to the emplacement of potentially diamondiferous kimberlitic or lamproitic diatremes.

To date, diamond exploration by industry also indicates that Alberta has potential to host diamondiferous kimberlite or lamproite deposits. The first kimberlitic intrusion reported in Alberta has been discovered in the Wapiti Group near Grande Prairie. Diamonds have been discovered in surficial sediments west of Edmonton at locations near Evansburg and Hinton, in southern Alberta in the Sweetgrass Hills area, and in Cretaceous-Tertiary sediments southeast of Red Deer. There are numerous diamond indicator mineral anomalies in Alberta, with some indicator grains having excellent chemistry indicative of possible local diamondiferous kimberlitic or lamproitic diatremes.

Although Alberta has the potential to contain diamondiferous diatremes, the province has barely been explored for such deposits. Extensive drift, poor bedrock exposure and reworking of diamond indicator minerals in multiple cycles has hindered exploration across much of Alberta. Further geoscientific work is required to delineate areas of high potential and to further stimulate industry exploration activities.

Introduction

The existence of diamondiferous kimberlite diatremes in the Northwest Territories (NWT), Saskatchewan and Ontario indicate that potential exists for diamondiferous kimberlite diatremes in Alberta and elsewhere in Canada. Areas underlain by thick Precambrian basement rocks, such as most of Alberta, are regarded as having the highest possible potential for the discovery of diamondiferous diatremes. Diatreme emplacement is controlled by structures that transect the Precambrian basement, the Phanerozoic cover, or both. Emplacement of diatremes into Phanerozoic bedrock may also give rise to economic diamond concentrations in placer or paleoplacer deposits, such as the deposits currently under evaluation in Saskatchewan.

A kimberlite has been discovered at Mountain Lake in the Peace River-Grande Prairie region of Alberta. Diamonds have been discovered in Recent stream sediments in central Alberta near Hinton and near Evansburg, in Cretaceous-Tertiary sediments near Red Deer, in the Black Butte diatreme and in Recent stream sediments near the Sweetgrass Hills in southeast Alberta. These discoveries, coupled with the favourable geology which exists in Alberta indicate that the potential is high for the discovery of economic diamond deposits.

A large literature database from government sources, universities and private industry provide geoscience information that can be used to delineate features that may be important in the exploration for diamondiferous kimberlite or lamproite diatremes in Alberta. This study was undertaken on behalf of the Canada-Alberta Partnership Agreement on Mineral Development (MDA project M93-04-037) in order to summarize and synthesize some of the key existing data that pertain to the geological potential of Alberta to contain important diamond deposits.

The objectives of preparing this regional synthesis of structural, stratigraphic, geophysical, geochemical and diamond indicator mineral data for Alberta were:

(1) To identify favourable geological anomalies and target areas for diamond exploration that would encourage and assist exploration by industry.

(2) To provide information about certain geologic and geographic domains in Alberta, based upon selected criteria such as: (a) potential for kimberlite versus lamproite diatremes based on the underlying Precambrian basement rocks; (b) timing of possible kimberlite or lamproite magmatism; (c) regional structures with potential to provide conduits for kimberlite or lamproite magmas; (d) stratigraphic data that may be indicative of local diatreme extrusion; and (e) state of preservation of kimberlite or lamproite intrusions.

(3) To identify existing exploration methods which may be useful for application in Alberta. This information is important to diamond exploration in Alberta because: (a) Phanerozoic kimberlite or lamproite diatreme activity in Alberta would probably have occurred under marine to subaerial conditions and would likely have been subsequently buried by further sedimentation; (b) there has been extensive reworking of sediments by Tertiary erosion and drainage systems originating in the Cordillera; and (c) the glacial history of western Alberta is complex, due to the interaction between Cordilleran and Continental glacier complexes.

Kimberlites and Lamproites

Kimberlites and lamproites are currently the only two known economic primary sources of diamonds. However, the Parker Lake discovery of a diamondiferous lamprophyre dyke in the eastern NWT may change current concepts regarding favourable diamondiferous host rocks (Northern Miner, 1995a). Diamonds in the kimberlite or lamproite magma occur as xenocrysts and are classified as either E-type (eclogitic) or P-type (peridotitic).

Two types of kimberlites are recognized worldwide, Group I and Group II, corresponding to the original classification by Wagner (1914) of olivine kimberlites and micaceous kimberlites. **Group I kimberlites** are petrographically complex rocks, containing material derived from three different sources: (1) upper mantle xenoliths; (2) primary mineral phases crystallizing directly from the kimberlite magma; and (3) the megacryst/macrocryst or discrete nodule suite (Mitchell, 1989, 1991; Skinner, 1989; Scott Smith, 1995). Xenocrysts in Group I kimberlites include G9 and G10 peridotitic garnets, olivine, chromium-diopside, high-chromium chromites and diamond (Mitchell, 1989, 1991; Skinner, 1989; Gurney and Moore, 1993). Megacrysts are large (1 to 20 cm) single crystals of G1 or G2 garnets, magnesian (picro) ilmenite, subcalcic to calcic diopside, olivine, titanium-poor chromite, enstatite, phlogopite and zircon. Macrocrysts are smaller crystals, that are rounded to subrounded and compositionally similar to the megacryst mineral suite, but with abundant olivine. The megacryst/macrocryst mineral suites are either xenocrysts or cognate phenocrysts, or a combination of both. They are believed to form in the upper mantle, and are indicative of kimberlite magmatism. Primary phenocryst and groundmass minerals include olivine, phlogopite, perovskite, spinel, monticellite, apatite, calcite and primary serpentine. Group I kimberlites are characterized by the presence of abundant olivine, the characteristic megacryst/macrocryst suite and minor phlogopite.

Group II kimberlites are comprised principally of rounded olivine macrocrysts in a matrix of abundant phlogopite and diopside, with spinel, perovskite and calcite (Mitchell, 1989, 1991; Skinner, 1989; Scott Smith, 1995). Group II kimberlites lack the megacryst suite and minerals such as monticellite and ulvöspinel. In addition, spinels and perovskite are relatively rare. To date, Group II kimberlites have been found only in southern Africa.

There are three textural-genetic groups or facies of kimberlites recognized worldwide (Figure 1): (1) crater facies; (2) diatreme facies; and (3) hypabyssal facies (Mitchell, 1986, 1989, 1991). The crater facies includes epiclastic deposits and tuffs that form a low ring around the kimberlite vent. Diatremes are upright, 'carrot-shaped' bodies comprised of tuffisitic kimberlite breccia or volcaniclastic kimberlite breccia (Mitchell, 1991). Kimberlite diatremes grade downward into irregularly-shaped root zones of hypabyssal facies kimberlite. Crater facies rocks can be significant sources of diamonds (Helmstaedt, 1992, 1993). Diamond grades can be highly variable in the diatreme and root zones.

Lamproites are petrographically complex, hybrid rocks consisting of complex mixtures of magmatic phenocrysts with upper mantle xenoliths and xenocrysts (Helmstaedt, 1993). Lamproites are referred to as ultrapotassic, peralkaline mafic to ultramafic rocks that exhibit a characteristic exotic mineralogy and distinctive geochemical signature (Bergman, 1987; Mitchell, 1989, 1991; Scott Smith, 1992). Mineralogically similar to kimberlites, lamproites are distinguished from kimberlites by the presence of leucite, amphibole (K-Ti richterite), sanidine, priderite, wadeite, armalcolite and jeppeite (Bergman, 1987; Mitchell, 1989, 1991; Scott Smith, 1992). Lamproites also differ from kimberlites by having matrix glass and a relatively low calcite content (Mitchell, 1991). Geochemically, lamproites typically contain 6 to 8 weight per cent (wt%) K_2O in comparison to 2 wt% or less for Group I kimberlites. They are peralkaline ($K_2O+Na_2O+Al_2O_3 \geq 1$), and they are enriched relative to kimberlites in incompatible elements such as barium, rubidium, strontium, zirconium and light rare earth elements (REE's) and depleted in cobalt, chromium and nickel.

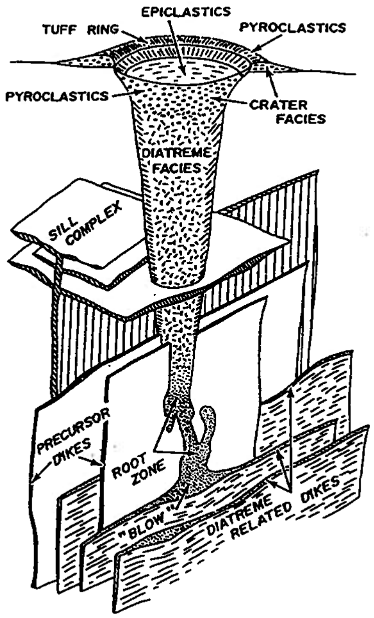
Lamproites occur primarily as extrusive, subvolcanic and hypabyssal rocks (Mitchell, 1991). They rarely form diatremes and root zones analogous to kimberlites. Their vents are shallow and wide, and commonly are fluted like a champagne glass (Figure 1). Composite craters with associated bedded volcaniclastic deposits and volcanic debris are common where craters are preserved. The crater facies is commonly intruded by magmatic lamproite. Diamonds occur mainly in the pyroclastic crater facies rocks (Scott Smith, 1995). The diamond tonnage potential of lamproites tends to be related to the volume of pyroclastics preserved (Helmstaedt, 1992, 1993).

It is generally accepted that diamonds form at pressures equivalent to 150 km to 300 km below the Earth's surface, and at temperatures less than 1,200 degrees Celsius (°C). These conditions occur within cool lithospheric roots, where the downward deflection of isotherms causes a corresponding upward expansion of the diamond stability field in the upper mantle. Macrodiamonds in kimberlite and lamproite host rocks are derived from the disaggregation of source rocks in the lithospheric upper mantle (Kirkley *et al.*, 1991, 1992; Gurney and Moore, 1993). Kimberlite and lamproite magmas, which originate in the upper mantle or deeper, then provide the transport medium to move diamonds formed in the upper mantle to the surface.

Four major factors influence whether a kimberlite or lamproite may contain an economic diamond deposit: (1) the source rock must originate in or below the diamond stability field; (2) the ascending kimberlite or lamproite magma must sample the diamond-bearing source region(s); (3) the host magma must ascend quickly and adiabatically for diamonds to survive the transport to the Earth's surface; and (4) there must be emplacement sites conducive to the formation of large pipes (Helmstaedt, 1993).

Kimberlites and lamproites occur within both Archean cratons and Proterozoic mobile belts, but 'Clifford's Rule', which is based on empirical observation (Clifford, 1966, 1970; Janse, 1991), states that economically viable diamond deposits are confined to Archean cratons. However, an exception to Clifford's Rule is the Argyle deposit in Western Australia, which is hosted in a lamproite that intrudes a Proterozoic fold belt and contains mostly E-type diamonds of Proterozoic age (Jaques *et al.*, 1986). The Argyle example illustrates that large accumulations of post-Archean, E-type diamonds can occur outside of, but adjacent to, Archean cratons (Helmstaedt, 1993).

a) Model of an idealized kimberlite magmatic system (not to scale) illustrating the relationships between crater, diatreme and hypabyssal facies rocks. The diatreme root zone is composed primarily of hypabyssal rocks (Mitchell 1986).



b) Plan and cross-sections of the Ellendale 4 lamproite vent. Note the distinctly different morphology as compared with kimberlite diatremes (Figure 1a) and the presence of hypabyssal magmatic rocks within the crater facies pyroclastic rocks.

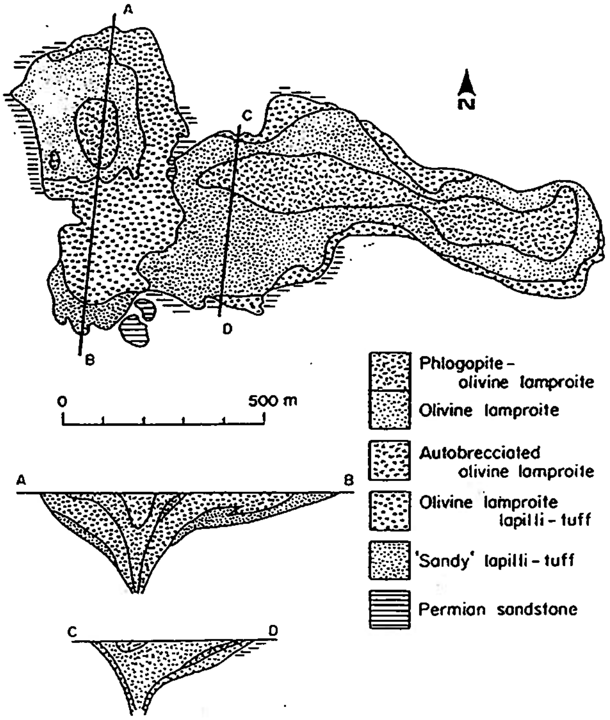


Figure 1. Model of an idealized kimberlite with plan view and cross-sections of the Ellendale 4 lamproite, Australia.

Recent Diamond Exploration in Canada

Outside Alberta

Major diamond-bearing kimberlite and lamproite pipes occur in Archean cratons and Proterozoic mobile belts in South Africa, Russia and Australia. Canada contains abundant rocks of similar geological setting and age, but the existence of an important diamond deposit in this country has only recently been given credence.

Prior to 1991, diamond exploration in Canada had been limited and mostly unsuccessful. The few kimberlite pipes that had been discovered were generally estimated to contain uneconomical grades of diamond. During 1991, Dia Met Minerals Ltd. announced the discovery of diamond-bearing kimberlite near Lac de Gras in the NWT. This prompted one of the largest staking rushes in world history (Northwest Territories Government, 1993). To date, more than 120 pipes have been discovered in the Lac de Gras region, of which approximately 80 are believed to be diamondiferous (Pell, *pers. comm.*, 1996). The BHP-Dia Met Joint Venture expects to enter commercial production in late 1997.

The Keewatin District of the NWT has yielded diamond occurrences in a lamproite near Dubawnt Lake (George Cross Newsletter, 1993) and, in the case of the Parker Lake discovery, in a potassic lamprophyre near Baker Lake (Armitage *et al.*, 1994). The Parker Lake lamprophyre recently yielded 1,511 microdiamonds and 2 macrodiamonds in a 22 kg surface bulk sample (Northern Miner, 1995a). This discovery indicates that, not only is there potential for significant concentrations of diamonds in rocks other than kimberlites and lamproites, but potential exists for the discovery of diamondiferous diatremes in the Churchill Structural Province, which underlies much of the province of Alberta.

During 1988, a diamond-bearing kimberlite pipe was discovered near Prince Albert, Saskatchewan by Uranerz Exploration and Mining Ltd. (Lehnert-Thiel *et al.*, 1992). Diamond grades in the Prince Albert kimberlite and in the kimberlite pipes subsequently discovered near Fort à la Corne, range from less than 2 carats/100 tonnes (cts/100t) up to 23 cts/100t, with most of the diamonds being gem-quality (Lehnert-Thiel *et al.*, 1992). The kimberlites in the Fort à la Corne area intrude the Lower Cretaceous Mannville and Colorado group sediments and range in age from 94 to 101 Ma (Lehnert-Thiel *et al.*, 1992; Kjarsgaard, 1995; Leckie *et al.*, *In Press*).

Two facies of kimberlite are recognized in the Fort à la Corne pipes: crater facies and reworked crater facies. To date, hypabyssal facies or feeder diatremes have not been intersected in drilling (Lehnert-Thiel *et al.*, 1992; Scott Smith *et al.*, 1994; Kjarsgaard, 1995; Leckie *et al.*, *In Press*). Continued sedimentation and wave action in Late Cretaceous times has redistributed and buried the Fort à la Corne kimberlites. Diamonds have been discovered within crater facies kimberlite and within associated reworked kimberlitic sediments.

In Ontario, diamondiferous kimberlites have been discovered in the James Bay Lowlands and near Kirkland Lake. To date, the Kyle Lake discovery near James Bay has yielded 370 diamonds from 364 kg of core with a grade of about 125 cts/100t (Edmonton Journal, 1995; Northern Miner, 1996).

Although diamond exploration in British Columbia (BC) has not been as extensive as elsewhere in Canada, the discovery of diamondiferous lamprophyres and/or lamproites near Golden, BC is significant to Alberta exploration because many of these pipes, including the Jack and Mark diatreme clusters, straddle the BC – Alberta border (Northcote, 1983a, b; Pell, 1987a, b; Fipke *et al.*, 1989). In addition, two of four reported pipes on the Ice Property near Elkford, BC have yielded diamonds in mini bulk samples (George Cross Newsletter, 1994).

Within Alberta

During 1995, two important announcements were made in Alberta with respect to diamond exploration through assessment file reports and news releases. A kimberlite located in northwestern Alberta about 75 km northeast of Grande Prairie and 35 km north of Sturgeon Lake in the Puskwaskau Hills was confirmed for the first time in an assessment report filed by Monopros Ltd. (Wood and Williams, 1994). In this report, a ground magnetometer survey outlined two weak positive magnetic anomalies that are elongated in a northwesterly direction in the vicinity of Mountain Lake, at least one of which is associated with a kimberlite diatreme. The diatreme, hereafter referred to as the Mountain Lake Kimberlite, had previously been identified by creek sediment sampling for kimberlitic diamond indicator minerals. With the permission of

Monopros Ltd., a joint drilling project targeting the Mountain Lake Kimberlite was completed by the Alberta Geological Survey (AGS) and the Geological Survey of Canada (GSC) during December, 1995. The core will be stored in Edmonton at the Mineral Core Research Facility (MCRF) and be available to the public at the completion of the study. Monopros Ltd. continues to operate a processing facility in Grande Prairie to handle exploration samples from across Canada (Wood, *pers. comm.*, 1996).

The second important announcement was that 23 diamonds were recently recovered from streams on the "Rich Property" north of Hinton in west-central Alberta (Northern Miner, 1995c; New Claymore Resources Ltd. News Release, 1995; Montello Resources Ltd. News Release, 1995). In addition, New Claymore Resources Ltd., Montello Resources Ltd. (Montello) and Troymin Resources Ltd. have granted an option to Kennecott Canada Inc. who will commit two million dollars to exploration over three years at the "Rich Property." To date, Montello has completed 22,000 line km of airborne magnetometer surveys over 440,000 ha. 146 geophysical anomalies were identified, of which 43 are regarded as high priority targets. The anomalies are oriented in a northwest-southeast direction. In addition, favourable chromites of diamond inclusion composition, pyrope garnets, chrome diopsides and angular to subangular olivines have been recovered from stream sediments, possibly indicating a proximal source for the indicator minerals and diamonds (Northern Miner, 1996).

It can only be expected that other important information about Alberta's diamond potential will be disclosed as assessment reports become public. The claim staking rush for diamond exploration in Alberta peaked during 1992 and 1993, and saw both major and junior mining companies acquire significant land holdings in the province. In Alberta, an assessment report must be filed after the initial and each subsequent two year period in order to carry the ground to the next period. Assessment work at the rate of $5.00 per ha is initially required. These reports become public one year after filing. Table 1 shows the number of permit applications over a five year period and the estimated number of assessment reports expected to be released to the public. Under Alberta's reporting regulations, an assessment report can cover a block of claims. Therefore, the 30 estimated assessment reports to be filed during 1995 (Table 1), actually cover 370 permits that, in total, encompass approximately 1.4 million ha of land.

The first clue to the presence of possible diamond-bearing source rocks in Alberta was the discovery of a perfect octahedral diamond, estimated at about 1 carat in weight, by farm worker Einar Opdahl during 1958 in the Evansburg area of west-central Alberta (Edmonton Journal, 1992a). Also referred to as the Pembina or Burwash diamond, the stone was apparently sold to an Edmonton gem cutter who brought it to Dr. R. Burwash at the Department of Geology at the University of Alberta for positive identification. Its present whereabouts are unknown, however, three junior exploration companies subsequently staked ground on what they all claim to be the original discovery site (Edmonton Journal, 1992a).

Table 1: Metallic and industrial mineral permit applications in Alberta (1990 to 1995).

Year	Permit Applications	Hectares	Estimated Reports To Be Filed
1990	120	800 000	2
1991	5	1 355	2
1992	2 489	22 400 000	0
1993	1 132	10 180 000	2
1994	706	6 350 000	8
1995	189	1 665 000	32

The first well-documented diamond discovery in Alberta occurred in 1992 when a prospector, Tom Bryant, found two microdiamonds, weighing 0.14 and 0.17 carats, in Recent stream sediment at Etzikom Coulee, near Legend in southern Alberta (Edmonton Journal, 1992b; Morton *et al.*, 1993; Takla Star Resources Ltd., 1993a, b). Bryant reportedly discovered the diamonds during 1988, but did not announce their discovery until prompted by increased claim staking in the area four years later. A large number of peridotitic G9 and G11 garnets, chromium diopsides and picroilmenites in alluvial sediments along Etzikom Coulee were discovered in 1992 (Sraega, 1994). The peridotitic garnets reportedly have orange-peel textures and, in one case, a partial kelphytic rim.

One beige-green diamond chip measuring 100 x 92 microns resulted from a 38.2 kg sample taken from the Black Butte diatreme, located about 150 km east-southeast of Lethbridge. The intrusion is a northeast-southwest trending topographic high, measuring approximately 450 m long and 200 m wide (Boulay, *pers.comm.,* 1996). An airborne magnetic survey released by the GSC in 1994 shows a well-defined bulls-eye spatially associated with the Black Butte intrusion. Petrological studies determined the intrusion to be a minette plug with lamproitic affinity (Kjarsgaard, 1994a).

Diamonds are also reported to have been discovered in gravels of the North Saskatchewan River and associated tributary creeks east of Edmonton (Bryant, *pers. comm.*, 1993; Morton *et al.*, 1993), and in Cretaceous-Tertiary sediments along the Red Deer River in central Alberta (Science City News, 1992).

In summary, recent exploration in Alberta has been successful in discovering at least one kimberlite diatreme, several diamond occurrences, favourable diamond indicator minerals, and in identifying abundant geophysical anomalies which may represent kimberlite or lamproite pipes or dykes.

Regional Geology of Alberta

Bedrock in Alberta ranges from Archean (>2.5 Ga) to Recent in age. The exposed bedrock geology of Alberta can be divided into several broad belts from northeast to southwest (Figure 2), with ages generally decreasing to the southwest (Green, 1972). In the northeast, Precambrian Shield and Athabasca Group sedimentary rocks are exposed (Figure 2). To the southwest, the Precambrian Shield and Athabasca Group sedimentary rocks are overlain by a homoclinal sequence of westerly dipping Paleozoic strata that comprise carbonate, evaporite and clastic rocks which reach a total thickness of up to about 3,000 m in the subsurface. Cretaceous sedimentary rocks up to 2,000 m in thickness overlie much of the Devonian sequence and exist over an extensive area of Alberta. Lower Tertiary (Paleocene) rocks, which locally reach thicknesses of up to 1,500 m in the subsurface, overlie Cretaceous strata in a belt along the Foothills that stretches from southern Alberta, northwest to just south of Grand Prairie. As well, Oligocene to Miocene continental clastic rocks exist in a few places throughout Alberta, but are typically thin, and are less than a few tens of metres thick. In the Rocky Mountains and Foothills, there is a thick sequence of sedimentary and, locally, volcanic rocks, that range in age from Helikian to Tertiary. These rocks have been complexly folded and faulted as a result of the Laramide Orogeny.

Extensive regional overviews of the geology of the Alberta Basin, the Western Canada Sedimentary Basin and the Cordilleran Orogen in Alberta are provided by McGrossan and Glaister (1964), Douglas (1970), Ricketts (1989), Gabrielse and Yorath (1992), Mossop and Shetsen (1994), and Stott and Aitken (1993).

An understanding of the geology of the Precambrian basement, the Phanerozoic succession and major structural elements is important to the evaluation of Alberta's diamond potential for the following reasons: (1) areas underlain by thick Archean crust are the most productive in terms of economic diamond deposits; (2) thicker and therefore colder continental roots are considered by many (Haggerty, 1986; Mitchell, 1986, 1987, 1991; Gurney, 1990) as a prerequisite for the formation and preservation of diamonds in the mantle; (3) diamonds are considered to be transported xenocrysts (Mitchell, 1989, 1991; Gurney, 1990; Gurney and Moore, 1993; Kirkley *et al.*, 1991, 1992; Helmstaedt, 1992, 1993); and (4) certain regional structures, such as anticleses, are considered by some workers to favour the emplacement of diamondiferous kimberlites or lamproites (Jennings, 1990; Helmstaedt, 1992, 1993). Therefore, a brief summary of the province's geology as it pertains to the potential for diamondiferous diatremes in Alberta follows. The description of selected time stratigraphic intervals is expanded where the potential to discover kimberlite or lamproite diatremes is deemed higher, or where the units are considered important for the sampling of diamond indicator minerals in order to trace diatremes.

Precambrian Basement

The Precambrian basement rocks of Alberta are an extension of the Churchill Structural Province. Ross and Stephenson (1989), Burwash (1993), Ross (1991, 1993) and Burwash *et al.* (1994) have subdivided the basement rocks beneath the Alberta Basin into distinct tectono-metamorphic domains (Figure 3), that range in age from Archean to Early Proterozoic (3,278 Ma to 1,779 Ma). Most of the basement north of the Snowbird Tectonic Zone (STZ) in Alberta is either accreted juvenile Proterozoic terrane or thermally reworked Archean basement that is part of the Rae Sub-province. Basement south of the STZ is predominantly Archean in age and is part of the Hearne Sub-province.

There are a number of different interpretations to explain the various Proterozoic ages (mostly Aphebian) that have been obtained for the basement rocks in northern Alberta. These include: (1) the Aphebian dates result from Archean basement that has been isotopically reset by Proterozoic magmatism and cataclasis through collision of Archean microcontinents during the Proterozoic (Burwash *et al.*, 1962; Burwash and Culbert, 1976; Burwash *et al.*, 1994); (2) the Aphebian zircon or monazite dates from northern Alberta are the result of discrete, juvenile Proterozoic terranes that have been accreted to the Archean Rae Sub-province (Ross and Stephenson, 1989; Ross *et al.*, 1991), and the Sm-Nd isotope systematics indicate that a strong Archean component is present in these Proterozoic terranes (Thériault and Ross, 1991; Villeneuve *et al.*, 1993; Ross *et al.*, 1993); and (3) the Sm-Nd isotope systematics along with recent Lithoprobe Program results indicate that the Proterozoic terranes in northern Alberta may actually represent thin-skinned thrust slices emplaced over composite Archean-Early Proterozoic basement during the Proterozoic, as has been proposed for the Trans-Hudson orogenic belt in Saskatchewan (Hajnal *et al.*, 1993).

Because of the limited extent of near-surface or exposed Precambrian basement in Alberta, the potential for discovery of kimberlites and lamproites in basement rocks is deemed low, except in northeastern Alberta where basement is near surface or exposed.

Proterozoic Strata

The Helikian Purcell Supergroup in southwest Alberta and southeast BC comprises an 11 km thick sequence of shallow-marine and nonmarine rocks which are underlain by a transitional sequence of basinal clastic rocks in the west and platformal carbonate and clastic sedimentary rocks in the east, with minor amounts of igneous intrusive and extrusive rocks (Aitken and McMechan, 1992). The Hadrynian Windermere Supergroup occurs in western Alberta south of 56° N and is represented by the Miette Group, a thick succession of clastic and carbonate sedimentary rocks (Gabrielse and Campbell, 1992). In southwest Alberta, the Helikian strata are host to a number of stratabound copper occurrences (Williamson *et al.*, 1993; Hamilton and Olson, 1994).

In northeastern Alberta, the Helikian Athabasca Group is comprised of a flat-lying sequence of clastic sedimentary rocks in excess of 1,255 m thick that appear in outcrop and subcrop south of and immediately north of Lake Athabasca (Wilson, 1985a, b).

The potential for discovery of kimberlites or lamproites in the Proterozoic strata of southwest or northeast Alberta is deemed low because of either the limited areal extent of near-surface exposures or large tracts of these rocks have been removed from exploration in National Parks or Provincial Reserves.

Paleozoic Strata

In northeast Alberta, exposed Paleozoic strata comprise Middle and Upper Devonian marine shales, carbonates and evaporites (Green *et al.*, 1970). At or near the Precambrian Shield edge in northeastern Alberta, extensive subsurface dissolution of the evaporitic units has resulted in widespread brecciation of the overlying Devonian strata.

In the remainder of Alberta, thick sequences of Paleozoic strata up to 3,000 m thick in the subsurface range in age from Cambrian to Permian (Gabrielse and Yorath, 1992; Mossop and Shetsen, 1994). Much of the Paleozoic succession consists of unconformity-bounded, thin to thick sequences of carbonate rocks, that are interlayered with predominantly fine- to medium-grained clastic marine sedimentary rocks.

Much of the Paleozoic succession in Alberta is considered prospective for the presence of kimberlites or lamproites, particularly Ordovician to Devonian strata. However, the potential to discover diatremes in Paleozoic strata is deemed low because the majority of rocks are too deep to explore effectively, or, where near surface, they are contained within National Parks or Provincial Reserves.

Mesozoic Strata

Cretaceous rocks outcrop or subcrop over greater than two-thirds of Alberta (Figure 2). In the northeastern Interior Plains, Lower Cretaceous marine to deltaic clastic sedimentary rocks unconformably overlie Paleozoic strata. To the south and west, the Lower Cretaceous strata are conformably overlain by Upper Cretaceous marine to continental clastic sedimentary rocks. Upper Cretaceous strata are up to 900 m thick in northern Alberta. In southern Alberta, Lower Cretaceous strata are greater than 750 m thick and Upper Cretaceous strata are greater than 1,650 m thick.

Mesozoic strata are exposed throughout the Foothills and Main Ranges, beginning just north of Waterton National Park and continuing northwesterly to near Grande Cache, Alberta. Widespread post-Permian regression of an inland sea and nondeposition accounts for the Cordilleran-wide sub-Triassic unconformity. The overlying Triassic system comprises a westward thickening marine sequence of easterly derived siliciclastic and carbonate lithologies that is greater than 1,200 m thick (Gordey *et al.*, 1992).

The Jurassic System records the transition from a passive continental margin to an active one. In Late Jurassic time this was characterized by orogenic uplift in the west (Columbian Orogeny) and an associated narrow arcuate foredeep to the east (Poulton, 1989). The Jurassic Period in Alberta was characterized by cyclic transgressions and regressions of the sea. Marine rocks dominate the lower Jurassic succession. The

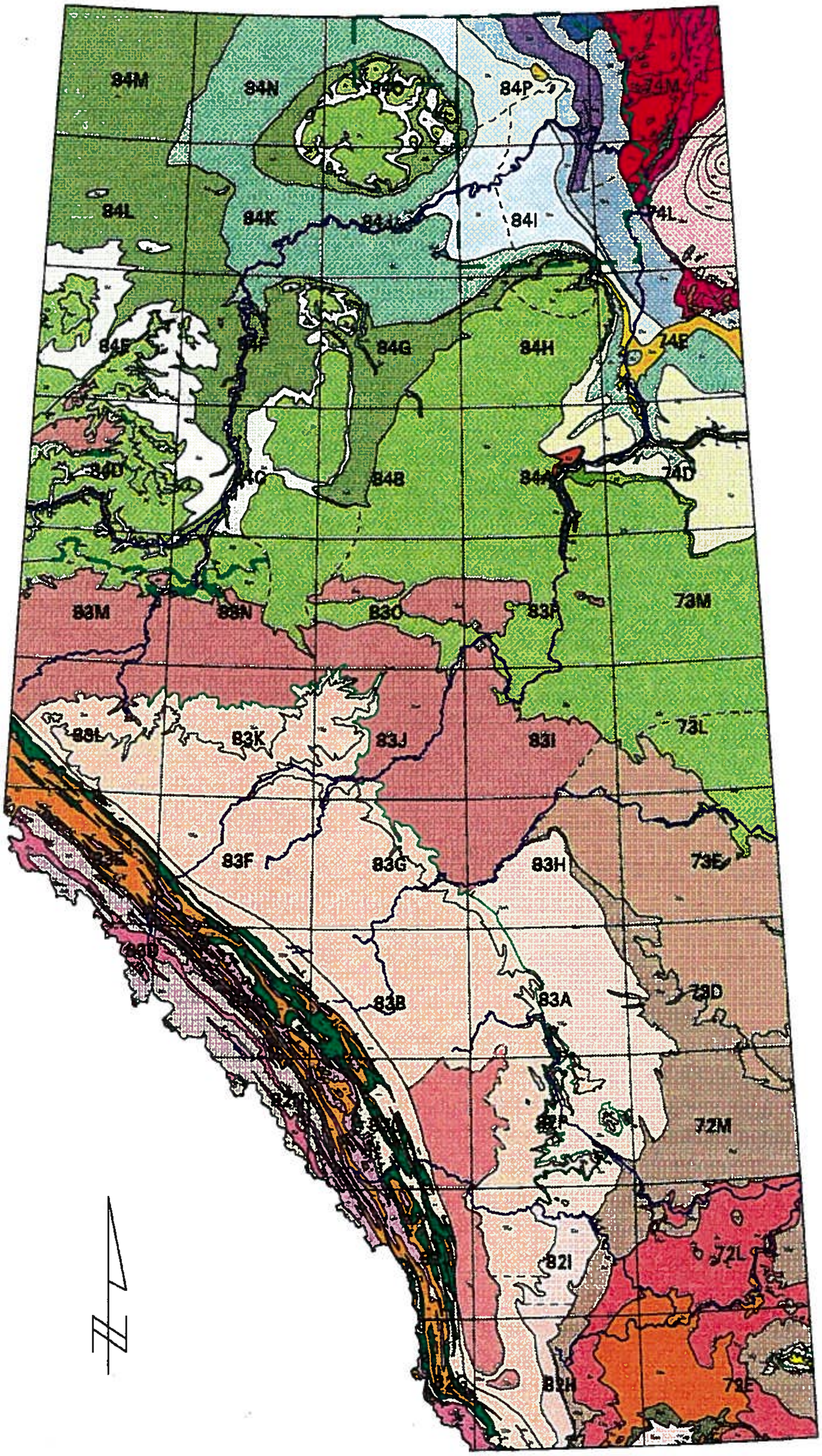


Figure 2. Geological map of Alberta (Hamilton et al., 1994)

LEGEND

NORTHWESTERN ALBERTA

TERTIARY AND CRETACEOUS

▨ Paskapoo Formation

CRETACEOUS

▨ Wapiti Formation
▨ Puskwaskau Formation
▨ Bad Heart Formation
▨ Kaskapau Formation
▨ Dunvegan Formation
▨ Shaftesbury Formation
▨ Peace River Formation

▨ Loon River Formation

NORTH CENTRAL ALBERTA

CRETACEOUS

▨ Wapiti Formation
▨ Smoky Group

▨ Dunvegan Formation
▨ Shaftesbury Formation

▨ Loon River Formation

▨ Basal Cretaceous?

NORTHEASTERN ALBERTA

CRETACEOUS

▨ Labiche Formation

▨ Pelican Formation
▨ Joli Fou Formation
▨ Alice Creek Tongue,
Grand Rapids Formation
▨ Grand Rapids Formation
▨ Clearwater Formation
▨ McMurray Formation

SOUTHWESTERN ALBERTA

TERTIARY

▨ Porcupine Hills Formation

TERTIARY AND CRETACEOUS

▨ Willow Creek Formation

CRETACEOUS

▨ St. Mary River Formation
▨ Blood Reserve Formation
▨ Bearpaw Formation
▨ Oldman Formation
▨ Foremost Formation
▨ Pakowki Formation
▨ Milk River Formation
▨ Alberta Group

SOUTHEASTERN ALBERTA

TERTIARY

▨ Cypress Hills Formation

TERTIARY AND CRETACEOUS

▨ Ravenscrag Formation

CRETACEOUS

▨ Whitemud and Battle Formations

▨ Eastend Formation

▨ Bearpaw Formation
▨ Oldman Formation
▨ Foremost Formation
▨ Pakowki Formation
▨ Milk River Formation
▨ Alberta Group

CENTRAL AND EASTERN ALBERTA

TERTIARY

▨ Hand Hills Formation

TERTIARY AND CRETACEOUS

▨ Paskapoo Formation

CRETACEOUS

▨ Horseshoe Canyon Formation

▨ Bearpaw Formation

▨ Belly River Formation

▨ Lea Park Formation

NORTHERN ALBERTA

DEVONIAN

▨ Grosmont Formation
▨ Mikkwa Formation
▨ Ireton Formation
▨ Waterways Formation
▨ Caribou Member,
Slave Point Formation
▨ Nyarling Formation

NORTHEASTERN ALBERTA

DEVONIAN

▨ Hay River Formation

▨ Caribou Member,

▨ Fort Vermilion Member,
Slave Point Formation
▨ Muskeg Formation
▨ Keg River Formation
▨ Chinchaga Formation
▨ Fitzgerald Formation

▨ Devonian
Undivided

ROCKY MOUNTAINS AND FOOTHILLS

TERTIARY AND CRETACEOUS

▨ Brazeau Formation

CRETACEOUS

▨ Alberta Group

MESOZOIC

▨ Lower Cretaceous, Jurassic
and Triassic

PALEOZOIC

▨ Upper Paleozoic
▨ Lower Paleozoic

HADRYNIAN

▨ Miette Group

HELIKIAN

▨ Purcell Supergroup

HELIKIAN

▨ Otherside Formation
▨ Locker Lake Formation
▨ Upper Wolverine Point Formation
▨ Lower Wolverine Point Formation
▨ Manitou Falls Formation
▨ Fair Point Formation

APHEBIAN

▨ Low Grade Metasedimentary Rocks
▨ Granitoids

APHEBIAN/ARCHEAN – Undivided

▨ Mylonitic Rocks
▨ Granitoids
▨ Undifferentiated

ARCHEAN

▨ Charles Lake Granitoids
▨ High Grade Metasedimentary
Rocks
▨ Granite Gneisses

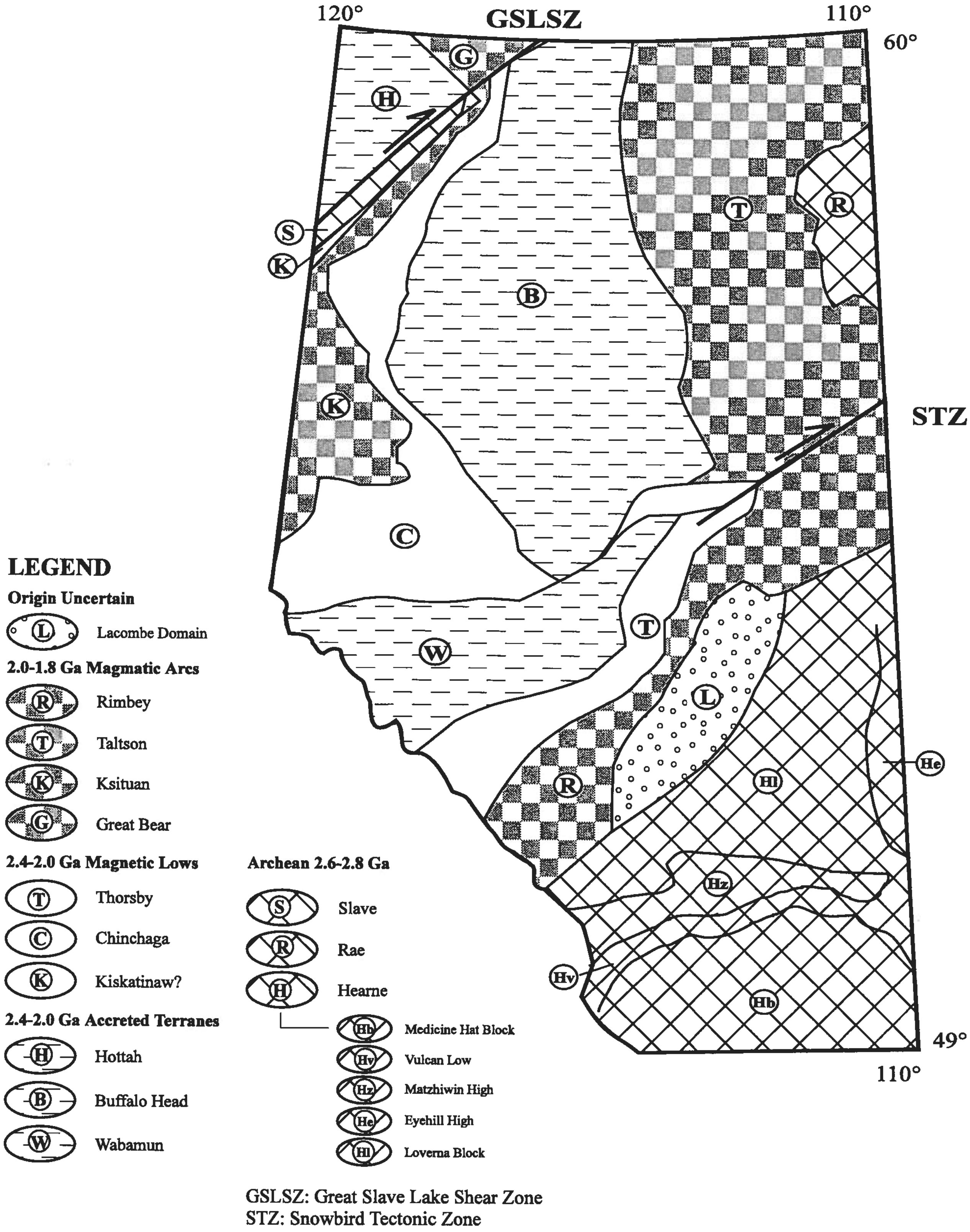


Figure 3. Domain map of the Alberta basement based on geophysical properties and U-Pb age data (modified after Ross *et al.*, 1991)

upper Jurassic sequence is characterized by interfingering of marine and continental sedimentary rocks. The Jurassic succession is locally up to a maximum of 2,100 m thick in the Rocky Mountains.

Uplift and erosion associated with the Laramide Orogeny produced clastic sedimentary wedges of Cretaceous and Early Tertiary strata (Poulton, 1989). In the southern Canadian Cordillera the sedimentary succession reflects Late Jurassic uplift, whereas to the northwest in the Yukon, sedimentation was not influenced by Cordilleran uplift until mid-Cretaceous time (Yorath, 1992). During the Early Cretaceous in Alberta, there were several cycles of Cordilleran orogenesis and associated westerly-derived clastic continental sedimentary wedges. The Late Cretaceous to Paleocene period was characterized by widespread marine flooding of the continental interior and widespread deposition of marine and, locally, near-marine to deltaic fine- to medium-grained clastic sediments. In southwestern Alberta, volcanic rocks of Late Albian Crowsnest Formation conformably overlie and are interbedded with upper Lower Cretaceous sedimentary rocks of the Blairmore Group.

Tertiary Strata

Continental sedimentation continued through uppermost Cretaceous into Paleocene time in Alberta in response to continued uplift and erosion during Laramide orogenic activity (Yorath, 1992). Paleocene strata of Upper Willow Creek, Porcupine Hills, Paskapoo and Ravenscrag formations were deposited during the last part of the uppermost Cretaceous-lowermost Tertiary clastic wedge. In the western Interior Plains of Alberta, the Paleocene succession ranges from greater than 1,525 m in the Porcupine Hills of southwestern Alberta to about 70 m in the Cypress Hills of southeastern Alberta (Taylor *et al.*, 1964). The last major stage of uplift in the Eastern Rocky Mountains and Foothills of Alberta likely occurred during Eocene to Oligocene time (Shaw, 1963; Bally *et al.*, 1966; Eisbacher *et al.*, 1974).

From Miocene to Quaternary the Alberta Rocky Mountains and Interior Plains continued to be eroded. Erosion during this time resulted in the removal of more than 1,000 m of stratigraphy, during this time, leaving scattered sand and gravel deposits at various elevations. Tertiary and early Quaternary erosion was extensive, leaving only small scattered patches of Oligocene to Pliocene age fluvial sand and gravel deposits in isolated preglacial valleys and uplands (Yorath, 1992). Most of these deposits range in thickness from a few metres up to, at most, a few tens of metres. In southern Alberta and northern Montana there are several mafic intrusions and dykes that are commonly referred to as the “Sweet Grass Intrusions.” These intrusions cut Upper Cretaceous strata, are classified as minettes and have been dated at about 49 to 54 Ma (Baadsgaard, 1961; Taylor *et al.*, 1964; Folinsbee *et al.*, 1965; Marvin *et al.*, 1980; Kjarsgaard, 1994a, b; Kjarsgaard and Davis, 1994).

Late Tertiary to Quaternary Sand and Gravel Deposits

Late Tertiary to Quaternary sand and gravel deposits of Alberta are volumetrically small in comparison to the thick sequences of Paleozoic and Mesozoic sediments. However, they represent an important sampling medium for diamonds and diamond indicator minerals in the search for diamondiferous kimberlites and lamproites. In addition, preglacial to Recent sand and gravel deposits may host important placer accumulations of diamonds.

The three primary categories of sand and gravel deposits in Alberta are: (1) Recent fluvial (river) deposits; (2) Pleistocene glaciofluvial deposits; and (3) preglacial Tertiary and Quaternary fluvial deposits. These sand and gravel deposits can be distinguished by their different mineral and rock suites, and by their stratigraphic relationships (Figure 4).

The sources of the minerals and rocks which exist in the present day river deposits include local bedrock, Laurentide and Cordilleran glacial deposits, and preglacial Tertiary and Quaternary fluvial deposits. Even though Recent river deposits are the most widely distributed of the three categories of sand and gravel deposits, diamond indicator minerals that are recovered from these deposits could have a multitude of sources and complex transport histories.

Pleistocene glaciofluvial deposits on the Alberta Interior Plains are irregularly distributed. The mineral and rock suites in Pleistocene glaciofluvial deposits may contain material derived from local bedrock, from up-ice bedrock or drift, and from preglacial Tertiary and Quaternary sand and gravel deposits. Similar to Recent river deposits, diamond indicator minerals that are recovered from glaciofluvial deposits could have a multitude of sources and complex transport histories.

Tertiary and Quaternary preglacial sand and gravel deposits (Figure 4) are useful for diamond indicator mineral sampling because they have a less complex transport history and their source areas are more easily defined. A unifying characteristic of all the preglacial deposits is the absence of any igneous or metamorphic rocks of Canadian Shield origin. Source areas for the preglacial deposits include bedrock exposed in the Foothills and Rocky Mountains of Alberta and the accreted terranes of the BC Cordillera.

To a large extent, the bedrock topography of the Alberta Interior Plains is the result of fluvial erosion over a span of about 50 million years from Early Tertiary to Late Quaternary. As a result, the oldest preglacial sand and gravel deposits are located on the highest hills on the Interior Plains. This phenomenon is due to uplift which exceeded the rate of erosion and resulted in down cutting, leaving the oldest deposits at the highest elevations (Figure 4). Based on age and elevation, four major units of preglacial sand and gravel deposits can be distinguished (Figure 4). Examples of the oldest deposits capping topographic highs include the Cypress Hills and Swan Hills, both of which are believed to be Oligocene in age (Dawson *et al.*, 1994). These four different age units can be further subdivided into seven groups (A to G on Figure 4), based on pebble lithology, geographic distribution and paleocurrent data. Deposits within any group may have a common source area yet be different in age.

The youngest of the preglacial deposits are often referred to as the Saskatchewan Sands and Gravels (Unit 1 on Figure 4). Deposits belonging to this unit are present along the Simonette River, at Watino along the Smoky River, and at Villeneuve and Wetaskiwin (Figure 4). These deposits occur in topographically low areas within the thalwegs of buried valleys, and are believed to be of Late Pleistocene age (Dufresne *et al.*, 1994a). The various preglacial sands and gravels are now overlain, in whole or in part, by Pleistocene till, Pleistocene glaciofluvial deposits and Recent river gravels.

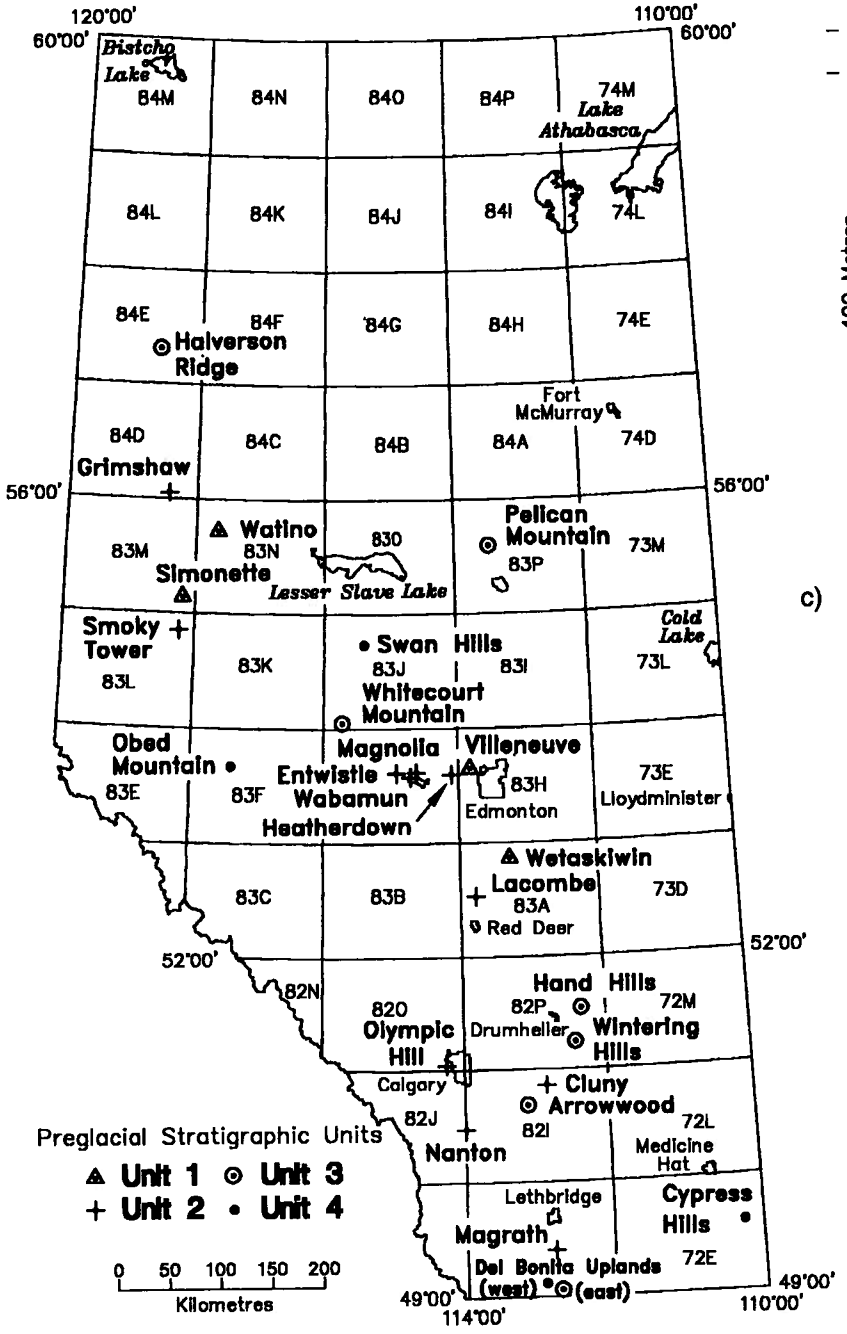
Quaternary Strata

Sampling Quaternary drift for diamond indicator minerals was a critical tool in the discovery of the Lac de Gras kimberlite field. Because similar sampling techniques are being employed in Alberta in the search for kimberlites and lamproites, it is important to have an understanding of the surficial material being sampled, particularly where multiple generations of drift are present.

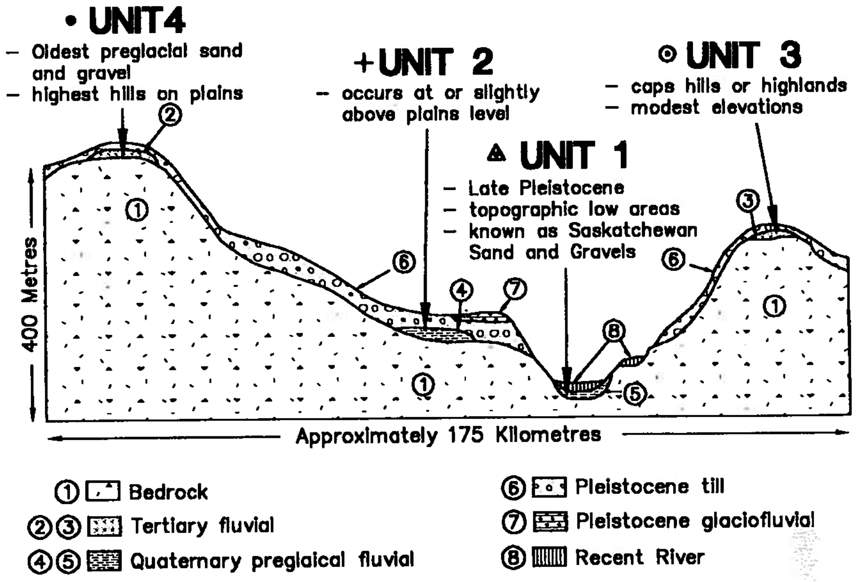
The surficial mapping of Alberta is incomplete, and restricted to areas of better access in the southern, central and northeastern parts of the province. The Quaternary deposits in the northern and northwestern part of the province have not been systematically mapped. Pertinent references for the Quaternary geology of Alberta include Barton *et al.* (1964), Prest (1970), Fenton (1987), Shetsen (1987, 1990) and Fulton (1989). Recent papers which provide information on the history and stratigraphy of the Quaternary succession, as well as pertinent references, include those by Fenton (1984), Fulton *et al.* (1984), Prest (1984), Fullerton and Colton (1986), Dyke and Prest (1987), Clague (1989), Klassen (1989), and Bobrowsky and Rutter (1992).

Episodic Quaternary glaciations and interstadials have resulted in a complex sequence of glacial, fluvial, lacustrine and minor amounts of aeolian and organic sediment of different ages over the Alberta Interior Plains (Andriashek and Fenton, 1989; Klassen, 1989; Barendregt *et al.*, 1991a). The earliest glacial advance from the Rocky Mountains is at least 720,000 years old and may be up to 2,470,000 years old or older (Barendregt *et al.*, 1991a). The earliest Laurentide advance into the southern Interior Plains may be 120,000 years old or older (Barendregt *et al.*, 1991b). The predominant glacial sediment is till, followed by lacustrine sediment. The till deposited by the continental Laurentide glaciers contains clasts of Precambrian and Paleozoic bedrock from the east and north. The till deposited by glaciers originating in the Cordillera or Rocky Mountains contains clasts of resistant quartzite, carbonate, argillite and chert. Locally, the till can be subdivided into a number of units or facies (Proudfoot, 1985; Levson and Rutter, 1988; Mougeot, 1991). Till units within the Interior Plains region, can be correlated over extensive areas on the surface and in the subsurface. These correlations are based on texture, mineralogy, geochemistry, petrology, stratigraphic position and geophysical log signature. Examples of such correlations may be found in Shetsen (1984), Andriashek and Fenton (1989), Klassen (1989), Schreiner (1990) and Christiansen (1992). Subsurface correlation of Quaternary materials is based mainly on geophysical log signatures, which are used to distinguish tills from other units but are unable to discriminate individual till units. In addition, correlation is hampered by a lack of good quality near-surface drill core and a lack of dateable organic material.

a) Non-glacial sand and gravel deposits of Alberta.



b) Schematic cross-section



c) Stratigraphic grouping

Stratigraphy of Preglacial Units based on increasing age with increasing elevation

Pebble lithology, geographic distribution and paleocurrent data are used to group sites

	▲UNIT 1	+UNIT 2	⊙UNIT 3	• UNIT4
Group A		Magrath	Del Bonita Uplands East	Del Bonita Uplands west
Group B		Olympic Hill Cluny Nanton	Wintering Hills Hand Hills Arrowwood	
Group C	Wetaskiwin	Lacombe		
Group D	Villeneuve	Entwistle Magnolia Wabamun Heatherdown		
Group E		Smoky Tower	Pelican Mtn. Whitecourt Mtn.	Swan Hills Obed Mtn.
Group F	Simonette Watino	Grimshaw	Halverson Ridge	
Group G				Cypress Hills

Figure 4. Selected preglacial sand and gravel deposits in Alberta, with schematic cross-section and stratigraphic grouping.

Glacial advances in Alberta originated from two directions: (1) northeast or north from the Canadian Shield (Laurentide source); and (2) west from interior Cordillera and Rocky Mountain sources (Figure 5). Cordilleran ice originated from the accreted bedrock terranes of the BC interior, while Rocky Mountain or montane ice originated in local valley and piedmonts of the Alberta Rocky Mountains. Figure 5 shows paleo ice-flow directions indicated by several types of surface features in Alberta. Laurentide glaciers flowed generally toward the southwest or south, however, Laurentide glaciers of different ages did not always maintain a consistent flow direction (Andriashek and Fenton, 1989). Cordilleran and Rocky Mountain glaciers were influenced by the presence of valleys and low passes between valleys in the mountains. Those valley glaciers which reached the Foothills and Interior Plains, likely debouched to form piedmont glaciers that may have interacted with Laurentide ice. The interaction between the Laurentide and Cordilleran-Rocky Mountain glacial advances is complex and poorly understood (Clague, 1989; Jackson *et al.*, 1989; Bobrowsky and Rutter, 1992). As a result, diamond indicator minerals in Quaternary materials in or near the zone of glacial mixing may record a complex history of movement from one or more directions.

The majority of eastward glacial advances came from Rocky Mountain sources, with few Mountain glaciers actually escaping their valleys. Ice from interior Cordilleran centres flowed over and east of the Rocky Mountains only a few times, and from only two or three valleys (Bobrowsky and Rutter, 1992). North of Jasper National Park there is a zone in which the tills and related sediments may include a mixture of montane and Laurentide materials (Figure 5). The most recent Cordilleran ice advance flowed out of the Athabasca Valley, moving southeastward, forming the Athabasca Valley erratics train and Foothills erratics train (Figure 5). The till from this train contains clasts suggestive of mixed Cordilleran and Laurentide provenance (Stalker, 1956; Mountjoy, 1958; Roed *et al.*, 1967; Roed, 1975).

Bedrock surface contours range from about 1,200 m asl in the foothills to slightly more than 200 m asl near the margin of the Precambrian Shield (Figure 6). There are three basic topographic elements: (1) the broad generally northeastward and eastward trending valleys; (2) uplands underlain by erosional bedrock remnants; and (3) broad, relatively level interfluve areas. The valleys were primarily formed during preglacial time, as demonstrated by the presence of preglacial sediment at the base of the valley fill sequences.

Figure 7 shows the thickness of unconsolidated sediment overlying the bedrock in Alberta and includes sediment of both Late Tertiary and Quaternary age. The Tertiary sediment included in the map unit is confined largely to the lower portions of the preglacial channels (thalwegs on Figure 6). The Late Tertiary and Quaternary materials were mapped as a single unit since deposition was more or less continuous from the close of the Tertiary into the Quaternary. The total thickness of the Late Tertiary to Quaternary sediments ranges from 300 m in a few preglacial valleys to zero on some of the interfluves and highlands.

Figure 7 shows only the regional trends in drift thickness in Alberta, therefore, local variations in drift thickness render this map unsuitable for obtaining site specific information. The most prominent feature on Figure 7 is a broad northwest trending belt of thick sediment (>150 m) across northern Alberta. In contrast, those areas where the sediment is thin or absent include the Swan Hills, Clear Hills, Milligan Hills, north-central and northeastern Alberta north of 58°N, and most of the southern half of the province (Figures 5 and 7). In many areas, the preglacial channels have been substantially infilled with Late Tertiary to Quaternary sediments, levelling the local relief of the present day land surface.

Factors influencing sediment accumulations are: (1) preglacial valleys; (2) bedrock highlands; (3) areas of ice marginal still stands; and (4) bedrock contacts or scarps. The preglacial valleys also influenced later sedimentary deposition by: (1) acting as sediment traps; (2) influencing glacial dynamics; (3) forming lows favourable to the deposition of stratified sediment; and (4) preserving the existing sediment from erosion during subsequent glacial advances. Examples of these factors which have affected sediment accumulations, are presented in Dufresne *et al.* (1994b).

Regional Structures

The regional structures and tectonic evolution of the Alberta Basin have been discussed by several workers, including Webb (1964), Lorenz (1982), Cant (1988), Podruski (1988), Leckie (1989), Cant and Stockmal (1989), Osadetz (1989), McMechan and Thomson (1989), Ross and Stephenson (1989), Ross (1991) and McMechan *et al.* (1992). The major structures and tectonic elements of Alberta are illustrated on Figure 8 and are discussed in some detail below.

Great Slave Lake Shear Zone and Snowbird Tectonic Zone

The Great Slave Lake Shear Zone (GSLSZ) is a major northeast trending crustal lineament that extends from near Chantrey Inlet in the Keewatin District of the NWT, southwest across northwestern Alberta and into northeastern BC (Ross, 1991, 1993; Ross *et al.*, 1991). The GSLSZ was predominantly active about 1.9 Ga (Hoffman, 1987), but tectonic movement may have occurred along this structure until at least the late Middle Devonian (Skall, 1975).

The STZ is a second major northeast trending crustal lineament, and extends from near Baker Lake, NWT, southwest to just north of the Lac La Biche area, Alberta (Figure 8). It separates the Churchill Structural Province into two discrete basement domains (Ross *et al.*, 1991). The STZ is a prominent lineament on the aeromagnetic and gravity maps of Canada (Geological Survey of Canada, 1990a, b). Ross *et al.* (1991) suggested that the STZ bifurcates into two zones below the Phanerozoic basin southwest of the Lac La Biche area. The southern zone, which encompasses the Thorsby Low, appears to intersect the Foothills region of Alberta in the vicinity of Nordegg. Other important northeasterly trending geological features exist in the vicinity of Nordegg, including the axis of the doubly plunging Late Cambrian to Devonian West Alberta Arch (Verrall, 1968), the Late Devonian Cline Channel (Geldsetzer and Mountjoy, 1992) and the Cretaceous Bighorn Tear Fault (Verrall, 1968). In addition, more recent work by Edwards and Brown (1994) has documented the existence of basement faults that extend into the Paleozoic and Mesozoic succession in the vicinity of the Thorsby Low. Further work is needed to clarify the actual position of the STZ and to document its relationship to other Phanerozoic structures which exist in the vicinity of Nordegg in the Rocky Mountains, and in the Foothills and Interior Plains of Alberta.

Southern Alberta Rift

Kanasewich (1968) suggested that the Southern Alberta Rift (SAR) is traceable for 450 km from just north of Medicine Hat, Alberta to the Rocky Mountains southwest of Cranbrook, BC. Kanasewich *et al.* (1969) suggested that this rift is Precambrian in age, penetrates the crust to the Mohorovicic Discontinuity (Moho) and has associated faults with vertical displacements of up to 5 km. McMechan (1981) subsequently described evidence for synsedimentary extensional faulting throughout the Precambrian Belt-Purcell Supergroup in BC. As well, regional Bouguer gravity anomaly maps show significant differences in the gravity field on either side of the postulated trace of the SAR, possibly marking the margins of a long-lived, crustal-scale rift (Price, 1981; Fountain and McDonough, 1984).

Examples of rifting during Late Proterozoic to Early Cambrian time along the western edge of the North American Continent have been described by a number of authors (e.g., Leech, 1962; Stewart, 1972; Lis and Price, 1976; Benvenuto and Price, 1979; Struik, 1987; Devlin and Bond, 1988; Devlin, 1989). Evidence for younger reactivation of the SAR, associated with faults of lesser magnitude, has been presented by a number of authors and is well summarized by Olson *et al.* (1994) and Dufresne *et al.* (1994a). The SAR has been active during several periods from Precambrian to at least Late Cretaceous based on: (1) the presence of syndepositional faults that cut various Paleozoic and Mesozoic strata and are oriented parallel to the regional trend of the rift; and (2) spatially associated syndepositional Cretaceous volcanism (Pearce, 1970; Price and Lis, 1975; Adair, 1986; Hopkins, 1987, 1988; Pope and Thirlwall, 1992; Brandley and Krause, 1993; Brandley *et al.*, 1993; Jerzykiewicz and Norris, 1993a, b).

Peace River Arch

Regional syntheses of the geological history of the Peace River Arch (PRA) have recently been published by Cant (1988), O'Connell *et al.* (1990) and O'Connell (1994). This east-northeasterly trending structure extends from the Front Ranges in northeastern BC across north-central Alberta for approximately 750 km. At the Alberta-BC border, basement in the core of the PRA protrudes about 1,000 m above the regional basement elevation, decreasing towards the east. The Arch has created a wide zone of structural disturbance in the basement and overlying Phanerozoic rocks, and has a width of approximately 140 km at about 116° W. Seismic refraction analysis shows that a subtle crustal uplift at the Moho boundary is partially coincident with the axis of the PRA (Stephenson *et al.*, 1989; Zelt, 1989; Ross, 1990). The PRA appears to have been superimposed upon a pre-existing Precambrian basement feature and was active as early as the Late Proterozoic (Ross, 1990; O'Connell *et al.*, 1990). The oldest expression of the PRA consists of uplifted and truncated Upper Proterozoic and Lower Cambrian sediments that are exposed in the Cordillera (Stelck *et al.*, 1978; McMechan, 1990). Pre-Middle Devonian rocks are largely absent in the vicinity of the PRA.

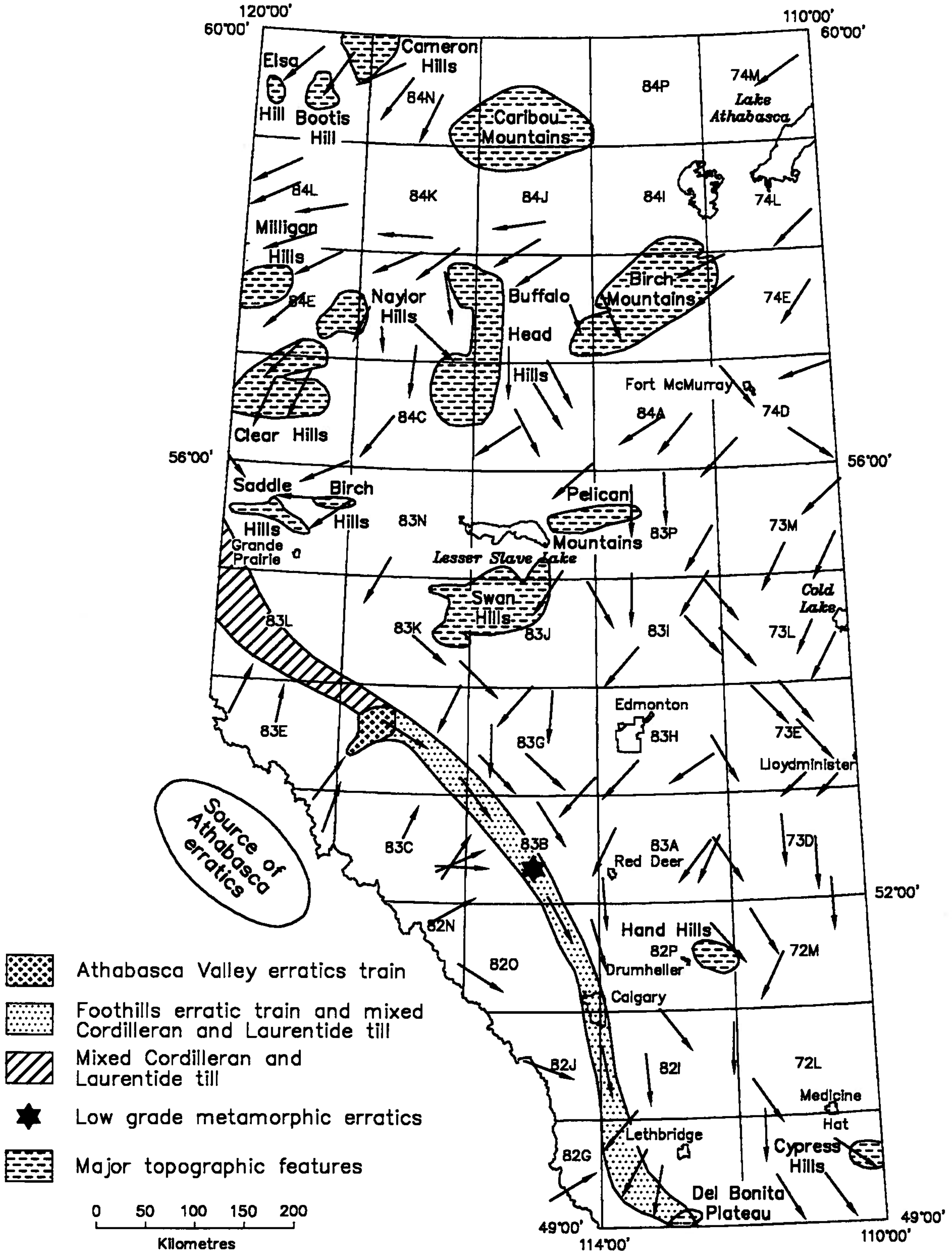


Figure 5. Glacial flow directions and major topographic features in Alberta.

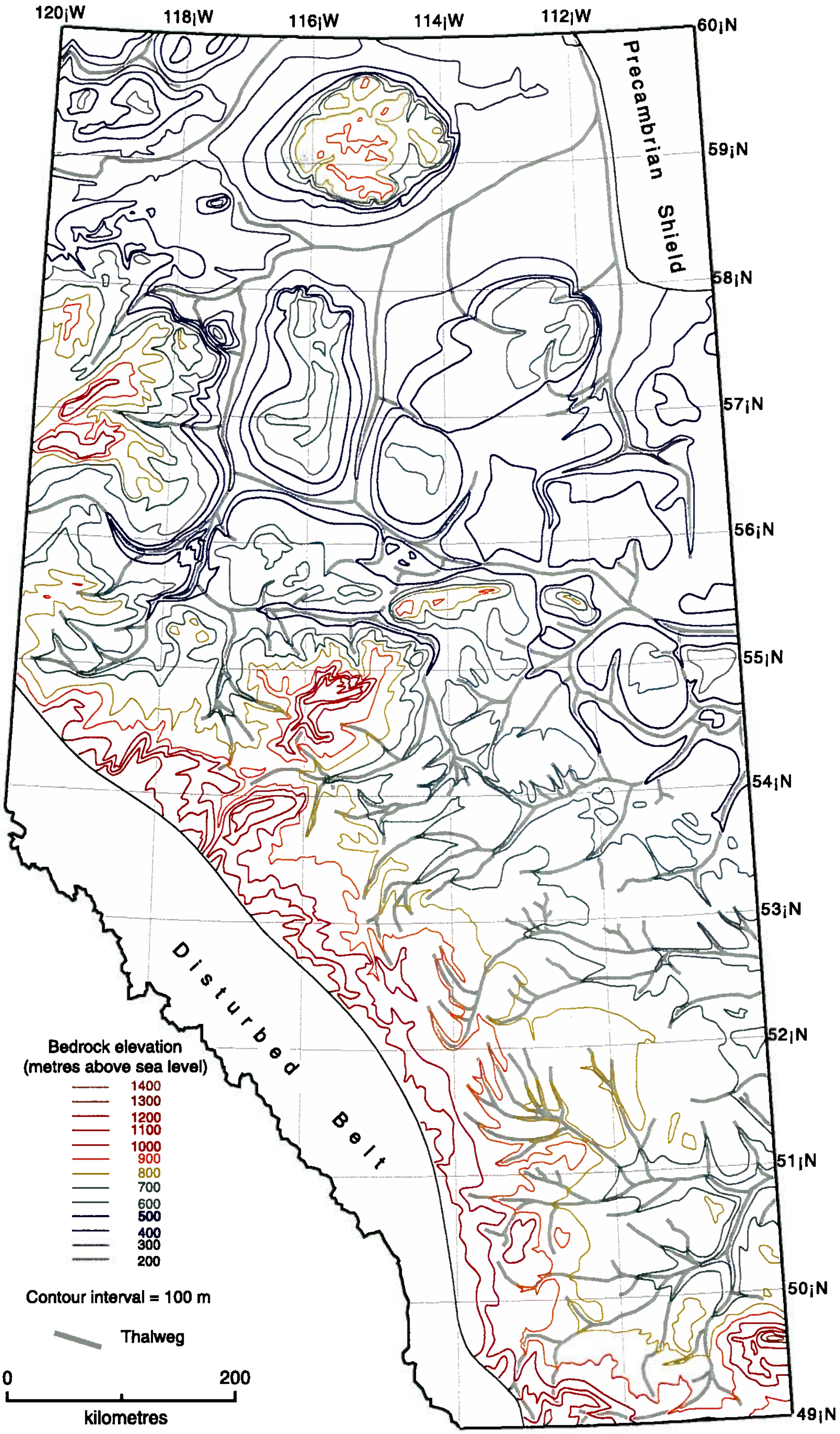


Figure 6. Bedrock topography map of Alberta (Modified after Pawlowicz and Fenton, 1995a).

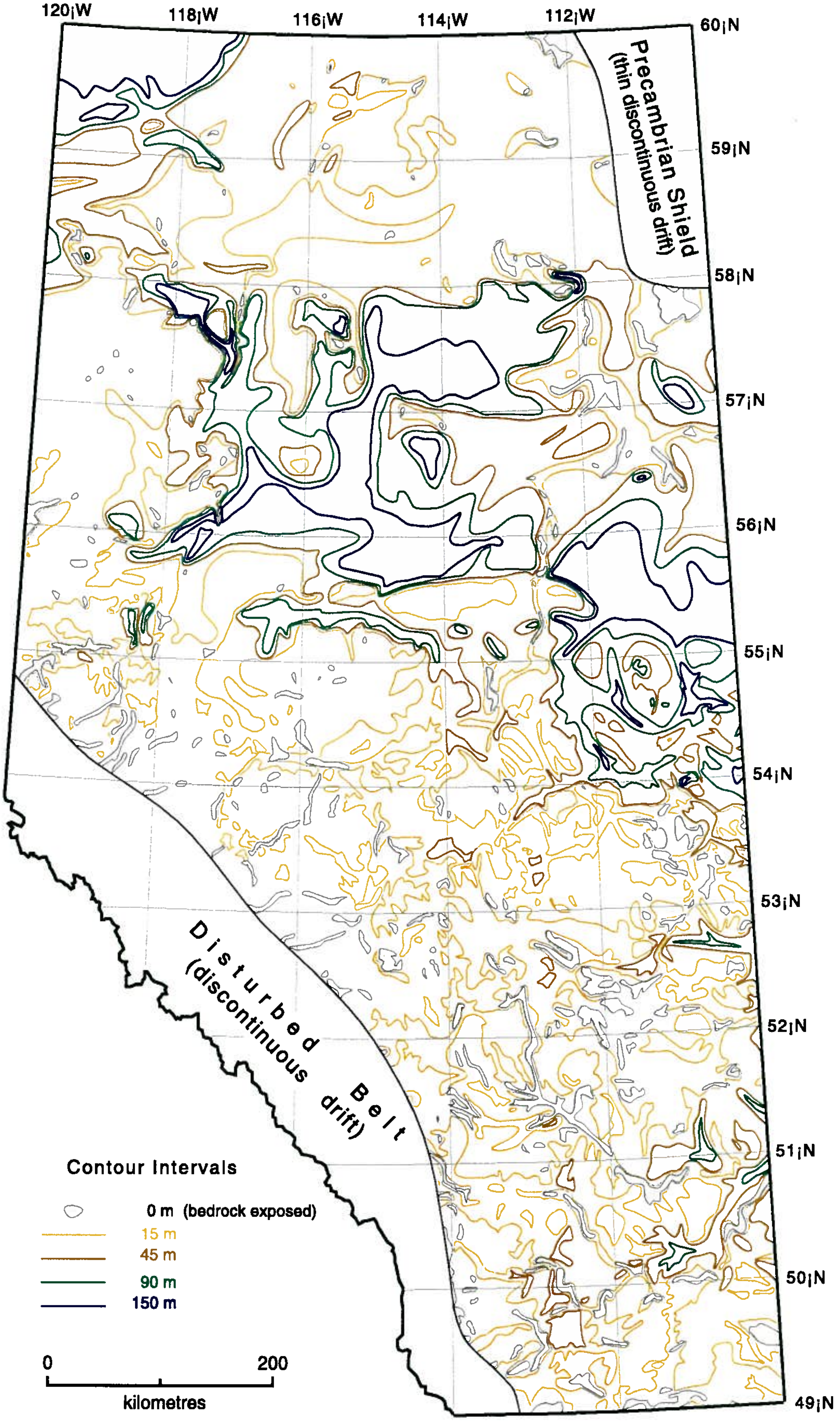


Figure 7. Drift thickness map of Alberta (modified after Pawlowicz and Fenton, 1995b).

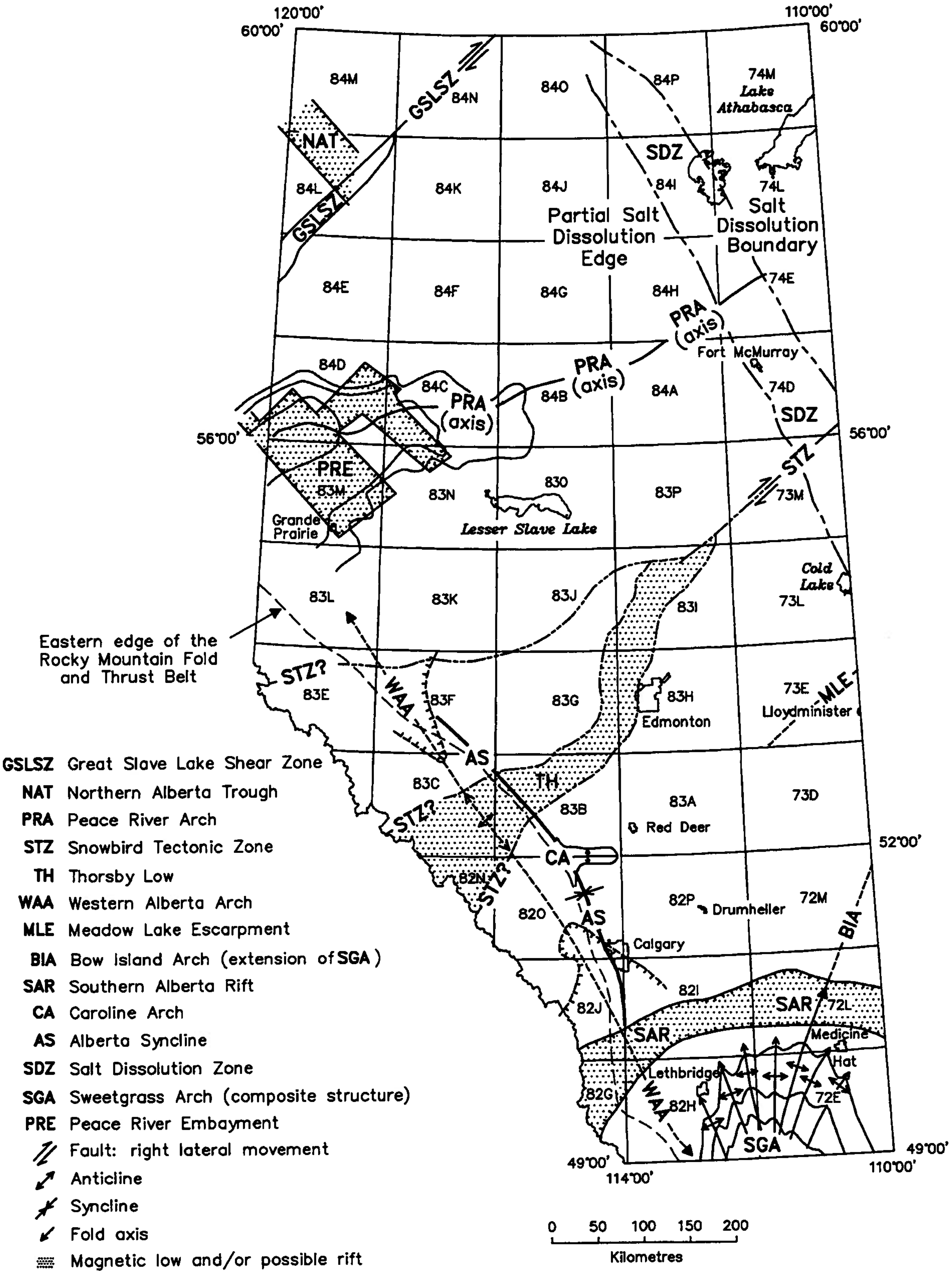


Figure 8. Major structures and tectonic features in Alberta.

Throughout the Middle and Late Devonian the PRA was a topographically emergent feature that was gradually onlapped by carbonate sedimentation. Episodic tectonism reactivated Precambrian fault zones and influenced sedimentation patterns within and around the Arch (Dix, 1990). By the end of the Devonian, the PRA was no longer emergent and shallow marine deposition reflected a continuation of Late Devonian subsidence trends (O'Connell *et al.*, 1990).

During the late Early Carboniferous, the central region of the PRA began to subside and form a large northeast trending basin. By the early Visean, the Arch had been fundamentally transformed by the development of a series of linked grabens into the Peace River Embayment (PRE). The development of the PRE is the product of a complex extensional environment with kilometre scale subsidence and significant displacements along normal faults (Barclay *et al.*, 1990). The PRE persisted throughout the Permian and Triassic.

During the Cretaceous, evidence indicates that accentuated subsidence occurred in the Peace River region and this influenced Lower Cretaceous channel and shoreline trends. Minor structural offsets within the Late Cretaceous may have been caused by the reactivation of underlying PRA and PRE structures (Hart and Plint, 1990). Burwash (1990) suggested that the effects of the PRA can be seen as far east as the Saskatchewan border and that the Arch may have been active as late as Recent based upon the positive topographic relief and high heat flow in the underlying basement rocks along its axis.

O'Connell *et al.* (1990) have demonstrated the possibility that regionally significant Precambrian fault zones in the Peace River region have been reactivated throughout the Phanerozoic. Some underlying major basement terrane contacts are spatially coincident with: (1) the trends of Devonian and Carboniferous grabens; (2) the location of Late Devonian dolomitization fronts; and (3) a linear Cretaceous erosional feature. It is also important to note that these basement structures near the margins of the Arch, such as the Belloy Fault, may have played an important role during the intrusion of kimberlite magma, as evidenced by the location of the Mountain Lake Kimberlite (Figure 9). Various mechanisms have been proposed for the origin and development of the PRA, none of which is entirely satisfactory. In summary, the PRA is a deeply buried structural feature that has had a complex tectonic history extending from the Late Proterozoic until at least the Late Cretaceous.

West Alberta Arch

The West Alberta Arch (WAA) is a northwest-trending, possibly doubly plunging antiform that is at least 500 km in length, with its axis located at the eastern limit of the Rocky Mountains (Verrall, 1968). It was active from at least Silurian to Middle Devonian time (Geldsetzer and Mountjoy, 1992). The presence of debris flows, spectacular megabreccias and deep-water channels within Upper Devonian carbonates (e.g. the Cline Channel), may indicate that the WAA was active during the Late Devonian (Geldsetzer and Mountjoy, 1992) and during the Carboniferous (Brandley *et al.*, 1993). It is also noteworthy that the northeast trending hinge of the WAA is located near, and is roughly parallel to: (1) the Upper Devonian Cline Channel; (2) the axis of the Thorsby Low; and (3) the projected trend of the STZ and the northeasterly trending Bighorn Tear Fault (Figures 8 and 9).

The reason for uplift of the WAA is not known, but Bingham *et al.* (1985) reported that a conductive ridge underlies the Eastern Rocky Mountains. They suggested that in the American Rockies, similar conductive structures are correlated with high heat flow and low seismic velocities in the lower crust. As a result, they further suggested that partial melting and periodic uplift may have been associated with the conductive ridge beneath the Eastern Rocky Mountains.

Meadow Lake Escarpment

The northeasterly trending Meadow Lake Escarpment (MLE) forms the erosional edge of the Ordovician Red River Formation in east-central Alberta (Van Hees and North, 1964). In Saskatchewan and Manitoba, the MLE trends easterly and runs south of and parallel to the Kisseynew Lineament. To the west, in Alberta, the MLE widens out and flattens. In general, the MLE is believed to have formed as a result of broad uplift to the north, with the escarpment acting as a hinge line during latest Silurian to earliest Devonian time. Some authors, however, have referred to the MLE as a "cuesta" or attribute its origin to transcurrent faulting (Haites, 1960; Douglas *et al.*, 1970).

Sweetgrass Arch

The Sweetgrass Arch (SGA) is a northward plunging, complex antiform in southern Alberta that encompasses a region of approximately 32,000 km^2 (Christopher, 1990). Recent summaries of the SGA are provided by

Herbaly (1974), Lorenz (1982), Leckie and Rosenthal (1986), Podruski (1988) and Christopher (1990). This complex antiform forms a broad divide between the Alberta foreland basin to the west and the Williston Basin to the east. The central core of the SGA is in Montana at the Kevin-Sunburst Dome. The Arch plunges northwards into Alberta where it meets the southwest plunging anticlinal nose of the Bow Island (or Battleford) Arch. This structural low between the Sweetgrass and Bow Island Arches is known as the Suffield Saddle (Herbaly, 1974). There are indications of uplift and erosion, possibly associated with the SGA, in pre-Devonian times (Kent, 1986, 1994). Carboniferous and Permian sediments wedge out against the eastern flanks of the Arch, accentuated by downwarp of the Williston Basin. The cumulative tectonic relief of the SGA throughout this time is estimated at 600 m (Christopher, 1990). Uplift was enhanced during the Triassic and the Arch was widely emergent, with deposition onlapping its eastern flanks.

The Alberta Syncline (AS) is situated between the SGA and the deformed belt of the Rocky Mountains (Leckie, 1989). The axis of the AS corresponds to the trend of the thickest portions of the Tertiary sequences and coincides with the axis of the Tertiary foreland basin. The AS was active during Late Cretaceous to Early Tertiary, during formation of the Eastern Rocky Mountains of Alberta.

Rocky Mountain Fold and Thrust Belt

There are three linear belts of distinctive deformation style in the Alberta portion of the Canadian Cordillera: the Foothills, Front Ranges and Main Ranges. Foothills bedrock geology is characterized by thrust faults, with Tertiary and Mesozoic strata in the footwall, and Mesozoic strata or Carboniferous and younger strata in the hanging wall. Front Range geology is characterized by thick Devonian to Proterozoic carbonate sequences over Cretaceous rocks. In the Main Ranges, the thrust sheets are predominantly composed of Paleozoic and Proterozoic strata, with the Mesozoic strata not preserved. The structural style changes from discrete overthrust faults of significant stratigraphic offset in the southeast to large amplitude box and chevron style folds with little stratigraphic separation, underlain by blind thrusts of significant stratigraphic offset in the northwest. This change in structural style from south to north coincides with a significant change in the dominant lithology of the deformed rocks (McMechan *et al.*, 1992).

In Alberta, the Rocky Mountains and Foothills are dominated by northwest-trending folds and thrust sheets that developed during accretion of land masses west of the Rocky Mountain Trench. The structural geology of the Eastern Rocky Mountains and Foothills is well-summarized by Charlesworth (1959), Shaw (1963), Bally *et al.* (1966), Dahlstrom (1970), Jones (1971) and Price (1981). Work during the, 1970's and 1980's has been focused on the details of imbricate thrusting and the actual mechanisms responsible for the formation of such structures as floor thrusts, roof thrusts and duplexes (Price and Lis, 1975; Fermor and Price, 1987).

The Canadian Cordillera formed during the Laramide Orogeny, with most of the deformation occurring from the Late Cretaceous to early Tertiary. Uplift to the west is documented as early as the Jurassic by the Kootenay Group-Blairmore Formation clastic wedge (Eisbacher *et al.*, 1974). The formation of the Eastern Rocky Mountains and Foothills of Alberta was probably ongoing from Late Jurassic to Paleocene time, however the last major stage of uplift is thought by many authors to have occurred during Late Eocene to Oligocene (Shaw, 1963; Bally *et al.*, 1966; Eisbacher *et al.*, 1974).

Local Structures

In addition to the foregoing major tectonic features that are present within and beneath the Alberta Basin, there are many other smaller, more local structural elements, including: folds, faults, fractures, salt dissolution features, and a few inferred astroblemes (Moffat and Gardner, 1981; Osadetz, 1989; Osadetz and Haid, 1989). Examples of such local structures are shown on Figure 9, are summarized below and are described in greater detail in Appendix 1.

Transverse, Tear and Normal Faults

Northeast-trending transverse, tear and normal faults have been reported along the Alberta Rocky Mountains and Foothills by Beach (1942), Birnie (1961), Fitzgerald (1962), Price (1967), Verrall (1968), Dahlstrom (1970), Moffat and Spang (1984), McGugan (1987) and McMechan (1988). Excellent summaries of the early mapping and geological setting of these structures are given in Price (1967), Dahlstrom (1970), Olson *et al.* (1994) and Dufresne *et al.* (1994a).

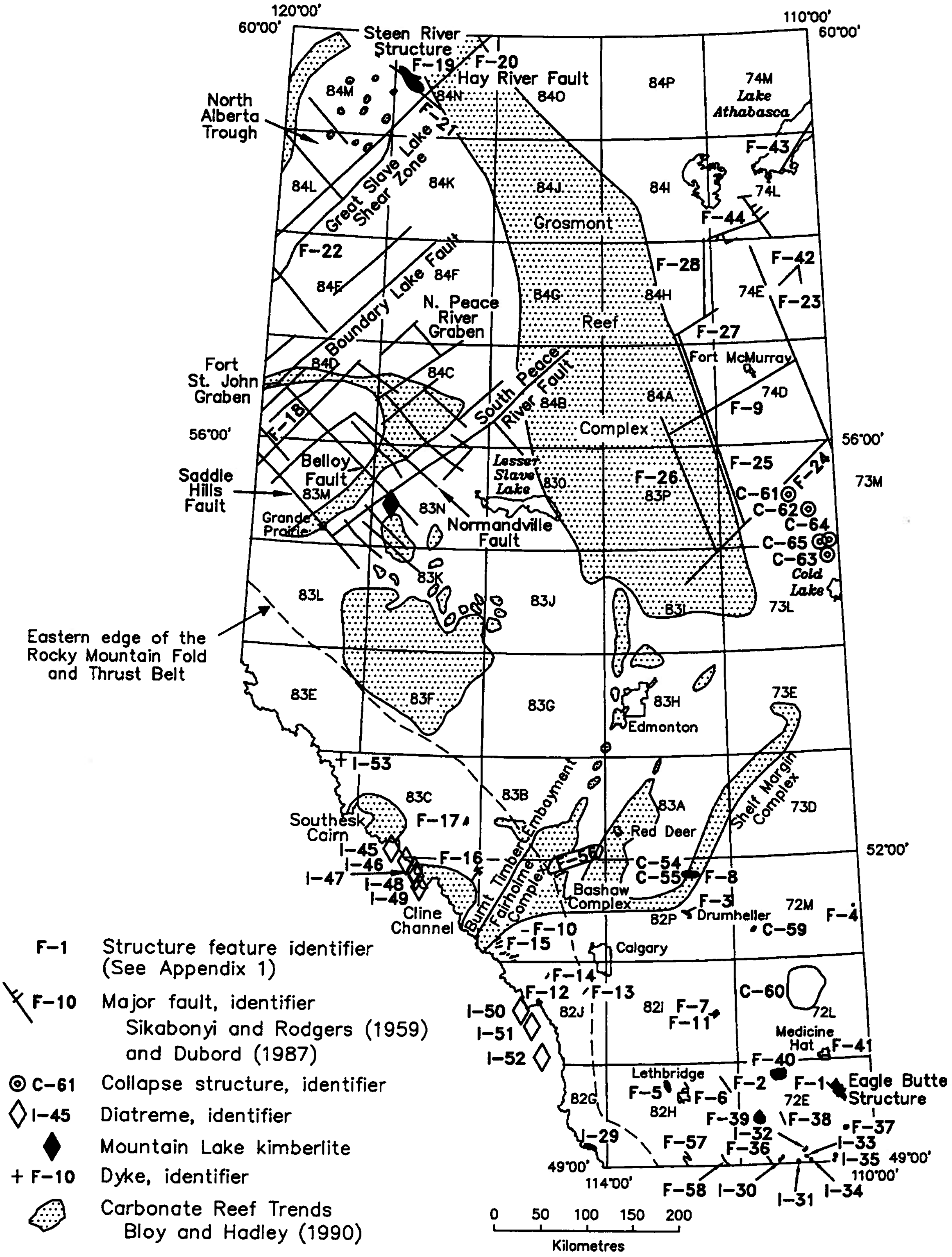


Figure 9. Major faults, carbonate reefs, diatremes, dykes and collapse structures in and adjacent to Alberta.

Large prominent tear faults that have been identified in the Alberta Rocky Mountains include the Bighorn Tear Fault (Verrall, 1968; Dahlstrom, 1970), the Ghost River Fault (Fitzgerald, 1962) and a possible tear fault near Moose Mountain (Beach, 1942), although subsequent mapping by Ollerenshaw (1975) indicated that this structure may be an oblique thrust fault.

Areas where northeast trending transverse and normal faults have been documented in the Alberta Rocky Mountains and Foothills include: (1) Indianhead Creek; (2) the Clearwater River; (3) southwest of Banff; (4) southwest of Canmore; (5) in the Elk, Opal and Misty ranges east of Kananaskis Lakes; and (6) in the Mount Head area (Douglas, 1958; Birnie, 1961; Price, 1967; Verrall, 1968; Moffat and Spang, 1984; McGugan, 1987; McMechan, 1988).

Other Structural Anomalies

In the Alberta Interior Plains, folds or fractures or both have formed as a result of differential compaction by dissolution of underlying salts in the Paleozoic evaporitic successions or by other mechanisms related to post-Laramide epeirogenesis (Leckie, 1989). Fractures have had a profound influence on the location of many oil and gas pools, and the quality of reservoirs in Western Canada as a result of their affect on host rock porosity (Osadetz, 1989). The conditions of such fracturing are controlled by crustal stresses (Bell and Babcock, 1986). Possible astrobleme structures include the Steen River Structure (SRS) in the north and the Eagle Butte Structure in southern Alberta (Winzer, 1972; Sawatzky, 1975).

Metamorphism and Metasomatism

Langenberg and Nielsen (1982) stated that there are two distinct cycles of metamorphism in northeastern Alberta. Archean metamorphism of metasediments (M_1) is represented by high pressure granulite conditions. During Aphebian times, the metasediments underwent transitional granulite-amphibolite metamorphism (M_2) retrogressing to greenschist facies metamorphism.

Elsewhere in Alberta, including the Cordillera, metamorphic conditions are low-grade. The exposed Precambrian rocks are commonly metamorphosed to greenschist facies, whereas the Paleozoic and some Mesozoic strata are predominantly prehnite-pumpellyite facies (Greenwood *et al.*, 1992). The majority of Mesozoic rocks are metamorphosed to zeolite facies only.

The Alberta Basin contains an unusual amount of dolomitized carbonates. Dolomitization is widespread in the Paleozoic carbonate rocks of Alberta, particularly within the Cambrian to Devonian formations, with most of this dolomitization probably being post-diagenetic (Douglas *et al.*, 1970). Some dolomite occurrences include: (1) the dolomite belt at the western margin of the Cooking Lake platform in east-central Alberta (Andrichuk, 1958); (2) the Leduc buildups of the Rimbey-Meadowbrook trend in central Alberta (Machel and Mountjoy, 1987) and the Leduc platform in the PRA region (Dix, 1990); (3) the Nisku buildups of central Alberta (Machel and Anderson, 1989); and (4) the linear dolomite trend that is present within the Wabamun Formation in the PRA region (Stokes, 1987; Workum, 1991). As well, Dawson (1886) reported extensive marble alteration and dolomitization in southwest Alberta. The dolomitization patterns in Alberta may be a product of fluid movement along basement structures (Hitchon, 1993) or may reflect fluid-driving mechanisms such as basin compaction flow and meteoric input. Recent work by Nesbitt and Muehlenbachs (1993a, b) has documented extensive pre-thrusting, likely Late Devonian, fluid flow that may have caused the formation of massive epigenetic to replacement dolomites with local deposition of base metals, magnesite and talc in southeastern BC and the Rocky Mountains and Foothills of Alberta.

Volcanic Events in Alberta and Around the World

The global spatial and temporal distribution of kimberlites and lamproites has been reviewed by Dawson (1980, 1989), Janse (1984), Bergman (1987), Mitchell and Bergman (1991) and Helmstaedt (1993). Kimberlite and lamproite diatremes occur on all major continents and they range in age from Lower Proterozoic to Recent (Table 2). To date, one occurrence of kimberlite, the Mountain Lake Kimberlite, has been reported in Alberta. The potential existence and age of other kimberlites and lamproites in Alberta are discussed in the following section by reviewing known occurrences of these rock types in the vicinity of Alberta and by examining the evidence for volcanic activity within Alberta.

Kimberlites and Lamproites in Western North America

Kimberlite and lamproite magmatism has occurred throughout almost every time period around the world (Table 2). However, those periods that have been more favourable for the emplacement of diamondiferous varieties are shown in Table 2 and are summarized in Table 3. Dawson (1989) suggested that Middle Jurassic to mid-Cretaceous was the most prolific period of kimberlite magmatism in the world. Most of the important ages for kimberlite or lamproite magmatic events are represented on the North American continent, with some diatremes occurring within and near Alberta (Figure 10, Table 2).

Proterozoic ultrapotassic volcanism is represented by the Aphebian Christopher Island Formation of the Dubawnt Lake to Baker Lake area, NWT, which forms one of the largest lamproite-minette magmatic provinces in the world (Peterson, 1993). The Parker Lake lamprophyre, which is likely equivalent in age to lamproites of the Christopher Island Formation, yielded two macrodiamonds and 1,511 microdiamonds in a 22 kg sample (Northern Miner, 1995a).

Paleozoic diatreme breccias, dykes, sills and stocks that predate Laramide compressional deformation in the Canadian Cordillera exist in the Rocky Mountains of BC between Williston Lake and Cranbrook. They form a complex suite of rocks comprised of carbonatites, nepheline syenites, some ijolite series rocks, numerous ultramafic and lamprophyric diatreme breccias and associated dykes, and one kimberlite diatreme (Pell, 1987a, b). Dating of these intrusions by many workers has been summarized by Pell (1987a, b). There are at least three discrete periods of Paleozoic alkaline mafic to ultramafic magmatic activity in BC. These are: Ordovician-Silurian, Late Devonian-Mississippian and Permian-Triassic.

An example of the Ordovician-Silurian intrusions in southeast BC is the Russel Peak diatreme, an ultramafic lamprophyre (Pell, 1987a, b). More important examples are the Mountain diatreme in the Mackenzie Mountains, NWT (Godwin and Price, 1986) and the Cross Lake kimberlite north of Yellowknife, NWT (Pell, 1996), both of which are diamondiferous (Figure 10, Table 2).

The Mark and Jack diatreme clusters, located north of Golden, BC, are believed to be part of the Devonian-Mississippian group of intrusions based on age dates from the HP pipe (Table 2), which occurs near the Mark diatreme cluster (Pell, 1987b). The Mark diatreme cluster straddles the Alberta-BC border and contains some of the largest diatremes in the Canadian Cordillera, such as the Mark 1 diatreme, which has a surface areal extent of about 250 m by 1,200 m (Fipke *et al.*, 1989). The Mark 1 diatreme extends well across the border into Alberta (Fipke *et al.*, 1989). Bulk samples of the Jack and Mark diatremes, and nearby stream sediments yielded lamproitic indicator minerals, including a few microdiamonds (Northcote, 1983a, b; Dummett *et al.*, 1985; Fipke *et al.*, 1989; Fipke *et al.*, 1995). Pell (1987a, b), and Ijewliw and Schulze (1988) suggested that the diatremes are alkalic, ultramafic lamprophyres and not kimberlites or lamproites. Fipke *et al.* (1989) and Fipke *et al.* (1995), however, suggested that the main Jack pipe is a lamproite and that the Mark 1 diatreme is lamproitic based on mineralogy and whole rock chemistry.

Table 2. Ages of kimberlite and lamproite intrusions

PERIOD	Series	Stage	Kimberlites World Wide	Lamproites World Wide	Kimberlites North America	Lamproites & Ultramafic Lamprophyres North America	Alberta Volcanic Events
QUATERNARY		Holocene 0.01		Gaussberg, ANT (Recent)			
		Pleistocene 1.6				Leucite Hills, WY (1-2)	
TERTIARY		Pliocene 6		Mercia & Almeira, SP (6-8)			
		Miocene 24		Kef Hahouner, AG (9-11) **Noonkanbah (18-20) & Ellendale (20-25), AL**		Navajo Volcanic Field, UT & AZ (UML's 20-30)	
		Oligocene 37				Smoky Butte, MT (27)	
		Eocene 58	**Mwadui, TZ (53)** Nzega, TZ (51-54)		Williams Ranch, MT (47-52) **Lac de Gras, NT (52)**	Kamas & Moon Canyon, UT (40) Bearpaw Mountains, MT (50-54)	**Sweetgrass Intrusions (49-50)**
		Paleocene 66	Mukerob, NB (61), Deutsche Erde, NB (66)				Kneehills Tuff (66)
CRETACEOUS	Upper	Maastrichtian 75	**Mbuji-Mayi, ZA (71)**		**Lac de Gras, NT (74)**		Belly River Bentonites (75) Mountain Lake (75?)
		Campanian 84	**M1, BT (77), Bultfontein, SA (78-84), Dutoitspan, SA (84)**		Ison Creek, Elliot Co., KY (80)		
		Santonian 88	**Jagersfontein, SA (86)**		**Somerset Island, NT (88-105)**	Rose & Hills Pond, KN (88-91)	
		Coniacian 89					
		Turonian 91	**DeBeers, SA (90), Wesselton, SA (90)** **Koffiefontein, SA (90), Monastery, SA (90)**				
		Cenomanian 98	**Koidu, SL (92), Orapa, BT (93), Finsch, SA (94), Kimberly Pool, SA (95)**		**Fort a la Corne, SK (94-101)** **Sturgeon Lake, SK (98)**		Crowsnest Volcanics (96)
	Lower	Albian 113	Uintjes Berg, SA (100)		**Somerset Island, NT (99)** Riley County, KN (110-120)	**Prairie Creek, AK (106)**	Viking Bentonites (100)
		Aptian 119	**Newlands (114), Frank Smith (114), Mayeng (117) all SA**				
		Barremian 124	**Bellsbank (119), Finsch (119), Star (124) all SA**	Lomam, CIS (119-124)	Syracuse, NY (121-128)		
		Hauterivian 131	New Elands, SA (126) **Roberts Victor, SA (128)**			Ile Bizard, QU (UML 126)	
		Valanginian 138	Obnazhennaya, CIS (135-143)	Murun (132-138), Kayla (133) & Ryabinovaya (137-142) all CIS			
		Berriasian 144		Yakokut, CIS (142-147)	Ithaca, NY (139-146)		
JURASSIC	Upper		**Swartruggens, SA (156), Mzongwana, SA (152)** Slyudyanka (147), Irina (149), Muza & Tokur (151), Marichka (156), Khrizolitovaya (159) all CIS		**Kirkland Lake, ON (155)**	Hearst, ON (UML 152)	
	Middle		**Klipfontein, SA (159), Orroroo, AL (170)** Elandskloof, SA (165-176),				
	Lower	208	Pyramidefjeld, GL (193) **Dokolwayo, SZ (204)**		**Lake Ellen, MC (190)**	Hearst, ON (UML 180)	

PERIOD	**Series**	**Stage**	**Kimberlites World Wide**	**Lamproites World Wide**	**Kimberlites North America**	**Lamproites & Ultramafic Lamprophyres North America**	**Alberta Volcanic Events**
TRIASSIC	Upper		Pozdnyaya, CIS (217), Nigerdlikasik, GL (220)	**Kapamba, ZM (220?)**			
	Middle						
	Lower	245	**Jwaneng, BT (235)**		Crossing Creek, BC (244)		
PERMIAN	Upper						
	Lower	286					
PENNSYLVANIAN	Upper	295		Pendennis Point, UK (280-320?)			
	Middle	310					
	Lower	320					
MISSISSIPPIAN	Upper		**Sytykanskaya, CIS (344)** Rassvet (344), Svetlaya (344) & Kollektivnaya (347) all CIS			Ospika River, BC (UML 323-334)	
	Lower	360	Festivalnaya, CIS (358) **Internationalnaya, CIS (360)**		**Sloan, CO (350)**	HP Pipe, BC (UML 348-396)	
DEVONIAN	Upper	Famennian 367	**Mir, CIS (361), Fuxian, CH (366-398)** Iskorka, CIS (363)				Exshaw tuffs
		Frasnian 374	Zagadochnaya, CIS (370), Svetlaya, CIS (372)			Elbow Diatreme, SK (Comp. unknown)	
	Middle	Givetian 380			Avon, MI (377-399)		
		Eifelian 387					
	Lower	Emsian 401			**Kelsey Lake, CO (390)**		
		Siegenian	Tayezhnaya, CIS (403)				
		Gedinnian 408					
SILURIAN		438	Druhza, CIS (412)	Mt. Bayliss, ANT (413-430)		**Mountain Diatreme, NT (UML? 427-445)** Russell Peak, BC (UML 435-440)	
ORDOVICIAN	Upper		Amakinskaya, CIS (450), Muna Field, CIS (450)		**Cross Lake, NT (450)**		
	Middle						
	Lower	505	**Shengli, CH (482-498)**				
CAMBRIAN	Upper	515					
	Middle	540					
	Lower	570					
PROTEROZOIC	Upper	Hadrynian 955	**Venetia, SA (600)** Holsteinsborg (587), Umivit (589) & Sarfartoq (593-598) all GL Skerring, AL (810), Pteropus Ck, AL (810), Lattavaram, IN (940-1023)		**George Creek, CO (600)**		
	Middle	Helikian 1,735	**Premier, SA (1,202)** Zero (1,635), Elston (1,674) & Bathlaros (1,649) all SA	**Argyle, AL (1,178), Bobi, IC (1,400)** **Majhgawan, IN (1,056-1,140)** Yinniugou, CH (1,100-1,200), Chelima, IN (1,200) Holsteinborg, GL (1,214-1,227)	**Kyle Lake, ON (1,140)**		Purcell Lavas (1,100) Moyie dykes (1,400-1,580)
	Lower	Aphebian 2,480				**Outlet Bay & Parker Lake, NT** Christopher Island Fm, NT (1,840)	

AG=Algeria, AK=Arkansas, AL=Australia, ANT=Antarctica, AZ=Arizona, BC=British Columbia, BT=Botswana, CH=China, CIS=Former USSR, CO=Colorado, GL=Greenland, IC=Ivory Coast, IN=India, KY=Kentucky, MC=Michigan, MI=Missouri, MT=Montana, NB=Namibia, NM=NewMexico, NT=NorthwestTerritories, NY=NewYork, ON=Ontario, QU=Quebec, SA=SouthAfrica, SK=Saskatchewan, SP=Spain, SZ=Swaziland, TZ=Tanzania, UK=England, UT=Utah, WY=Wyoming, ZA=Zaire, ZM=Zambia, BOLD=Diamondiferous, HIGHLIGHTED INTERVAL=most prospective age interval to discover DIAMONDIFEROUS intrusions in Alberta

The Crossing Creek kimberlite, which crops out near the Alberta border about 8 km northwest of Elkford, BC, is the only recognized occurrence of kimberlite in the Canadian Rocky Mountains (Grieve, 1982; Hall *et al.*, 1989). The Crossing Creek kimberlite is of Permian-Triassic age and has been reported to be barren of diamonds (Grieve, 1982; Pell, 1987a, b; Hall *et al.*, 1989). However, recently discovered kimberlitic intrusions in the vicinity have yielded at least two diamonds (George Cross Newsletter, 1994).

The Colorado-Wyoming State Line District kimberlite field contains the only other known Paleozoic kimberlites in western North America. The Kelsey Lake kimberlite and the Sloan kimberlite, both of which are diamondiferous, are examples from this field (Shaver, 1988; Otter and Gurney, 1989; Coopersmith, 1991, 1993a, b). In the former Soviet Union, most of the economic and prolific diamond producing kimberlites of the East Siberian platform, such as Mir, Internationalnaya and Udachnaya, are Late Devonian to Early Mississippian in age (Davis *et al.*, 1982; Milanovskiy and Mal'kov, 1982; Jerde *et al.*, 1993).

Paleozoic diatremes of unknown composition are believed to have been intersected in three oil wells in Saskatchewan (Gent, 1992). Upper Devonian carbonate breccias that contain one or more of olivine, eclogitic and pyropic garnets, chromite, phlogopite, zircon and shocked quartz were intersected by Imperial Elbow No. 1, Birsay Crown No. 1 and Imperial Barnes wells (Gent, 1992). The Imperial Elbow No. 1 and Birsay Crown No. 1 diatremes are located in south-central Saskatchewan near the town of Elbow. The Imperial Barnes diatreme occurs northwest of Meadow Lake, in northwest Saskatchewan about 100 km east of the Alberta border. The diatremes occupy structures that appear to be related to salt solution, but may alternatively be the result of post emplacement collapse of the diatremes. Therefore, unusual and perhaps "out of place" salt solution structures in Alberta should be evaluated for potential diamondiferous kimberlite diatremes.

The Middle Jurassic to mid-Cretaceous was perhaps the most extensive and voluminous period of diamondiferous kimberlite magmatism in the world (Dawson, 1989). Diamondiferous kimberlites of Middle and Late Jurassic age have been recognized at Lake Ellen, Michigan (Jarvis and Kalliokoski, 1988; Duskin and Jarvis, 1993) and at Kirkland Lake, Ontario (Brummer, 1978, 1984; Fipke *et al.*, 1989). Significant to the Alberta setting is the discovery of Early to mid-Cretaceous diamondiferous kimberlites on Somerset Island, NWT (Fipke *et al.*, 1989; Kjarsgaard, 1993; Pell and Aitkinson, 1993; Kjarsgaard and Heaman, 1995) and at Fort à la Corne, Saskatchewan (Lehnert-Thiel *et al.*, 1992; Kjarsgaard, 1995; Leckie *et al.*, *In Press*). In addition, mid-Cretaceous diamondiferous lamproites have been discovered at Prairie Creek, Arkansas (Gogineni *et al.*, 1978; Scott Smith and Skinner, 1984; Fipke *et al.*, 1989) and Twin Knobs, Arkansas (Waldman *et al.*, 1987). At Fort à la Corne, three clusters that contain up to seventy kimberlitic bodies have been identified by airborne or ground geophysics (Lehnert-Thiel *et al.*, 1992). Forty-four kimberlites that range in age from 94 to 101 Ma with grades as high as 23 cts/100t, have been positively identified by drilling (Lehnert-Thiel *et al.*, 1992; Scott Smith *et al.*, 1994; Kjarsgaard, 1995; Leckie *et al.*, *In Press*). One of the more significant aspects of the Fort à la Corne kimberlites is the fact

Table 3: Main ages of diamondiferous intrusive events, world wide

Period	**Age Range (Ma)**	**Examples**
Early Tertiary	45 – 60	Mwadui, Tanzania; some pipes in the Lac de Gras region, NWT
Late Cretaceous to Middle Jurassic	80 – 170	Finsch, De Beers and numerous other famous southern Africa diamond producers
Mississippian to Late Devonian	340 – 370	Mir and other diamond producing pipes in Yakutia on the Siberian Platform
Late Middle Helikian	1,100 – 1,200	Premier, South Africa; Argyle lamproite, Western Australia

Figure 10. Location and age of North American kimberlites and lamproites

No.	Locality	Age (Ma)	Reference
Canada			
1	Somerset Island	88-105,99	Kjarsgaard & Peterson (1992); Kjarsgaard & Heaman (1995)
2	Mountain Diatreme	427-445	Godwin & Price (1986)
3	Lac de Gras	52, 74	Kjarsgaard & Heaman (1995)
4	Cross Lake	450	Pell (1996)
5	Dry Bones Bay	450 (?)	Pell, *pers. comm.* (1996)
6	Outlet Bay	1,840 (?)	Peterson (1993); association with Christopher Island Fm.
7	Parker Lake	1,840 (?)	Peterson (1993); association with Christopher Island Fm.
8	Ospika River	323-334	Pell (1987b)
9	HP & Jack Pipes	348-396	Pell (1987b)
10	Crossing Creek kimberlite	244	Grieve (1982); Fipke *et al.* (1989)
11	Mountain Lake Kimberlite	75 (?)	This volume.
12	Sweetgrass Intrusions	48-50	Folinsbee *et al.* (1965); Kjarsgaard & Davis (1994)
13	Sturgeon Lake	98	Kjarsgaard (1995)
14	Fort à la Corne	94-101	Lehnert-Thiel *et al.* (1992); Scott Smith *et al.* (1994); Kjarsgaard (1995)
15	Picton & Varty Lake		Arima & Kerrich (1988)
16	Kirkland Lake	155	Fipke *et al.* (1989)
17	Michaud Township		Watson (1973)
18	Coral Rapids		Brown *et al.* (1967)
19	Hearst	152,180	Nixon (1987); Janse *et al.* (1989)
20	Keith Township		Watson (1973)
21	Wawa		Mitchell & Janse (1982)
22	McKellar Harbour		Platt & Mitchell (1982)
23	Kyle Lake	1,140	KWG Resources, *pers. comm.* (1996)
24	Castignon Lake		Dimroth (1970); Dawson (1989)
25	Chicoutimi		Janse (1984)
26	Ile Bizzard	126	Fipke *et al.* (1989)
27	Bachelor Lake		Dawson (1967); Watson (1967)
28	Saglek		Collerson (1976)
29	Aillik Bay		Hawkins (1976); Dawson (1989)
United States Of America			
30	Haystack & Eagle buttes	48-52	Marvin *et al.* (1980); Hearn (1989); O'Brien *et al.* (1991)
31	Williams Ranch	47-52	Hearn & McGee (1984); Hearn (1989)
32	Smokey Butte	27	Marvin *et al.* (1980); Mitchell *et al.* (1987); Hearn (1989)
33	Iron Mountain	308,395	McCallum *et al.* (1975); Smith (1983)
34	Leucite Hills	1-2	Kuehner *et al.* (1981); Bergman (1987)
35	Kamas & Moon Canyon	40	Bergman (1987)
36	Mule Ear & Moses Rock	28-30	Brookins (1970a); Roden *et al.* (1979)
37	Garnet Ridge	30-34	Watson (1967b); Roden *et al.* (1979)
38	Buell Park	25-30	Roden *et al.* (1979); Smith (1979)
39	Green Knobs	25	Smith (1979)
40	Sloan, Kelsey Lake, George Creek	350,390,600	Helmstaedt (1993); Coopersmith (1993b); Carlson & Marsh (1989); Fipke *et al.* (1989)
41	Green Mountain		Meyer (1976); Meyer & Kridelbaugh (1977)
42	Riley Co.	110-120	Brookins (1970a, b); Brookins & Naeser (1971)
43	Rose & Hills Pond	88-91	Zartman *et al.* (1967); Bergman (1987)
44	Prairie Creek	106	Gogineni *et al.* (1978)
45	Avon	377-399	Erlich *et al.* (1989)
46	W. Kentucky & S. Illinois	257	Koenig (1956); Zartman *et al.* (1967)
47	Ison Creek, Elliot Co.	80	Basu *et al.* (1984); Zartman *et al.* (1967)
48	Norris Kimberlite		Meyer (1976)
49	Mt. Horeb		Sears & Gilbert (1973); Meyer (1976)
50	Masontown	185	Meyer (1976); Hunter & Taylor (1984)
51	Dixonville		Hunter & Taylor (1984)
52	Syracuse	121-128	Basu *et al.* (1984)
53	Ithaca	139-146	Basu *et al.* (1984)
54	Lake Ellen	190	Jarvis & Kalliokosk (1988)

that they are mostly flat to mushroom shaped in cross-section and they are dominantly composed of crater facies pyroclastics and reworked pyroclastics. This configuration has been attributed to explosive subaerial emplacement of the source diatremes with subsequent reworking and redistribution by marine and/or fluvial processes (Kjarsgaard, 1995; Leckie *et al.*, *In Press*). Diamonds have been discovered in crater facies and apron pyroclastics and in reworked volcanics in the Fort à la Corne area, similar to diamond deposits of the Yakutia region of Siberia (Nixon *et al.*, 1993; Nixon, 1995).

Lehnert-Thiel *et al.* (1992) reported that no feeder diatremes have been identified to date at Fort à la Corne. This indicates that the diatreme and root zone facies of the pipes are likely to be insignificant in terms of volume, even if found in the future. Therefore, it is reasonable to assume that any mid-Cretaceous kimberlite magmatic activity in Alberta may have formed rootless, flat to mushroom shaped kimberlites similar to those near Fort à la Corne, Saskatchewan.

Late Cretaceous and Early Tertiary ages have been recently determined for a few of the diamondiferous kimberlite pipes at Lac de Gras, NWT (Northern Miner, 1993b; Kjarsgaard and Heaman, 1995). This is of particular importance in light of the fact that the Mountain Lake Kimberlite near Grande Prairie, Alberta, intrudes and is intercalated with Wapiti Group sediments and, therefore, may be about 75 Ma.

Early to Middle Tertiary kimberlites have been discovered in North America, Montana and in the Lac de Gras region, NWT (Figure 10, Table 2). Although the Mwadui kimberlite in Tanzania is the only known early Tertiary producer of diamonds (Table 2), there are indications that several of the diamondiferous BHP-Dia Met kimberlite pipes at Lac de Gras, NWT, are Tertiary in age, and that they will be world class producers of diamonds.

Volcanic Events in Alberta

There is evidence of at least four, and possibly five, ages of volcanic activity in Alberta, some of which may be related to possible diamondiferous kimberlites or lamproites (Olson *et al.*, 1994; Dufresne *et al.*, 1994a). The ages of volcanic activity are: (1) Helikian; (2) Late Devonian to Early Mississippian; (3) mid-Cretaceous; (4) Late Cretaceous; and (5) Early Tertiary. Alkaline mafic volcanic activity has occurred in Alberta during at least four of these episodes (Table 2).

The oldest generation of volcanic activity is represented by the Helikian Moyie Sills and Purcell Lavas, which have been dated between 1,100 Ma and 1,580 Ma and are restricted to the Clark Range in southwest Alberta (Hunt, 1962; Hoy, 1989). The composition of the Helikian dioritic Moyie Sills and the andesitic Purcell Lavas differs significantly from the potassic, mafic to ultramafic compositional fields of kimberlites and lamproites, which are the most common primary host rocks for economic concentrations of diamonds.

The second oldest phase of volcanic activity consists of Upper Devonian to Lower Mississippian alkaline, mafic to ultramafic diatreme breccias, dykes and sills that are spatially and temporally related to the cluster of diatremes in southeast BC. Specifically, the Mark diatreme cluster straddles the Alberta-BC, border and a few dykes within the Mark cluster exist on the Alberta side of the border (Pell, 1987a, b; Fipke *et al.*, 1989). Other evidence of Late Devonian to Early Mississippian volcanic activity includes a massive marine extinction and an iridium anomaly (Wang *et al.*, 1993) associated with volcanic tuffs that have been identified in the Lower Exshaw Formation at the type section at Jura Creek near Exshaw (Richards *et al.*, 1993). Other volcanic tuffs also have been identified in the Exshaw shale near Nordegg (Folinsbee and Baadsgard, 1958), and in oil wells in the Peace River area (Packard *et al.*, 1991; Meijer-Drees and Johnston, 1993).

The third generation of volcanic activity in Alberta is represented by the mid-Cretaceous Viking Formation bentonites and the Crowsnest Formation volcanics. At least three regionally correlatable bentonites that are used as marker horizons across a large portion of Alberta have been identified within the Viking Formation (Amajor and Lerbekmo, 1980; Amajor, 1985). These bentonites exist below the Fish Scales marker horizon of the Shaftesbury Formation and have an average radiometric age of 100 Ma (Tizzard and Lerbekmo, 1975), which closely corresponds to the age for several diamondiferous kimberlites in the Fort à la Corne area of Saskatchewan (Gent, 1992; Lehnert-Thiel *et al.*, 1992; Kjarsgaard, 1995). Bentonites with a much more local distribution have also been identified in the Viking Formation (Tizzard and Lerbekmo, 1975; Amajor and Lerbekmo, 1980). As well, Carrigy (1968) reported the presence of numerous thin tuff layers interbedded with undisturbed Lower Cretaceous shales in the oil well I.O.E. Steen 16-19 near the SRS in northwestern Alberta.

The Crowsnest Formation volcanics consist mainly of pyroclastic and epiclastic deposits, with rare flows and intrusive rock that are restricted to southwest Alberta in the vicinity of Coleman. The volcanics are sodic-rich trachytes to phonolites and do not appear to have a chemistry that is favourable for diamond preservation (Peterson and Currie, 1993). The reported age for the Crowsnest volcanics is 96 Ma (Folinsbee *et al.*, 1957), which corresponds closely to the reported age of 94 to 101 Ma for several diamondiferous kimberlites in the Fort à la Corne area of Saskatchewan (Gent, 1992; Lehnert-Thiel *et al.*, 1992; Kjarsgaard, 1995). These dates for the Crowsnest volcanics indicate that alkaline volcanism was occurring in the Alberta Rocky Mountains and Foothills at the same time as diamonds were being transported from the upper mantle to the surface during the mid-Cretaceous in Saskatchewan, NWT, Arkansas and across much of southern Africa. As a result, mid-Cretaceous continental marine sedimentary rocks, such as those in the Viking Formation, may be a potential host to diamondiferous bedded kimberlite or lamproite pyroclastic, volcaniclastic or crater facies sediments.

The fourth distinct generation of volcanic activity in Alberta is represented by the Mountain Lake Kimberlite and Late Cretaceous bentonites in the Belly River Formation and in the Kneehills Tuff Zone within the Edmonton Formation. The Mountain Lake Kimberlite is hosted within the Wapiti Group sediments (approximately age equivalent to Belly River Formation) and is therefore Late Cretaceous in age or younger.

The youngest generation of magmatic activity in Alberta is represented by the Tertiary Sweetgrass Intrusions in southeast Alberta (Williams and Dyer, 1930; Russell and Landes, 1940; Irish, 1971). Price (1962) suggested that the trachytic to syenitic stocks and dykes, which straddle the Alberta-BC border in the Clark Range in southwest Alberta, are also early Tertiary in age. However, the chemistry of these intrusions indicates they may have a closer affiliation with the magmatic event responsible for the Crowsnest Formation volcanics. The Sweetgrass Intrusions are potassic in composition and have been dated at 49 Ma to 54 Ma (Baadsgaard, 1961; Taylor *et al.*, 1964; Folinsbee *et al.*, 1965; Kjarsgaard, 1994a, b; Kjarsgaard and Davis, 1994). Based on fieldwork and laboratory studies, Kjarsgaard (1994a) suggested that the intrusions are mostly minettes with low diamond potential, because of their overall geochemistry and the contained indicator minerals. However, kimberlites of a similar age do exist in the Missouri Breaks area of central Montana (Hearn, 1989) and in the Lac de Gras region, NWT (Table 2). As well, a microdiamond is reported to have been recovered from the Black Butte diatreme in southeast Alberta, which is one of the Sweetgrass Intrusions (Boulay, *pers. comm.*, 1996).

Bentonites and Volcanics in the Phanerozoic Succession

Current theory on the formation of diamond bearing diatremes recognizes the development of several facies within the uppermost part of the pipe. The intrusion, upon reaching the earth's surface, establishes a ring-shaped pyroclastic crater facies surrounding an epiclastic core (Mitchell, 1991). In the case of the Fort à la Corne kimberlites, successive beds of pyroclastics form a tephra cone with volcanic aprons, however, distal pyroclastics are also observed. (Garnett, 1994; Kjarsgaard, 1995; Leckie *et al.*, *In Press*). From an exploration point of view, these pyroclastic deposits should provide a relatively large, characteristic target in both terrestrial and marine environments.

'Bentonite' is defined as a clay formed from the devitrification and alteration of volcanic ash or tuff and is largely composed of clay minerals of the montmorillonite group plus colloidal silica (Bates and Jackson, 1987). In the Fort à la Corne area, increased numbers and thicknesses of bentonites have been observed in close proximity to the kimberlites but little work has been conducted on them (Garnett, *pers. comm.*, 1994; Kjarsgaard, 1995; Leckie *et al.*, *In Press*). Distal crater facies ash horizons could form apron to elongate domal shaped bentonite bodies in both Saskatchewan and Alberta. The geochemical signature of the bentonite deposits should reflect the original type of volcanism (ie. kimberlite, andesite, etc.).

Therefore, one aspect of examining the diamond potential of Alberta was to investigate the usefulness of bentonites in diamond exploration. Following are some of the aspects considered in the present study:

(1) Examination of the regional character of selected anomalously thick bentonites in Alberta which have been reported in the literature;

(2) Investigation of existing government databases and published literature for anomalous occurrences of tuff, volcanics and bentonites (for example, chemistry, thickness and geological associations); and

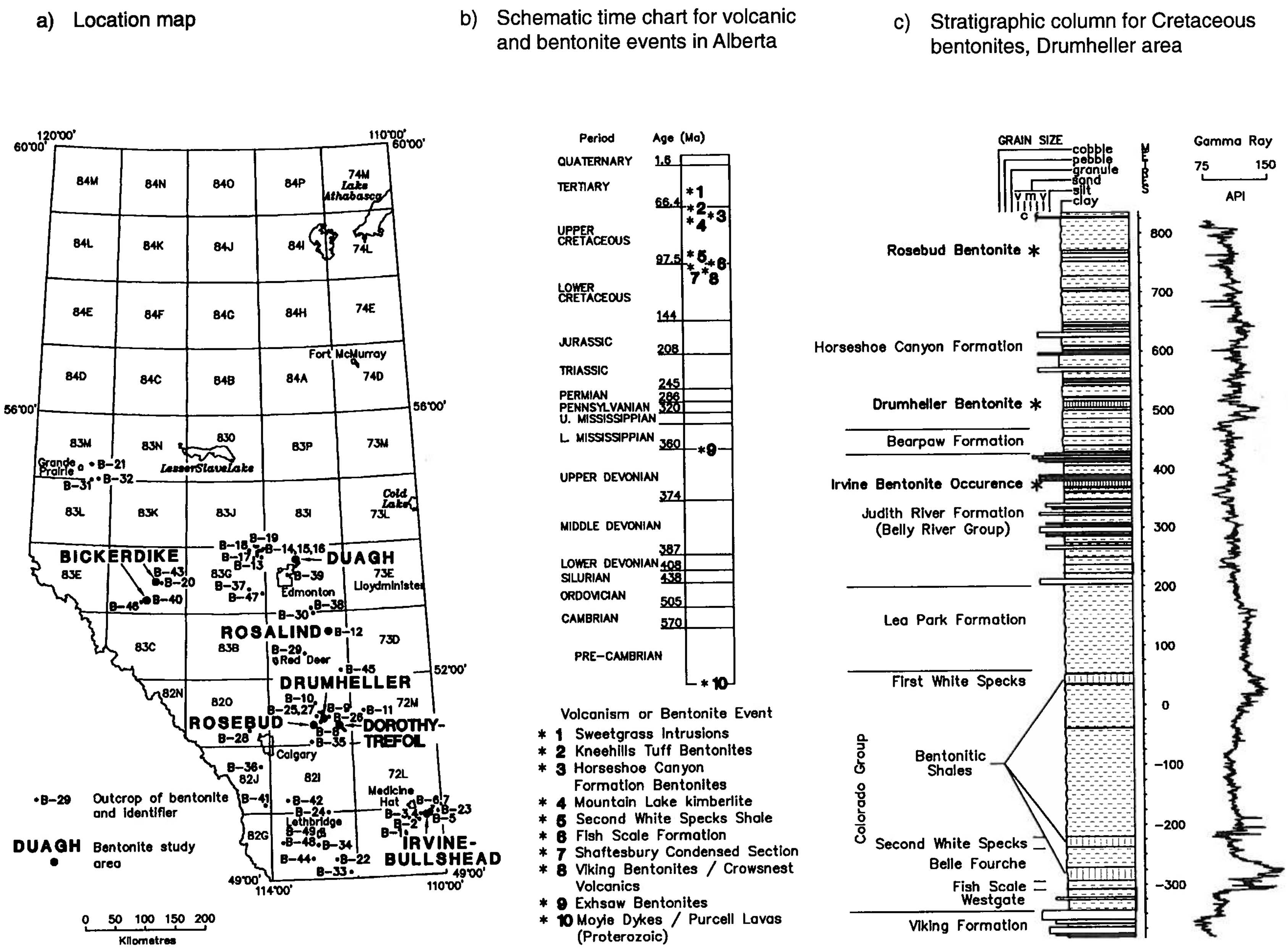
(3) Provision of guidelines in the use of bentonites as a diamond exploration tool.

Figure 11 and Appendix 2 identify surface localities in Alberta having anomalously thick occurrences of bentonite, as cited in various publications. Several of these localities were selected for a more detailed surface and subsurface investigation in this study. They include the bentonite occurrences in the Drumheller area, the Bickerdike and Rosalind area showings, and bentonites in the Irvine-Bullshead area. Also included in this study is an appraisal of subsurface information on bentonites in the Duagh area near Edmonton.

Volcanism and Bentonites in Alberta

Within Alberta, recognized products of volcanic activity are restricted to the Moyie dykes and Purcell lavas (Middle Proterozoic), the Exshaw Formation bentonites (Late Devonian-Early Mississippian), the Crowsnest Formation volcanics (late Early Cretaceous), the Mountain Lake Kimberlite (Late Cretaceous), the Belly River Group and Horseshoe Canyon Formation bentonites (late Late Cretaceous) and the Sweetgrass Intrusions (Eocene). The Proterozoic Purcell lavas and the Moyie dykes, which are restricted to the Clark Range of southwest Alberta, are compositionally very different from kimberlites and offer little incentive for diamond exploration potential.

Little information is available on the source volcanism for the thin volcanic tuffs identified in the lower shale of the Devonian-Mississippian Exshaw Formation in the PRA area (Bloy and Hadley, 1989). However, beds and laminae of marine tuff up to 1.5 m thick are present in the Exshaw shale at many localities from southwestern Alberta into east-central BC (Richards *et al.*, 1993). These authors consider volcanism to have taken place in the western Prophet Trough and westward. This is not well substantiated and should be investigated further, looking for evidence of more local volcanism as this was the age of the most prolific diamondiferous event on the Siberian Platform. In addition, diamondiferous kimberlites such as the Cross Lake kimberlite in the central Slave Province, NWT, and the Kelsey Lake and Sloan kimberlites in Colorado, span from Late Ordovician to Early Mississippian (Figure 10, Table 2). Therefore, it is possible that some of the Exshaw bentonites could be locally derived from kimberlite or lamproite volcanism.


a) Location map

b) Schematic time chart for volcanic and bentonite events in Alberta

c) Stratigraphic column for Cretaceous bentonites, Drumheller area

Figure 11. Bentonite study areas and occurrences in Alberta, with schematic stratigraphic columns depicting volcanic events and bentonites.

The Colorado Group

The Viking Formation bentonites, which are part of the Lower Colorado Group (Table 4) and are dated at about 101 Ma, are considered isochronous and genetically related to the Crowsnest volcanics (96 Ma) and the bentonitic Vaughn Member of the Blackleaf Formation of Montana (Amajor, 1985). Amajor (1985) determined that within each bentonite bed, biotite grain size decreased in a northeasterly direction away from the volcanic source. Up to eight bentonite beds have been recognized, with thicknesses ranging from 5 cm to 60 cm. The bentonites are rich in biotite grains and are considered regional ash fall products that were deposited distally in marine waters.

Overlying the Viking Formation are the Shaftesbury and Second White Specks formations of Albian to Turonian age (Figure 11, Table 4). Within the Shaftesbury Formation are three very distinctive units, the Westgate, Fish Scales and Belle Fourche members, that span the time interval from 92 Ma to 99 Ma. Within the time interval from 97 Ma to 99 Ma is a regional marker unit known as the Fish Scale Marker Horizon. The Fish Scale Marker Horizon is part of the Fish Scale Member and is characterized by high total organic carbon content, phosphatic bioclastic debris, fish remains and algal cysts, black phosphatic beds and numerous bentonites with some containing biotite and feldspar (sanidine?) grains that may be time correlative to some of the Upper Viking Formation bentonites (Bloch *et al.*, 1993). This unit is also characterized by a pronounced increase in gamma response on the geophysical log (Figure 11). It is particularly significant that diamond bearing kimberlite diatremes that have been dated at 94 Ma to 101 Ma have been discovered in the Fort à la Corne area of Saskatchewan (Lehnert-Thiel *et al.*, 1992; Garnett, 1994; Scott Smith *et al.*, 1994; Kjarsgaard, 1995; Kjarsgaard and Heaman, 1995; Leckie *et al.*, *In Press*). In the Fort à la Corne area, a reworked horizon containing enriched concentrations of diamonds, ilmenites, chrome diopsides and other heavy minerals overlies kimberlitic breccia, ejecta and tuffaceous kimberlite. Aprons of waterlain bedded tuffs can be recognized as a connective interlayered pyroclastic facies between adjacent kimberlite pipes. These marine tuffs are underlain and overlain by black shale and mudstone (Garnett, 1994). Overlying the Belle Fourche Member is the Second White Specks Formation, which is comprised of claystones, siltstones and bentonites. The base of this unit is defined by a distinctive and regionally persistent bentonite bed as well as many other localized bentonite beds. The presence of fecal pellets composed of coccoliths best characterize this rock unit.

The Belly River Group

The Upper Cretaceous Belly River Group bentonites are best developed in the uppermost part of this 610 m to 760 m thick sequence (Figure 11, Table 4). The sediments are predominantly mudstones with minor amounts of coal, bentonites, sandstones, conglomerates and nodular limestone. The bentonites are up to 1.1 m in thickness and are alteration products of glassy volcanics. Radiometric K-Ar dating of biotite and sanidine in the bentonites gave an age of 74 to 77 Ma. Based upon grain size, the Belly River bentonites in the southwest part of Alberta are considered to have had a western volcanic source within 160 km of the sediments (Lerbekmo, 1963) . However, the Mountain Lake Kimberlite, which is located northeast of Grande Prairie and is hosted in Wapiti Formation sediments, is likely similar in age to the Belly River bentonites based on geological relationships. Therefore, some of the Belly River bentonites may have had a more local source.

The Horseshoe Canyon and Battle Formations

Within the Horseshoe Canyon and Battle formations there are several bentonite tuff horizons (Figure 11, Table 4). The Kneehills Tuff Zone, which is near the top of the Battle Formation, is the most well known, and can be recognized across much of Alberta, being traceable for some 480 km in a northwest to southeast direction. The Kneehills Tuff is Maastrichtian in age and can be either a single tuff bed or a series of up to four beds over a 1.5 m interval. The Kneehills Tuff is comprised of greater than 90% silica, with vugs often filled with opaline silica or bentonitic clay (Ritchie, 1960). Heavy mineral suites of this vitric crystal tuff compare well with that of the Butte Rhyolite of Montana and the age is considered to be 66 Ma (Binda, 1969). Based on thin section study, Binda (1969) demonstrated that size sorting of the fragments in the tuff occurs away from this rhyolite source.

From the foregoing, there is evidence that volcanism persisted from the Albian to the Paleocene in close proximity to and, possibly within Alberta. Additionally, it is apparent that distal products of a volcanic eruption, such as the Kneehills Tuff or the Viking Formation bentonites, are characterized by extensive areal distribution and relatively good stratigraphic continuity, heavy mineral grain size gradation away from the volcanic source, thin bed thickness and may have a mineralogical composition reflective of the volcanic source. However, Byrne (1955), Babet (1966) and Scafe

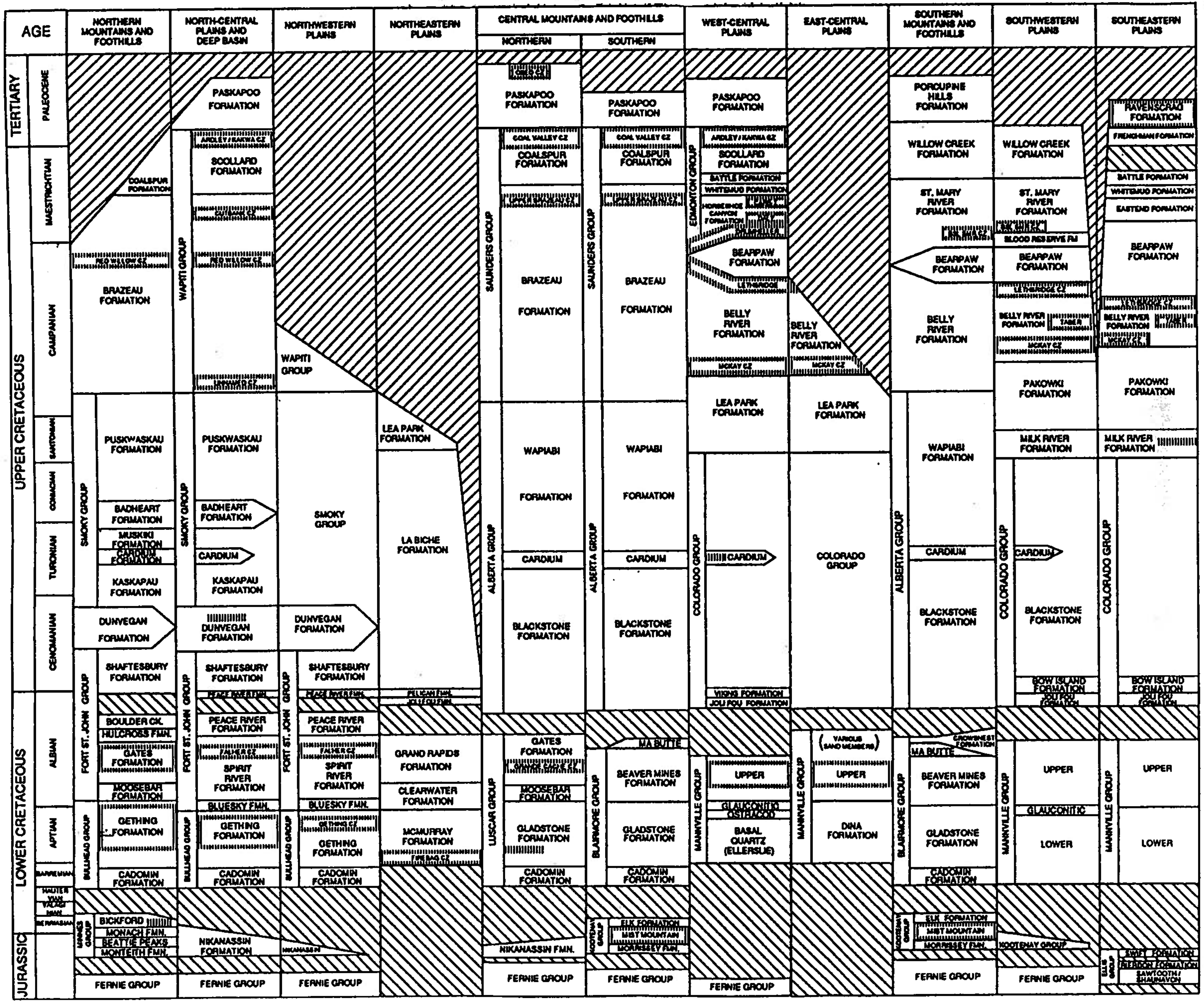


Table 4. Mesozoic/Cenozoic stratigraphic correlation chart of Alberta.

(1975) have identified numerous occurrences of thick, locally developed bentonites in Alberta, including some with unusual mineralogical compositions. This is in contrast to the above cited characteristics for distally deposited tuffs. The following discussion will present the results of recent detailed subsurface studies carried out to identify and characterize reported occurrences of thick bentonites.

Bentonite Subsurface Investigations

Method of Study

Scafe (1975) detailed numerous thick bentonite showings throughout the province of Alberta (Figure 11, Appendix 2). In addition, a computer search of reported bentonite occurrences within the AGS coal database identified 248 drill hole intersections with bentonites that exceed 3 m in thickness (Appendix 3). Using information from these tabulations, four major localities, as shown on Figure 11, were selected for the present study: (1) the Drumheller-Dorothy-Trefoil area of south-central Alberta; (2) the Irvine-Bullshead area in southeast Alberta; (3) the Bickerdike showing near Coalspur; and (4) the Rosalind bentonite . An additional study was also conducted on the subsurface Duagh bentonites near Edmonton, which were identified during coal prospecting in 1978 (Shell Canada Limited, 1978).

Subsurface data which pertain to bentonites were assembled and compiled for each of the five areas. This included searching for drilling and geophysical information from both the coal and oil/gas geophysical log data files of the Alberta Energy and Utilities Board (EUB) of Alberta. These data are available on microfiche at various establishments, including the EUB and the AGS.

Bentonite is best discerned on the Gamma Ray Log as a sharp increase in gamma response. Although there are no empirical guidelines, a response greater than 150 API units may be considered significant. However, it is the contrast of the bentonite 'spike' to the rest of the gamma ray trace, in particular the 'shale line', which provides the best means of identification. Occasionally, swelling of the bentonite in interaction with the drilling fluids may reduce the hole diameter and affect the Caliper Log. Bentonite also can exhibit a strong conductivity on the Resistivity Log.

Distinctive responses of specific lithologies to the various geophysical tools provide the means to effectively correlate key beds from one borehole to the next (Wyllie, 1963; Pirson, 1963; Schlumberger, 1972; Asquith, 1982; Crain, 1986). This study utilized various geophysical logs, including Gamma Ray – Density, Sonic, Gamma Ray – Neutron, and Spontaneous Potential – Resistivity, to enhance correlation of units. Correlating the bentonites often involved utilizing the log responses of various other lithologies, including coal seams and fining or coarsening upward clastic sequences.

Upon successful correlation, isopach maps and structure contour maps of the base of each bentonite were constructed. In addition, lithologies were interpreted using both the Gamma Ray – Density Log and cuttings/core descriptions, and a stratigraphic columnar section was drafted for each area of interest. The results of this work are presented in the following discussions.

Drumheller-Rosebud Bentonites

Among the reported thick accumulations of bentonite in Alberta, there are zones up to 5 m thick in the Drumheller area of central Alberta (Byrne, 1955; Scafe, 1975). This thickness is significant in light of cited compaction rates for tonsteins of about 5:1 (Bohor and Triplehorn, 1993). These montmorillonite-rich beds are located within the coal bearing sediments of the Horseshoe Canyon Formation, in close proximity to the city of Drumheller (Figures 12 and 13). The Horseshoe Canyon Formation is noteworthy for the presence of extensive interbedded bentonite (Glass, 1990). The sand/silt fraction of a heavy mineral analysis on one of these bentonites indicates a primary mineralogy of plagioclase, biotite and quartz, with secondary calcite, cristobalite, gypsum, barite and witherite (Scafe, 1975).

In addition, about 32 km to the south and east of Drumheller, between Townships 26 to 28 and Ranges 16 to 18 West of the 4th Meridian, there is a 10 m thick bentonite exposed along the Red Deer River between the towns of Dorothy and Trefoil (Scafe, 1975). This bentonite bed is considered to be within the Bearpaw Formation, some 30 m beneath the upper contact (Figure 11). The Horseshoe Canyon and Bearpaw Formations are, however, stratigraphically equivalent in part. Heavy mineral analysis of the Dorothy-Trefoil bentonite unit indicates a primary mineralogy of plagioclase, biotite, zircon and apatite, with secondary cristobalite, calcite, barite, gypsum, siderite, heulandite and hematite.

In a follow up on the Drumheller-Dorothy-Trefoil bentonites, a study of both coal and oil/gas gamma-density well logs was undertaken to investigate the subsurface distribution of the reported bentonite occurrences and their relationship to surface outcrops. It was determined that between the top of the Viking Formation and the middle of the Horseshoe Canyon Formation of the Edmonton Group, only two bentonite horizons were correlatable over a wide area: the Drumheller and Rosebud bentonites. Figures 12 and 13 show in detail, using information from coal borehole 47-84, at Section 1, Township 27, Range 22 West of the 4th Meridian (1-27-22W4M), the stratigraphic position of these two bentonite beds within the Horseshoe Canyon Formation.

The Drumheller bentonite is the lowest bed within the Basal Coal Zone, which comprises an interfingering sequence of marine sediments of the Bearpaw Formation and terrestrial clastics and coal measures of the Horseshoe Canyon Formation. The coal seams are thin and not as continuous as those within the Drumheller Coal Zone. This zone varies from 20 m to 60 m in thickness and represents the first major regressive sequence above the Lethbridge Coal Zone of the Belly River Group. It is recognized as a coal bearing zone underlying major coarsening upward sequences of marine shore face clastics (McCabe *et al.*, 1986). The Drumheller bentonite is within the Basal Coal Zone, approximately 30 m above the contact with the Bearpaw Formation, 80 m to 100 m above the Belly River Group and 60 m stratigraphically above the bentonite reported at Dorothy-Trefoil. The Drumheller bentonite is evident as a pronounced gamma log 'kick' on sections D-D', E-E' and F-F' within the Basal Coal Zone in the publication of McCabe *et al.* (1986). This bentonite interfingers with shale in the northern part of the study area and is observed to shale out eastward. It is distributed over a wide area (Townships 26-31, Ranges 16-22, W4M), with its thickest development in the vicinity of the town of Beynon, Alberta.

Overlying the Basal Coal Zone, the Drumheller Coal Zone comprises much of the economically attractive coals of the Horseshoe Canyon Formation. A strong marine influence is still evident in the form of major coarsening upward clastic sequences adjacent to and underlying the coal seams of the Drumheller Coal Zone. Fining upward sequences become more frequent and influence the stratigraphic position, lateral continuity and thickness trends of the coals. The stratigraphy is thought to represent a depositional environment of shore-parallel peat swamps some distance from actual shorelines of the Bearpaw Sea. Peat development was interrupted during periods of marine transgression. Repeated regressive-transgressive cycles produced a series of interfingering coal seams and coarsening upward sequences (McCabe *et al.*, 1986).

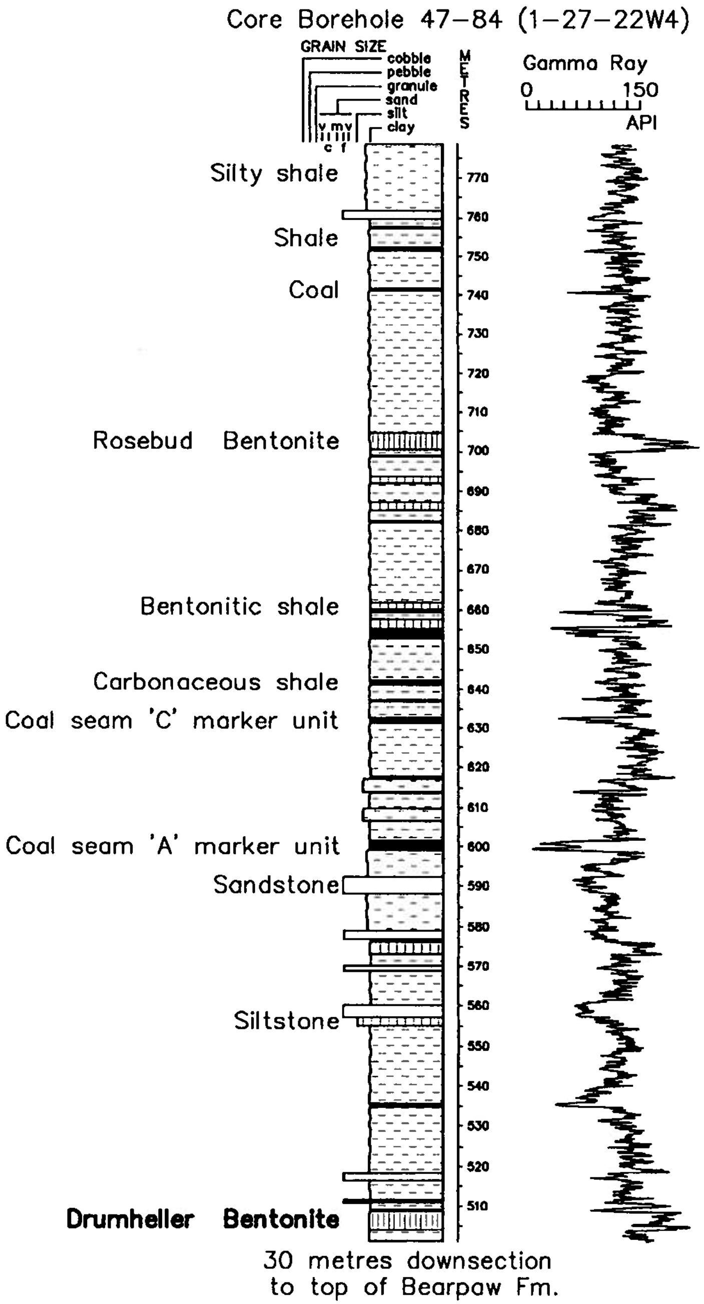
The second bentonite, here termed the Rosebud bentonite, is located some 190 m stratigraphically above the Drumheller bentonite and lies within the Drumheller Coal Zone (Figures 11 and 13). This bentonite is best developed locally near the town of Rosebud, which is about 25 km southwest of Drumheller. Geophysical log evidence indicates that this bentonite rapidly thins to the east, west and north. There is also a subtle thin interfingering relationship with the enclosing shale to the northeast.

A geophysical log analysis, using a combined total of 90 wells, provided the control for the construction of the structure contour and isopach maps for each of these bentonites. Correlation was facilitated using four continuous and regionally extensive coal seams in the Basal Coal Zone, as well as a prominent 30 m thick coarsening upward clastic sequence.

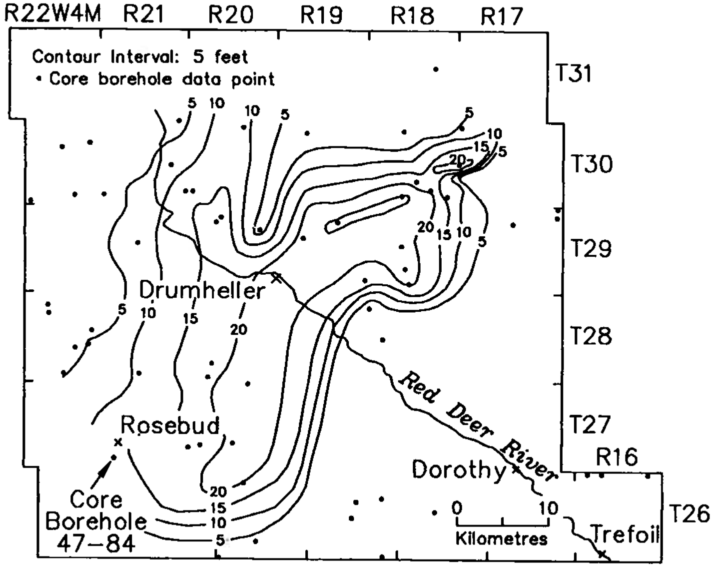
Both the Drumheller and Rosebud bentonites trend north-south and dip westward between 5 m and 7 m per kilometre. However, there is a sharp contrast in the isopach map patterns between the two bentonites. The Rosebud bentonite appears to have a pronounced elongate thickness trend oriented west-northwesterly. As well, there is a facies transition to shale to the north. The thickness isopach trend for the Drumheller bentonite shows elongation to the north or northeast.

Nurkowski and Rahmani (1984) carried out a detailed study of Upper Cretaceous stratigraphy (Maastrichtian) in an area approximately 16 km north of Drumheller. Dips in this area are 2.5 m to 9 m per km and the results of the study reconfirmed previous work (Eisbacher *et al.*, 1974) which established a paleodrainage trend from northwest to southeast. This paleodrainage is reflected in elongate, linear northwest-southeast cumulative thickness isopach patterns for both coal and sandstones lithologies. Geophysical log responses indicate that the fluvial pattern was of a meandering style, with fining upward sequences and a sharp contact at the base of each sequence. Figure 13 illustrates that the Rosebud bentonite conforms to this general pattern. Localized thicknesses up to 8.3 m are preserved in two narrow elongate domal bodies trending west-northwesterly. This indicates that the volcanic ash may have been reworked after deposition, with thicker accumulations occurring

a) Stratigraphic column



b) Isopach thickness map



c) Structure contour map

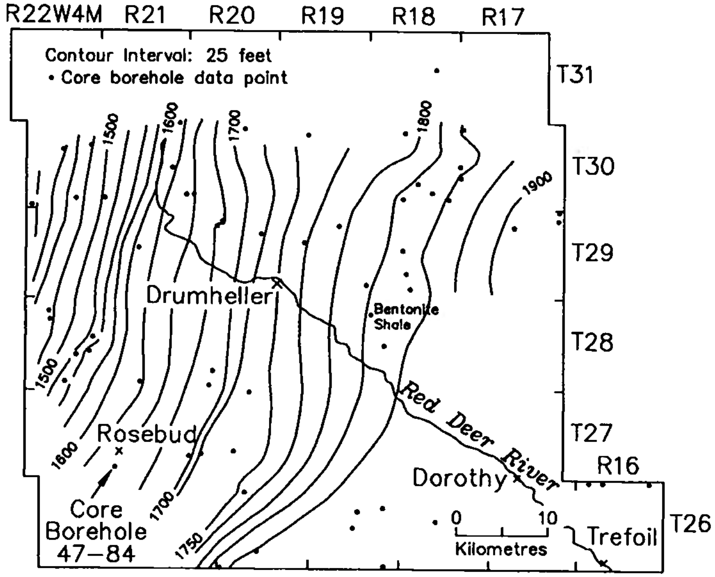
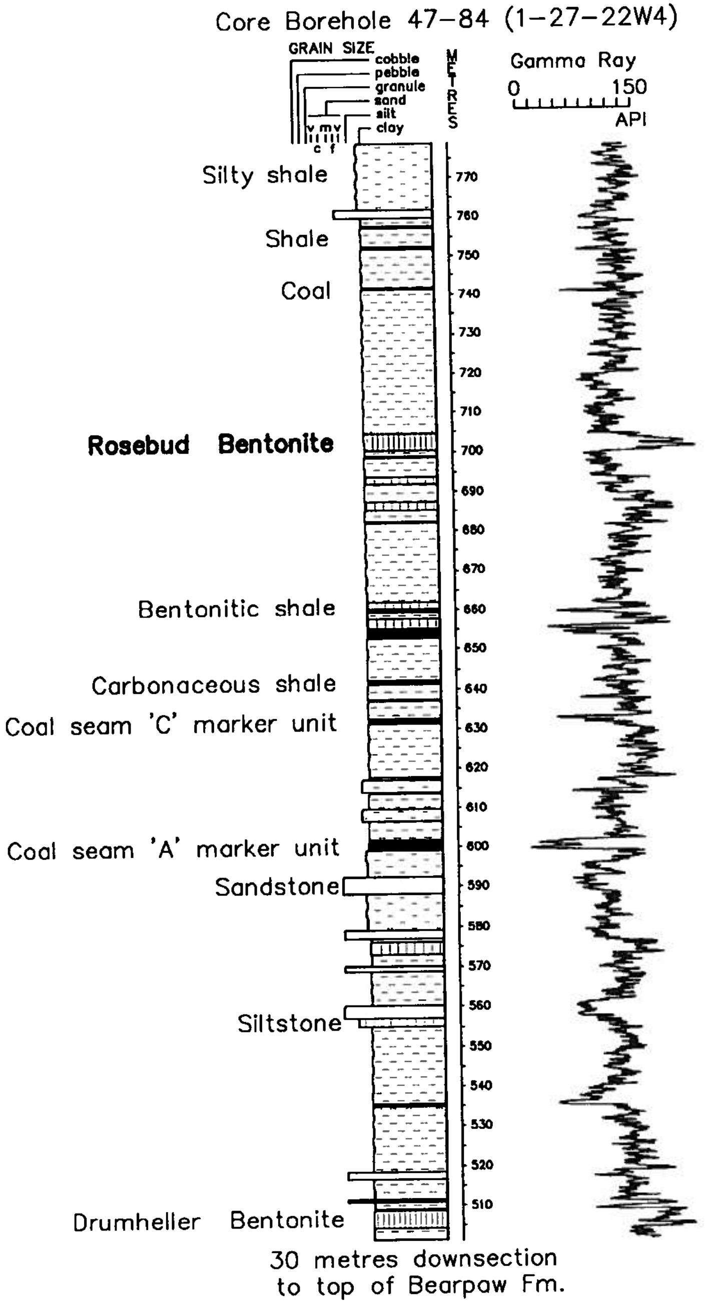
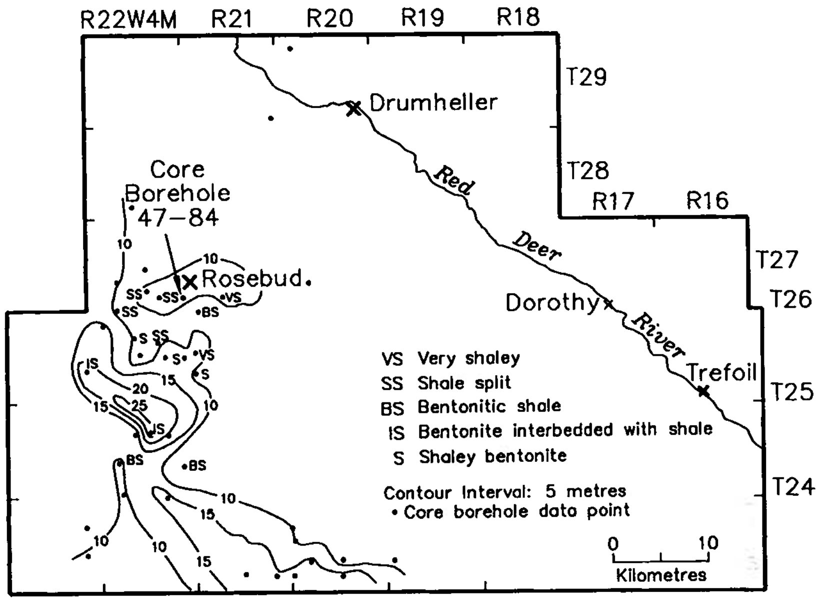


Figure 12. Stratigraphic position, thickness and structure contour for the Drumheller bentonite, Horseshoe Canyon Formation, Drumheller area.

a) Stratigraphic column



b) Isopach thickness map



c) Structure contour map

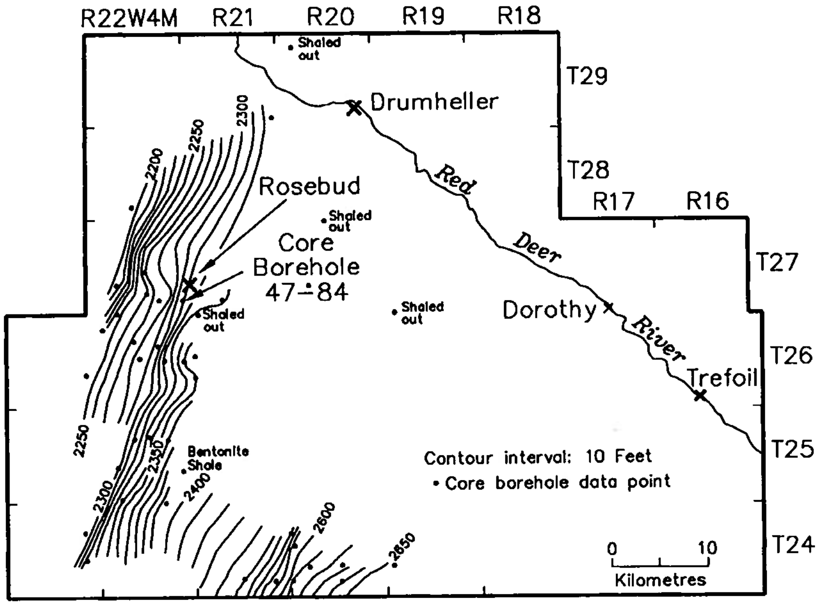


Figure 13. Stratigraphic position, thickness and structure contour for the Rosebud bentonite, Horseshoe Canyon Formation, Drumheller area.

in interfluvial areas between stream or river channelways in a fluvial floodplain environment. However, it is difficult to suggest that this process was responsible for the Drumheller bentonite isopach pattern. The thickness trend is almost perpendicular to the northwest to southeast depositional trend (Figure 12). Moreover, a regionally persistent and extensive thin coal seam immediately overlies the Drumheller bentonite, suggesting that a relatively quiescent depositional environment was established after the volcanic tuff was deposited. The preceding evidence, as well as the elongate broad domal shape and the rapid transition to shale to the north, west and southeast, may indicate that more proximal volcanic activity is responsible for the deposition of this bentonite.

It is unlikely that either the Rosebud or the Drumheller bentonites are the subsurface extension of the Dorothy-Trefoil bentonite occurrence. Careful examination of boreholes east and west of the Dorothy area failed to show any geophysical signature indicative of bentonite at the appropriate stratigraphic level. The Dorothy-Trefoil bentonite is either areally restricted in outcrop or its subsurface mineral composition does not respond to downhole geophysical instruments.

Irvine-Bullshead Bentonites

Byrne (1955) and Scafe (1975) reported several bentonite occurrences in the Irvine-Bullshead area near Medicine Hat, which is north and west of the Cypress Hills (Figures 11 and 14). The thickness of these reported bentonites varies from 0.8 m to 3 m and they all are within the Bearpaw Formation. The thickest bentonite lies approximately 30 m stratigraphically above the base of the Bearpaw Formation, and varies in thickness from 0.5 m to 3 m. In the present study, no well control could be obtained for the Bearpaw Formation from coal exploration drill holes. Additionally, oil/gas casing requirements prevented the Bearpaw Formation from being effectively logged in any of the nearby oil and gas exploration drill holes.

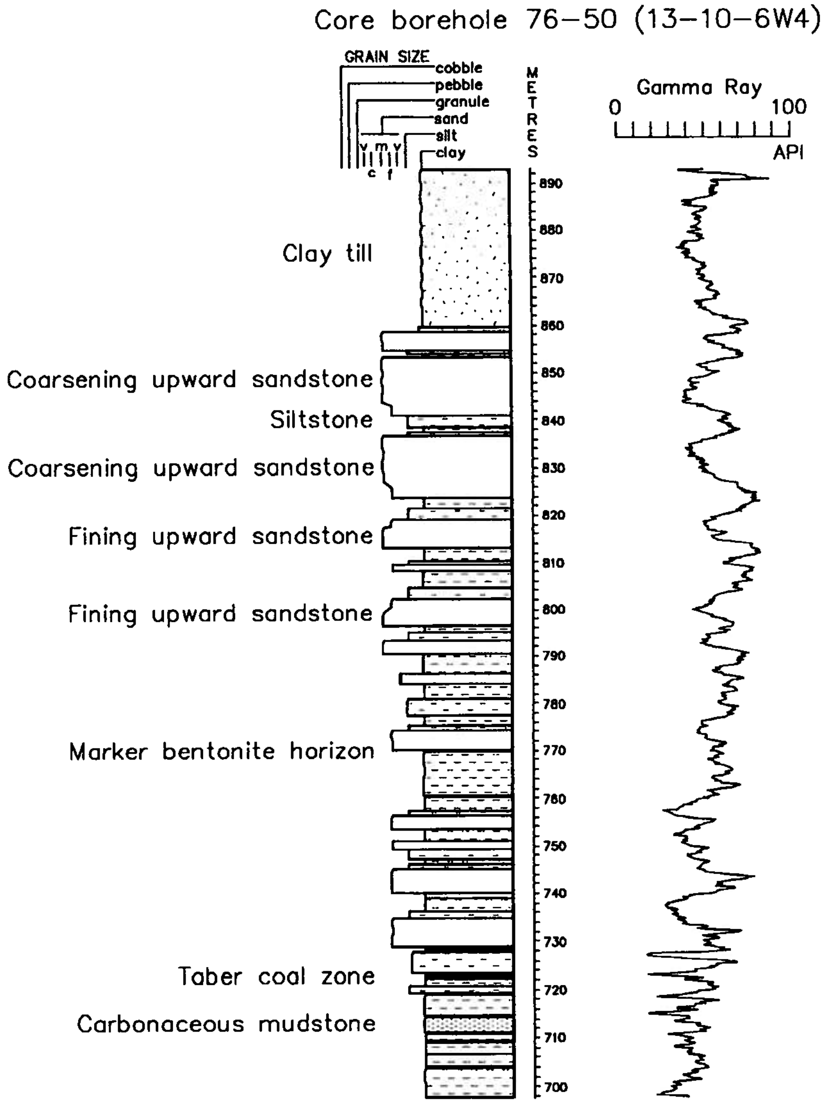
However, the coal drill hole database did provide geophysical information from a series of 28 exploration wells which intersected much of the underlying Belly River Group (Campanian) south and west of Irvine, in Townships 10 to 12 , Ranges 4 to 6, W4M. These holes intersected a bentonitic horizon that is located between sandstone cycles of the Oldman Formation, approximately 50 m above the Taber Coal Zone. The stratigraphic interval studied in the Irvine area included 160 m of section within the Belly River Group.

The Taber Coal Zone comprises 7 to 11 thin coal seams which are difficult to correlate. The thickest accumulations of coal are found along a northwest-southeast trend. The coals are thought to have formed from peat swamps in a coastal plain environment some distance westward of the paleoshoreline (McDonald *et al.*, 1987). This coal zone separates coarse clastic deposits of the overlying Oldman Formation from the finer grained sediments of the underlying Foremost Formation of the Belly River Group.

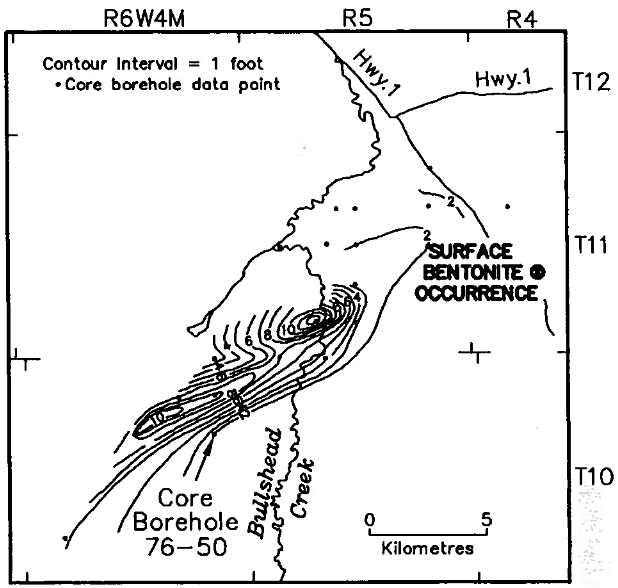
The Oldman Formation sediments were deposited in southeast draining estuarine channels as coarse clastics or an inclined heterolithic series of channel sediments (Koster, 1987). These stacked channel deposits often display sharp erosional bases. The Irvine-Bullshead bentonite which was recognized in the boreholes, is stratigraphically located approximately 40 m below the Lethbridge Coal Zone within the Lower Oldman Formation and is not part of the Bentonitic Zone of the Upper Belly River Group. It is preserved at the top of a fining upward channel sandstone sequence and is overlain by another channel sandstone sequence. The gamma ray log signature indicates a strong shale component to the bentonite, particularly with the thicker accumulations, indicating that the ash was intimately mixed with very fine grained clastic sediment during deposition. However, this bed can still be effectively correlated throughout all boreholes. Figure 14 indicates that the bentonite bed trends northeast and dips approximately 3 m per km to the northeast. There is a suggestion that the SGA to the west was exerting a slightly positive, although not emergent, influence on sedimentation at this time (McLean, 1971).

The depositional environment in which the Irvine-Bullshead bentonite was preserved would likely have promoted intense reworking of any pyroclastic air fall by strong fluvial or offshore current forces. However, the thickness isopach trend is oriented northeasterly, which is perpendicular to the regional depositional trend (McDonald *et al.*, 1987). If the paleoshoreline during this time was some distance to the east, this pattern is difficult to explain as a product of fluvial erosion and subsequent reworking. However, if the shoreline was considerably nearer, offshore currents acting parallel to shoreline may have concentrated the water lain tuffs into the present observed trend. Alternatively, the anomalous trend may also reflect a local volcanic source for the bentonite precursor material, as bentonites within the Belly River Group may be approximately age correlative to the Mountain Lake Kimberlite in the Grande Prairie region.

a) Stratigraphic column



b) Isopach thickness map



c) Structure contour map

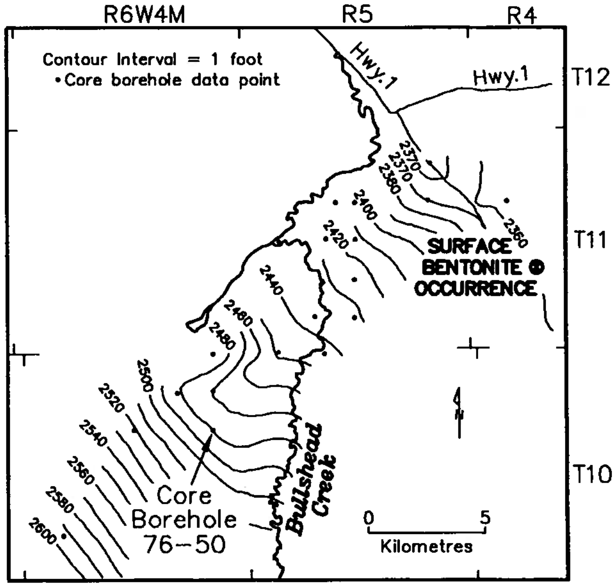


Figure 14. Stratigraphic position, thickness and structure contour for the Bullshead Creek bentonite, Oldman Formation, Irvine area.

Bickerdike Bentonites

Byrne (1955) reported the presence of a 2 m to 5 m thick bentonite in the Bickerdike area of west-central Alberta, Township 52, Range 18, West of the 5th Meridian (52-18W5M). This showing occurs in the Early Tertiary Paskapoo Formation (Paleocene). The Paskapoo Formation consists of interbedded mudstone, siltstone and sandstone that is often developed into thick sequences of sharp-based, fining upward, fine to medium grained clastic sediments.

A subsurface study, using coal exploration well logs, indicates the presence of at least two bentonite layers within the Paskapoo Formation. A bentonite drilling program carried out by Imperial Oil Limited during 1977-1978 intersected two bentonitic horizons west of the Bickerdike showing in the vicinity of Prest and McNeil creeks. Boreholes that intersect the upper bentonitic mudstone had vertical thicknesses ranging from 3 m to 16.7 m (Table 5). Vertical thicknesses for the lower bentonite ranged from 0 m to 10 m. The two bentonitic zones are separated by 12 m to 14 m of fine grained sediments. Further east, Canadian Occidental Petroleum carried out a coal exploration program during 1981-1982 in order to investigate the McPherson Coal Zone within the Coalspur Formation. Seven boreholes intersected a distinctive bentonite with vertical thickness ranging from 3.5 m to 6 m (Table 5). This bentonite was intersected some 265 m stratigraphically above the McPherson Coal Zone. The proximity of the Occidental holes to the Bickerdike outcrop indicate that these bentonite intersections may be the subsurface expression of this showing, although a lack of structural control in the area precludes making a definitive assessment. A lack of well control, topographic and surface geological information prevented the construction of isopach and structure contour maps for the Bickerdike bentonites.

Table 5: Exploration well log data for the Bickerdike bentonite study area.

Imperial Oil Limited Drill hole Data

Hole Id	Bentonite # 1			Bentonite # 2		
	Top (m)	Base (m)	Vertical Thickness (m)	Top (m)	Base (m)	Vertical Thickness (m)
7	77.1	84.1	7.0	98.1	108.2	10.1
2	45.4	57.0	11.6	72.2	80.1	7.9
17-78	99.0	104.5	5.5			
18-78	112.5	115.7	3.2			
5	61.5	73.7	12.2			5.2
6	35.7	52.4	16.7	67.6	76.5	8.8
9	67.4	81.1	13.7			

Canadian Occidental Petroleum Drill hole Data
Bickerdike Area

Hole Id	Top (m)	Base (m)	Vertical Thickness (m)
81-06	150.4	155.6	5.2
82-05	148.5	152.5	4.0
82-03	118.5	123.0	4.5
82-04	117.5	122.5	5.0
82-08	120.0	123.5	3.5
82-02	147.5	152.5	5.0
3-27-51-19	135.0	141.0	6.0

Rosalind Bentonites

Previous reports have documented bentonite occurrences in the Rosalind area (43-17W4M) with thicknesses ranging from 1.5 m to 2.5 m (Scafe, 1975). In fact, this is one of the few localities where bentonite has been actively mined in the past. Strata in the area dip southwest at about 3 m per km. The bentonite is reported to occur within the Horseshoe Canyon Formation and is underlain by black carbonaceous shale. A search of the coal and oil/gas geophysical logs within Townships 42 and 43, Ranges 16 to 30, W4M failed to identify any significant and correlatable subsurface bentonitic horizons to a depth of 305 m. However, locally there were several intersections of thick bentonitic material, namely 5.5 m in borehole TH34-74 located at Section 20, Township 43, Range 26, West of the 4th Meridian(20-43-26W4M) and 7.0 m within borehole TH33-74 (16- 43-27W4M).

Duagh Bentonites

A coal exploration program that was carried out by Shell Canada Limited during 1978 in the Duagh area, which is some 20 km northeast of the city of Edmonton, intersected two thick bentonite beds within Upper Cretaceous Horseshoe Canyon Formation (Figures 15 and 16). After Shell's initial drilling results, the emphasis was shifted from coal to bentonite exploration (Fietz, *pers. comm.*, 1994). Based upon the coal seam development and geographical location of outcrops, the incomplete 80 m thick section which was investigated at Duagh is probably part of the Weaver Coal Zone (McCabe *et al.*, 1986). This zone is characterized by thin, discontinuous, marginally economic coal seams that are intercalated within coarsening upward clastic sediments. The Duagh section contains up to six relatively thin coal seams within a predominantly shale-rich sequence. Although thin sands are present, they are fine grained and lensoid, with no distinctive signature on the gamma ray log response. Moreover, they occur in the basal part of the section beneath the bentonites. Strata dip gently southwest at about 4 m per km and are eroded to the northeast, west and northwest by the incising profile of the Sturgeon River valley.

Bentonite No. 1 is located some 3 m above a thin persistent coal seam and attains a maximum thickness of about 2.4 m. The isopach map for this bentonite reveals a domal elongate shape trending southwest-northeast (Figure 15). However, deep erosional effects to the northeast, west and east may have influenced this pattern. Nonetheless, evidence indicates that the bentonite rapidly thins to the west into the adjoining shales. Interestingly, the observed thickness isopach trend is perpendicular to the depositional trend and the bentonite is overlain by a series of thin bedded shales.

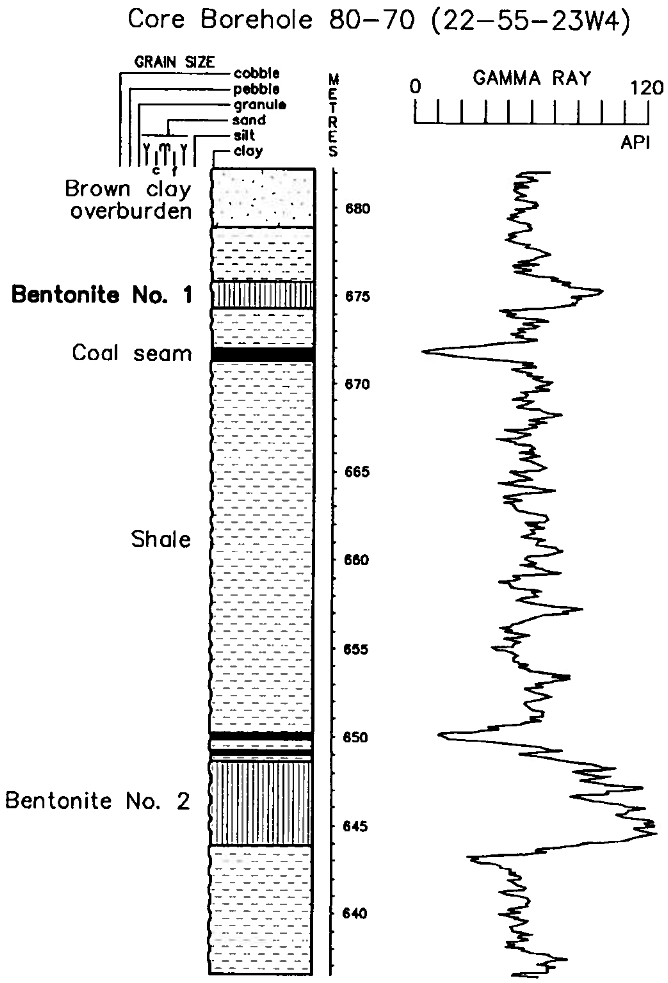
Bentonite No. 2, which is about 30 m below Bentonite No. 1 provides better well control for the construction of isopach and structure contour maps (Figure 16). Thickness varies from zero to about 5.8 m, with isopach contours defining a complex, broad elongate domal pattern trending northwest-southeast, but thinning rapidly to the northwest approaching the Sturgeon River valley. The isopach trend of this bentonite is parallel to the regional depositional trend (Nurkowski and Rahmani, 1984) and, hence, post-depositional reworking of the ash layer may have been a significant factor in developing the observed complex thickness patterns. However, the overlying coal seams and carbonaceous shales provide little evidence to support the presence of strong fluvial, wave or current forces that may have reworked the deposited ash. Although surface occurrences of these bentonites have not been reported in the literature, this may be a function of the level of erosion in the area, lack of outcrop exposure or the thickness of glacial overburden.

Discussion

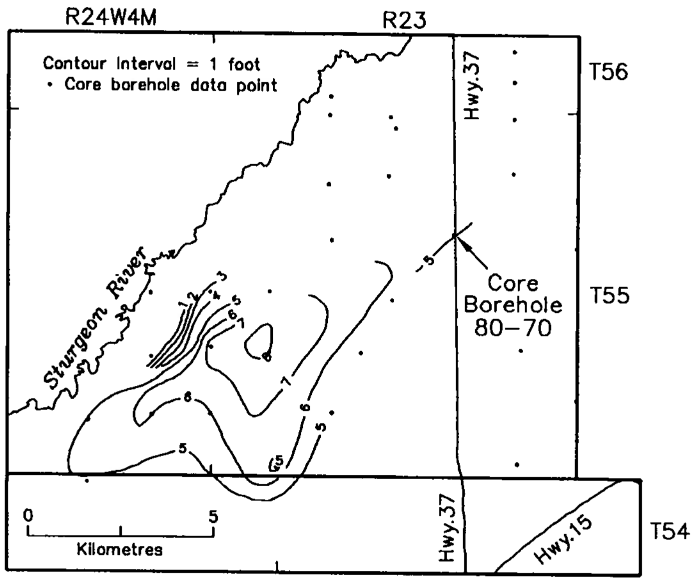
Regional air fall ash deposition from distal volcanic sources (e.g., Kneehills Tuff Zone and the Viking Formation bentonites) is characterized by extensive areal distribution, relatively thin bed thickness and good stratigraphic continuity. These bentonites can provide an excellent reference frame for timing of geological events, and they often develop a graded size distribution away from their volcanic source. The volcanic source can often be identified based on the distribution and composition of the tuff or bentonite. However, several anomalously thick, locally developed, discontinuous bentonites in Alberta do not readily fit this mould. These anomalously thick bentonites must be the result of either secondary sedimentological processes or more proximal volcanism.

The present study has examined some thick bentonite occurrences located in southeast, central and west-central Alberta. The bentonites range in age from Late Cretaceous (Campanian) to Early Tertiary (Paleocene). Although the geometry of some of the bentonite deposits are undoubtedly a product of sedimentary processes such as fluvial reworking, not all are adequately explained in this manner (e.g., the Drumheller and Irvine-Bullshead bentonites). Indeed, except for the paleoenvironment that existed in the Irvine-Bullshead bentonite area, there is little evidence to suggest that there were contemporaneous or post-depositional dynamic fluvial processes available to rework the tuffs.

a) Stratigraphic column



b) Isopach thickness map



c) Structure contour map

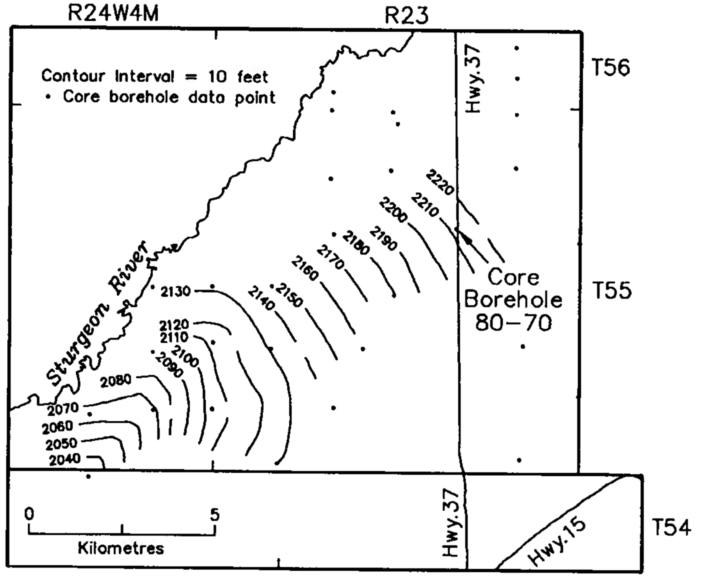
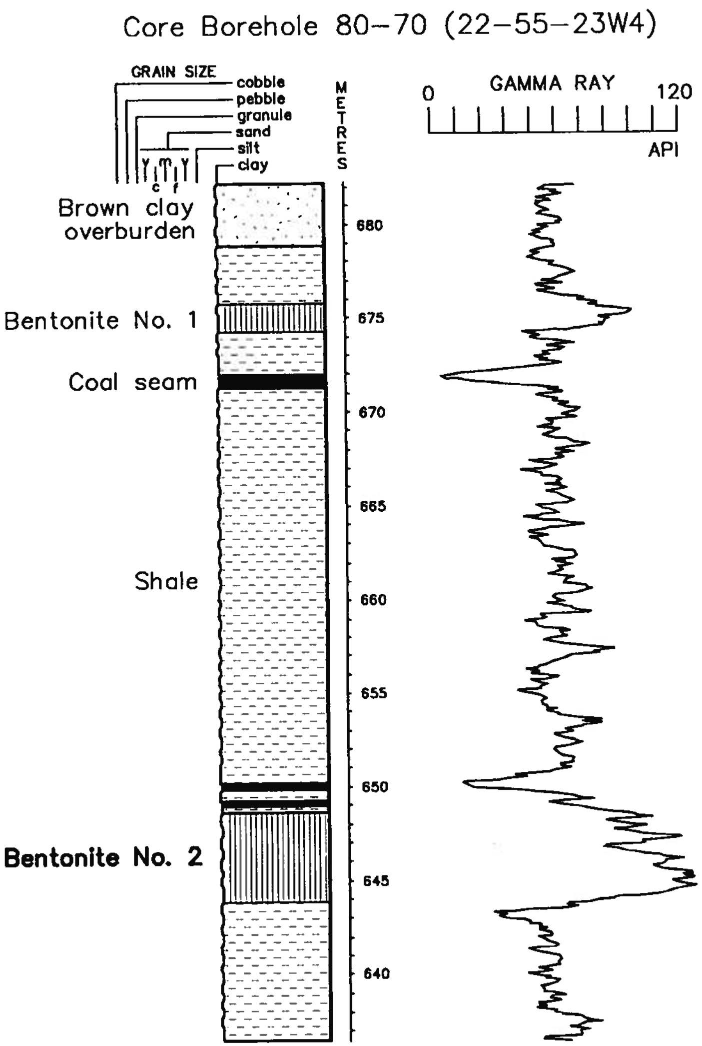
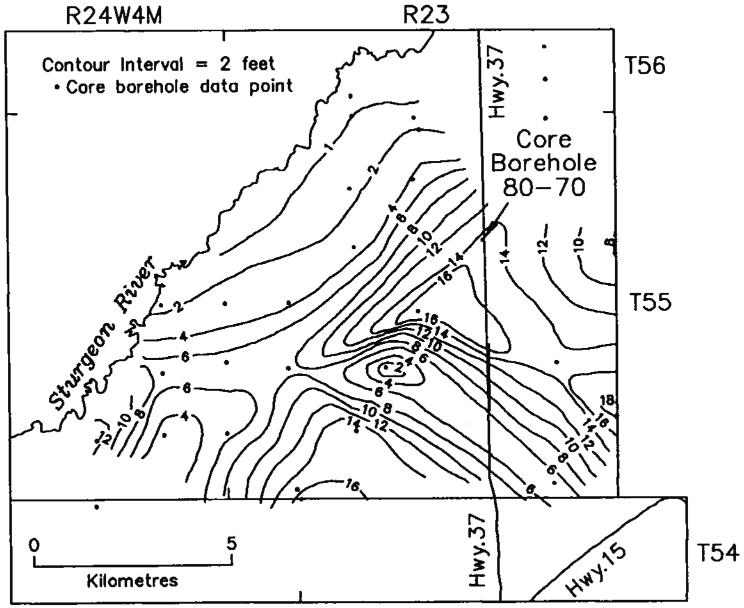


Figure 15. Stratigraphic position, thickness and structure contour for Bentonite No. 1, Horseshoe Canyon Formation, Duagh area.

a) Stratigraphic column



b) Isopach thickness map



c) Structure contour map

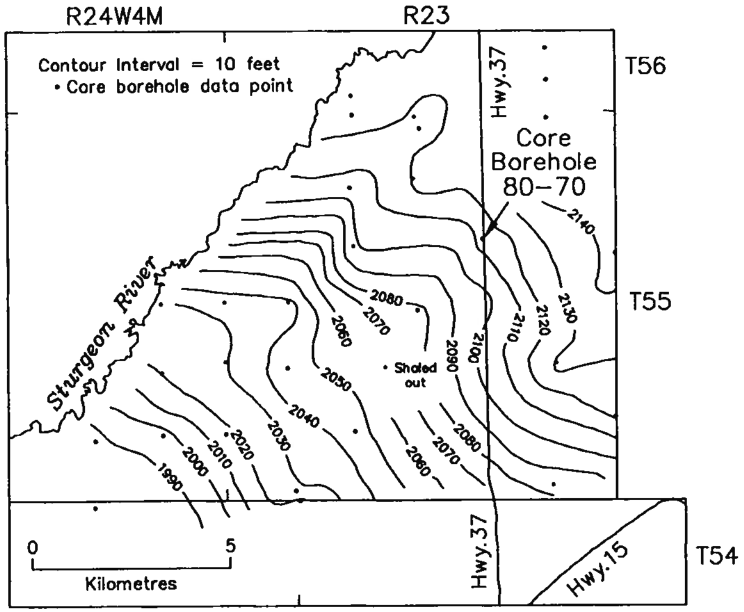


Figure 16. Stratigraphic position, thickness and structure contour for Bentonite No. 2, Horseshoe Canyon Formation, Duagh area.

Instead, it is more likely that any secondary sedimentological controls comprised wave or current action as suggested by Amajor (1985).

The emplacement of the Boulder batholith and adjacent satellite bodies in western Montana are considered to have occurred between 83 and 68 Ma (Decelles, 1986). These igneous intrusions, as well as volcanic activity in the magmatic arc to the west of the thrust and fold belt (Dickinson, 1976), are often cited as the volcanic source for ash fall tuffaceous horizons within the Late Cretaceous and Early Tertiary sediments in Alberta. This ongoing volcanic activity certainly contributed significantly to the development of tuff and bentonite horizons in Alberta. However, the anomalously thick Upper Cretaceous bentonite deposits, which have an isopach thickness trend that is perpendicular to sub-perpendicular to paleodrainage patterns, are enigmatic and may indicate that more localized volcanic activity, such as that associated with the Mountain Lake Kimberlite, occurred within the Alberta foreland basin during Late Cretaceous to Early Tertiary time.

Bentonites and Structural Elements

Figure 17 shows the locations of the bentonite study areas in relation to those major structural features of Alberta that have been interpreted from geologic relationships, aeromagnetic, seismic and gravity data from various sources. The outline of the Devonian reef complexes has also been included, because the position of these reefal bodies may, in part, be partially controlled by pre-existing basement structures (Burton and Machel, 1992; Edwards and Brown, 1994). Interestingly, Figure 17 shows that the Bickerdike bentonite showing is along the proposed southern margin of the Beaverhill Reef platform edge. The Drumheller showings are also near the edge of the Shelf Margin reef complex and the Duagh bentonites are near the southern edge of the Redwater reef complex and the proposed western extension of the STZ. Moreover, the Irvine-Bullshead showings (Township 8-9, Range 4-5, W4M) are in close proximity to the Eagle Butte structure (Haites and van Hees, 1962; Sawatzky, 1975). The only bentonite locality not associated with any significant basement structure or reef trend is the Dorothy-Trefoil occurrence which lacks any substantial areal distribution and was not observed in the subsurface.

Current thinking on the genesis of diamondiferous kimberlites indicates that kimberlite magma must ascend from the mantle source to surface in a very short time frame in order to prevent the oxidation of diamonds to carbon dioxide (CO_2) or graphite. However, these conditions of emplacement almost certainly necessitate movement of the magma to the Earth's surface along pre-existing deep-seated fractures within the crust. Although no association has been conclusively documented between kimberlite emplacement and the bentonites examined in this study, the spatial association of these relic tuff deposits with suspected deep-seated basement structures is of both academic and potential exploration interest.

Aspects of Bentonite Composition

Bentonites are primarily composed of the clay mineral smectite. Where kaolinite is the principal clay mineral (greater than 50%), the term 'tonstein' is used (Lyons *et al.*, 1992). Tonstein deposits are generally developed as *in situ* alteration of air-fall volcanic ash in nonmarine coal-forming environments. Demchuk and Nelson-Glatiotis (1993), described the presence of tonsteins in the Ardley Coal Zone near Wabamun, Alberta. They observed that areas of thick peat accumulation, or mires, provide suitable sites for preservation of volcanic ash falls. If the mires are raised above groundwater level, a highly acidic environment is developed. This environment provides optimum conditions for the diagenetic development of kaolinite from the ash. Where there is peat accumulation under conditions of low-leach rate, flow-through groundwater and near neutral pH, diagenetic alteration to smectite would be more likely to occur. This sensitivity of clay diagenesis to depositional environment has been demonstrated in mapping the lateral transformation of bentonites to tonsteins from marine to nonmarine depositional settings (Waage, 1961).

Atypical or unusual mineral composition within bentonites and tonsteins would be best reflected in the sand to silt fractions. The presence of garnet, olivine, phlogopite and pyroxenes in these fractions may indicate anomalous volcanic or detrital sources. As noted by Bohor and Triplehorn (1993), the mafic character of a tuff may be inferred by the presence of abundant hornblende and zoned plagioclase and the absence of sanidine. Within the clay size fraction, unusual ash chemistry may also indicate unique volcanism. Appendix 2 lists several sites where atypical or unusual mineralogy or geochemistry was observed in Alberta bentonites. In particular, sites 28 (Bow River), 46 (Embarras River), 48 (Oldman River) and 49 (St. Mary River) warrant further investigation.

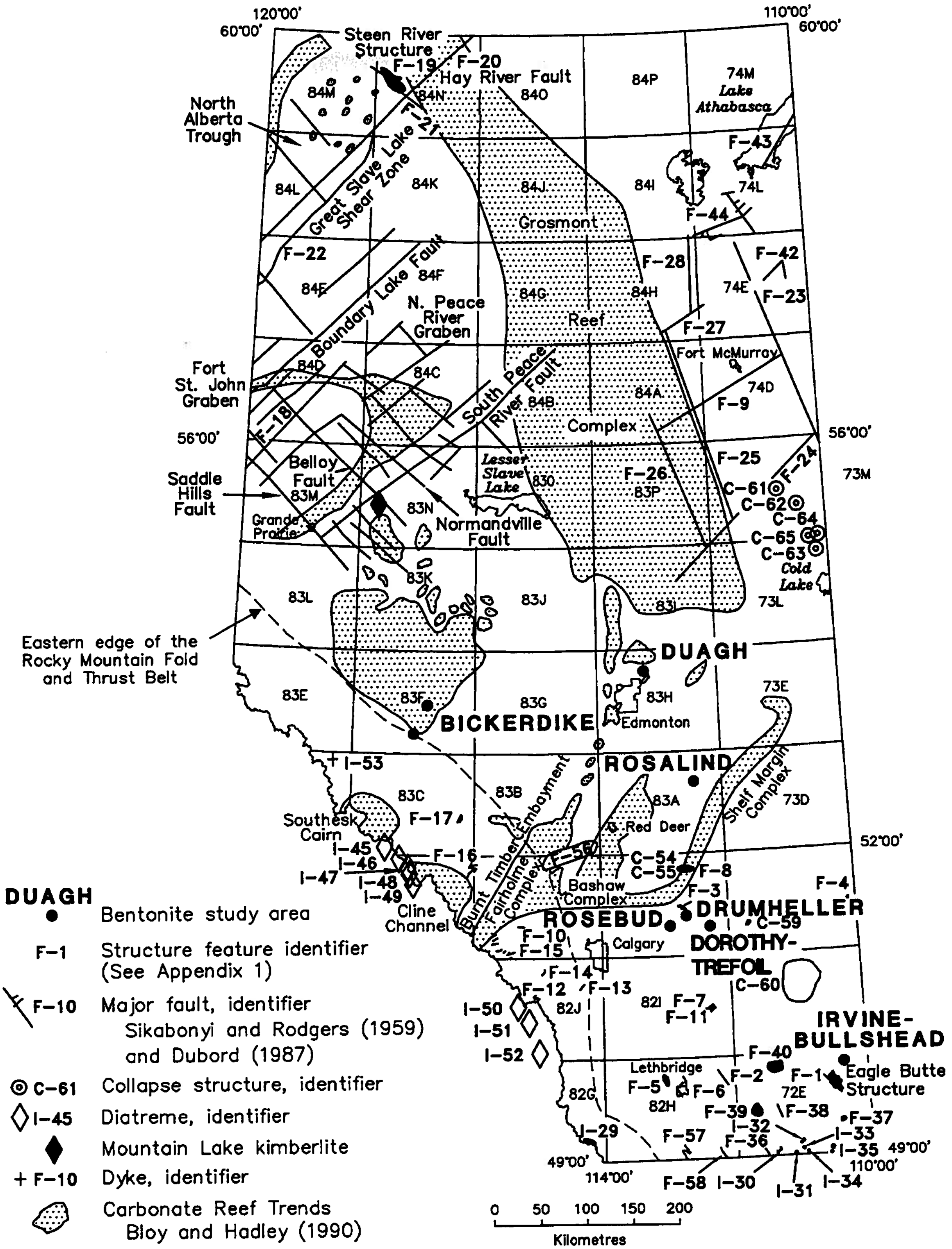


Figure 17. Spatial relationship of study bentonites to major faults and carbonate reef trends in Alberta.

Commercial Database Investigations

A search was initiated with a Calgary-based commercial database for observed occurrences of igneous, volcanic or bentonitic rock types that had been logged in previously drilled conventional oil and gas exploration drill holes. All igneous rock type listings proved to be cuttings descriptions from deep boreholes intersecting Precambrian basement rocks. A complex pattern of interlayered volcanics, thin bentonites and sedimentary rocks in two boreholes near the Waterton area of southwest Alberta was the result of drilling through a series of imbricate thrust sheets involving Crowsnest Formation volcanics and associated sedimentary formations. However, four holes within the database intersected unexpected volcanic intervals within a sequence of interlayered sedimentary lithologies. These anomalies include the wells CS Sabine Keho 16-31 at Land Sub-Division 16, Section 31, Township 11, Range 23, West of the 4th Meridian (16-31-11-23W4M), Imperial Fedorah No. 1 (13-22-57-23W4M), Pacific Petroleum Angelus Ashmont No. 1 (13-03-60-11W4M) and Westcoast Petroleum AEC Suffield 6-30EP (06-30-18-08W4M). Wells (16-31-11-23W4M), (13-22-57-23W4M) and (13-03-60-11W4M) lacked any anomalous geophysical response to the logged volcanic intervals. However, well (06-30-18-08W4M) showed a moderate resistivity response at the top of the logged volcanic interval. Interestingly, the volcanics logged in well (16-31-11-23W4M) are stratigraphically situated immediately beneath the Fish Scales Horizon. Further study of the presence of volcanics is recommended for these four wells.

All bentonite occurrences that were identified in this commercial database are less than 3 m in thickness, with the majority being less than 2 m in thickness (Dufresne *et al.*, 1994a). The depths at which most of these reports occur offer little assistance in the exploration for near-surface diatremes. However, their existence re-affirms the presence of anomalously thick bentonite layers, both at surface and in the subsurface, at least locally, within the Alberta Basin.

Government Coal, Oil and Gas Well Databases

The province of Alberta has seen considerable coal, oil and gas drilling. The acquisition of downhole geophysical information is routine, although there is considerable variation in the type and detail of geophysical information obtained. Alberta regulatory considerations have required the submission of these data to the EUB as part of an assessment process. This information is available for public use after a suitable period of confidentiality.

An additional source of information is the AGS's coal relational (INGRES) database (Richardson *et al.*, 1989). This database contains information on past coal exploration in Alberta, including coal geophysical 'picks', petrography, palynology, geophysical log type used, structural geological information and borehole coordinates.

The data on file from past coal, oil and gas exploration can complement one another due to the different technical considerations in setting casing depths during a drilling program. Of primary concern for the explorationist is the use of gamma, density, caliper, resistivity and, to a lesser extent, sonic and neutron geophysical logs in the detection and correlation of volcanic or bentonitic horizons in the subsurface. Near-surface geophysical log information is much more readily available in the coal database than in the oil and gas databases, hence, the coal database should prove more useful for diamond exploration. However, care must be taken in picking top and base depths to a prospective horizon and the reader is encouraged to review some of the texts on well log interpretation.

Bentonites as a Tool for Diatreme Exploration

The unique response of bentonites to downhole gamma ray geophysical surveying, and their relatively easy recognition in cuttings and core samples provide a convenient tool for identification of periods of volcanic activity in a sedimentary basin. Providing diagenesis is not extreme, the bentonites should also provide clues to the original geochemistry of the source volcanism. In particular, those bentonites that are the proximal or distal products of kimberlite or lamproite volcanism should reflect the unique chemistry of these source lithologies. Unlike regionally distributed and widespread thin ash fall tuffs that are genetically related to distal volcanic sources, such as for the Kneehills Tuff Zone bentonite deposits, a more proximal tuff would be areally limited, with an uneven and irregular thickness distribution. The shape of such proximal deposits may be lensoid, lobate, lenticular or various other irregular forms. In addition, the tuffs may be interconnected with nearby diatremes or volcanic vents. However, one must evaluate bentonite thickness distribution and deposit shape with care, because these ash fall deposits are susceptible to reworking by later sedimentary processes. Nonetheless, an association with a geologically favourable horizon (e.g., the Fish Scales Horizon) or favourable geochemistry or indicator mineralogy may allow some bentonites to be an effective prospecting tool for kimberlite or lamproite diatremes or vent deposits.

Regional Geophysics and Other Remotely-Sensed Data

Regional analysis of the existing public domain geophysical data is important to the explorationist for two reasons. First, to present the existing geophysical evidence, albeit limited, as to the state of the upper mantle, lithosphere and crust beneath Alberta that could be important in the evaluation of the potential of certain regions to have formed diamonds. Second, to delineate any regional crustal features which may have served as favourable conduits or settings for the emplacement of diamondiferous kimberlites or lamproites.

Regional Seismic Data Relevant to Alberta

The Alberta Basin is among the most heavily geophysically explored regions on the Earth in terms of seismic reflection profiling. However, the larger scale features of the upper mantle and crust beneath Alberta have not been studied in great detail. The source regions for diamonds probably occur at depths of about 150 km or more. That diamonds are observed at the Earth's surface attests to the interactions between the upper mantle and the crust of the Earth.

Seismological Observations of the Upper Mantle

Seismological studies of earthquake data useful for diamond exploration include the analysis of surface waves with changes in wavelength (or frequency), and tomographic analysis of P or S waves utilizing different source and detector locations. Surface wave analysis provides a one-dimensional image of geological structures represented by variations in the seismic velocity with depth. Tomographic analysis provides a two-dimensional image of velocity with depth.

A number of seismic studies have been conducted for Alberta; however, the interpretation of these studies are limited by the technique employed and by the large wavelengths of the seismic energy used. Since the wavelengths can exceed 100 km for certain types of long period seismic arrivals, the spatial resolution of these techniques is of nearly the same magnitude and, therefore, the results must be interpreted with this limitation in mind.

Surface wave analysis by Walcott (1970), Wickens (1976, 1977), Nakanishi and Anderson (1984) and Nataf *et al.* (1984, 1986) indicates that: (1) 30 km thick crust is underlain by thin lithosphere below the Cordillera, (2) 30 km thick crust near Hudson Bay is underlain by lithosphere up to 120 km thick; and (3) the lithosphere thickens from the Cordillera to the Shield, with the lithosphere beneath Alberta being intermediate between the two end member cases. In general, the tomographic studies by Dziewonski and Anderson (1981) support the conclusions from the surface wave studies. However, seismic refraction and Bouguer gravity data indicate that the crust below the Cordillera is much thicker than what is indicated by the surface wave analysis. This demonstrates that there are limitations to one-dimensional surface wave analysis.

Alberta appears to fall along the axis of a transition between the slow seismic velocities of the Cordillera and the fast velocities of the Canadian Shield. Large scale seismic surface wave analyses coupled with tomographic studies indicate that seismic velocities generally increase from west to east across Alberta at all depths less than 400 km (Grand, 1987). These velocity variations could be primarily related to temperature, with fast mantle indicative of cooler temperatures (Hoffman, 1990), although Jordan (1981) and Boyd (1989) indicate that subtle variations in mineralogy of the mantle may be partially responsible. If such is the case, the thickness of the lithosphere also would be expected to increase from west to east across Alberta. These seismic observations of lateral heterogeneity in velocity are also concordant with modelling of the deformation (flexure) of the lithosphere due to its loading since the Lower Jurassic by the advancing Rocky Mountain Foreland Belt (Wu, 1991).

Refraction and Reflection Surveys

The refraction and reflection methods are the two principal seismic survey techniques used to study the crust. The refraction technique is most useful for delineating flat-lying contacts and was the method used by Mohorovicic to discover the discontinuity between the crust and upper mantle. It can resolve the changes in actual velocities with depth, but provides poor resolution of lateral variations in seismic velocity. Reflection uses the echos of seismic body waves to produce an image of the subsurface that may be likened to a geological cross-section. Reflection seismics are highly useful to resolve lateral changes in the geology, but are prone to error in the determination of the velocity structure with depth.

Chandra and Cumming (1972) reviewed the refraction results obtained by a number of earlier studies for southern Alberta (Weaver, 1962; Maureau, 1964; Chandra, 1966; Kanasewich, 1966; Cumming and Kanasewich, 1966; Kanasewich *et al.*, 1969), and determined that crustal thickness ranges from 34 km to 47 km due to rapid lateral changes in seismic velocities with depth to the Moho. In addition, the thinnest regions of the crust are spatially coincident with Bouguer gravity and magnetic lows that define the SAR or Vulcan Low (Kanasewich *et al.*, 1969). Chandra and Cumming (1972) also noted the existence of a deep seismic structure along their profile, which is up to 50 km below sea level and is coincident with the Rocky Mountain Trench (Figure 18). Their profile also indicates that the region above the Moho to the west, rapidly thins to as shallow as 30 km (Figure 18).

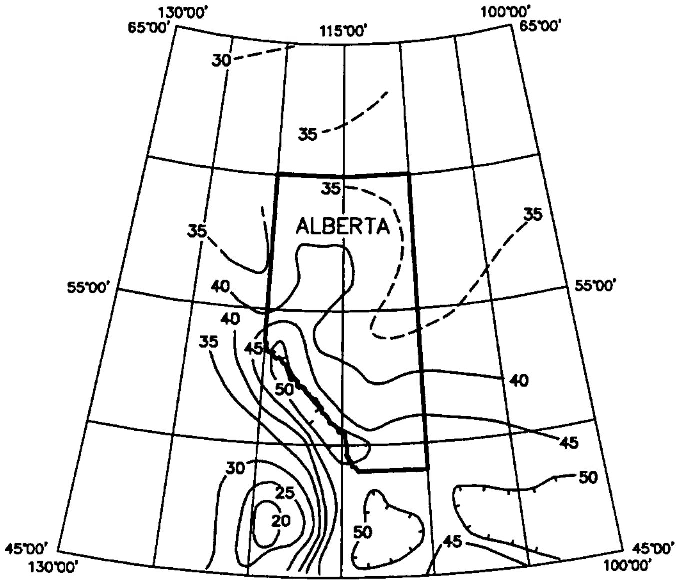


Figure 18. Contour map of crustal thickness or depth to the Mohorovicic discontinuity in kilometres, measured from sea level.

Northern Alberta, in the vicinity of the PRA, exhibits thickened crust or depth to the Moho of between 40 km to 45 km as displayed in Figure 18. This map was developed from the refraction data discussed above and using data presented by Hall and Brisbin (1965), Barr (1971), Berry (1973), Forsythe and Berry (1974), Mereu *et al.* (1976), Allenby and Schnetzler (1983), Morel-à-l'Huissier *et al.* (1987), Stephenson *et al.* (1989), Zelt and Ellis (1989a, b, 1990), and Halchuk and Mereu (1990). Figure 18 does not include estimates of crustal thickness based on recent reflection profiles from several Alberta Lithoprobe transects. Without doubt this map will be modified in future with the data obtained from these and other Lithoprobe transects. However, it is interesting to note the decreasing crustal thicknesses to the north and northeast of northern Alberta, and west of the Rocky Mountains into accreted portions of the Cordillera (Figure 18). The crust underlying much of Alberta is relatively thick (greater than 40 km), in contrast to ascribed thicknesses on the order of 30 km for models of 'typical' continental crust.

Until recently there were few studies of the deeper crust which employed seismic reflections. Early deep seismic reflection studies by Kanasewich and Cumming (1965), Cumming and Kanasewich (1966), and Clowes *et al.* (1968) led Kanasewich *et al.* (1969) to observe changes in relief on both the Riel and Moho discontinuities that spatially corresponded to Bouguer and magnetic lows associated with the SAR. In addition, Clowes and Kanasewich (1970) suggested that deep reflections were consistent with a geology comprised of thin, interleaving layers throughout much of the crust.

Preliminary analysis of data from Lithoprobe transect number 10, which runs from Lloydminster to Entwistle (Kanasewich *et al.*, 1993), indicates that considerable variation in the depth to the Moho, between 35 km to 45 km, exists along this transect. The thickest crust is observed towards the east, spatially coincident with the Eyehill High. At mid-crustal depths, a series of east dipping reflections and abrupt changes in reflection patterns are observed, which may correlate with the crossing of basement domains previously defined on the basis of potential field data. Further Lithoprobe transects are planned for Alberta and should yield additional information about areas potentially underlain by thick, cool crust.

Regional Gravity Anomalies

Bouguer gravity maps for Alberta, including the observed regional trends, residual profiles and horizontal gradient, are shown on Figures 19 and 20. In general, a high Bouguer value indicates high density rock of increased mass and, hence, increased gravitational acceleration. High Bouguer values can result from either increased density of the crust or thinning of the crust, which in turn means dense rocks of the upper mantle are closer to surface.

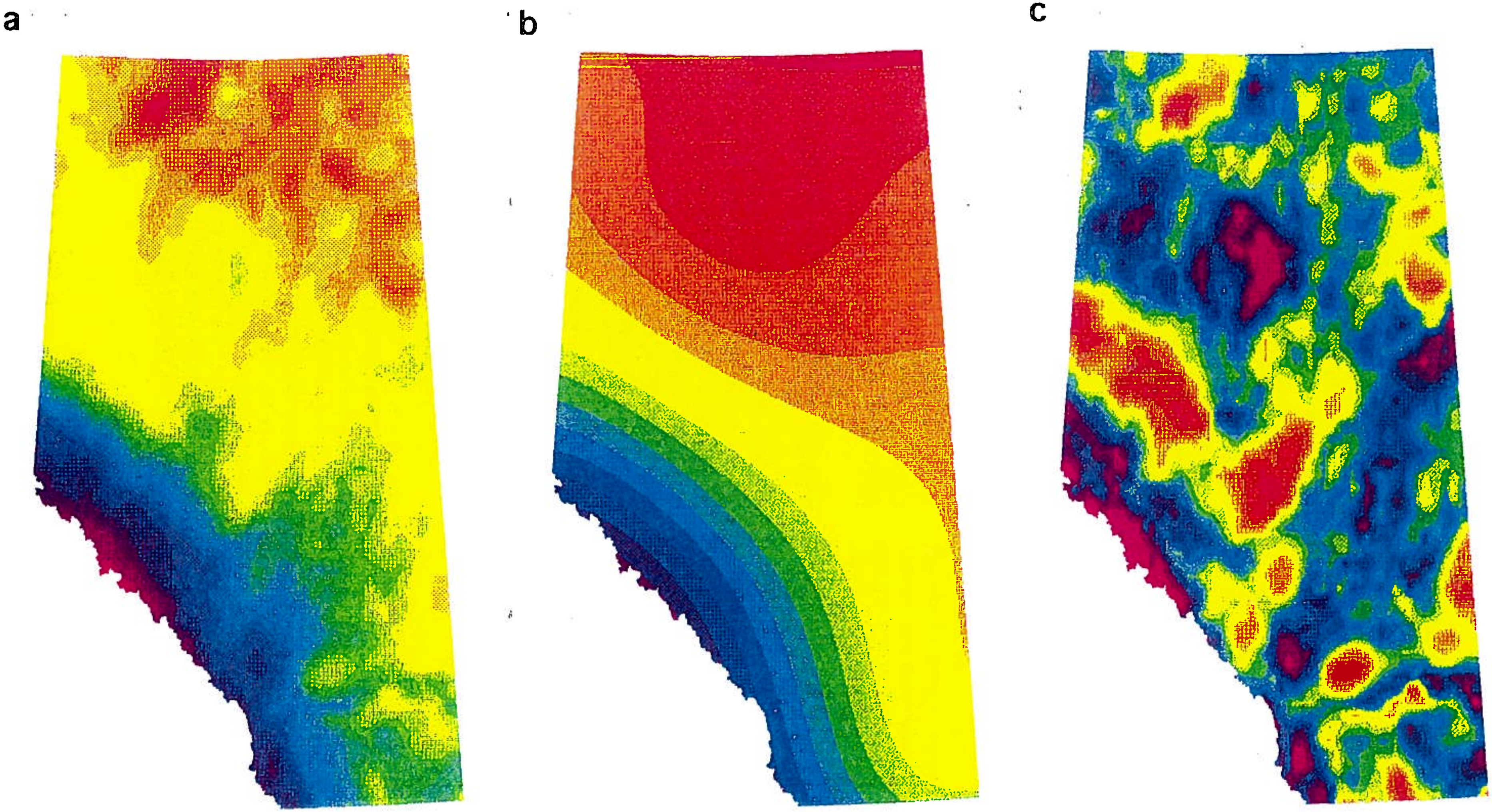
The observed Bouguer gravity map (Figure 19a) shows a region of very low Bouguer gravity (in purple) corresponding to thick continental crust beneath the Rocky Mountains. Thick crust beneath the highest ranges of the Rocky Mountains indicates, for the most part, that the mountains are isostatically compensated according to the theories of Airy (Fowler, 1990). Figure 19a shows the presence of strong Bouguer anomalies (orange to red) in northern Alberta, which may indicate that northern Alberta is isostatically overcompensated due to incomplete rebound in response to unloading after glaciation (Sprenke and Kanasewich, 1982). Stephenson *et al.* (1989) suggested that the northern Alberta anomalies may be the result of ancient tectonic regimes rather than glacial rebound. Figure 19a shows a long narrow region of low Bouguer gravity that strikes northeasterly from the Rocky Mountains and is believed to represent the STZ. In addition, Figures 19a, 19b, 19c and 20 show an arcuate trend of low gravity in southern Alberta that is spatially coincident with the SAR or Vulcan Low, which was also identified from seismic and magnetic data by Kanasewich *et al.* (1969).

Figure 19b illustrates the average low resolution (higher wavelength) trend of Bouguer gravity for Alberta. Figure 19c is the Residual Bouguer gravity map for Alberta, which is derived from the difference between the data of Figures 19a and 19b. The Residual Bouguer gravity map enhances the higher resolution (shorter wavelength) variations in the Bouguer gravity field. The features on this map are more representative of lateral changes in the crust and upper mantle and are therefore more useful for tectonic interpretation and, possibly, for depicting those areas most likely to have formed and preserved diamonds. Similarly, the horizontal gradient of the Bouguer gravity field (Figure 20) also enhances the variations of the Bouguer gravity and, therefore, is more useful for tectonic interpretation. However, the anomaly trends illustrated by Figures 19c and 20 should be interpreted with care. For example, on Figure 19c, a bulge of high gravity values is roughly coincident with the PRA at the western border of Alberta. However, a more extensive detailed study of this region using a different image enhancement process found no correlation between the observed gravity field and the PRA (Ross, 1990).

Regional Magnetic Anomalies

Magnetic field measurements across Alberta are useful at the regional scale for delineating the tectonic framework of the crust beneath Alberta. The actual source of a given magnetic field variation depends principally on variations in the magnetic susceptibility of the rocks at depth.

Figure 21, a shaded relief map of aeromagnetic anomalies with an outline of the basement domains shown in Figure 3, highlights a number of large, crustal-scale features in Alberta that are primarily related to the evolution of the craton. Regions of non-publicly available data are not coloured. Several important crustal features and magnetic domains visible on Figure 21 include: (1) the GSLSZ (Hoffman, 1987), which borders a narrow lineament of magnetic highs that commences near the western border of Alberta at about 58° N; (2) the STZ, which is a northeast trending crustal discontinuity extending from the Foothills to Hudson Bay (Ross *et al.*, 1991) and which separates the Rimbey magnetic high to the south and the north trending Taltson Magmatic Arc; (3) the northwest to north trending boundary between the Chinchaga magnetic low near 57° N and the Buffalo Head magnetic high, which may



a) Observed Bouguer gravity. Map is not enhanced and the colour scheme of purple-blue-green-yellow-red represents variations in Bouguer gravity from -21 mgal to -3.1 mgal.

b) Regional trends of Bouguer gravity. Colour scheme of purple-blue-green-yellow-red represents variations in Bouguer gravity from -20.1 mgal to -46.7 mgal.

c) Residual Bouguer Gravity (difference between data of 6a and 6b). Colour shceme of purple-blue-green-yellow-red represents increasing values of the Bouguer gravity residual.

Figure 19. Bouguer gravity maps for Alberta.

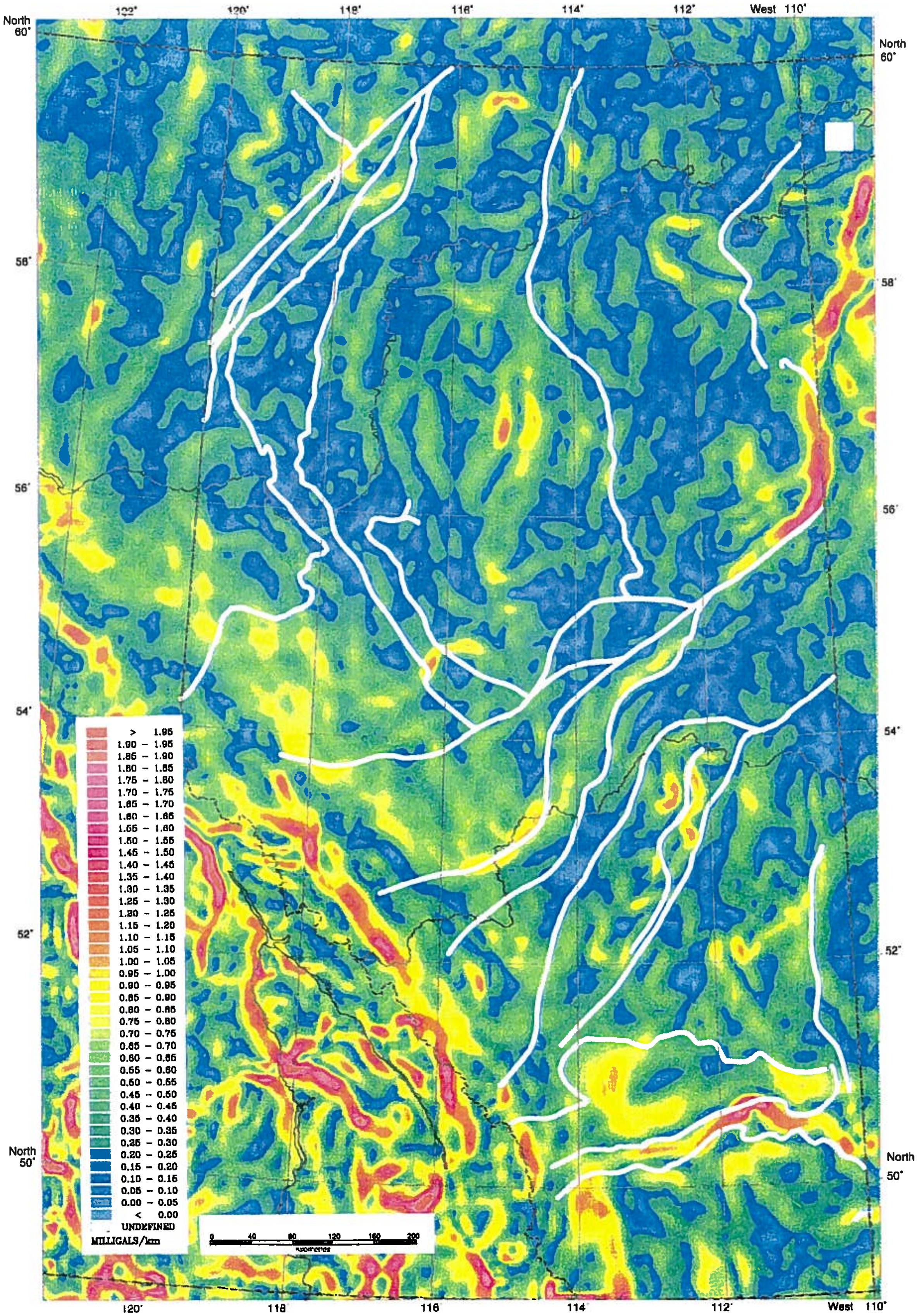


Figure 20. Horizontal gradient of Bouguer gravity anomalies for the Province of Alberta and surrounding regions (Villeneuve et al., 1993).

be a faulted contact; (4) the northeast trending Thorsby magnetic low of central Alberta, which may be the southwestern extension of the STZ; and (5) a prominent magnetic low in southern Alberta that is coincident with the SAR or the Vulcan Low.

Electrical Measurements of the Crust

The electrical conductivity of rock depends on the temperature, porosity, and chemistry of any pore fluids, including magmas. In general, the conductivity of a rock decreases with temperature, but increases with fluid saturation (Olhoeft, 1980). Gent (1992), in his analysis of diamond potential in Saskatchewan, suggests that there is a possible association between the occurrence of diatremes and a prominent electrical conductivity anomaly that bisects southern Saskatchewan and is referred to as the North America Central Plains Conductivity Anomaly (Alabi *et al.*, 1975). This large structure is roughly coincident with the Trans-Hudson Orogen (Handa and Camfield, 1984). The low conductivity associated with this conductivity anomaly is a consequence of graphite or fluid-filled fractures. In this context, the Trans-Hudson Orogen is possibly a zone of crustal weakness and, hence, is, or was, a preferred pathway for magma movement upwards through the crust.

Bingham *et al.* (1985) reports that a zone of high conductivity underlies the eastern Rocky Mountains of Alberta. Similar conductive structures underlie the American Rockies and are correlated with high heat flow and low seismic velocities in the lower crust. Bingham *et al.* (1985) suggested that partial melting and periodic uplift may have been associated with this conductive ridge.

There is a zone of low conductivity, called the Southern Alberta-BC Conductor which was discovered by Gough *et al.* (1982). This highly conductive zone in southern Alberta trends in a northeasterly direction (Hutton *et al.*, 1987) and, although possibly related to the more east-trending Vulcan Low, appears to deviate to the north of it.

Measurements of the Geothermal Gradient and Heat Flow

Using petroleum exploration well data, there have been a number of independent studies of the geothermal field within the Alberta sedimentary succession (Anglin and Beck, 1965; USGS-AAPG, 1976; Majorowicz *et al.*, 1984; Bachu and Burwash, 1991). Bachu (1988) suggested that some of these studies show a definite trend of increasing geothermal gradients from south-southwest to north-northeast across the Alberta Basin.

Jessop (1992) outlined a number of distinct zones of heat flow in the basement. A region of high values of basement heat flow (>80 mW/m^2) follows a linear trend that roughly parallels the Rimbey High which was delineated by Ross *et al.* (1991). Moderate basement heat flows are also expected for the Ksituan Arc, Chinchaga and Buffalo Head terranes, and in the south associated with the Medicine Hat Block (Ross *et al.*, 1991). The complex pattern of vertical and lateral heat flow in the Alberta Basin is explained by Jessop (1992) as being the result of lateral transfer of fluids through permeable aquifers and, hence, differs from the normal heat flow patterns in crystalline rocks which show no vertical variation. In contrast, Bachu (1988), and Bachu and Cao (1992) argued that the aquifers, because of low rock permeability, cannot transport fluid mass sufficiently rapidly to influence the conductive nature of the terrestrial heat flow. Subsequent hydrogeological studies, synthesized by Bachu (1995), show that the pattern of formation water flow in the Alberta Basin is much more complex than initially assumed by Jessop (1992) and, hence, it cannot contribute to the observed geothermal pattern. In addition, in his analysis of basement heat flow in the Alberta Basin, Bachu (1993) correlated the heat flow and geothermal patterns with the basement structures described by Ross *et al.* (1991) and the lithology of the sedimentary succession covering the Precambrian basement. Local-scale variations in heat flow and geothermal field were correlated with heat production by radiogenic elements in the crust (Bachu and Burwash, 1991) and crustal heterogeneities (Bachu, 1993).

The above geothermal studies are general in nature and do not provide any indication of potential structures that could serve as the focus of further work for assessing Alberta's diamond potential. Identification of such potential structures would require additional detailed surveys of the existing thermal data.

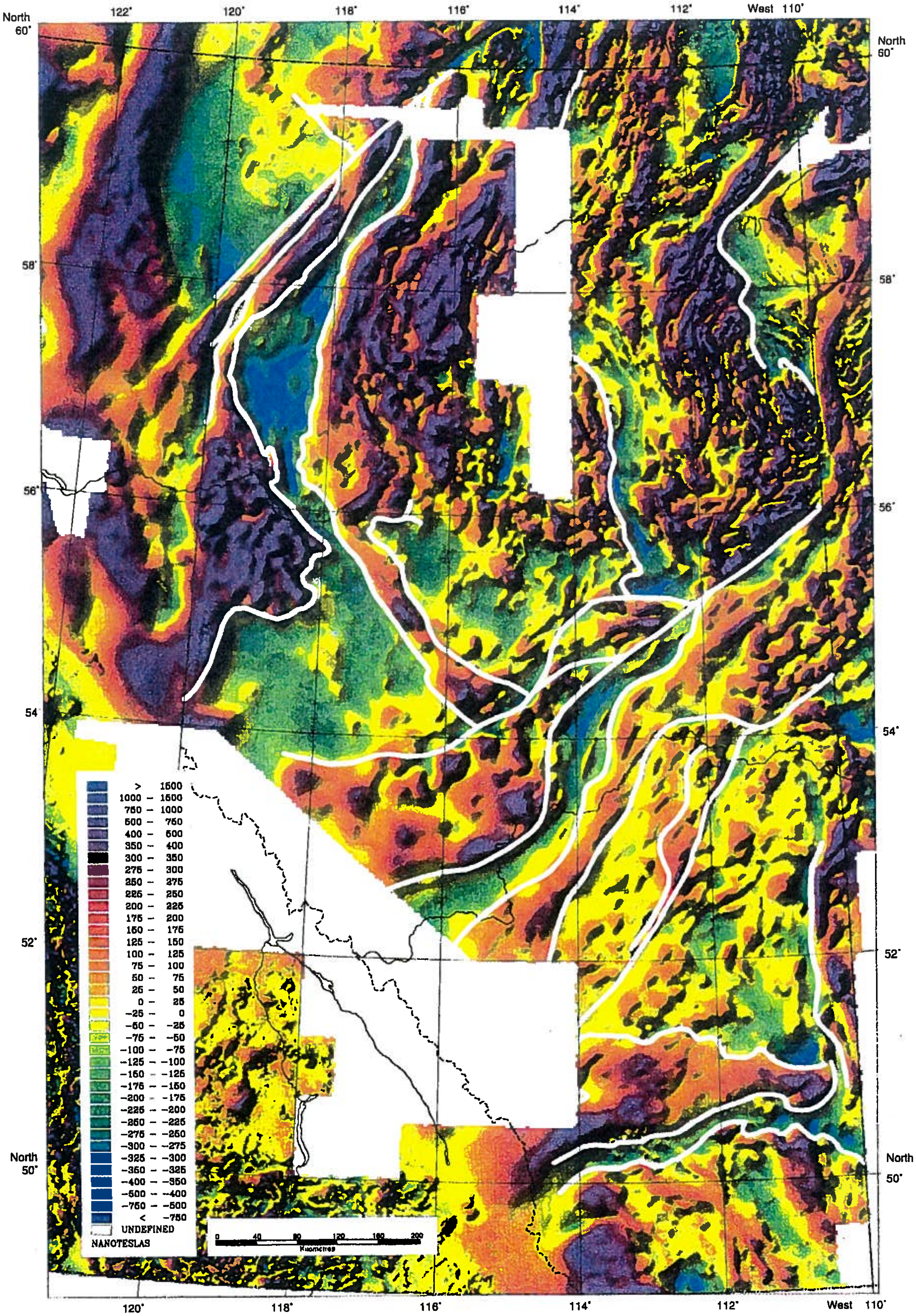


Figure 21. Shaded relief map of aeromagnetic anomalies covering the Province of Alberta and adjacent areas (Villeneuve et al., 1993).

A Review of Relevant Geophysical Exploration Methods

Geophysics can play a two-fold role in the exploration for diamondiferous kimberlites or lamproites by: (1) the widespread detection of targets that may represent kimberlite or lamproite diatremes; and (2) in the subsequent detailed delineation and evaluation of the located prospects. Diatremes are not large, typically being only a few ha to tens of ha in surface area and commonly having cross-sectional diameters of less than 500 m (Nixon, 1980a). As a result, regional airborne geophysical surveys with a line spacing of only a few hundred metres could easily miss those portions of a vent that provide the greatest signal . In such a case, the diatreme may not readily be seen in the final plotted versions of the geophysical data and, hence, could be missed by the explorationist. This section includes a description of the techniques that have been most commonly used in the geophysical exploration for kimberlites.

Magnetic and gravity data for Alberta are available for purchase from the GSC at a variety of scales, although the surveys in some areas are not scheduled for release for the next few years. Alternatively, there are a number of vendors and brokers of proprietary gravity, magnetic and seismic data for Alberta. These companies may be found under the headings of Geophysical Brokers, Geophysical Contractors or Geophysical Services in the Calgary Yellow Pages telephone directory.

For more details as to the means of data acquisition, data processing, analysis and interpretation the reader is referred to selected introductory and advanced texts in the field of geophysical exploration (e.g. Dohr, 1974; Dobrin and Savit, 1988; Robinson and Coruh, 1988; Beaumont and Foster, 1989; Milsom, 1989; Kearny and Brooks, 1991). As well, the latest trends and techniques in geophysical exploration are reported annually in the Canadian Mining Journal (e.g. Kileen, 1994).

Magnetic/Electromagnetic and Resistivity Methods

Most mafic igneous rocks, including kimberlites and lamproites, have a distinct positive magnetic signature due to the presence of certain accessory minerals such as magnetite, pyrrhotite and ilmenite. Igneous rocks, such as gabbro, basalt and diorite have average magnetic susceptibilities near 7.5×10^{-2} (dimensionless S.I. units), which is more than four times that for average acidic igneous rocks and at least 50 times that for typical sediments with magnetic susceptibilities near 10^{-4}. Atkinson (1989) reported magnetic susceptibilities of kimberlite that range from 10^{-4} to 10^{-1}, but more typically lie between 1.25×10^{-4} and 1.25×10^{-1}. Lamproites have slightly smaller, but still significant susceptibilities of 2.3×10^{-3} to 2.3×10^{-2} with an average of 8×10^{-3}. Janse *et al.* (1986), who measured susceptibilities on alkaline ultramafic cores in Ontario, found they range from approximately 10^{-3} to 2×10^{-2}. Litinskii (1963) provides a range of kimberlite susceptibilities from 1.2×10^{-3} to 7.2×10^{-2}, which corresponds to magnetite modes of about 1 to 8 wt%. Concentrations of magnetite are typically much lower in metamorphic rocks and, for most practical purposes, nonexistent in many sedimentary rocks. Therefore, kimberlite or lamproite diatremes that have been emplaced into sedimentary successions, such as those in Alberta, should provide small, but definite circular magnetic patterns.

Electromagnetic (EM) methods rely on measuring the ground's induced response to the propagation of EM fields. EM methods often do not require actual contact with the Earth and, as a result, are amenable to airborne applications. However, their depth of penetration into the Earth is typically less than that available in the resistivity methods and hence EM methods are better suited to initial regional exploration. An overview of very recent work in the general area of airborne EM sounding is given by Smith (1994).

Electrical or resistivity techniques require current to be applied directly to the ground using electrodes; the variations in the electrical potentials at the surface are then mapped. As a result, electrical or resistivity techniques are more suitable for the detailed follow-up exploration of prospects.

Essentially, however, both the electrical and EM methods attempt to map out the resistivity, which for Earth materials is the most variable of all the physical properties. The heterogeneity of kimberlite and lamproite diatremes affect the EM signature that might be expected. For example, Gerryts (1970) reported kimberlite resistivities that range from less than 20 Ωm to more than 150 Ωm, but did not indicate whether this is for weathered or fresh material. Resistivities for unweathered hardebank kimberlite are reported to range from 200 Ωm to 1,000 Ωm by Erdmer and Downing (1993), from 100 Ωm to more than 200 Ωm by Nixon (1980b), and to an estimated value of 500 Ωm by Macnae (1979). Near-surface resistivities of weathered kimberlite range from 10 Ωm to 20 Ωm (Nixon, 1980b; Smith, 1985; Erdmer and Downing, 1993), and more specifically from 2 Ωm to 5 Ωm and from 50 Ωm to 100 Ωm for yellow and blue ground, respectively (Macnae, 1979).

The most prominent EM characteristic that might be detected in exploration for diamondiferous diatremes is the lower conductivity of the near-surface yellow ground (Nixon, 1980b). A further point to consider is that magnetite may be destroyed during weathering, with the result that the magnetic susceptibility is lowered. This has the interesting consequence that if a kimberlite pipe is heavily weathered, then its magnetic signature might be expected to be weak, but it may still be distinguished in airborne EM methods by highly conductive near-surface anomalies. EM geophysical surveys in Alberta will also be complicated by the possible existence of conductive near-surface clays, shales and saline ground waters.

Magnetic Exploration for Diatremes in Sedimentary Terranes

Diatremes, dykes and sills of fresh kimberlite should provide an observable magnetic susceptibility contrast relative to the enclosing sedimentary rocks. As a result, kimberlite diatremes and dykes should appear as distinct positive or negative anomalies in a contour map of the total magnetic field. The surrounding breccias and tuffs are a melange of the original magma and the surrounding country rocks, and this heterogeneous material may not have a significant magnetic response. Magnetic response also will be severely attenuated by weathering of magnetic minerals (Macnae, 1979). The bulk of the published studies describe magnetic responses of kimberlites or lamproites intruding sediments.

The results of a high resolution aeromagnetic survey which was conducted in the southernmost portion of Alberta by the Geological Survey of Canada (1993) have recently been released. Ross *et al.* (1994a, b) discussed the possible interpretation of these magnetic maps at the 1994 Lithoprobe Conference, and noted the existence of numerous linear magnetic trends that radiate from portions of the Sweetgrass Hills immediately across the border in Montana. Ross *et al.* (1994a, b) interpreted the linear trends in the magnetic data to be due to igneous dykes at shallow depth. These dykes may highlight potential areas for further exploration in southern Alberta because clusters of diatremes are often found to be spatially associated with such dykes.

Elsewhere in Alberta, the GSC has completed an airborne magnetic survey over central Alberta. The results of this joint GSC-industry funded survey are currently unavailable, but it is anticipated that the results of this survey will be published in the near future.

The Mountain Lake Kimberlite near Grande Prairie exhibits two positive magnetic responses of about 25 nT above the local background in a detailed ground magnetic survey (Wood and Williams, 1994). The Mountain Lake Kimberlite also appears to have been more resistant to glacial erosion because it forms a distinct positive topographic feature. The GSC has recently completed an orientation airborne geophysical survey over the Mountain Lake Kimberlite, and the data from this survey is expected to be released in mid to late 1996 or early 1997. Preliminary data from this survey indicate that the Mountain Lake Kimberlite forms a distinct positive magnetic anomaly (Leckie, *pers.comm.*, 1996). The reader is referred to a summary discussion of magnetic responses over kimberlites and lamproites in Canada, the United States of America (USA), the former Soviet Union, South Africa and Australia in Dufresne *et al.* (1994a).

Magnetic Exploration for Diatremes in Igneous and Metamorphic Terranes

Kimberlite and lamproite diatremes intruding igneous or metamorphic rocks may or may not have sufficient magnetic susceptibility contrasts to be distinguished. However, many of the world's known kimberlites have distinctive geophysical signatures. For example, many kimberlites in the Canadian Shield produce circular or roughly circular aeromagnetic signatures. Erdmer and Downing (1993), for example, documented positive results in the search for kimberlites in the Lac du Sauvage area of the NWT by a low level (45 m altitude), high resolution aeromagnetic survey. The total magnetic field response identified a kimberlite pipe with a magnetic high of less than 20 nT centred on a circular anomaly with a diameter of approximately 600 m. This pipe was also apparent in a contour map of the vertical gradient of the magnetic field. The reader is referred to Dufresne *et al.* (1994a) for a summary discussion of magnetic responses of kimberlites that have intruded Precambrian Shield rocks of the USA.

Resistivity and Electromagnetic Surveys

There appear to be no public domain studies or data relating to electrical or EM surveys for diatremes within Alberta. However, studies in Lesotho (Macnae, 1979) and Western Australia (Smith, 1985) showed that EM airborne surveys are useful in delineating diatremes, primarily because they weather to highly conductive clays at and near the surface. However, southern Africa and Australia have higher average mean temperatures and precipitation than Alberta, which might allow for more rapid or differential weathering. In addition, these regions have not undergone recent glaciation and therefore the diatremes have presumably weathered *in situ* since emplacement. As a result, these studies may not be directly comparable to the Alberta situation. However, most of the EM surveys which have been conducted in the State Line District of Colorado and Wyoming, where climatic conditions are not that different from the arid sections of southern Alberta, appear to have generally yielded positive results, as did surveys discussed by Erdmer and Downing (1993) for kimberlites in the NWT. Hence, the EM and resistivity methods may well have application to Alberta since diatreme facies rocks are porous, and therefore may form good conductors.

The Phanerozoic sedimentary strata which forms the bedrock across much of Alberta, might substantially complicate the interpretations of geophysical data as noted in the preliminary studies described by Gent (1993) in Saskatchewan. Thus, without data from actual airborne and ground geophysical surveys conducted over known diatremes in Alberta, it is difficult to speculate on the potential merits of the EM methods.

Gravity

There are few published gravity survey results that relate directly to kimberlite exploration. In general, regional gravity surveys appear to have little application towards kimberlite exploration (Atkinson, 1989), although Jennings (1990) suggested that kimberlites may appear along a regional positive gravity expression indicative of the upper hinge of a crustal flexure. Burley and Greenwood (1972), as reported by Nixon (1980b), show such a gravitational response over a kimberlite pipe in Lesotho. Gerryts (1970) reported on studies carried out in the former Soviet Union and in Tanzania. In the former Soviet Union, for example, gravity measurements were able to detect the presence of blind pipes beneath trap lavas on the basis of negative Bouguer anomalies. In Tanzania, the kimberlite pipes reside in a host of metamorphic rocks.

In the State Line District of Colorado and Wyoming, Hausel *et al.* (1979) suggested that gravity surveys are not expected to be successful due to the fact that the serpentinized kimberlite in the area has a density very close to that of the host granites. However, Carlson *et al.* (1984) detected a small negative Bouguer anomaly associated with the surface expressions of the Maxwell 1 kimberlite pipe, which is located near the Schaffer pipe cluster.

Seismic Measurements

The components of a kimberlite pipe will exhibit different seismic velocities. During refraction experiments, Burley and Greenwood (1972) found that weathered kimberlite has seismic velocities which increase with depth from 900 metres per second (m/s) to 1,620 m/s, whereas unweathered kimberlite has seismic velocities from 2,900 m/s to 4,200 m/s. Hausel *et al.* (1979) stated that weathered kimberlite has seismic velocities from 670 m/s to 1,590 m/s, with a seismic velocity of 3,529 m/s in the dense kimberlite. The low seismic velocities indicate there is a porosity in the kimberlite rock that results either from weathering or primary porosity due to gas exsolution.

Gent (1992) described a seismic reflection profile across the Maple Creek structure in southwestern Saskatchewan. This structure is associated with a 3 mgal gravity anomaly which Gent (1992) suggested can only be associated with an intrusive body. The reflection seismic profile over the gravity anomaly shows considerable faulting and tilting of the sedimentary horizons, and a loss of continuity in the reflections. Shallow drilling over the anomaly was carried out during 1993 in order to test Gent's (1992) interpretation of this structure as a possible diatreme. The drillhole, which was drilled to a depth of 206 m, did not intersect any intrusive material. The uplifted sediments do not confirm the existence of a diatreme, but could be consistent with a deep intrusion.

More recently, high resolution reflection seismic profiles were conducted over a known diatreme in the Fort à la Corne area of Saskatchewan. The preliminary findings will soon be published (Gendzwill, *pers. comm.*, 1994). The profiles over a known kimberlite indicate the presence of an intrusion with breccia and crater phases; this complex structure is approximately 1 km in diameter. The structure contains numerous discontinuities that are indicated by scattered seismic energy and with velocity 'pull up' effects. These effects are a consequence of the higher velocity of 4.5 km/s of the igneous material which is up to 18% porous.

In general, regional reconnaissance prospecting for diatremes with reflection seismic profiling is not practical due to the small size and proximity to surface of most of the diatremes. However, salt solution collapse structures in which overlying sediments are disturbed by the dissolution of deeper salt units to form sinkholes filled with breccias, together with further deposition of sediments are distinctive in seismic profiles. These features may be of interest in kimberlite exploration in

Alberta because Gent (1992) described a number of these structures in Saskatchewan and suggested a possible, but unproven, link between some collapse structures and diatreme activity. Examples of seismic profiles over salt solution collapse structures may be found in Anderson *et al.* (1989).

Radiometric Surveying

Kimberlites are enriched in potassium, uranium and thorium and, on this basis, could be expected to have a radioactive signature. Leucite bearing lamproites also have high concentrations of potassium. As a result, radiometric surveys may show some promise in the detection of kimberlites and lamproites. However, published findings of relevant radiometric studies are rare.

Nixon (1980b) found that laboratory radiometric measurements on approximately 100 kimberlites were disappointing. The only samples which gave a positive response were those containing phlogopite (a potassic mica) and crustal basement xenocrysts. In the field, it was found that thin layers of soil were sufficient to mask any radiometric signal. Paterson *et al.* (1977) suggested that airborne spectrometer information was a useful diagnostic as a follow-up role to magnetometer surveys for kimberlites in Lesotho. In contrast, Hausel *et al.* (1979) could not distinguish the kimberlites in the State Line District of Colorado and Wyoming from the surrounding granites because both produced similar scintillometer readings. In this same region, Carlson and Marsh (1986) indicated that neither total count radioactivity surveys nor differentiating gamma ray spectrometer surveys (Carlson *et al.*, 1984) were effective due to variations of overburden thickness and host rock radioactivity. In Australia, Atkinson (1989) found that the success of radiometric surveying was highly dependent on the amount of exposure or cover, in addition to the dimensions and radioactivity of the lamproite. In this study, only six of the 26 pipes that were detected in the Ellendale field by magnetics and EM showed any radiometric response, and all of these bodies were large (> 7 ha) and had no surface cover. Finally, Gent (1992) reported that an airborne radiometric survey conducted in Saskatchewan, which was flown in order to search for dispersed kimberlitic material in overburden, was unsuccessful.

Borehole Geophysics

Gamma-ray log information from hydrocarbon wells may be used as an aid in exploring for kimberlites and lamproites. Group I kimberlites can contain up to 2 wt% K_2O, and lamproites from 6 wt% to 8 wt% K_2O. Due to the presence of radioactive potassium isotope (^{40}K), these rocks and their associated tuffs will give strongly positive responses on a gamma-ray log. In Alberta, the presence of kimberlites or lamproites that have intruded the sedimentary succession may be detected, indirectly, by intersecting the genetically related bedded volcaniclastics near the site of an alkaline diatreme or, more distally, by intersecting anomalously thick bentonite beds within the stratigraphic column.

Remote Sensing

Remote sensing in the search for kimberlites has been discussed by a number of authors in the context of either delineating regional or local structures, or by directly detecting kimberlites based on their spectral reflectance character.

For example, Nixon (1980b) described an Earth Resources Technology Satellite (Landsat) study of Lesotho by Barthelemy and Dempster (1975) that located numerous regional lineaments. In particular, kimberlite pipes were observed to exist at the intersection points of regional lineaments. Nixon (1980b) suggested that a few kimberlites could be detected in this manner, but that the locations of clusters of pipes in southern Africa appeared to be more controlled by the deep-seated spacings of diapirs. In short, he suggested that the Landsat satellite images were useful as a structural mapping tool and not for direct identification of kimberlites. Similar studies and results are described by Woodzick and McCallum (1984). In contrast, Hausel *et al.* (1979) described the use of both aerial photography and satellite imagery in finding lineaments and related diatremes in the State Line District in Wyoming. Some of the diatremes were directly apparent in the low altitude colour aerial photographs (1:24,000 scale). In particular, the differing colours of the diatreme material contrast markedly with the surrounding reddish granite. Another interesting observation made by Hausel *et al.* (1979) is that the ground cover over the diatremes contains substantially more clay than the weathered products over the granites, and this results in noticeable changes in the vegetation which may easily be observed in aerial photography. Such observations were also made by

Jones (1970) who noted that dense stands of alder and larch grew in kimberlitic soils in the Daldyn region of the former Soviet Union. In Australia, Longman (1980) described a study in which multispectral Landsat data allowed detection of additional potential kimberlite targets after spectral calibration over a known kimberlite. An additional constraint with these types of measurements is that often an extensive calibration of the ground reflectance is required in order to correlate geologic features and spectral reflectance character. Kingston (1986), for example, described preliminary measurements of the reflective properties in the visible and infrared portions of the spectrum between 0.4 and 2.5 μm of carbonatites and kimberlites, and found that the former were detectable at two locations in Colorado and California. However, the associated alkaline rocks were not distinguishable on the basis of the spectral reflectance signature.

At present, the remote sensing field is advancing rapidly. This is due to the high resolution satellite images that have become commercially available from previously confidential military sources and improvements in the spatial and spectral resolution of civilian sensors. Advances in computing speed and image processing capabilities have also been rapid, and the inclusion of such data into Geographic Information Systems (GIS) relational databases is becoming commonplace. Although there has been little data published pertinent to diamond exploration, these recent developments will undoubtedly make remote sensing more important for future diamond exploration purposes.

Summary

A listing of the regional scale geophysical anomalies in the literature which are pertinent to diamond exploration in Alberta follows.

(1) Seismic tomography and surface wave studies indicate that the upper mantle beneath Alberta is a transitional zone between the shallow, slow seismic velocities in the Cordillera and the deep, fast seismic velocities in the Canadian Shield, possibly representative of hot and cool mantle, respectively. This is supported by studies of the flexure of the Alberta Foreland Basin which indicate that the lithosphere thickens to the north and east of Alberta.

(2) Controlled source seismic refraction experiments indicate a general shallowing of the depth of the Mohorovicic discontinuity in the northeastern sections of the province. The crust in the southern portions of Alberta, and beneath the Rocky Mountains is thicker than 'normal' continental crust. However, the crust in southern Alberta may show thinning beneath the SAR or Vulcan Low.

(3) Deep reflection seismic experiments show a complex deep crustal structure in southern Alberta and perhaps also in central Alberta near Edmonton. In contrast, the PRA region may show less lateral variation in depth to the Mohorovicic discontinuity and seismic velocity. These earlier studies, however, will soon be supplanted by higher resolution seismic profiles that will result from data obtained by several Alberta Lithoprobe transects..

(4) Bouguer gravity increases from the Rocky Mountains to the north and east and may also indicate a general thinning of the crust away from the mountains. A large, nearly linear Bouguer gravity low, which possibly is related to the STZ, strikes northeast from the Rocky Mountains across the province to the Alberta-Saskatchewan border. A nearly horizontal, arcuate region of low Bouguer gravity, which is commonly referred to as the SAR or Vulcan Low, traverses the southern portion of Alberta.

(5) Magnetic data show the existence of major regional crustal features, such as the GSLSZ, the STZ and the Thorsby, Chinchaga and Vulcan lows. In addition, the Mountain Lake Kimberlite was detected with a detailed ground magnetic survey.

(6) A northeast trending, low electrical conductivity lineament, which possibly is related to the Vulcan Low, traverses the southern portion of Alberta.

(7) Regional heat flow studies do not identify any major structures of potential interest for diamond exploration within Alberta. One study has highlighted a region of high geothermal gradient that exists between the towns of Edson and Hinton. The geothermal anomaly in this region is possibly related to deep magma or to flow of hot fluids along faults.

Geochemical, Geological and Geophysical Anomalies in Alberta

The following section will discuss the potential for diamondiferous diatremes in Alberta based on the present state of knowledge of the basement geology, structural setting and considering the potentially favourable stratigraphic intervals. In addition, other reported geological, geophysical and geochemical anomalies will be summarized, including the results to date of regional diamond indicator mineral surveys that have been conducted within Alberta.

Potentially Favourable Basement Terranes and Structures

It is now generally well accepted that diamonds in kimberlites or lamproites are xenocrysts derived from the dissaggregation of mantle peridotite or eclogite that exist at depth beneath thick, cool crust. In addition, most peridotitic diamonds are thought to be Archean, whereas eclogitic diamonds span an age range from Archean to at least 990 Ma (Kramers, 1979; Richardson *et al.*, 1984, 1990; Richardson, 1986, 1989; Smith *et al.*, 1989). Based on these observations, the most favourable areas for the intrusion of diamondiferous kimberlites or lamproites in Alberta should be those areas that are underlain by basement terranes comprised of old, thick and cold crust that has not been subjected to thermal reheating through time.

Southern Alberta

Well documented Archean basement terranes in Alberta include the Medicine Hat Block, SAR (Vulcan Low), Matzhiwin High, Loverna Block and the Eyehill High in the southern third of the province. These terranes are favourable for the formation and preservation of diamonds based on their Archean age and long time crustal stability. The petrogenesis of the Crowsnest volcanics of southwest Alberta (Peterson and Currie, 1993), the minette intrusions of southern Alberta (Kjarsgaard, 1994a; Kjarsgaard and Davis, 1994; Luth, 1994) and many mafic alkalic intrusions in Montana (Dudas, 1991; O'Brien *et al.*, 1991, MacDonald *et al.*, 1992) indicate that considerable partial melting of the lower crust has occurred at least locally in the southern portion of the Medicine Hat Block. If this partial melting is related to a widespread Cretaceous to Tertiary thermal event that has heated the lower crust and upper mantle in the area from the Cordilleran deformation front to the SGA, then the potential for diamond preservation in this area may be low. If, however, the thermal event was more localized, then it is possible that the region of the Milk River Drainage Divide may represent a favourable area to explore for diamondiferous intrusions based on the existence of potassic minette intrusions (Williams and Dyer, 1930; Russell and Landes, 1940; Irish, 1971; Kjarsgaard, 1994a, b; Kjarsgaard and Davis, 1994) and potentially extensive dyke swarms identified by Ross *et al.* (1994a) as a result of the recently released Cypress Hills airborne magnetic survey (Geological Survey of Canada, 1993). In addition, the Milk River Drainage Divide is a major continental divide that separates the drainage to Hudson Bay from the Columbia River drainage to the Pacific Ocean. Such drainage divides may reflect thickened crust, with sub-cratonic roots or keels that penetrate well into the upper mantle, based on the laws of isostasy, and they are sometimes referred to as crustal Anticlinoria or Anticleses. These sub-cratonic roots or keels are the preferred locus for the formation and preservation of diamonds (Haggerty, 1986; Gurney, 1990).

Other potentially favourable areas for the intrusion of kimberlites or lamproites in the southern third of Alberta might include the margins of the SAR, the southwest trending MLE and the Eyehill High basement terrane. Deep seated graben-like movement in the vicinity of the SAR is documented during the Proterozoic (Kanasewich, 1968; Kanasewich *et al.*, 1969; McMechan, 1981; Olson *et al.*, 1994), the Upper Paleozoic (Price and Lis, 1975; Brandley and Krause, 1993; Brandley *et al.*, 1993) and, possibly, as young as Middle Cretaceous based on the work of Jerzykiewicz and Norris (1993a, b) and on the extrusion of the Crowsnest volcanics, which have their thickest portions centred within the bounds of the SAR. Further evidence of possible Cretaceous movement associated with the SAR exists in the Alberta Interior Plains near Brooks, where Hopkins (1987, 1988) has described synsedimentary subsidence associated with possible movement along faults that reach from the Precambrian basement into the Cretaceous section.

Little is known about the MLE, but it is believed to be a Devonian escarpment that corresponds to a shelf margin reef complex (Kent, 1994; Oldale and Munday, 1994; Switzer *et al.*, 1994; Wright *et al.*, 1994). Local faulting, which is attributed to salt removal in the Devonian Wabamun Group, has been documented along the trend of the escarpment about 40 km northeast of Trochu, Alberta (Oliver and Cowper, 1983). Interestingly, microdiamonds were discovered in Cretaceous-Tertiary boundary sediments by D. Braman (Tyrrell Museum) and D. Carlisle (Environment Canada) along the west bank of the Red Deer River (Science City News, 1992; Braman, *pers. comm.*, 1994) approximately 20 km northwest of the abnormal sections near Trochu which were documented by Oliver and Cowper (1983).

Ross *et al.* (1994b) suggested that seismic data from the Lithoprobe Central Alberta Transect indicate significantly thickened crust beneath the Archean Eyehill High near the Saskatchewan border. As a result, the lower crust and upper mantle below the Eyehill High may have been favourable for the formation and preservation of diamonds, and therefore this area may be a favourable place to explore for diamondiferous kimberlites or lamproites. In particular, perhaps the most favourable portion of the Eyehill High to explore may be where it is transected by the MLE.

Central and Northern Alberta

Of the Proterozoic or reworked Archean terranes in the northern two thirds of Alberta, the least favourable areas for diamond formation and preservation are likely the strongly magmatic terranes, such as the Taltson, Great Bear, Rimbey and Ksituan terranes, because they are indicative of high thermal gradients in the crust during the Proterozoic. The strong thermal pulse responsible for the magmatic rocks in these terranes would likely have destroyed any pre-existing diamonds in the upper mantle below these terranes. If, in fact, some of these terranes represent accreted microcontinents (Villeneuve *et al.*, 1993), then there is potential to have created Proterozoic or younger diamonds in subducted eclogite during accretion of these microcontinents. The more favourable terranes are likely the Chinchaga and Thorsby Lows, and possibly, the Wabamun and Buffalo Head Terranes because, as Villeneuve *et al.* (1993) suggested, these terranes may have a significant Archean component to them based on their Sm-Nd isotope systematics. The Thorsby Low and its margins are of particular interest because it possibly represents the southwest extension of the STZ, which is a major crustal lineament that divides the Churchill Province into the Rae and Hearne subprovinces. The STZ can be traced to the northeast at least as far as Baker Lake, and perhaps into Hudson Bay. A major continental drainage divide coincides very nearly with the north margin of the Thorsby Low. This may reflect thickened crust beneath the divide, which is somewhat corroborated by seismic data from the Central Transect of Lithoprobe (Ross *et al.*, 1994b). Other local structures and faults in the basement and overlying sedimentary rocks indicate that the Thorsby Low has been periodically active during the Phanerozoic as recently as Cretaceous. These include extensional basement faults (the Erith Graben) that offset Cambrian carbonates to Cretaceous sedimentary rocks in the Erith and Hanlon hydrocarbon fields (Edwards and Brown, 1994), the Cline Channel in Devonian carbonates (Geldsetzer and Mountjoy, 1992), and the Bighorn Tear Fault which exists along the North Saskatchewan River southwest of Nordegg (Verrall, 1968; Dahlstrom, 1970). The Bighorn Tear Fault marks the southern termination of the Bighorn Range. Verrall (1968) suggested that this fault has experienced vertical movement along with shearing because the south side is significantly downthrown. The major period of movement was during the Laramide Orogeny because the fault cuts Upper Cretaceous rocks in the Cripple Creek thrust sheet, but is overridden by the McConnell thrust sheet.

Other areas of interest for diamond exploration include those parts of Alberta that are underlain by the Chinchaga and Buffalo Head terranes where they have been affected by periodic movement associated with the PRA or the GSLSZ. The PRA was a positive feature during the Late Proterozoic to Late Devonian (Stelck *et al.*, 1978; O'Connell *et al.*, 1990) and, possibly, during the Late Cretaceous to Tertiary (Leckie, 1989; Hart and Plint, 1990). The PRA failed during the Late Paleozoic, forming the Fort St. John Graben Complex (PRE), which was a negative relief feature from the Late Paleozoic to Early Cretaceous (Cant, 1988; Leckie *et al.*, 1990; O'Connell *et al.*, 1990). Many of the pronounced faults that were formed during Late Paleozoic to Cretaceous subsidence influenced sedimentary depositional patterns and they parallel and overlie prominent basement fabrics. An example of this is the Lower Cretaceous Fox Creek Escarpment (O'Connell *et al.*, 1990), which overlies the Late Paleozoic Belloy Fault (Sikabonyi and Rodgers, 1959), both of which overlie and parallel the contact between the Ksituan and Chinchaga basement terranes. Hart and Plint (1990) suggested that this escarpment influenced Late Cretaceous sedimentation patterns, and was indicative of renewed uplift during that time. Coincidentally, these structures, particularly the Belloy Fault, which is northeast of Grande Prairie, trend southeast and lie in close proximity to the Mountain Lake Kimberlite (Figure 9).

The Kimiwan basement anomaly, which was described by Muehlenbachs *et al.* (1993, 1994), is a distinct northwest trending, linear, oxygen and deuterium isotope depletion anomaly in basement rocks that exists northwest of Edmonton. The anomaly is the result of extensive chlorite-epidote alteration in the basement rocks and corresponds spatially to the strong linear magnetic high that forms the southwest margin of the Buffalo Head Terrane in contact with the Chinchaga Terrane. The alteration along this trend may be indicative of a strong structural control, such as by a fault, and therefore the strata overlying this anomalous trend may be an area to explore for kimberlites or lamproites.

Other Regional Structural Elements

Other regional structural elements that may have played important roles in the emplacement of kimberlite or lamproite diatremes in Alberta include the WAA and the GSLSZ, which includes associated intersecting structures such as the Northern Alberta Trough (NAT) and the SRS. With respect to the WAA, the Paleozoic alkalic igneous intrusions in the Rocky Mountains of BC are distributed west of, but sub-parallel to the Alberta – BC border. The northwest trending WAA was periodically active during the Paleozoic, and its western edge crudely approximates the distribution of these Paleozoic, alkalic intrusions in BC. Bingham *et al.* (1985) suggested that a conductive ridge below the Eastern Rockies may be indicative of high heat flow in the lower crust and it also may be responsible for periodic uplift, extension and igneous activity such as that which occurred during the Paleozoic. Therefore, perhaps the eastern margin of the WAA, which exists well within Alberta, is also a favourable location to search for kimberlites and lamproites, particularly because it is closer to being 'on Archean craton', which is considered important for the existence of diamondiferous kimberlites and, possibly, lamproites.

Pell (*pers.comm.*, 1996) suggests that many of the Lac de Gras kimberlites form fields that trend parallel to the Bathurst Fault and the GSLSZ. Movement along the GSLSZ occurred predominantly during the Proterozoic, but Skall (1975) has documented movement at least as recently as Devonian. The SRS is an elliptical to subcircular basement high that exists very near the junction of the GSLSZ and a major northwest trending lineament that corresponds to the basement contact between the Hottah and Great Bear Magmatic terranes. The SRS is postulated to be a meteorite impact feature with spatially associated horst- and graben-like structures, with direct evidence of 'shock metamorphism' coming from a single oil well (I.O.E. Steen 12-19) and associated seismic data (Winzer, 1972; Wilson *et al.*, 1989). Alternatively, Carrigy (1968) suggested that the SRS may have formed as a result of volcanic activity because several of the horizons, which were intersected in the oil well, resemble mafic alkaline volcanic to volcaniclastic or pyroclastic layers. In addition, extensive bentonites and pyroclastic horizons have been identified in adjacent drill holes through the rim syncline (Carrigy, 1968; Winzer, 1972). In well I.O.E. Steen 12-19, Carrigy (1968) reported the presence of vesicular volcanic agglomerate and "*five feet of dark green glassy rock (pitchstone), in the bottom of the hole . . . .* [that has] *a more basic chemical composition than the plutonic or vesicular rocks above.*" Radiometric K-Ar dating of pyroclastic material in I.O.E. Steen 12-19 indicates an age of about 95 Ma (Carrigy, 1968), which is approximately the same age as (1) the kimberlites near Fort à la Corne, Saskatchewan; (2) the Crowsnest volcanics in southwest Alberta; (3) the Fish Scale Horizon which is purported to be the result of a condensed section formed in an anoxic basin; and (4) bentonites associated with the Fish Scale Horizon. It seems highly fortuitous that a massive fish extinction, thought to be related to a change to an anoxic environment during a quiescent period associated with a transgressive still stand (Leckie *et al.*, 1990, 1992), occurred at about the same time that a meteorite is thought to have impacted in the Steen River area and widespread volcanic eruptions took place in southwest Alberta and in the Fort à la Corne area, Saskatchewan. Further geoscientific work is needed to determine the origin of the SRS. The area surrounding the SRS may be a favourable area to search for kimberlites or lamproites.

Potentially Favourable Stratigraphic Intervals and Structures

The dominant episodes of diamondiferous kimberlite and lamproite volcanism are Late Middle Helikian, Late Devonian to Mississippian, Middle Jurassic to Late Cretaceous and Early Tertiary (Tables 2 and 3). Volcanism within or near Alberta is evident during all of these important intervals in one form or another. As well, alkaline mafic volcanic activity is evident in Alberta during the three Phanerozoic episodes. During these three periods, much of Alberta was covered by shallow epeiric seas. Therefore, based on the kimberlites near Fort à la Corne, Saskatchewan (Lehnert-Thiel *et al.*, 1992), the appropriate diamond exploration model for Alberta may consist of searching for diamondiferous, stratabound, horizontal to lenticular pyroclastic or paleoplacer deposits. As a result, it is critical to know which stratigraphic horizons are most likely to contain evidence of these intrusions in the form of diatremes, volcaniclastics or bentonites.

Late Devonian to Mississippian

There are three episodes of Paleozoic kimberlitic volcanism in BC, NWT and the western USA. All three of these episodes have yielded diamondiferous diatremes including a number of diamonds from the Ordovician Cross Lake kimberlite, north of Yellowknife, NWT (Pell, 1996) and the Silurian Mountain diatreme in the MacKenzie Mountains, NWT (Godwin and Price, 1986; Fipke *et al.*, 1989), and grades of up to 20 ct/100t from Devonian-Mississippian kimberlites in the State Line District, Colorado (Fipke *et al.*, 1989; Coopersmith, 1991, 1993a, b). The Crossing Creek kimberlite near Elkford, BC, which was emplaced during the last period of Paleozoic kimberlitic volcanism from Permian to Triassic, is reported to be barren (Grieve, 1982; Pell, 1987a, b; Hall *et al.*, 1989; Fipke *et al.*, 1989). However, diamonds have been reportedly recovered from some nearby diatremes associated with the Crossing Creek kimberlite (George Cross Newsletter, 1994).

The few known Ordovician-Silurian mafic alkaline intrusions in North America occur in the Canadian Cordillera, the Mackenzie Mountains and the Slave Structural Province. The Cross Lake kimberlite and Mountain diatreme, NWT are the only known diamondiferous intrusions of this time period. Identification of the Mountain diatreme, NWT as a kimberlite is tenuous (Fipke *et al.*, 1989). In Alberta, Ordovician-Silurian carbonates are restricted to mountainous regions and in the deepest portions of the Alberta Basin. Therefore, the potential is low for discovery and development of Ordovician-Silurian kimberlites or lamproites in Alberta.

The Crossing Creek kimberlite and associated diatremes are the only North American example of the Permian-Triassic alkaline volcanic event. The likelihood of extensive Permian-Triassic volcanism in Alberta is low, even though the potential for preservation is high due to regionally extensive Permian-Triassic sedimentary rocks. Nonetheless, this time-stratigraphic interval should not be ignored because the Jwaneng kimberlite pipe in Botswana is Triassic in age and is one of the richest diamond mines (140 ct/100t) in the world (Helmstaedt, 1992, 1993).

The most prospective time-stratigraphic interval for Paleozoic diamondiferous kimberlites or lamproites in Alberta is probably the Late Devonian to Mississippian succession. This is based on: (1) the existence of diamondiferous alkaline diatremes near to the Alberta-BC border (Northcote, 1983a, b; Dummett *et al.*, 1985; Fipke *et al.*, 1989); (2) possible diatremes of this age in Saskatchewan (Gent, 1992); (3) the presence of volcanic related rocks that have been identified in the Upper Devonian Big Valley Formation in Saskatchewan (Halbertsma, 1994) and in the Lower Mississippian Exshaw Formation at several locations in Alberta (Folinsbee and Baadsgard, 1958; Packard *et al.*, 1991; Meijer-Drees and Johnston, 1993; Richards *et al.*, 1993); (4) the wide distribution and large volume of Upper Devonian to Mississippian rocks in the Alberta Basin; and (5) several regional structures that were active in Alberta during that time period. Interestingly, the most prolific diamondiferous kimberlite event in the northern hemisphere occurred during the Devonian-Mississippian period on the east Siberian platform in Yakutia (Tables 2 and 3). These Siberian pipes include world class diamond producers (Davis *et al.*, 1982; Milanovskiy and Mal'kov, 1982; Jerde *et al.*, 1993). As well, the Late Devonian to Mississippian period is already known to be an important event in North America based on the discovery of more than twenty diamondiferous kimberlites in the State Line District, Colorado, with grades of up to 20 ct/100t in the Sloan pipe (Fipke *et al.*, 1989; Coopersmith, 1991, 1993a, b).

The burial depth of the Devonian ranges from zero to more than 2,000 m from northeast to southwest across Alberta (Mossop and Shetsen, 1994). Exploration for near-surface diamondiferous deposits in Devonian and older Phanerozoic rocks will generally be restricted to northern Alberta, and the Rocky Mountains and Foothills, where Upper Devonian to Mississippian rocks are less than 500 m below surface. Important structures that were active during this time in northern Alberta include: (1) the PRA (Cant, 1988; O'Connell *et al.*, 1990); (2) the GSLSZ and the spatially associated NAT (Sikabonyi and Rodgers, 1959; Skall, 1975); and (3) other poorly documented structures in northeast Alberta (Garland and Bower, 1959; Martin and Jamin, 1963; Stewart, 1963; Hackbarth and Nastasa, 1979; Dubord, 1987; Dufresne *et al.*, 1994a, b). In the Rocky Mountains and Foothills, important tectonic elements that may have influenced the intrusion of deep-seated Devonian-Mississippian diatremes include the WAA, the Thorsby Low and the SAR.

Middle Jurassic to Late Cretaceous

Worldwide, the Middle Jurassic to Late Cretaceous is the most prolific period of diamondiferous kimberlite intrusion, most of which has been restricted to the African continent (Table 2). With respect to North America, the available data indicate that this epoch may also be an important period of diamondiferous kimberlite and lamproite activity (Table 2).

At present, kimberlite or related rocks which intruded during the Jurassic in North America are mostly restricted to eastern Canada and the USA. Examples include diatremes in the James Bay Lowlands and at Kirkland Lake, Ontario (Brummer, 1978, 1984; Reed and Sinclair, 1991), Lake Ellen, Michigan (Jarvis and Kalliokoski, 1988; Duskin and Jarvis, 1993) and Ithaca, New York (Watson, 1967; Zartman *et al.*, 1967; Meyer, 1976; Basu *et al.*, 1984). Diamonds have been discovered in the kimberlitic diatremes at both Kirkland Lake and Lake Ellen. There is little evidence of volcanism during the Jurassic period in western Canada and the western USA. Nonetheless, because of the importance of this time period in South Africa and the presence of diamondiferous intrusions of this age in eastern North America, the Jurassic succession in Alberta should not be discounted entirely as an exploration target.

Data indicate that Cretaceous kimberlites are widespread across North America. Examples include multiple mid-Cretaceous diamondiferous kimberlites in the Fort à la Corne area, Saskatchewan (Gent, 1992; Lehnert-Thiel *et al.*, 1992; Scott Smith *et al.*, 1994; Kjarsgaard, 1995; Leckie *et al.*, *In Press*), at Somerset Island, NWT (Fipke *et al.*, 1989; Kjarsgaard, 1993), and at Prairie Creek, Arkansas (Zartman *et al.*, 1967; Zartman, 1977; Gogineni *et al.*, 1978; Scott Smith and Skinner, 1984; Morris, 1987; Waldman *et al.*, 1987). The Prairie Creek intrusions may in fact be lamproitic in composition (Scott Smith and Skinner, 1984; Morris, 1987; Waldman *et al.*, 1987). The Fort à la Corne kimberlites were intruded about 94 to 101 Ma (Lehnert-Thiel *et al.*, 1992; Scott Smith, 1994; Kjarsgaard, 1995; Leckie *et al.*, *In Press*), which is the approximate age of the Fish Scale Horizon (Leckie *et al.*, 1990, 1992; Bloch *et al.*, 1993), the Crowsnest volcanics in southwest Alberta (Folinsbee *et al.*, 1957), and the subsurface Viking Formation bentonites (Tizzard and Lerbekmo, 1975). McCallum *et al.* (1975) have suggested that many of the undated and dated alkaline intrusions which occur along the Alberta- BC border, such as the Jack and Mark diatremes, are in fact syn- to post-orogenic and were likely intruded between 60 and 98 Ma based on structural relationships (Fipke *et al.*, 1989). Another potentially important mid-Cretaceous magmatic event includes volcanism associated with the SRS in northern Alberta (Carrigy, 1968; Winzer, 1972; Wilson *et al.*, 1989). Finally, recent exploration in northern Alberta by Monopros Ltd. indicates that Late Cretaceous volcanism may be an important event based on the discovery of the Late Cretaceous Mountain Lake Kimberlite northeast of Grande Prairie. In short, evidence exists for widespread mid- to Late Cretaceous volcanic activity across the Alberta Basin. Thus, Cretaceous sequences are likely the most favourable to explore for diamondiferous kimberlites or lamproites in Alberta.

The depth from surface to the top of the Fish Scales Horizon is illustrated by Dufresne *et al.* (1994a). Economic considerations probably will restrict diamond exploration to where mid- to Late Cretaceous units, such as the Fish Scales Horizon and Wapiti Formation are less than about 500 m below surface. The most prospective areas include: (1) a wide belt in northern Alberta from Grande Prairie to Cold Lake; (2) in the vicinity of the Caribou Mountains near the NWT border; and (3) in and near the Rocky Mountains and Foothills. Important structures that may have been active in northern Alberta during the mid-Cretaceous include the PRA, the SRS and, possibly, reactivation of faults associated with the GSLSZ and the STZ (Figures 8 and 9). These structures are obvious loci to search for kimberlite or lamproite intrusions and any associated volcanic related rocks in the mid- to Late Cretaceous sequences.

In the Rocky Mountains and Foothills, important regional structures include the SAR and the STZ. Evidence of Early to mid- Cretaceous movement and volcanism associated with the SAR is described by Price (1962), Gordy and Edwards (1962), Pearce (1970), Adair (1986) and Jerzykiewicz and Norris (1993a, b). Some structures in the vicinity of the Thorsby Low indicate that the STZ may have been reactivated during Cordilleran orogenesis. Verrall (1968) and Edwards and Brown (1994) describe extensional faults that have affected Cretaceous sequences in the vicinity of the Thorsby Low.

Tertiary

Late Cretaceous to Early Tertiary may well prove to be the dominant diamondiferous kimberlite event on the North American continent based on early indications from the Lac de Gras area, NWT, where initial studies (Kjarsgaard and Heaman, 1995) indicate that a few of the diamondiferous kimberlites were emplaced during the Late Cretaceous (74 Ma) with the majority of the kimberlites being emplaced during the Eocene (49-52 Ma). Therefore, selected early Tertiary strata in southern and western Alberta warrant exploration for diamondiferous diatremes. In particular, early Tertiary strata that overlie favourable basement terranes, and/or are associated with major structural zones, such as the STZ, the Thorsby Low, the WAA, the PRA, the SAR or other such structures should be explored for diamondiferous diatremes.

There also is potential for secondary diamondiferous deposits to occur in later Tertiary or even Quaternary gravels or other clastic strata that have been deposited by fluvial, alluvial or other such erosional-depositional processes. These secondary deposits may be geologically analogous to the placer beach sands or alluvial river deposits that are mined for diamonds in southern and western Africa (Gurney and Levinson, 1991, Levinson *et al.*, 1992; Helmstaedt, 1992, 1993; NWT Government, 1993).

Diamond Indicator Mineral Anomalies

Summary of Government Till and Sediment Surveys

Sampling for diamond indicator minerals across Alberta is being conducted by both federal and provincial agencies by sampling of tills, and fluvial sand and gravel from preglacial deposits and modern drainages. Table 6 gives the details of the known sampling surveys conducted up until the end of 1995 in Alberta and the pertinent references where the data have been or will be released.

The regional coverage for tills in central to southern Alberta is good (Garrett and Thorleifson, 1993; Thorleifson and Garrett, 1993; Thorleifson *et al.*, 1994), with an average sample density of about 20 sample sites per National Topographic System (NTS) 1:250,000 map-area for 13 such map-areas (Figure 22). However, the coverage across the remainder of Alberta is much less comprehensive, with a total of only 154 till sample sites distributed over 34 NTS 1:250,000 map-areas and at least 16 of the remaining 34 map-areas have 5 or less sample sites per 1:250,000 map area. Some of the major preglacial sand and gravel deposits have been sampled in Alberta, but the coverage for sand and gravel from modern drainages is much less comprehensive. The interpretation for data derived from modern sand and gravel deposits is extremely difficult because there may be significant contributions of indicator minerals from a variety of sources, including tills, preglacial deposits, Mesozoic to Tertiary clastic sedimentary rocks and, possibly, local diatremes.

The reader is referred to the referenced sources in Table 6 for the details with respect to the methodology for processing of the various types of samples and microprobe analyses. The AGS and GSC microprobe data for selected favourable indicator minerals, which were used to construct Figures 23 to 28, are included in Appendix 4. For the complete analytical results of all the minerals microprobed, the reader is referred to Fenton and Pawlowicz (1993), Garrett and Thorleifson (1993), Thorleifson and Garrett (1993), Ballantyne and Harris (1994), Dufresne *et al.* (1994a, b), Fenton *et al.* (1994), Thorleifson *et al.* (1994), and Edwards and Scafe (1995). Appendix 4 contains previously unreleased microprobe data for the northern Alberta tills and preglacial sand and gravel deposits from across Alberta. Processing of the AGS samples was performed at the

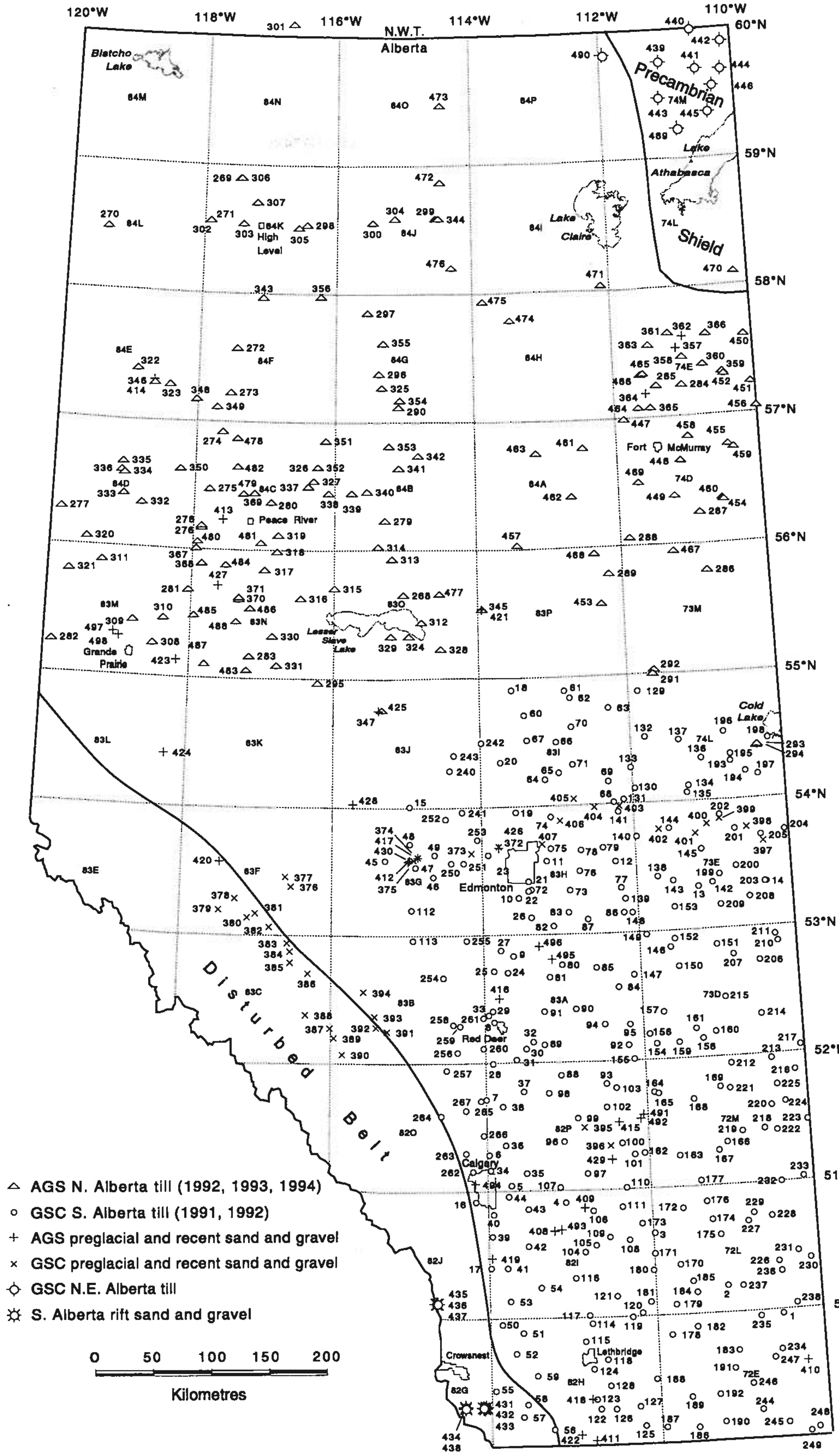


Figure 22. Location, sample number and data source of diamond indicator mineral sample sites.

Saskatchewan Research Council (SRC) and Loring Laboratories, with microprobe analyses performed at CANMET (1992 surveys) and the University of Saskatchewan (1993 to 1995 surveys). A summary of the processing and microprobe procedures at the SRC and the University of Saskatchewan are given in Swanson and Gent (1993). All of the microprobe data that have been released to date were processed using mineral identification programs written in QBASIC and provided by the SRC (Quirt, 1992a, b; Gent, 1993). The results that are currently available were evaluated by using major and minor element scatter plots of the sample data versus diamond inclusion compositions or compositions of minerals from other diatremes which are provided in Fipke *et al.* (1989), or diamond inclusion fields illustrated on scatter plots by Gurney (1984), McCandless and Gurney (1989), Fipke *et al.* (1989), Griffin *et al.* (1991, 1992), Gurney and Moore (1993), Griffin and Ryan (1993, 1995), Fipke *et al.* (1995) and many others.

Based strictly on the mineral identification programs, there appear to be many sample sites in Alberta that yielded pyropic garnets, clinopyroxenes, chromites and picroilmenites of potential diamond exploration interest, but the anomalous samples have few discernible geographic patterns based solely on total indicator minerals recovered. This is well illustrated in Figure 23, which is a plot of the total number of potentially favourable diamond indicator minerals recovered at each site. In order to determine if any meaningful geographic patterns exist, the data were classified and compiled on base maps of Alberta based on the number of indicator minerals present (Appendix 5), and those samples with particular indicator minerals of excellent chemistry relative to diamondiferous source rocks (Figures 24 to 28).

There are essentially three types of indicator minerals that may have meaning in low density regional surveys: (1) those indicative of kimberlites or lamproites; (2) those indicative of peridotite or eclogite; and (3) those indicative of diamondiferous peridotite or eclogite source rocks. The number of anomalous indicator minerals for each sample were tallied (Appendix 5) after the favourable grains were selected based on scatter plots of selected major or minor elements and the concentrations of other discriminating trace elements, such as manganese, potassium, sodium, nickel and zinc.

Indicator minerals that are probably indicative of kimberlites or lamproites include: (1) high titanium G1 or G2 pyrope garnets and high magnesium ilmenites (picroilmenites) for kimberlites; and (2) high magnesium (variable chromium) P3 chromites for lamproites (Bergman, 1987; Mitchell, 1989; 1991; Mitchell and Bergman, 1991; Griffin *et al.*, 1991, 1992; Scott Smith, 1992; Griffin and Ryan, 1993, 1995; Fipke *et al.*, 1995).

Indicator minerals that are indicative of peridotite source rock include: (1) chromium-rich G7, G9, G10 and G11 pyrope garnets (Dawson and Stephens, 1975, 1976); (2) chrome diopsides (>0.5 wt% Cr_2O_3) as defined by Stephens and Dawson (1977); and (3) P1 xenocrystic chromites. Indicator minerals that are indicative of eclogite source rocks include: (1) low iron (<20 wt% total Fe as FeO), high magnesium (>6.5 wt% MgO) G3, G4, G6 and, to a lesser extent, G5 almandine garnets (eclogitic garnets); (2) low chromium, high sodium and high aluminum diopsides; and, in some cases, (3) sodic diopside, jadeite, corundum and kyanite. Indicator minerals that are indicative of **diamondiferous peridotite** include: (1) subcalcic, high chromium G10 pyrope garnets; and (2) high magnesium (≥11 wt% MgO), high chromium (≥61 wt% Cr_2O_3) P1, P2 and P4 xenocrystic chromites (Gurney, 1984; Gurney and Moore, 1993; Fipke *et al.*, 1995). Indicator minerals that are used to identify **diamondiferous eclogite** source rocks include: (1) high sodium (>0.07 wt% Na_2O), high titanium, low iron and high magnesium G3, G4 and G6 eclogitic garnets; and (2) high potassium (≥0.1 wt% K_2O) eclogitic clinopyroxenes (McCandless and Gurney, 1989; Fipke *et al.*, 1989; Gurney and Moore, 1993; Fipke *et al.*, 1995). Other elements that are used to help discriminate important mantle or diamond window varieties of certain minerals from crustal or non-diamond window varieties include: (1) manganese in garnets, particularly eclogitic garnets; (2) nickel in garnets; and (3) zinc in chromites (Griffin *et al.*, 1991, 1992; Griffin and Ryan, 1993, 1995; Fipke *et al.*, 1995).

High manganese in garnet (>1.5 wt%) was used to eliminate crustal garnets, even if they exhibited low iron and high magnesium. Chromites from other sources, such as those from the Troodos ophiolite complex, Cyprus (Greenbaum, 1977) can exhibit diamond inclusion chemistry based on major elements such as high chromium and magnesium. However, the zinc content of such chromites tends to re-equilibrate and increase in concentration as these types of rocks are subjected to lower temperatures with time (Griffin *et al.*, 1991, 1992; Griffin and Ryan, 1993, 1995; Fipke *et al.*, 1995).

Table 6: Summary of indicator mineral sampling for Alberta

Year Sampled	Number of Samples	Material & Location	Result Status	Reference
1991 (GSC)	14	Till (Orientation Survey)	All Data Released	Garrett and Thorleifson, 1993
1992 (GSC)	252	Till (Central & Southern Alberta)	All Data Released	Thorleifson and Garrett, 1993; Thorleifson *et al.*, 1994
1992 (GSC)	36	Recent Sand & Gravel (Foothills, N. Sask. & Red Deer rivers	Chromite Data Reviewed Herein	Ballantyne and Harris, 1994
1993-1994 (GSC)	10	Till (Northeast Alberta)	In Progress; All Data Reviewed Herein	Geological Survey of Canada
1992 (AGS)	34	Till (Northern Alberta)	All Data Released; Data Reviewed Herein	This Volume; Fenton and Pawlowicz, 1993; Fenton *et al.* 1994
1993 (AGS)	68*	Till (Northern Alberta)	Data Partially Released; All Data Reviewed Herein	This Volume; Dufresne *et al.*, 1994a, b; Fenton *et al.*, 1994
1992-1993 (AGS)	28	Preglacial Sand & Gravel (Alberta-wide)	Data Partially Released; All Data Reviewed Herein	This Volume; Edwards and Scafe, 1995
1993 (AGS)	13	Recent Sand & Gravel (NTS 74E; 82G,J; 83M)	Data Partially Released; All Data Reviewed Herein	This Volume; Dufresne *et al.*, 1994a, b
1994 (AGS)	42**	Till (Northern Alberta)	Data Partially Released; All Data Reviewed Herein	This Volume; Dufresne *et al.*, 1994a; Fenton *et al.*, 1994
1994 (AGS)	55⁺	Till (Northern Alberta)	Sample Processing in Progress	Alberta Geological Survey, *In Preparation*

* During 1993, 11 samples were collected from boreholes, the remainder from surface

** During 1994, six samples were collected from glacial sand and gravel, that may or may not be till

⁺ During 1995, 17 samples were collected from boreholes, the remainder from surface

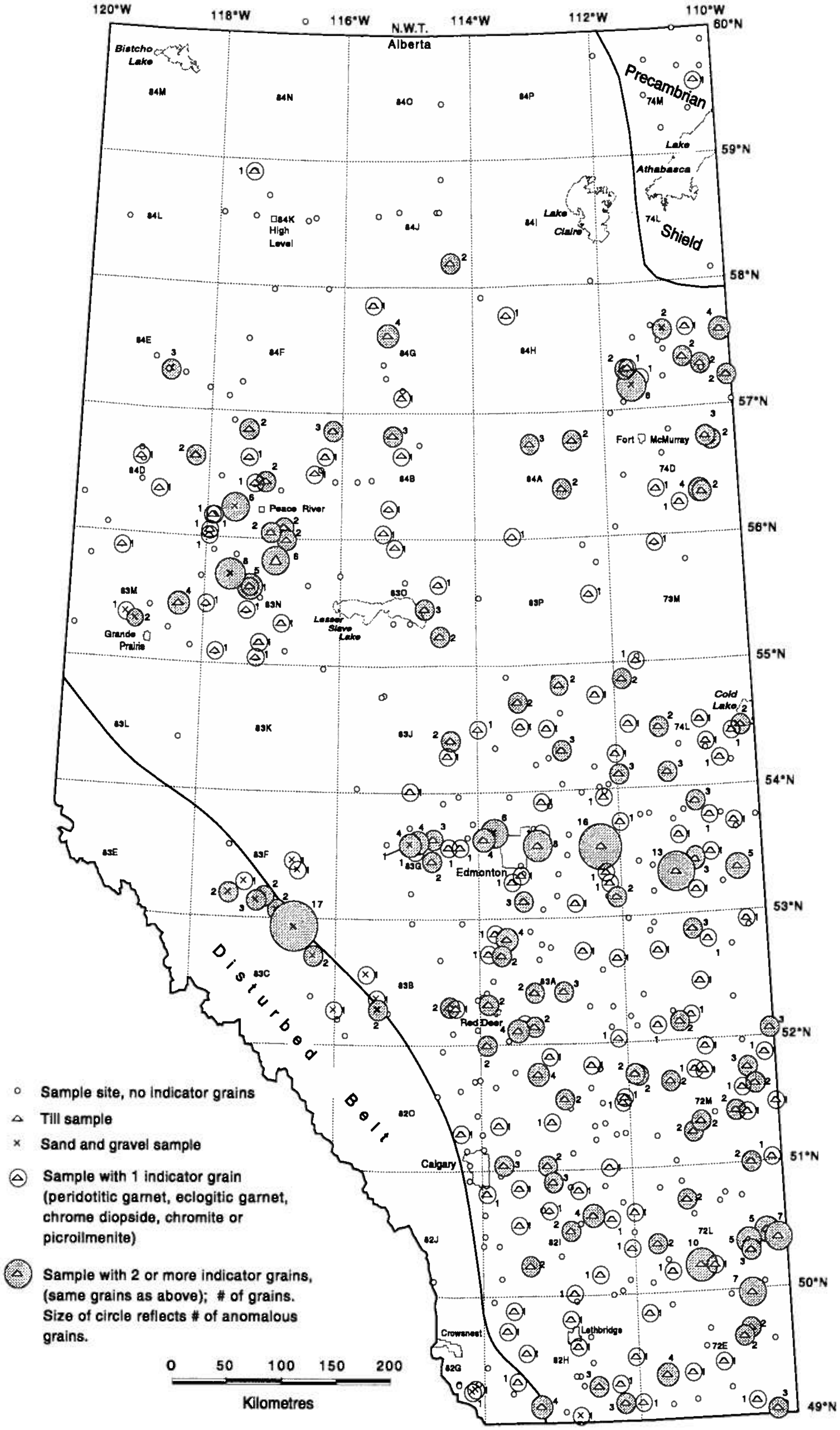


Figure 23. Total diamond indicator minerals.

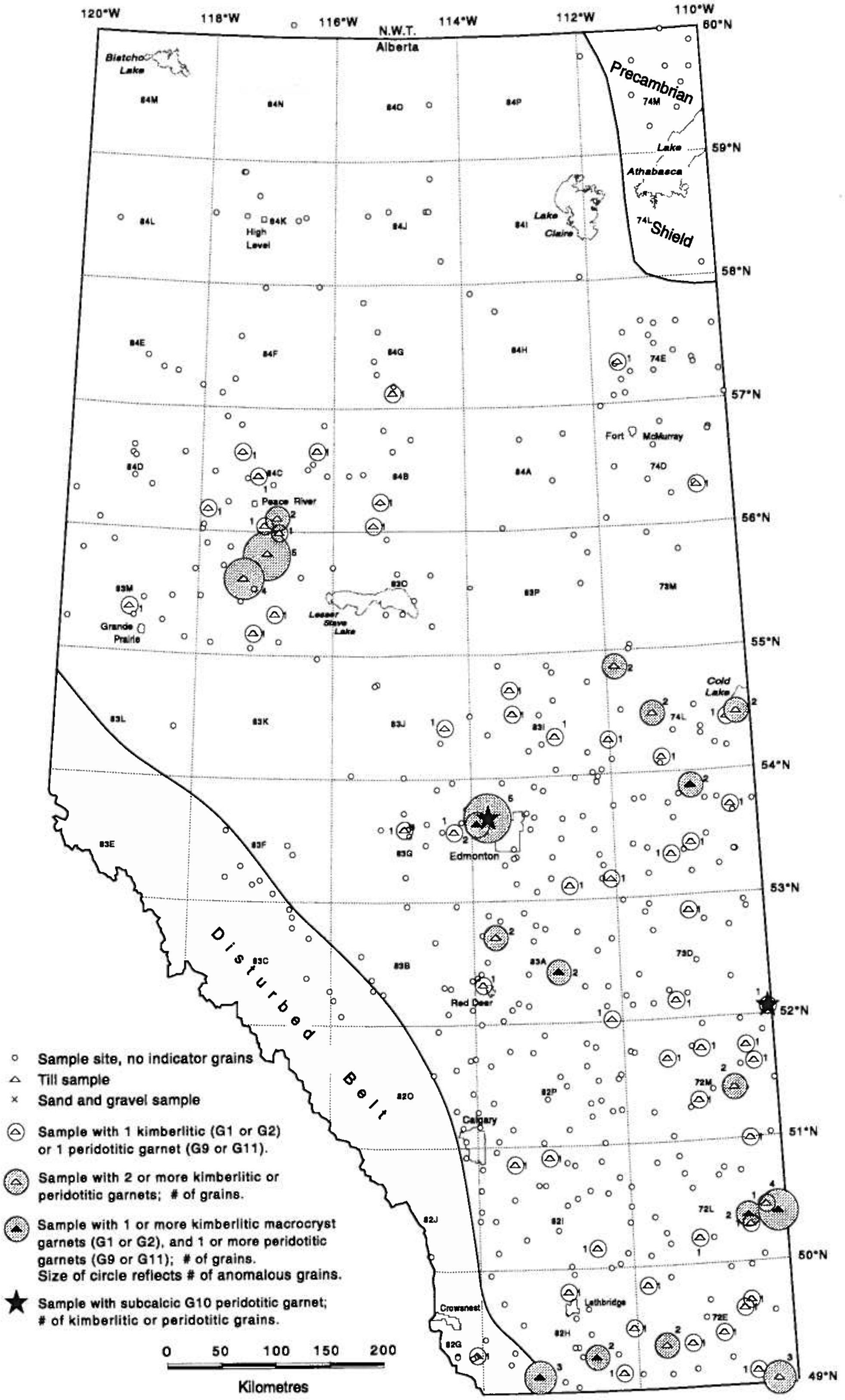


Figure 24. Indicator map of G1, G2, G7, G9, G10 and G11 kimberlitic garnets.

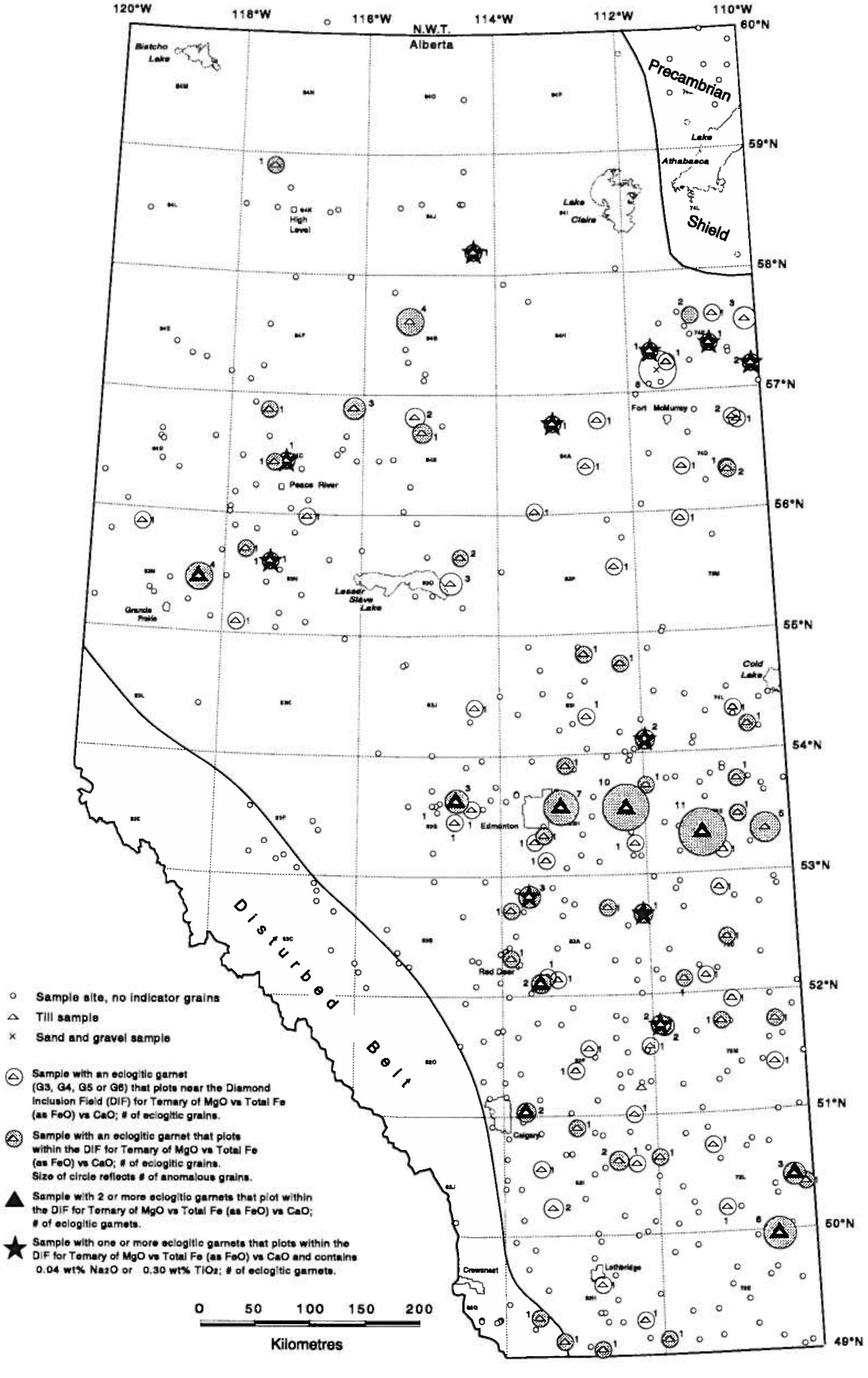


Figure 25. Indicator map G3, G4, G5, and G6 eclogitic garnets.

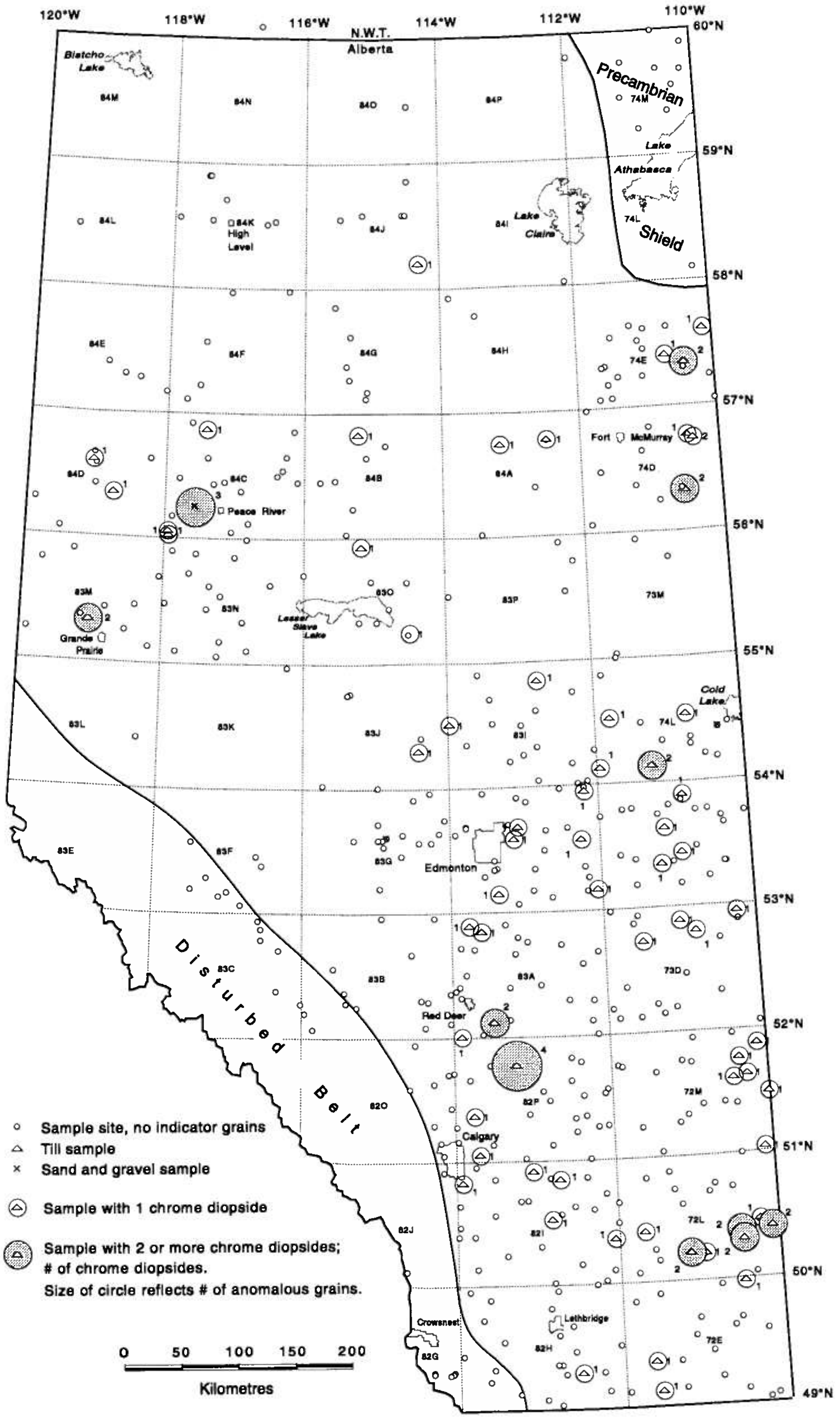


Figure 26. Indicator map of chrome diopsides with ≥ 0.5 weight per cent Cr_2O_3.

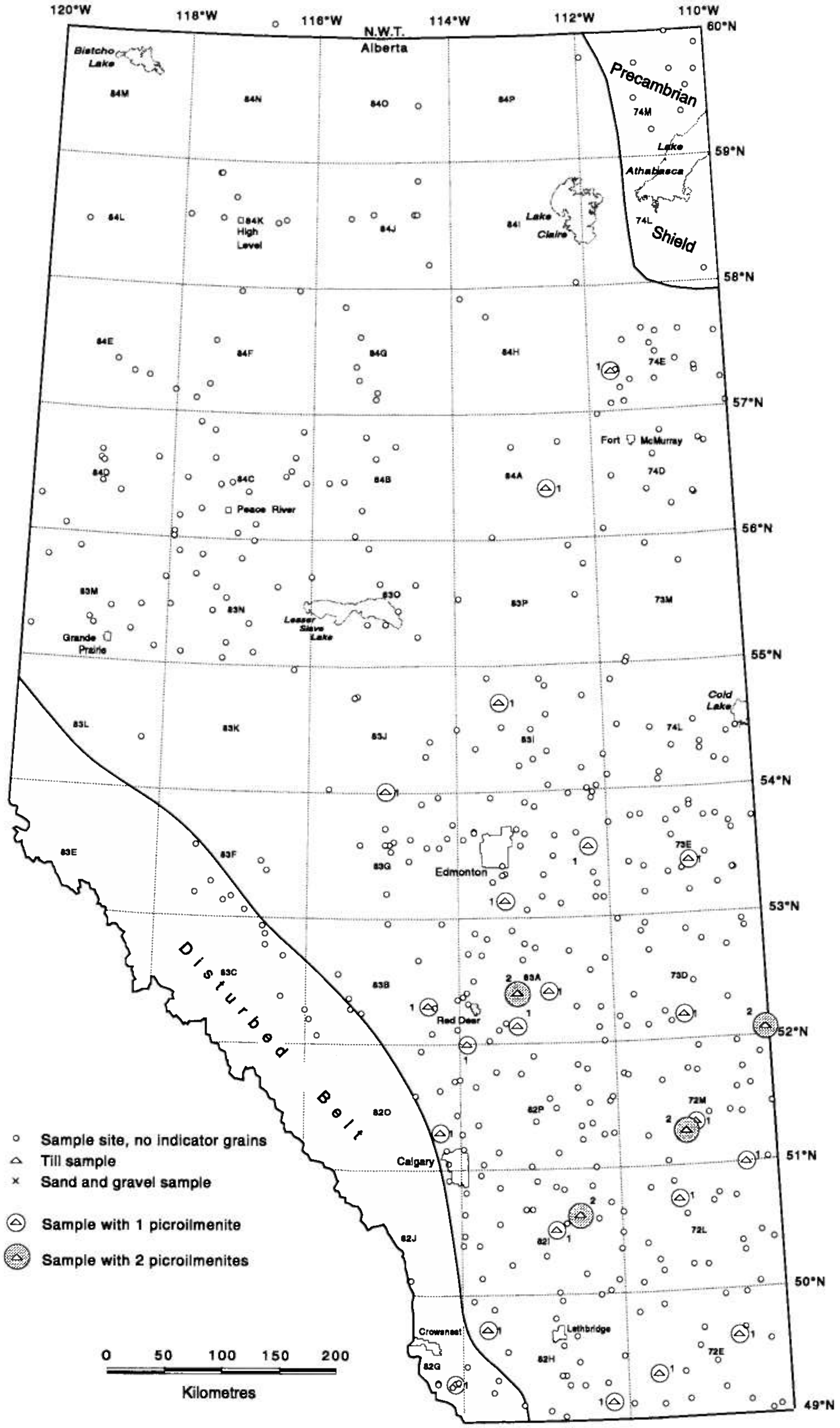


Figure 27. Indicator map of picroilmenites with ≤ 40 weight per cent total Fe as FeO and ≥10 weight per cent MgO.

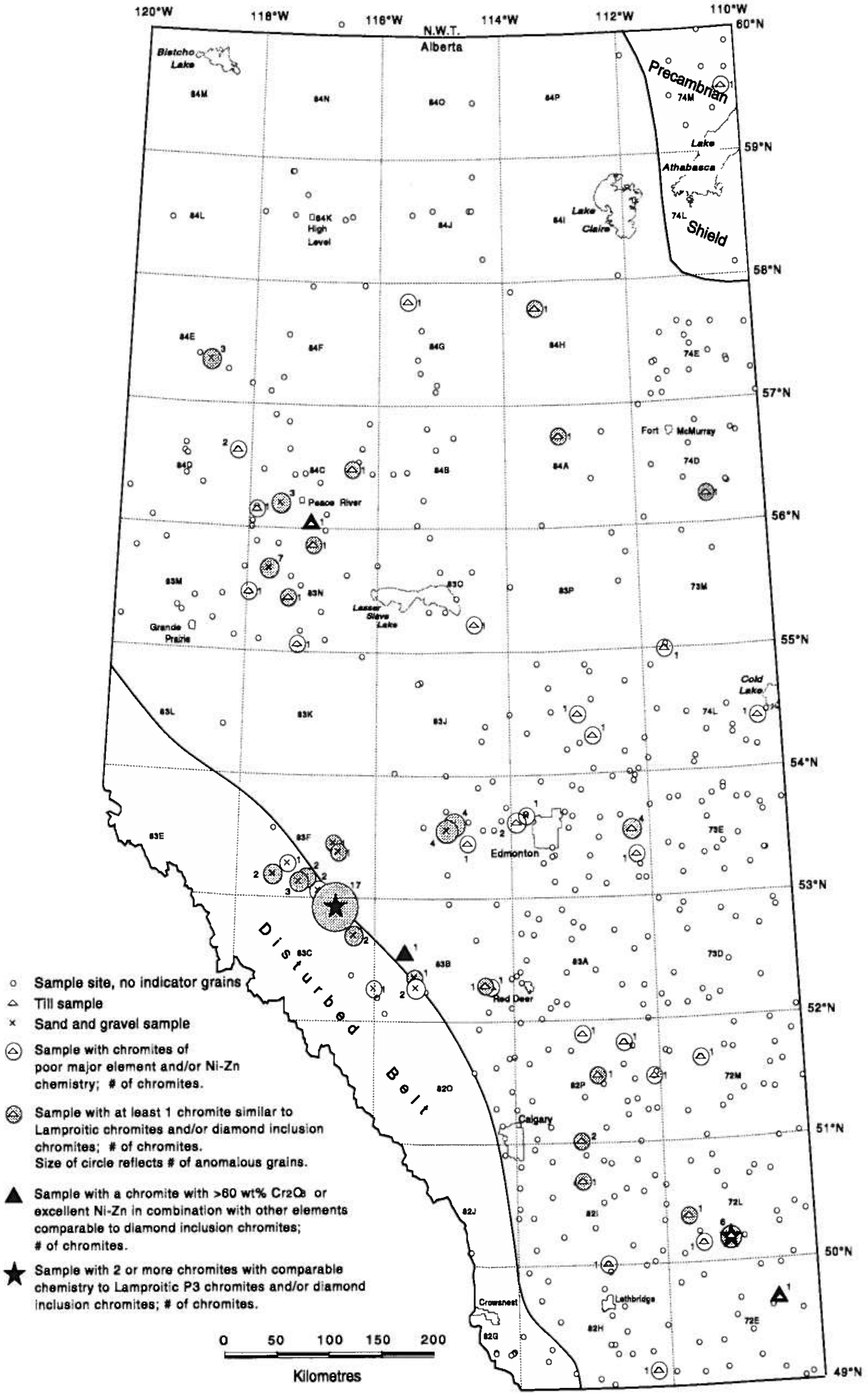


Figure 28. Indicator map of anomalous chromites.

Based on the aforementioned parameters, selected scatter plots were constructed for southern and northern Alberta; these include: (1) Cr_2O_3 vs. CaO for high chromium (>2 wt% Cr_2O_3) G9, G10 and G11 peridotitic pyrope garnets; (2) a ternary of FeO (total Fe) vs. MgO vs. CaO, TiO_2 vs. CaO and TiO_2 vs. Na_2O for eclogitic G3, G4, G5 and G6 garnets; (3) Cr_2O_3 vs. CaO for chromium diopsides (>0.5 wt% Cr_2O_3); (4) Na_2O vs. Al_2O_3 for low chromium diopsides; (5) FeO (total Fe) vs. MgO, Cr_2O_3 vs. MgO and Cr_2O_3 vs. FeO (total Fe) for picroilmenites; and (6) Cr_2O_3 vs. MgO, Cr_2O_3 vs. Al_2O_3, Cr_2O_3 vs. TiO_2, TiO_2 vs. Al_2O_3 and Zn vs. Ni for chromites (Figures 29 to 32). From these scatter plots, anomaly maps have been prepared based on the number and types of indicator minerals present at each sample site in comparison to the chemistry of diamond inclusions minerals (Figures 24 to 28). Figure 23 shows a compilation of the sites with the total number of 'anomalous' mineral grains that are reported for each site. In contrast, Figure 33 is a summary anomaly map, which includes the regional geology of Alberta, that depicts selected better sample sites based on: (1) the abundance of indicator minerals in Figures 24 to 28; (2) the quality of the chemistry for selected minerals, such as peridotitic garnets, eclogitic garnets, chromium diopsides, picroilmenites and chromites, in comparison to the chemistry of diamond inclusion minerals; and (3) the presence of other potentially important diamond indicator minerals such as jadeite, olivine, kyanite and corundum.

In Appendix 5, all the sample sites in Alberta have been labelled with sequential numbers from 1 to 498. In the following discussion, a reference to a specific sample site will comprise the sequential number plus the sample number from the original survey source (in brackets). In the case of the AGS's northern Alberta till samples (NAT92-1 to NAT92-34, NAT93-35 to NAT93-89, NAT93-500 to NAT93-503 and NAT 94-90 to NAT 94-120), the prefixes of the original sample numbers have been dropped in the following discussion.

Results for Southern to Central Alberta

In southern to central Alberta, several important trends of diamond indicator minerals can be recognized (Figure 33). These include: (1) an arcuate east-west trend north of and parallel to the Milk River near the Alberta-Montana border (Milk River Trend); (2) an east-west trend from Brooks to the Saskatchewan border (Brooks Trend); (3) a southwesterly trend that extends from the Saskatchewan border south of Provost to southwest of Oyen (Provost-Oyen Trend); (4) a north to northwest arcuate trend that is close to and roughly parallels the exposed Cretaceous-Tertiary boundary from Gleichen to Wabamun Lake (Wabamun-Gleichen Trend); (5) a somewhat scattered grouping southwest of Cold Lake in the vicinity of Vegreville (Vegreville Trend); and (6) a southeasterly trend that is within the eastern edge of and parallel to the Foothills belt from southeast of Hinton to west of Rocky Mountain House (Hinton Trend).

The Milk River Trend consists almost entirely of samples with kimberlitic garnets (G1 and G2 pyropes), G9 and G11 peridotitic garnets, chrome diopsides and one magnesium-titanium rich chromite. These indicator anomalies are of exploration interest, but the indicator minerals that have been recovered to date and the work of Kjarsgaard (1994a, b), Kjarsgaard and Davis (1994) and Luth (1994) on the outcropping minettes near the Milk River, indicate low diamond potential based on the lack of deep-sourced xenoliths, sub-calcic G10 garnets, favourable eclogitic garnets or favourable high chromium, low titanium chromites. Industry, however, has reported the discovery of two microdiamonds in Recent stream sediment south of Legend (Edmonton Journal, 1992b; Morton *et al.*, 1993; Takla Star Resources Ltd., 1993a), the discovery of a diamond in the Black Butte diatreme (Boulay, *pers. comm.*, 1996) and the presence of picroilmenites, chrome diopsides, and G9 and G10 garnets with kelphytic rims and orange peel texture (Takla Star Resources Ltd., 1993b).

Other than the microdiamonds and G10 garnets reported by industry (Edmonton Journal, 1992b; Morton *et al.*, 1993; Takla Star Resources Ltd., 1993a), the indicator mineralogy of the Milk River Trend is similar to many of the diamond indicator mineral anomalies that exist in till and fluvial sediments in southern Saskatchewan south of Assiniboia, which consist of samples with up to 11 peridotitic garnets and 14 chrome diopsides (Simpson, 1993; Garrett and Thorleifson, 1993; Swanson and Gent, 1993; Thorleifson and Garrett, 1993; Thorleifson *et al.*, 1994; Kjarsgaard, 1995; Gent and Swanson, 1995; Richardson *et al.*, 1995). Simpson (1993) pointed out that the anomalies in Saskatchewan are proximal to outcrops of Miocene Wood Mountain Formation, and that few anomalies are spatially associated with outcrops of the older Tertiary rock units, such as the Ravenscrag and Cypress Hills formations. As a result, Simpson (1993) suggested that the indicator minerals in drift in southern Saskatchewan are derived from the erosion of the Wood Mountain Formation gravels. Kjarsgaard (1995) suggested that Wood Mountain Formation contains boulders and

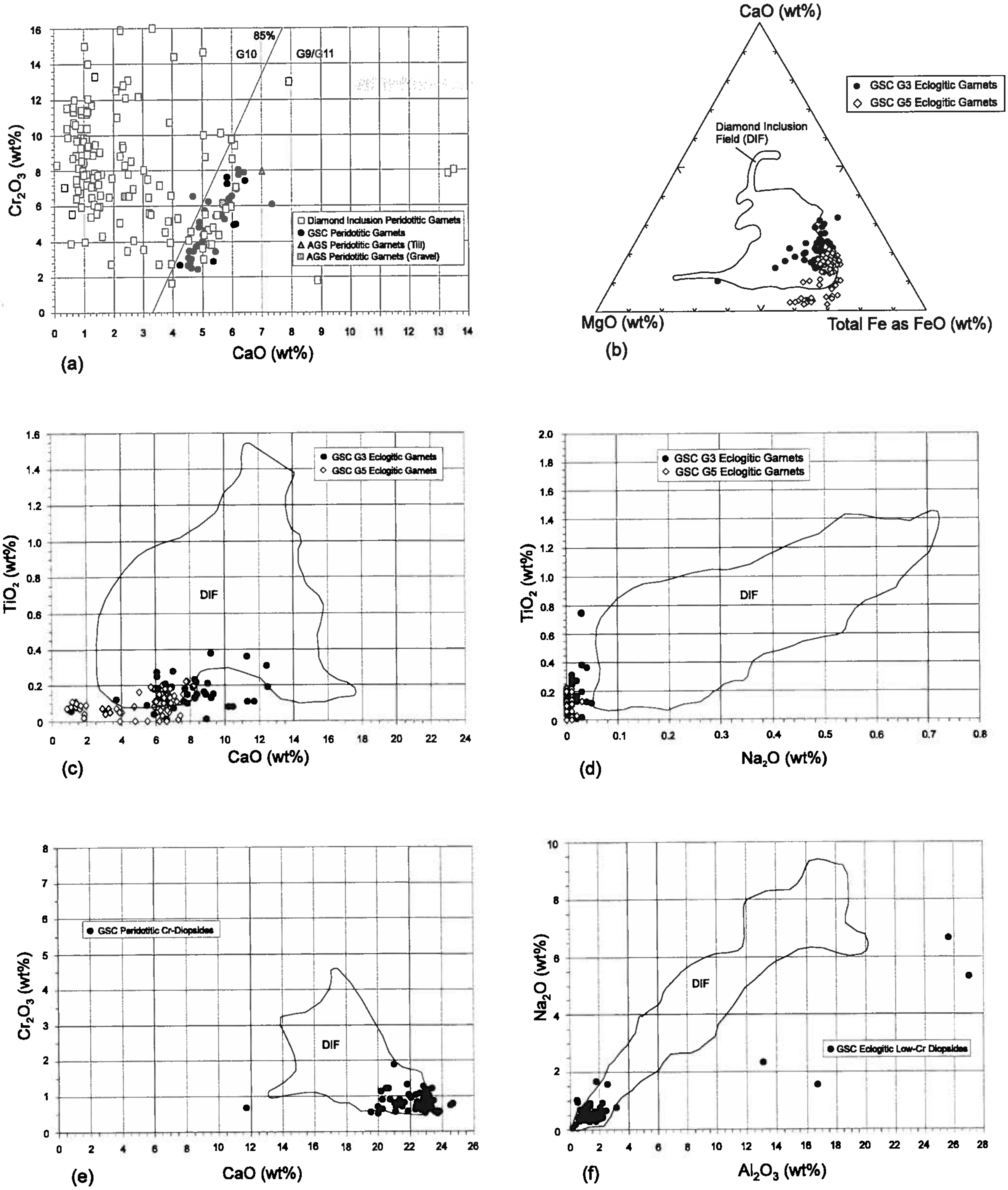


Figure 29. Scatter plots for selected silicate indicator minerals, Southern Alberta: a) Peridotitic Garnets; b-d) Eclogitic Garnets; e) Peridotitic Chrome Diopsides; f) Eclogitic Low-Chrome Diopsides.

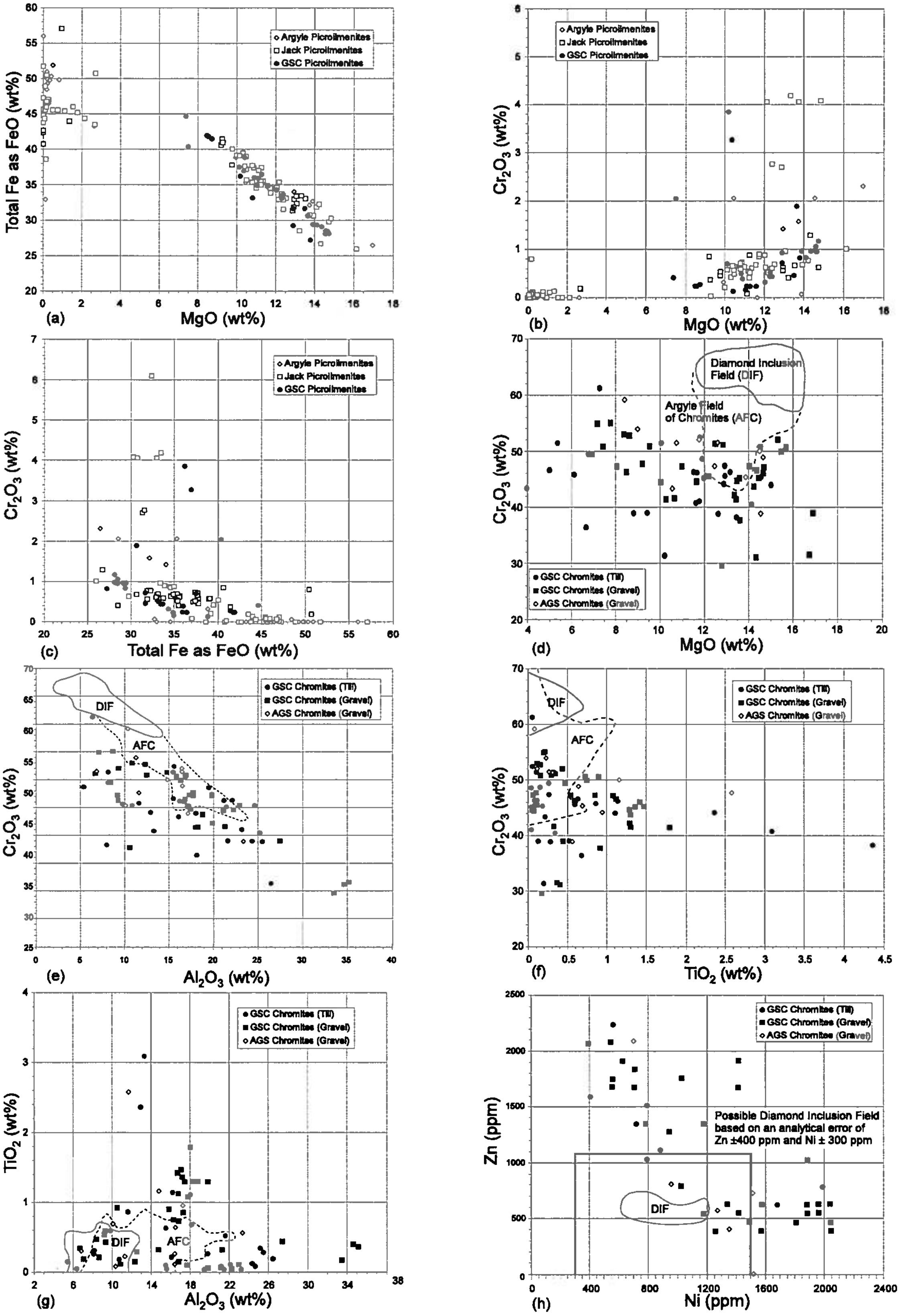


Figure 30. Scatter plots for selected oxide indicator minerals, Southern Alberta: a-c) Picroilmenites, d-h) Chromites.

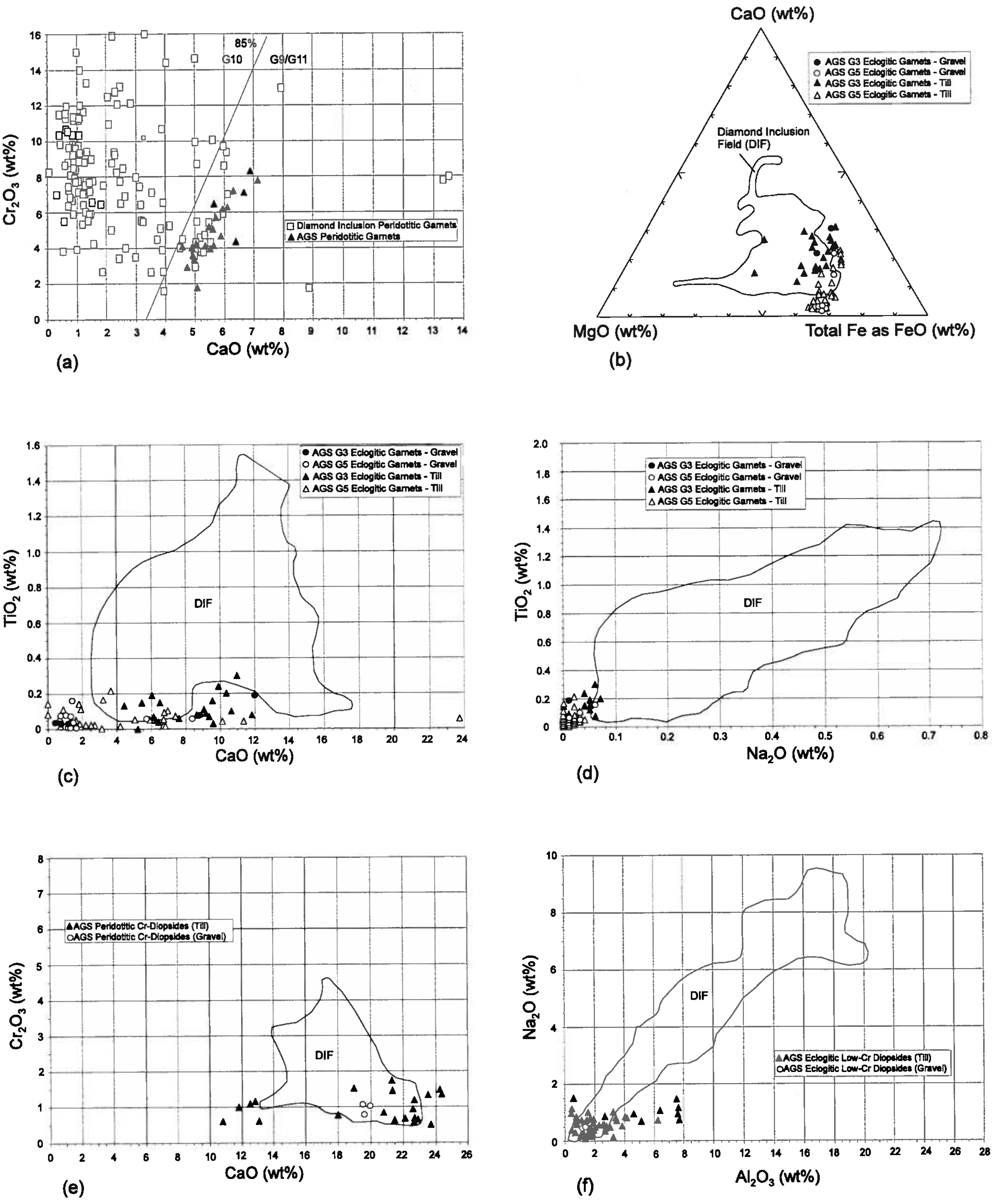


Figure 31. Scatter plots for selected silicate indicator minerals, Northern Alberta: a) Peridotitic Garnets; b-d) Eclogitic Garnets; e) Peridotitic Chrome Diopsides; f) Eclogitic Low-Chrome Diopsides.

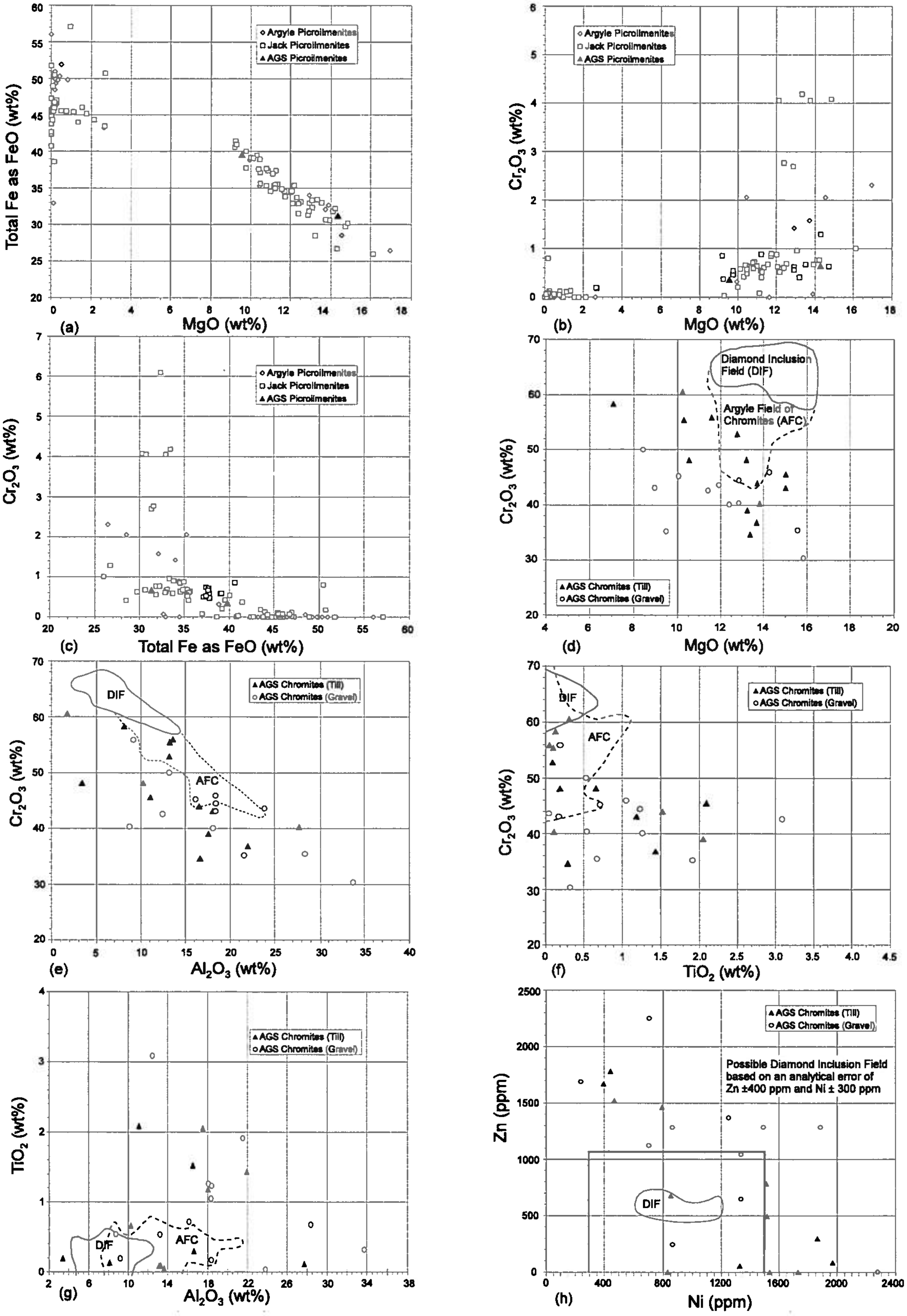


Figure 32. Scatter plots for selected oxide indicator minerals, Northern Alberta; a-c) Picroilmenites; d-h) Chromites.

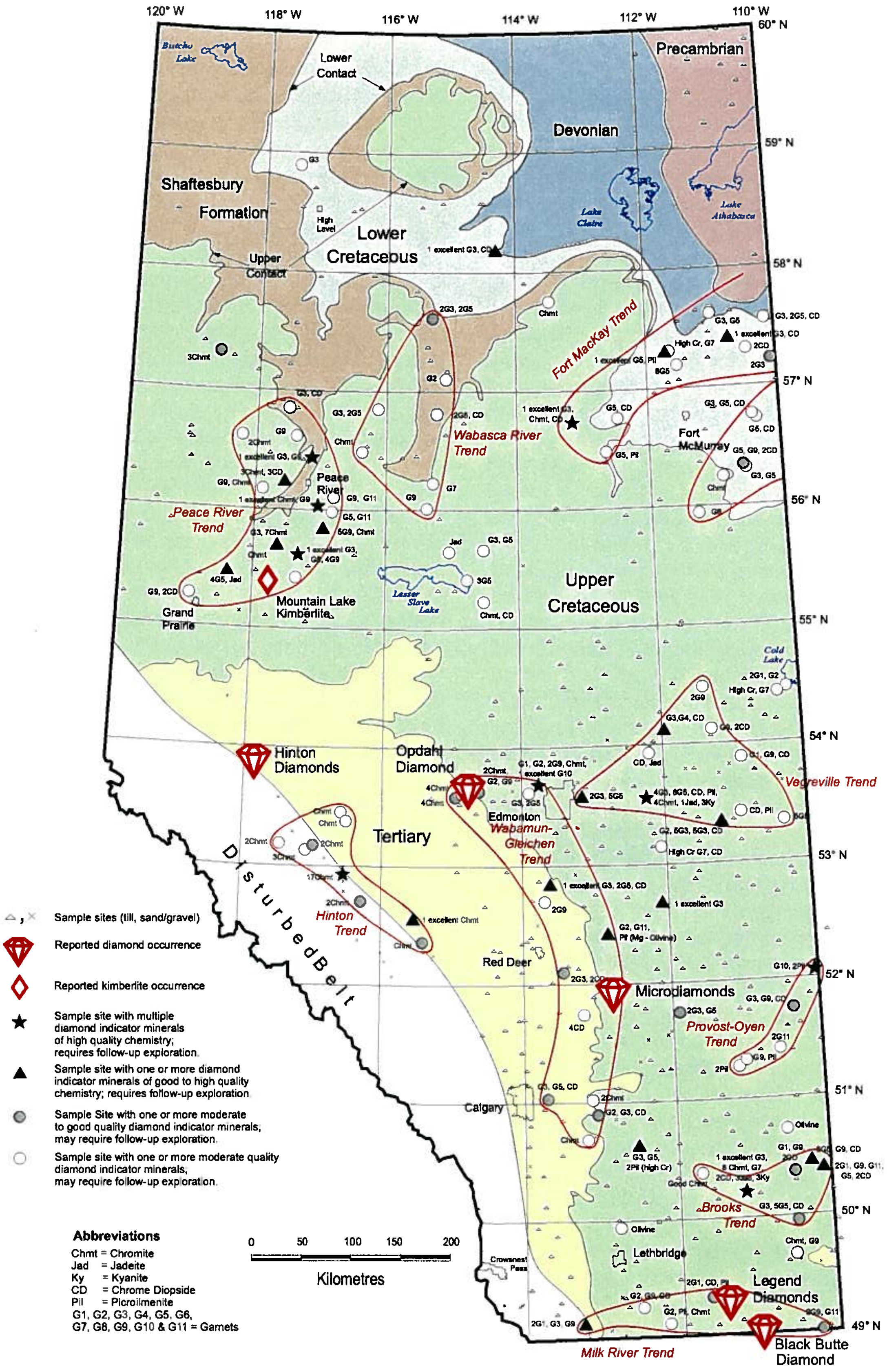


Figure 33. Diamond indicator mineral anomaly summary map.

cobbles of Eocene to Miocene age kimberlites and other associated lamprophyric volcanics that were likely derived from central and northern Montana. In contrast, Swanson and Gent (1993), have suggested that the indicator anomalies in the surficial sediments of southern Saskatchewan are possibly of more local origin. Leckie and Cheel (1989), have demonstrated that volcanic clasts within the older Oligocene Cypress Hills Formation in southeast Alberta and southwest Saskatchewan are also likely derived from central and southern Montana. As a result, Kjarsgaard (1994a, b, 1995) suggested that the indicator minerals which are proximal to the Cypress Hills Formation may also be derived from volcanic clasts that have been transported in Tertiary fluvial systems from Montana. However, in contrast to till sites near the Wood Mountain Formation of southern Saskatchewan, till sites in close proximity to the Cypress Hills Formation in southern Alberta did not yield increased numbers of indicator minerals relative to other sites in southern Alberta. Therefore, based on the current evidence, it is possible that the Milk River Trend of indicator mineral anomalies is not derived from the Cypress Hills Formation gravels. However, it is probable that at one time the Cypress Hills gravels were much more laterally extensive than today. As a result, the possibility that the indicator minerals in the Milk River Trend are derived from south of the Alberta-Montana border cannot be ruled out entirely. Alternatively, the Milk River Trend indicator minerals may be more locally derived based on the presence of the Sweetgrass Intrusions and extensive magnetic anomalies that may result from dykes and diatremes in the Milk River area. It is also possible that the indicator minerals that comprise the Milk River Trend are derived from significant distances to the north or northwest based on the presence of extensive terminal moraines in the vicinity of the Milk River (Shetsen, 1987).

The Brooks Trend consists of at least six till sites that yielded multiple indicator minerals, some of which have favourable chemistries comparable to diamond inclusion minerals. Northwest of Medicine Hat, sample site 2 (91-3020) yielded six high magnesium chromites (Figures 22, 28 and 33), four of which plot near the field of chromites from the Argyle deposit, Australia, based on major elements (Figure 30) and Cr_2O_3 vs. Ni, and plot within the diamond inclusion field on MgO vs. Ni and TiO_2 vs. Ni (Dufresne *et al.*, 1994). Griffin *et al.* (1991, 1992) and Griffin and Ryan (1993, 1995) suggested that zinc concentration exhibits a strong negative temperature dependence in chromite and, as a result, is perhaps the most critical element in determining whether a chromite was formed within the diamond stability field. The four chromites from site 2, which exhibit major element chemistry that is comparable to the Argyle chromites, plot outside of the diamond inclusion field on a Zn vs. Ni plot. However, two of the four grains plot close to the diamond inclusion field and when analytical error is considered, they may well plot within the diamond inclusion field. A fifth chromite from site 2 has low zinc (803 parts per million [ppm]) with high nickel (1,991 ppm) and high TiO_2 (3.09 wt%). Based on the work of Mitchell (1989), the high titanium content is characteristic of phenocrysts being formed in an evolved lamproitic, micaceous kimberlitic or minette magma. Griffin *et al.* (1991, 1992) and Griffin and Ryan (1993, 1995) suggested that high nickel in combination with low zinc is also characteristic of high temperature magmatic chromites (P3 chromites) in lamproites. The same sample also contains two chrome diopsides, a high chromium G7 almandine-grossular garnet (with 7.44 wt% Cr_2O_3), three jadeites (one of which has 0.35 wt% K_2O), three kyanites and an excellent G3 eclogitic garnet that plots very near to within the diamond inclusion field for FeO (total Fe) vs. MgO vs. CaO, TiO_2 vs. CaO, and TiO_2 vs. Na_2O, with 0.04 wt% Na_2O and 0.36 wt% TiO_2 (Figure 29). Elevated values of Na_2O in eclogitic garnets (usually ≥ 0.07 wt% Na_2O) are considered an excellent indication of formation in the diamond stability field (McCandless and Gurney, 1989; Fipke *et al.*, 1989; Gurney and Moore, 1993; Fipke *et al.*, 1995). In addition, high potassium in clinopyroxenes (≥ 0.1 wt% K_2O), particularly in sodic diopsides to jadeitic diopsides, is also considered an indication of formation in the diamond stability field. However, the use of the potassium indicator for clinopyroxenes is based on findings for a limited South African sample population (McCandless and Gurney, 1989) and its applicability to jadeites from elsewhere is uncertain. In summary, the minerals in the sample from site 2 indicate that an eclogite source, which is potentially diamondiferous based on the concentration of selected trace elements in some of the mineral grains in comparison to grains that were formed in the diamond stability field, probably exists to the northwest or north, that is in an up-ice direction. Furthermore, the number of eclogite indicator minerals in site 2 may indicate that the source area is proximal rather than distal. The other five samples in the Brooks Trend also have multiple indicator minerals of interest, including a favourable chromite, G1, G9 and G11 garnets, G3 and G5 eclogitic garnets, and several chrome diopsides (Figure 33). Till sample site 228 (48-2-1) which is near the Red Deer River, slightly north of the Brooks Trend, yielded a magnesium-rich olivine (Figure 33 and Appendix 5). In addition, till sample site 114 (30-1-1), which is north of Lethbridge and southwest of the Brooks Trend, also yielded a magnesium-rich olivine (Figure 33 and Appendix 5). Based on the low stability of olivine in the near-surface environment, it is possible that the olivine grains at these two sites represent first cycle erosion and that the source is proximal rather than distal.

Interestingly, the Brooks Trend corresponds to the approximate eastern extension of the southern boundary of the SAR (Kanasewich, 1968; Kanasewich *et al.*, 1969; Ross *et al.*, 1991). As well, the Brooks Trend is mostly north of the thick terminal moraine deposits mapped by Shetsen (1987) and the predominant glacial transport direction in this area was southeasterly. Therefore, the anomalous indicator minerals in the Brooks Trend may have been derived from near or within the bounds of the SAR. Alternatively, because local southwesterly ice flow directions are evident near the Saskatchewan border just south of the South Saskatchewan River, some of the indicator minerals in the samples from the Brooks Trend, particularly those that were collected near the Saskatchewan border, may have originated in Saskatchewan. It is also possible that the Cypress Hills Formation or equivalent strata to the Wood Mountain Formation of southern Saskatchewan existed this far north prior to uplift and erosion of the SGA. Hence, these sediments, with a source area in central Montana, may also have contributed indicator minerals to the Brooks Trend. To date, however, till samples in the vicinity of these Tertiary formations have yielded few chromites, eclogitic garnets, olivines, jadeites or kyanites, hence it seems improbable that the anomalous indicator minerals in the Brooks Trend were derived from Montana.

The Provost-Oyen Trend is comprised of five anomalous till sites that trend from near the Saskatchewan border south of Provost to southwest of Oyen (Figure 33). Sample site 217 (46-3-2), which is closest to the Saskatchewan border, yielded a sub-calcic G10 pyrope (Figures 24 and 33). The same sample also yielded two picroilmenites with low total iron (≤ 40 wt% reported as FeO) and high MgO (≥ 10 wt%), which are indicative of a highly reduced deep-seated intrusion such as a kimberlite or lamproite. Other indicator minerals of interest include: (1) sample site 166 (38-3-1), which produced a G9 pyrope garnet and a picroilmenite; (2) sample site 167 (38-3-2), which produced two picroilmenites with similar compositions to those from site 217; (3) sample site 225 (47-4-2), which produced a G9 (possibly a high chromium G7) pyrope, a G3 eclogitic garnet with good diamond inclusion chemistry and a chrome diopside with the highest chrome content (1.89 wt% Cr_2O_3) of all the diopsides analysed for Alberta; and (4) sample site 218 (47-1-1) with two G11 pyropes. The glacial transport direction in the vicinity of Provost appears to have been southerly to southwesterly, whereas to the southwest, closer to Oyen, there are indications of both southeasterly and southwesterly glacial paleoflow directions (Shetsen, 1987, 1990). Based on the fairly linear nature of the southwesterly trending Provost to Oyen indicator anomalies and the fact that a few anomalous sites exist northeast of site 217 on the Saskatchewan side of the border (Thorleifson and Garrett, 1993), the anomalous indicator minerals in this trend are likely derived from either near Provost or farther to the northeast, across the Saskatchewan border.

The Wabamun-Gleichen Trend comprises a large north-south arcuate trend of indicator mineral anomalies that exists from just west of Edmonton to east of Calgary (Figure 33). This trend consists of at least 10 anomalous till sites, 4 anomalous samples from Late Tertiary to Quaternary gravels, an occurrence of microdiamonds from Cretaceous-Tertiary boundary sediments, and a reported one carat diamond that was found in modern sediments along the Pembina River. The trend is roughly centered along and parallel to the Cretaceous-Tertiary boundary. The trend can be subdivided into a southern cluster of ten sites that extends from Ponoka to Gleichen, and a northern cluster of six sites that extends from Wabamun Lake to Edmonton. Samples from the southern half of the trend contain: (1) multiple G2, G3 and G5 garnets; (2) two G9 and one G11 pyropic garnets; (3) several chrome diopsides; (4) a few chromites; and (5) a picroilmenite. The northern anomalous till sites yielded G2, G3, G5 and G9 kimberlitic and eclogitic garnets. As well, sample sites 412 (6424) and 417 (6422), which are from Late Tertiary preglacial gravel deposits west of Wabamun Lake at Entwistle and Magnolia, each yielded four magnesium-rich chromites (Figures 28 and 33). Sample site 426 (3975) from a similar preglacial gravel deposit northeast of Wabamun Lake at Villeneuve, yielded G1 and G2 kimberlitic garnets, two G9 pyropic garnets, a favourable chromite, and a subcalcic G10 pyrope garnet (Figures 24 and 33). The G10 garnet plots well into the high chrome subcalcic field on Cr_2O_3 vs. CaO (Figure 29), and as such, has comparable chemistry to many of the diamond inclusion G10's from highly diamondiferous South African kimberlites.

The sources for the indicator mineral anomalies that exist in the tills and preglacial gravels of the Wabamun-Gleichen trend is difficult to ascertain. From Gleichen to about Innisfail, the transport indicators of glacial direction are predominantly southeasterly (Shetsen, 1987, 1990). This may indicate that most of the indicator minerals in the anomalous sites which exist southeast of Red Deer, are derived from areas underlain by Tertiary sedimentary rocks northwest of the Cretaceous-Tertiary boundary. Whether the indicator minerals are derived from local point sources, such as diatremes and their associated volcaniclastics, or from Tertiary sedimentary rocks as second or third cycle erosional products, is not known. It is important to note that the microdiamonds which were discovered southeast of Red Deer by scientists looking for evidence of extraterrestial impacts were found in Cretaceous-Tertiary boundary layer sediments (Science City News, 1992; Braman, *pers. comm.*, 1994). Although the microdiamonds may be the product of an extraterrestrial impact, it is also possible that Early Tertiary volcanism in the Alberta Basin is responsible for the microdiamonds along with the anomalous indicator minerals which exist in the Ponoka to Gleichen region.

The anomalous indicator minerals from the preglacial gravels in the vicinity of Wabamun Lake and Edmonton are derived from an easterly trending fluvial system with a source area to the west based on the paleodirection of the buried preglacial valleys (Figure 6). In Australia, it is well documented that pyropic garnets in an alluvial to fluvial setting can normally be found from a few km up to about ten km from their kimberlitic source (Mosig, 1980 Atkinson, 1989; Fipke *et al.*, 1989). However, in colder climates such as Yakutia in the former Soviet Union, transport distances of up to 50 km from a primary source have been documented for pyropic garnets in a fluvial setting (Afanasev and Yanygin, 1983; Afanasev *et al.*, 1984). Therefore, it is quite possible that the source area for the G10 pyrope and the other indicator minerals at site 426 is local, or at least from between the Foothills and Wabamun Lake, even if these grains represent second-cycle-erosion. Hence, the anomalous indicator minerals in the Wabamun-Gleichen area may be derived from diatremes and related volcaniclastic rocks of early Tertiary age that intrude or are intercalated with Tertiary sedimentary rocks of the Paskapoo Formation west of Lake Wabamun. Stewart and Bale (1994) stated that abundant eclogitic garnets, G9, G10 and G11 pyropes, and P3 and P4 chromites were found in tills down ice from the Onoway preglacial channel west of Edmonton. These anomalous indicator minerals may be derived from the Late Tertiary preglacial gravels. In addition, the Opdahl diamond is reported to have been discovered in or near the Pembina River about 15 km west of Wabamun Lake (Edmonton Journal, 1992a; Morton *et al.*, 1993). Based on the quality of the indicator minerals discovered to date and the discovery of the Opdahl diamond, further work is warranted in the vicinity of Wabamun Lake and in the area underlain by the Paskapoo Formation west and southwest of the Wabamun Lake area to search for diamondiferous diatremes or secondary diamond-bearing sedimentary deposits.

The Vegreville Trend is comprised of five anomalous till sites in an easterly trend south of the North Saskatchewan River between Edmonton and the Saskatchewan border, and five anomalous till sites north of the North Saskatchewan River (Figure 33). Anomalous indicator minerals include: (1) G1, G2 and G9 pyrope garnets; (2) many favourable G3, G4 and G5 eclogitic garnets; (3) chrome diopsides; (4) chromites; (5) a picroilmenite; and (6) two samples with jadeite (up to 0.48 wt% K_2O), one of which also yielded three kyanites (Figure 33). The glacial history of the area is complex because glacial transport indicators of ice direction indicate that the predominant ice movement was southwest in the vicinity of Cold Lake and Vegreville, except for indications of strong southeasterly flow in a linear belt that is located about half way between Cold Lake and Vegreville (Shetsen, 1990). The belt of southeasterly glacial transport indicators is about 20 km wide from Lac La Biche to Lloydminster. Based on these two different glacial directions, it is not clear where the source area is for the diamond indicator mineral anomalies which exist in the Vegreville trend. There are at least three possibilities:

(1) The indicator minerals were dispersed to the southwest towards Vegreville from the area between Cold Lake and Winifred Lake. Indicator minerals at sites 14 (91-3032), 202 (44-2-2), 134 (34-3-1) and 137 (34-4-2) might then indicate minor southeasterly transport modification of the original southwesterly indicator mineral train.

(2) Some or all of the indicator minerals originated from strata overlying the STZ from Lac La Biche to north of Winifred Lake via southwesterly ice movement with later modification by southeasterly movement. Evidence in favour of this possibility includes the many G9, G10 and G11 pyrope garnets, eclogitic garnets and chrome diopsides that have been reported north of Winifred Lake (Stewart and Bale, 1994) and a few anomalous till sites from near Lac La Biche in the GSC indicator mineral survey, where one magnesium rich chromite, two kimberlitic garnets and two chrome diopsides exist.

(3) A third potential source area for the indicator minerals anomalies, particularly for the till sites that are south of the North Saskatchewan River, is the preglacial gravels that exist along or near the North Saskatchewan River. Sites 11 (91-3029), 12 (91-3030), 13 (91-3031) and 14 (91-3032) south of the North Saskatchewan River all yielded G3 and G5 eclogitic garnets with good diamond inclusion chemistry. Of particular interest is site 12 (91-3030), which also yielded a high potassium jadeite (0.48 wt% K_2O), in combination with a possible P3 lamproitic chromite, three kyanites, a chrome diopside and a picroilmenite. This combination of indicator minerals is strongly suggestive of a relatively local eclogitic source, potentially diamondiferous, that is either up ice to the northeast or possibly somewhere to the west if the indicator minerals have been glacially dispersed from preglacial gravels spatially associated with the North Saskatchewan River.

It should be pointed out that sites 1 to 14, which were collected as part of the GSC's original orientation survey (Garrett and Thorleifson, 1993), had many more potential indicator mineral grains microprobed. As a direct result, sample sites 1 to 14 had a much higher chance of finding important diamond indicator minerals, especially those that are difficult to recognize visually such as eclogitic garnets, chromites and picroilmenites. This may, at least in part, explain why several of the more important sample sites, based on the number of diamond indicator minerals, are from sites 1 to 14.

The Hinton Trend, which is adjacent to and within the Foothills region between Hinton and Rocky Mountain House, comprises a southeasterly trending belt of anomalous chromites. The chromites in this trend are from Recent creek and river sediment samples that were collected under a Federal MDA project (Ballantyne and Harris, 1994). The chromite microprobe data, along with results of sampling for gold and platinum group metals have been partially released, and will be fully released in an upcoming publication. The complete chromite data set is in Appendix 4 and has been generously provided by Dr. Ballantyne of the GSC. The chromites have been classified based on major and trace element geochemistry into three groups which consist of: (1) those chromites that have chemistry similar to diamond inclusion chromites (low zinc, high chromium and high magnesium; (2) those chromites that are indicative of kimberlitic or lamproitic magmas (high nickel, chromium, magnesium and titanium); and (3) other chromites of marginal chemistry. On Figure 28, all the chromites recovered and analysed by Ballantyne and Harris (1994) are plotted regardless of their chemistry. The most important group are those chromites that might have formed in the diamond stability field, which is indicated by those chromites with zinc ≤700 ppm and nickel ≥600 ppm (Griffin *et al.*, 1991, 1992; Griffin and Ryan, 1993, 1995; Fipke *et al.*, 1995), and high chromium and magnesium. Only rocks that would have tapped deep upper mantle sources, such as kimberlites, lamproites and other allied volcanic rocks, or those that might represent slices of exhumed upper mantle, such as ophiolitic peridotite, should contain chromites with the high magnesium (≥11 wt% MgO) and high chromium (≥61 wt% Cr_2O_3) concentrations that characterize diamond inclusion chromites. Griffin and Ryan (1993) suggested that ophiolitic chromites should have high concentrations of zinc (>1,000 ppm) due to re-equilibration at lower temperatures upon slow exhumation and, therefore, can be distinguished from xenocrystic chromites that were formed within the diamond stability field with low concentrations of zinc (≤700 ppm) and were subsequently brought to the surface quickly in kimberlites and lamproites without reequilibration of the zinc. Zinc concentrations in chromite are strongly temperature dependent, whereas nickel is only moderately temperature dependent (Griffin *et al.*, 1991, 1992; Griffin and Ryan, 1993, 1995). Only one chromite, a grain from site 394 (B-23), which is west of Rocky Mountain House at Baptiste Creek, plots in the diamond inclusion field on a plot of Ni vs. Zn (Figures 28, 30 and 33). However, the detection limit for zinc and nickel can vary widely depending upon the electron microprobe analytical procedure employed. For instance, the detection limits for the University of Saskatchewan electron microprobe, which was used for the AGS analyses, are about ±400 ppm for zinc and ±300 ppm for nickel when the results are at or near the detection level. However, these levels tend to decrease with higher concentrations in the sample. As a result, any chromite grains with ≤1,100 ppm zinc can be considered of interest. There are seven chromites from four other sites in the Hinton Trend that may have possibly formed within the diamond stability field. These four sites include: (1) one grain from site 393 (B-22) west of Rocky Mountain House on the North Saskatchewan River; (2) one of two grains from site 386 (B-15) on the Blackstone River west of Nordegg; (3) four of seventeen grains from site 383 (B-12) on the Pembina River southeast of Coalspur; and (4) one of two grains from site 381 (B-10) on the upper Embarrass River near Coalspur (Figure 28 and Appendix 4). All but two of the eight chromites in the Hinton trend have >12 wt% MgO and >49 wt% Cr_2O_3, with six of the eight grains, including the grain from site 394, closely overlapping the chromite field from the highly diamondiferous Argyle lamproite (Figure 28 and Appendix 4). None of the grains overlap the diamond inclusion field for Cr_2O_3 vs. MgO, but this field is highly biased towards South African kimberlites because the data set is comprised of 138 diamond inclusion chromites from South African kimberlites, 8 diamond inclusion chromites from Siberian kimberlites and 1 diamond inclusion chromite from the Ellendale lamproite, which is in Western Australia and is diamondiferous but sub-economic (Appendix 3.1 in Fipke *et al.*, 1989).

A second group of low zinc chromites with high nickel (>1,800 ppm) is evident in the chromite data for the Hinton Trend. There are thirteen chromites in this group from sites 376 (B-5), 377 (B-6), 379 (B-8), 380 (B-9) and 383 (B-12) that are all restricted to the northwestern half of the Hinton Trend between the Brazeau River and Hinton. All of these chromites have elevated titanium, with all but one of the chromites containing >0.8 wt% TiO_2. These high titanium and high nickel chromites are probably high temperature magmatic phenocrysts, perhaps a related population to Griffin's P3 chromites, based on the work of Mitchell (1989), Griffin *et al.* (1991, 1992) and Griffin and Ryan (1993, 1995). As well, the low zinc, high nickel and high titanium content of these chromites may indicate that they are derived from a high temperature, possibly lamproitic melt. If this lamproitic melt originated in an area of thick crust, then it may have formed at a depth below the diamond stability field, and subsequently may have passed through the diamond stability field and acquired diamonds in conjunction with low zinc xenocrystic chromites (P1 or P4) with less nickel and titanium (less evolved chromites) from peridotitic or eclogitic rocks. Based on these data, it is possible that the Foothills region between Hinton and west of Rocky Mountain House, which is underlain by the Wabamun and Thorsby basement terranes, is prospective for deep-seated lamproites that are potentially diamondiferous. This hypothesis is supported by industry activity based on the discovery of diamonds (Figure 33) and chromites with favourable diamond inclusion chemistry north of Hinton (Northern Miner, 1995c; New Claymore Resources Ltd. News Release, 1995; Montello Resources Ltd. News Release, 1995; Northern Miner, 1996), and reports of phenocrystic and xenocrystic chromites, some of which plot within the diamond stability field, from the Foothills west of Hinton (Fipke, 1993; Takla Star Resources, 1993a). The potential for diamondiferous lamproites southeast and northwest of the Hinton trend is unknown due to a lack of sampling rather than a lack of favourable geology. That potential for diamondiferous diatremes may exist elsewhere in Alberta's Foothills is indicated, for example, by Ecstall Mining Ltd.'s report of "*abundant chromite, as well as eclogitic G-5 garnets indicative of a lamproitic source rather than kimberlite*" in samples from the Highwood, Oldman, Crowsnest and Castle rivers (Northern Miner, 1993a).

Results for Northern Alberta

Results to date for till and fluvial sediment samples, which were collected from northern Alberta, are biased towards a belt from Grande Prairie to Fort McMurray because the existing sampling in northern Alberta has largely been based on ease of transportation access. Although the current sample distribution in northern Alberta generally is sparse, a few trends of anomalous indicator minerals have been recognized. At present, minerals indicative of kimberlites, such as G1 or G2 garnets and picroilmenites, are rare. Nonetheless, several samples in the Peace River area contain G9 or G11 garnets, chromites and chrome diopsides that possibly are indicative of peridotitic or harzburgitic source rocks. The most common and perhaps the most important group of indicator minerals, which have been recovered from northern Alberta samples, are low iron, high calcium and high magnesium G3 and, to a lesser extent, G5 eclogitic garnets. Several of the G3 and G5 garnets recovered to date may be indicative of eclogitic source rocks (Figures 25 and 31), some of which could have been derived from the diamond stability field based on comparison with diamond inclusion eclogitic garnets from elsewhere in the world (Figures 25, 31 and 33). Three geographic trends, based on the number and quality of eclogitic and other indicator minerals, exist in northern Alberta. These include: (1) a southwesterly trend from just north of the town site of Peace River to Grande Prairie (Peace River Trend); (2) a southerly trend from the lower Wabasca River to the Loon River (Wabasca River Trend); and (3) a two lobed southwesterly trend in the Fort McMurray area (Fort MacKay Trend).

The Peace River Trend consists of several samples that contain eclogitic G3 and G5 garnets, peridotitic G9 and G11 garnets, chrome diopsides and several anomalous chromites. Two eclogitic G3 garnets from till samples, which were acquired by drilling at sample site 369 (93-3) north of the town site of Peace River, and sample site 370 (93-6A) south of Peace River, may indicate that high potential exists for diamondiferous eclogitic source rocks in the Peace River area. The composition of the garnets is well within the diamond inclusion field for eclogitic garnets on a ternary plot of FeO (total Fe) vs. MgO vs. CaO and a plot of TiO_2 vs. CaO. In addition, the two garnets contain 0.07 and 0.05 wt% Na_2O, respectively (Figures 25, 31 and 33). The till sample from site 369 (93-3) also yielded a G9 pyropic garnet. A second sample (93-6B), which was collected from a second till that is below that sampled by 93-6A, but in the same borehole (93-6), yielded a G5 eclogitic garnet and four G9 pyropic garnets. Several till sites between Peace River and site 370 yielded several G9's, G11's and a chromite with excellent diamond inclusion chemistry including >60 wt% Cr_2O_3, and nickel and zinc concentrations that plot within the diamond inclusion field (Figures 28, 32 and 33). Most of these till sites with highly favourable diamond inclusion indicator minerals, exist in an up-ice direction northeast of the Mountain Lake Kimberlite.

Other indicator minerals of interest within the Peace River Trend include: (1) four G5 eclogitic garnets that plot within or near the diamond inclusion field for FeO (total Fe) vs. MgO vs. CaO and TiO_2 vs. CaO, and a jadeitic diopside with 0.69 wt% K_2O from till site 310 (93-37), west of the Mountain Lake Kimberlite; (2) a G3 eclogitic garnet and seven chromites from the Watino gravel deposit (site 427); and (3) thirty-seven chrome diopsides and three chromites from the Grimshaw gravel deposit (site 43) west of Peace River. Three of the chrome diopsides were microprobed and plot within the diamond inclusion field for Cr_2O_3 vs. CaO. Both the Watino and Grimshaw gravel deposits exist north of the Mountain Lake Kimberlite and, therefore, are in a down-river direction from the kimberlite.

Hawkins (1994) and Consolidated Carina Resources Corp. (1993) reported that abundant G9 pyropic garnets and chrome diopsides that plot within the diamond inclusion field have been obtained from till samples collected from the Carmon Lake area east of Peace River, including those from a recently drilled Shell Resources Ltd. oil well. Hawkins (1994) stated that G1, G3 and G11 garnets were also found and that the presence of kelphytic rims on some of the garnets indicates that they are likely derived from "*a nearby kimberlite source*" and that the results "*appear to confirm the presence of unmapped kimberlitic intrusions in the Peace River area.*" This has obviously been confirmed by Monopros' discovery of the Mountain Lake Kimberlite in Late Cretaceous sediments of the Wapiti Formation. However, most of the sites with favourable indicator minerals tend to exist 'up-ice' from the Mountain Lake Kimberlite and 'down-ice' from outcrops of Shaftesbury, Dunvegan and Kaskapau formations. Possible explanations for this distribution of indicator minerals in the tills and gravel deposits include: (1) the indicator minerals have been carried significant distances northward in Late Cretaceous to Tertiary fluvial systems from Wapiti age equivalent diatremes such as the Mountain Lake Kimberlite, with minor subsequent reworking by glacial processes; (2) Wapiti sediments and intercalated Late Cretaceous diatremes were far more extensive to the north than present day, and these sediments and diatremes have since been completely eroded, leaving behind widespread indicator minerals which have been only locally dispersed; and (3) glacial activity has dispersed indicator minerals from undiscovered diatremes in older sediments, age equivalent to the Fort à la Corne kimberlites, such as the Shaftesbury and Peace River formations in the Peace River area.

Based on these preliminary results, the current geographic distribution of indicator minerals in the Peace River Trend indicate that the Mountain Lake Kimberlite and other undiscovered diatremes are likely no older than Early Cretaceous and are probably time equivalent with reactivation of the PRA during the mid- to Late Cretaceous.

The Wabasca River Trend is defined by a northerly belt of anomalous till sites in the vicinity of the lower Wabasca River and Loon River (Figure 33). This trend consists predominantly of tills that yielded G3 and G5 eclogitic garnets, (sites 341, 351, 353 and 355), some of which plot within or near the diamond inclusion field for FeO (total Fe) vs. MgO vs. CaO and TiO_2 vs. CaO (Figures 25, 31 and 33). Other grains of interest include: (1) a high chrome (4.62 wt% Cr_2O_3) G7 grossular garnet from site 279 (92-2) and a G9 garnet from site 314 (43-41) southwest of Peerless Lake; (2) an anomalous chromite from site 337 (93-60) west of Red Earth; and (3) a high titanium G2 kimberlitic garnet from site 290 (92-3) near the confluence of the Wabasca and Loon rivers. Although most of the sites that yielded favourable indicator minerals lie in close proximity to the Shaftesbury Formation, the interpretation of the source of these indicator minerals is difficult, because this area of north-central Alberta is underlain by thick drift (Figure 7).

Recent sampling and analysis of tills in the Fort McMurray area has supplemented and helped to discriminate the Fort MacKay Trend defined in Dufresne *et al.* (1994a). The original trend was predominantly defined by mostly eclogitic garnets, some of which exhibit diamond inclusion-like chemistry, with few indicators of kimberlite or lamproite intrusions. Recently received analytical data indicate the presence of additional eclogitic garnets along with several sites that yielded a high chromium grossular garnet, a chromite, chrome diopsides and picroilmenites of favourable composition (Figures 24 to 28 and 33). In addition, a subordinate southwesterly trend with eclogitic garnets, a G9 garnet, a chromite and chrome diopsides has been delineated southeast of Fort McMurray near the Saskatchewan border. The Fort MacKay Trend includes sites 360 (93-83), 463 (94-106) and 466 (94-109), all of which yielded an eclogitic garnet with comparable chemistry to diamond inclusion garnets, based on plots of FeO (total Fe) vs. MgO vs. CaO and TiO_2 vs. CaO. Each of the garnets from these sites also contains anomalous concentrations of sodium (up to 0.05 wt% Na_2O). In addition, each site yielded other indicator minerals possibly related to local kimberlite diatremes, such as chrome diopsides, picroilmenites and chromites (Figure 33).

Other sites with indicator minerals of interest in the Fort MacKay trend include: (1) a G5 from till sample site 366 (93-89), and a G3 and a G5 from fluvial sediment sample site 362 (93-85), both of which are located along the Marguerite River; (2) a G5 from till sample site 285 (92-25) east of the Muskeg River; and (3) seven G5 eclogitic garnets with greater than 11 wt% MgO and less than 26 wt% FeO (total Fe), one of which contains 0.06 wt% Na_2O, from fluvial sediment sample site 364 (93-87) along the Muskeg River. More recent sampling has identified additional sites with interesting indicator minerals that help to define the main trend and the subordinate trend east of Fort McMurray, including: (1) two G3 eclogitic garnets from till sample site 451 (94-94) northeast of Fort McMurray; (2) a G5 eclogitic garnet, a G9 pyropic garnet and two chrome diopsides from till sample site 460 (94-103), southeast of Fort McMurray; and (3) a high titanium, high calcium G6 garnet from till sample site 467 (94-110) south of Fort McMurray.

For those grains derived from tills, the interpretation of the possible source is somewhat more straightforward than for those grains derived from the fluvial samples. For the till samples, the predominant paleo-ice flow transport direction was either southwest or south, depending on which till sheet the samples were collected from. For the indicator minerals derived from the fluvial sediment samples, however, the interpretation is much more complicated because the indicator minerals could be derived from tills, glaciofluvial sediments or Cretaceous sedimentary strata in subcrop. Determining the possible source of origin for the anomalous indicator mineral grains in the Fort MacKay trend is beyond the scope of this study, but several of the indicator minerals have encouraging chemistry and should be followed up by industry.

Other diamond indicator minerals that were recovered from samples outside of the discussed trends but that may be of exploration interest, once further sampling is conducted, include: (1) a G3 eclogitic garnet with excellent FeO-MgO-CaO chemistry from site 269 (92-10) northwest of High Level; (2) a G3 eclogitic garnet with excellent diamond inclusion chemistry, including 0.06 wt% Na_2O, and a chrome diopside from site 476 (94-119), east of High Level; (3) three chromites from a preglacial gravel deposit, site 414 (6815) northwest of the Peace River area; and (4) a cluster of four sites, 268 (92-1), 312 (93-39), 328 (93-51) and 477 (94-120), near the east end of Lesser Slave Lake, which have yielded eclogitic garnets, a chromite, a chrome diopside and a jadeitic diopside with 0.54 wt% K_2O (Figure 33).

Selected Mineralogical and Lithogeochemical Anomalies

There are a number of mineralogical and lithogeochemical anomalies that exist within the Phanerozoic succession of Alberta. These anomalies are diverse in nature, and include such features as anomalous fluorine (F), gas (CO_2, He) and some other elements in groundwater, marl occurrences, placer and paleoplacer gold and platinum group elements (PGE's) in fluvial sediments, and apparent solution collapse or other subcircular structural features. Any or all of these anomalies may indirectly indicate the possible presence of diamondiferous kimberlites or lamproites in adjacent areas. Each of these anomalies are briefly discussed in the following section.

Fluorine Anomalies

Two near-surface, stratigraphically controlled regional fluorine anomalies exist within the groundwaters of southern Alberta (Levinson *et al.*, *In Press*). These anomalies comprise areas within which fluorine concentrations in groundwater are invariably greater than 1.5 ppm. In contrast, the average fluorine content of groundwaters for the world is approximately 0.2 ppm. The two fluorine anomalies occur within spatially separate areas, and within different stratigraphic horizons.

The more southerly of the two fluorine anomalies is known as the Milk River anomaly. It is semicircular and underlies an area of about 15,000 km^2 in NTS map-areas 72E and 82H. It occurs in groundwaters of the lower member of the Milk River Formation of Late Cretaceous age, at depths ranging from 175 m to 350 m. The aquifer ranges in thickness from 60 to 75 m in the southern part, to less than 15 m at the north end of the anomaly. The fluorine concentrations within the Milk River aquifer appear to be partly due to undersaturation of the groundwater with respect to fluorine. The source of the fluorine was not identified but may be related to bentonites (Levinson *et al., In Press*).

The northern fluorine anomaly is known as the Vulcan anomaly. It is elongated in a north-south direction parallel to the disturbed belt and is about 200 km long and 20 to 30 km wide. It extends from about 10 km west of Vulcan to about 20 km southeast of Red Deer, in NTS map-areas 82I, 82P and 83A. It occurs in sandstone beds of the Late Cretaceous to Early Tertiary Willow Creek Formation, at depths ranging from 35 m to 125 m (Levinson *et al., In Press*). The Willow Creek Formation was deposited in the Sifton (Alberta) Trough, a regional northwest-trending valley. The Vulcan anomaly appears to be superimposed upon the eastern limb of this structural feature. The fluorine content gradually decreases to the north, corresponding to a decrease in the aridity of the paleodepositional environment, but this relationship may be fortuitous. Levinson *et al.* (*In Press*) suggest that the Vulcan anomaly is the result of exchange reactions related to caliche deposits that reduce the amount of calcium in solution and therefore allow undersaturation with respect to fluorine and, therefore higher fluorine concentrations. They suggest that the fluorine source may be related to volcanics or tuffaceous units within the Upper Cretaceous to Lower Tertiary succession.

Several authors, including Koritnig (1972), Perel'man (1977), Fuge (1988) and Fleischer and Robinson (1963), suggest that fluorine-rich waters are associated with or are derived from local volcanic activity, metalliferous mineralized zones or leaching of a bentonitic source. If the Milk River and Vulcan fluorine anomalies are indeed related to a volcanic or bentonitic source, they identify at least one and possibly two unknown local centres of volcanic activity that may have been active during the Late Cretaceous and Early Tertiary periods. Therefore, the possibility exists that kimberlite, lamproite or other alkaline intrusions may be associated with these fluorine anomalies.

Levinson *et al.* (*In Press*), also identified a smaller groundwater fluorine anomaly in the Grande Prairie region in Upper Cretaceous sediments. They were unable to offer an explanation for the anomaly; however it is interesting that the anomaly exists in close proximity to the Mountain Lake Kimberlite and is in Upper Cretaceous sediments.

Helium and Other Inert Gases

Anomalously high concentrations of inert gases, such as helium and CO_2, exist locally within the Alberta Basin (McLellan and Hutcheon, 1993; Hutcheon *et al.*, 1994). These anomalous concentrations may indicate a possible mantle source for these gases, which in turn may provide indirect evidence for kimberlite or lamproite diatreme activity within the province.

Two intervals of anomalously high helium partial pressures occur in Alberta. The first interval is less than 500 m above the Precambrian basement, and occurs in hydrocarbon pools in Devonian carbonates in central and northern Alberta. The second occurs in Early Cretaceous and Mississippian sediments throughout the province, at an average level of about 1,000 m above the basement (McLellan and Hutcheon, 1993). The shallower of the two intervals is ^{3}He-rich, while the deeper interval is ^{3}He-poor, relative to global helium ratios. The enrichment of ^{3}He in the shallower interval is enigmatic, as it indicates a mantle source for the helium. If the helium were brought to the shallower level through crustal discontinuities such as faults, one would expect localizations of anomalous P_{He} values, which is not the case. Another possible source for the ^{3}He is mantle-derived volcanic material, which could have been brought to the surface through diatreme activity and deposited province-wide as bentonite beds. The anomalously high helium partial pressures in the shallower interval provide indirect evidence of igneous diatreme activity, likely during the Early Cretaceous. The anomalously high helium partial pressures in the deeper interval appear to be derived from a diffusive flux of helium from the underlying basement, rather than from a mantle source (McLellan and Hutcheon, 1993).

Anomalous concentrations of CO_2 occur in south-central Alberta in the same depth interval as the shallower of the two helium anomalies. The anomalous CO_2 concentrations occur in an area about 150 km long by 70 km wide, elongated in a northwesterly direction. Within this anomalous area, CO_2 partial pressures are up to 0.22 per cent or more, compared with less than

0.02 per cent for most of the province. The CO_2 may be derived from the mixing of low salinity and high salinity brines, which can catalyse bacterial sulphate reduction. Alternatively, the CO_2 may be derived from kimberlitic diatremes, which are enriched in CO_2.

Marl Anomalies

Unpublished assessment reports on marl occurrences (available at the AGS) and a summary report by McDonald (1982), which describes most of the significant marl occurrences in Alberta, were examined to determine whether or not some of the marl occurrences might provide indirect evidence of kimberlite or lamproite diatreme activity. Kimberlites are enriched in magnesium and carbonate minerals, while lamproites although enriched to a lesser degree in magnesium, are very low in carbonate minerals. The available literature was examined in order to determine if there might be any association between marl and the weathering of kimberlites or lamproites. In total, there are more than 140 marl deposits of greater than 10,000 tonnes in Alberta. In general, marl deposits form readily in Alberta under current climatic conditions, particularly in areas where groundwater discharges at surface. Based on our examination of the data, it was not possible to distinguish between marls which may have formed from the weathering of carbonate minerals in kimberlites and marls which have formed under ordinary climatic conditions.

Platinum Group Elements and Gold in Fluvial Sediments

On a worldwide basis, the occurrence of placer gold and PGE's is a rarity. Yet, in Alberta, significant amounts of gold and PGE's are present sporadically in several widely dispersed stream drainages. These occurrences are summarized in maps and in tables by Olson *et al.* (1994) and Dufresne *et al.* (1994a). Many of the gold and PGE grains have primary and pristine features that indicate they are proximally sourced. The origin of these metals in Alberta streams is uncertain, but it is possible that they may be derived from kimberlite or lamproite diatremes (Ballantyne and Harris, 1994; Harris and Ballantyne, 1994). Varying amounts of gold and PGE grains can be found at several sites in the North Saskatchewan River, at and downstream from Edmonton. Gold and PGE grains are also present in several streams in the Foothills of Alberta, including the Pembina, McLeod, Embarrass, Lovett, North Ram, Red Deer and upper North Saskatchewan Rivers, and Baptiste, Prairie and Cripple Creeks (Ballantyne and Harris, 1994; Harris and Ballantyne, 1994). Most of the PGE grains comprise Pt-Fe alloys, with minor Os-Ir-Ru alloys and rare native platinum, hongshiite (PtCu) and sperrylite ($PtAs_2$) grains. Numerous inclusions of other PGE alloys are also present in the Pt-Fe grains, with rhodium concentrations of up to 7.1 wt%. Gold grains range in fineness from 550 to 950, and are alloyed mainly with silver. Some grains contain mercury, as a thin outer rim, as partial replacement or occasionally as a Au-Hg or Ag-Hg alloy. Rare gold grains appear to be alloyed with platinum and palladium as well (Ballantyne and Harris, 1994).

Primary enrichment of PGE's is often associated with chrome spinel segregations in mafic-ultramafic intrusions and ophiolite-type complexes. Many of the chromites which have been recovered from heavy mineral concentrates in Alberta, have chemical compositions that indicate a potentially diamond-bearing kimberlite or lamproite source, and often they display pristine morphologies (Ballantyne and Harris, 1994; Harris and Ballantyne, 1994). Gold or PGE occurrences are coincident with diamond indicator chromite grains along several creeks and rivers in the Alberta Foothills. The occurrence of gold and PGE's is as native grains and complex alloys, often with primary and pristine features, together with the presence of potentially mantle-derived chromites in Alberta, indicates that the metals may also be mantle sourced. Nekrasov *et al.* (1990) have documented the occurrence of native gold, intermetallic gold-lead compounds, nickeliferous phases and PGE's from the Mir kimberlite in Siberia. Yeremeyev *et al.* (1990) have documented the presence of native metals and associated alloys from lamproites of the central Aldan Province in the former Soviet Union. In short, it is possible that the alluvial PGE grains which exist in Alberta may act as 'indicator minerals' for kimberlite and/or lamproite fields, some of which may be enriched in gold, PGE's, native metals or diamonds.

Apparent Salt Solution Collapse Features

Solution collapse structures, which are commonly believed caused by salt dissolution, are a widespread phenomenon in Alberta. Most of the salt dissolution is associated with the pre-Cretaceous or post-Cretaceous erosional unconformities that exist along the northeast edge of the Alberta Basin (Figures 2 and 8). However, there are a number of other anomalous structural features in Alberta that resemble salt solution collapse structures, but are geographically distant from these unconformity edges. Recent work in Saskatchewan has determined that a number of similar structural features are associated with igneous diatremes, and not with salt dissolution as was previously thought (Gent, 1992). Therefore, the possibility exists that diamondiferous kimberlites or lamproites may be responsible for some of the anomalous structures in Alberta that are currently believed to be related to salt solution collapse.

One such anomalous structure exists in the Rumsey area, about 40 km north of Drumheller (site C-54 and C-55 on Figure 9). About 77 m of evaporites from the Upper Devonian Wabamun Group have been removed in an oil well (3-30-33-19W4) in this area (Oliver and Cowper, 1983). In contrast, nearby wells, which are only 1.5 km away have not encountered salt removal. This thinning has been compensated by 65 m of thickening of Upper Cretaceous shales, with the remaining 12 m accounted for by subsequent shale compaction. The removal of salt took place during deposition of the Late Cretaceous Colorado Group and Milk River Formation. Oliver and Cowper (1983) stated that the salt solution is likely unrelated to either basement control, surface fresh waters or to an erosional unconformity. The lack of cores from wells in the Rumsey area makes it impossible to determine the cause of the salt removal, but it is possible that an igneous diatreme may be responsible for this apparent structural feature.

A second anomalous structure exists in northeast Alberta, north of the Primrose Lake Air Weapons Range. Widespread salt solution has taken place in the Lower Devonian Keg River Formation adjacent to the pre-Cretaceous unconformity edge, creating numerous paleo-lows in the area. However, two wells in the area (7-34-73-4W4 and 10-16-75-6W4 at site C-61 and C-62 on Figure 9) show anomalously thin Devonian successions in which there appears to have been no removal of evaporites (McPhee, *pers. comm.*, 1994). In well 7-34-73-4W4, an 'abnormally thick succession' of high conductivity was also logged (McPhee, *pers. comm.*, 1994). The cause of these anomalous successions is unknown, but it is possible that they are associated with kimberlite or lamproite intrusive activity.

Other Geochemical and Mineralogical Anomalies

Anomalous concentrations of the minor elements magnesium, lithium, bromine and iodine are present within formation waters associated with various stratigraphic horizons in the Alberta Basin (Hitchon, 1993; Hitchon *et al.*, 1995). Magnesium is present in concentrations of up to 12,000 mg/l in the Elk Point aquifer slightly north of Edmonton. Anomalous calcium and bromine are associated with magnesium in the aquifer. Anomalous magnesium is also present in the Beaverhill Lake aquifer east and southeast of Calgary with concentrations of up to 13,410 mg/l and associated anomalous calcium (up to 97,790 mg/l) and bromine (up to 2,786 mg/l). Lithium is present in concentrations of up to 140 mg/l in the vicinity of and to the southeast of the Peace River Arch, within Devonian formation waters of Woodbend Group strata. Anomalous iodine is present in concentrations of up to 128 mg/l in aquifers of the Lower Cretaceous Viking and Upper Cretaceous Belly River formations in central and southern Alberta. The significance of elevated concentrations of these elements is not known, but it is possible that they are related to unidentified magmatic events including kimberlite or lamproite magmatism and associated deposition of bentonites.

Other selected mineralogical anomalies that may be pertinent to diamond exploration in Alberta are tabulated in Dufresne *et al.* (1994a). These anomalies include favourable garnets in till or other surficial sediments and anomalous chromites reported by industry, bentonites with unusual chemistry that may indicate associated diatreme activity, and reported occurrences of diamonds in Alberta.

Geophysical Anomalies

There are a number of aeromagnetic, ground magnetic and gravity anomalies present in the subsurface of Alberta and these are summarized on maps and in tables by Dufresne *et al.* (1994a). The anomalies range in size from a few hundred metres across to as much as 30 km across and 150 km long. Most of the magnetic anomalies are relatively weak, generally less than 100 gammas above or below background levels. Very little is currently known about most of these anomalies, but it is possible that some of them may correspond to kimberlite or lamproite diatremes.

A cluster of thirteen circular to elliptical aeromagnetic anomalies (P-7 on Figure 6.44 in Dufresne *et al.*, 1994a) has been identified in the Legend area, about 50 km southeast of Lethbridge, where two small microdiamonds were found in 1992. Most of these anomalies are less than 2 km across, and may represent the magnetic expression of pipe-like intrusions (Takla Star Resources Ltd., 1993c). As well, Ross *et al.* (1994b) have identified a series of linear aeromagnetic anomalies in southern Alberta, that occur in the same general area as the Legend aeromagnetic anomalies. Some of these linear anomalies extend from known intrusive bodies in the Sweetgrass Hills, and are up to tens of km long, extending from the Canada – USA border to as far north as Lethbridge. The linear anomalies generally trend in a northwesterly direction, and geophysical modelling has indicated that these anomalies are relatively shallow. Follow-up ground geophysical surveys have shown that the magnetic anomalies are not cultural features. Ross *et al.* (1994b) suggested that these aeromagnetic anomalies may correspond to igneous dyke swarms that are related to the Sweetgrass Intrusives, and may be of kimberlitic or lamproitic affinity.

In the Pincher Creek – Crowsnest Pass area of southwest Alberta at least fifteen discrete aeromagnetic anomalies have been identified (Steiner, 1958; Takla Star Resources Ltd., 1993a; Dufresne *et al.*, 1994a; Olson *et al.*, 1994). As well, a cluster of twenty-two circular to elliptical aeromagnetic anomalies has been identified in northeast Alberta, extending from near the headwaters of the Christina River to the Saskatchewan border near Cold Lake (Takla Star Resources Ltd., 1993c). Other magnetic anomalies include an isolated aeromagnetic feature about 800 m across, that is 50 km south of Turner Valley (Steiner, 1958), and an isolated ground magnetic anomaly about 500 m long that is near the border of Banff National Park, about 30 km northeast of Banff townsite, near which chromium-bearing "green and brown silicate rocks" have been identified (Renn, 1956).

Conclusions

The primary objectives of this study were to identify favourable geological anomalies and target areas for diamond exploration, and to provide selected geological, geophysical and geochemical data that would assist industry in their exploration for diamonds in Alberta. We believe the foregoing text, figures, tables and appendices have provided much information and data that will be useful to industry.

Alberta is favourable for diamondiferous deposits because:

(1) The Province is underlain by large areas of thick Precambrian crust, hence there is a good possibility that diamond-bearing source rocks exist at least locally in the mantle beneath Alberta.

(2) Alberta contains major faults and other tectonic features that have been active during several geologic time periods and that may have acted as conduits for the intrusion of diamond-bearing kimberlitic or lamproitic magmas.

(3) Kimberlite and lamproite intrusions, several of which are diamondiferous, exist in several provinces, territories and states adjacent to or near Alberta. In Alberta, at least one kimberlite has been discovered in the Mountain Lake area near Grande Prairie. As well, there are also excellent indications that kimberlite or lamproite diatremes have been discovered, or may soon be discovered in the Hinton area (Fipke *et al.*, 1989; Dufresne *et al.*, 1994a; Northern Miner, 1996). Although the Sweetgrass Intrusions in southern Alberta are regarded as having low diamond potential because the intrusions are predominantly or entirely minettes (Kjarsgaard, 1994a, b), there still may be potential for diamondiferous deposits in this area because of the interpreted extensive dyke swarm that has been identified from recently published aeromagnetic data (Ross *et al.*, 1994b). As well, two diamonds are reported to have been discovered at Etzikom Coulee near Legend (Edmonton Journal, 1992b; Morton *et al.*, 1993; Takla Star Resources Ltd., 1993a) and in the Black Butte diatreme (Boulay, *pers. comm.*, 1996). Furthermore, kimberlitic and lamproitic diatremes that are age equivalent to the Sweetgrass Intrusions exist in the Missouri Breaks and Smoky Butte region of central Montana (Hearn, 1989).

(4) There is evidence of at least four, and possibly five, ages of volcanic activity in Alberta that are age equivalent to kimberlitic or lamproitic magmatic events elsewhere in North America and the world (Tables 2 and 3). The most important of these magmatic events in Alberta may have occurred during the mid-Cretaceous, Late Cretaceous and Early Tertiary, because diamondiferous diatremes, vent facies and volcaniclastics have been found in mid-Cretaceous successions in the Fort à la Corne area of Saskatchewan as well as Late Cretaceous and Early Tertiary diamondiferous diatremes that have been discovered in the Lac de Gras region, NWT. In Alberta, the Mountain Lake Kimberlite and the Black Butte diatreme are Late Cretaceous and Early Tertiary in age, respectively.

(5) Numerous bentonites and tuffs exist in the Phanerozoic succession in Alberta. There are anomalously thick bentonitic horizons (e.g., the Drumheller, Duagh and Irvine-Bullshead bentonites), some of which are localized and have a trend that crosses the major sedimentary depositional strike. These anomalous bentonites may be the result of local volcanic venting as opposed to being ash-fall debris derived from outside Alberta. All of the above thick bentonites are of Late Cretaceous age, which is the age of the Mountain Lake Kimberlite and the most extensive and voluminous period of diamondiferous magmatism in the world (Dawson, 1989).

(6) There are numerous diamond indicator mineral anomalies within Alberta, with some indicator grains having excellent chemistry indicative of possible local kimberlitic or lamproitic diatremes and, possibly, diamondiferous source rocks. As well, diamonds have been found in drift or fluvial sediments in at least five publicized locales in southern and central Alberta.

(7) There are a large number of geological, geophysical or geochemical anomalies in Alberta, some of which may be spatially and genetically related to emplacement of potentially diamondiferous kimberlitic or lamproitic diatremes, or reflect erosional secondary deposits derived from such primary diamondiferous source rocks.

In conclusion, Alberta has at least a moderate to, possibly, high potential to contain diamondiferous diatremes and vent-related deposits. At present, the province has been barely explored for such deposits, even though extensive staking has occurred. As well, if primary diamondiferous deposits are found in Alberta, then exploration should also be directed towards the discovery of secondary diamondiferous deposits, such as paleoplacer or placer deposits in Tertiary, preglacial or Recent fluvial sediments.

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Appendix 1. Summary of major faults and other structural anomalies in Alberta

Anomaly # (General Area)	Location	GEOLOGICAL FEATURES						Source
		Nature of Anomaly	Approximate Size	Orientation	Relative Age or Horizons Affected	Associated Anomalies	Comments	
FAULTS CUTTING PHANEROZOIC STRATA								
F-1@@ (Eagle Butte)	Twp. 7-9, @@R. 4-5W4M	Two transcurrent faults, connected by three thrust faults and one normal fault.	The Bullstead Creek Fault is at least 27 km long, and the Medicine Lodge Coulee Fault at least 20 km. Displacements of up to 165 m vertically. @@Note: 1,000 m vertical dis-placement cited in Westgate (1968).	BCF= N44°W@@MLCF= N26°W@@BCF= sinistral movement@@MLCF= dextral movement	Post-Cretaceous	Positive gravity anomaly; close proximity to bentonite occurrence #'s B1-7	There are numerous other smaller-scale faults in the vicinity, and there is evidence that a deep-seated plutonic dome or plug may be the source of this anomaly.	Haites and van Hees (1962); Gallup (1956) and Westgate (1968)
F-2@@ (Taber)	Twp. 9-10, @@R.16-17W4	Transcurrent to normal, dextral (?) fault.	The fault is at least 20 km long with up to 30 m vertical and 2 km horizontal displacement.	Strike = N37°W@@Dip = 65°SW	Post-Cretaceous	None	A N-S channel, over 100 m deep, of early Early Cretaceous age cuts Jurassic and Mississippian rocks in the same area.	Haites and van Hees (1962); Russell and Landes (1940)
F-3@@ (Drumheller)	14-29-20W4	Transcurrent, dextral fault.	At least 5 km long, with variable vertical displacement (up to 25 m) and about 1.5 km of horizontal displacement.	Strike = N37°W@@Dip = 80°SE(?)	Post-Cretaceous	Close proximity to bentonite occurrence #'s 8-9 and 25-27	Vertical displacement changes sign along the strike of the fault (normal to reverse to normal), indicating dominant strike-slip movement.	Haites and van Hees (1962); Haites (1960)
F-4@@ (Albercan)	1-12-29-2W4	One or two (?) normal faults.	Up to about 100 m of vertical displacement.	Unknown	Post-Mississippian and Pre-Cretaceous, with possibly some post-Cretaceous movement.	None	About 100 m of Devonian to Mississippian rocks are missing from the anomalous hole, while at the same time 60 m of Mississippian carbonates are present in this hole and no where else. Evidence of graben-type faults.	Workman (1954); Haites and van Hees (1962)
F-5@@ (Monarch Fault Zone)	Twp. 9-10, @@R.23-24W4	An imbricate series of E-dipping thrust faults of small displacement.	The faults are present in an area about 10 km long and about 3 km wide.	Strike = N20°W to N25°E@@Dips to the SW and NW	Post-Cretaceous (Laramide)	None	None	Irish (1971)
F-6@@ (Lethbridge)	Twp. 8-10, @@R.21-22W4	Three or more small-scale tear faults, with normal components.	Faults are up to 10 km long, with up to 30 m of vertical displacement and definite, but undetermined horizontal displacement.	Main fault strike is N35°W, other faults strike about N40°W and N60°W	Post-Cretaceous, cuts across Sweetgrass Arch folding.	None	Small-scale faults, unknown extent at depth.	Russell and Landes (1940); Haites (1960)
F-7@@ (Bassano Fault Block)	Twp. 17, @@R.18W4	Small-scale normal fault.	About 7 km long, with unknown vertical displacement.	About N75°W	Post-Cretaceous	Intersects anomaly F-11.	None	Stewart (1943) Irish (1971)

Anomaly # (General Area)	Location	GEOLOGICAL FEATURES						Source
		Nature of Anomaly	Approximate Size	Orientation	Relative Age or Horizons Affected	Associated Anomalies	Comments	
F-8@@ (Mud Buttes and Tit Hills and/or Misty Hills)	Twp. 33,@@R.19-20W4	Severely folded and faulted beds, on a local scale.	About 15 km E-W and 5 km N-S.	Strike = N100°E@@Dip 20° to 50°N	Bearpaw and "Pale" beds of Cretaceous age. Structures are Quaternary, related to glacial activity.	None	Glacial in origin; "ice-thrust" bedrock.	Slater (1927); Williams and Dyer (1930)
F-9@@ (Clearwater River)	Extends SW from Twp. 90, R.4W4	Transcurrent fault?	About 160 km long	About N55°E	Basement structure. May be younger movement affecting overlying units.	Salt dissolution (F-54 and F-55)?@@Intersects anomalies F-9, F-25 and F-26.	None	Dubord (1987); Garland and Bower (1959)
F-10@@ (Ghost River)	Twp. 27,@@R.9-10W5	Dextral transcurrent (or normal) fault.	About 8 km long; stratigraphic throw from 150 m to 200 m (N side up).	About N85°E	Syn-Laramide Orogeny. Cuts one thrust fault and is terminated at its ends by other thrust faults.	None	None	Fitzgerald (1962)
F-11@@ (Bassano Fault Block)	Twp. 17-18,@@R.17-18W4	Three normal faults.	Up to 6 km long, with unknown amounts of vertical displacement.	Faults strike about N50°E.	Post-Cretaceous	Intersects anomaly @@F-7.	None	Irish (1971); Stewart (1943)
F-12@@ (Kananaskis Country)	Twp. 19,@@R.8W5	Five transcurrent faults, containing "horses" of fault transported rock.	Up to 2.5 km long. The northern most fault has _ 80 m sinistral displacement, while the other 4 faults have 90 m to 300 m dextral displacement.	Between N40°E and N55°E.	Post-Jurassic. They are also believed to be pre-Laramide Orogeny.	None	There is evidence that these are not tear faults between thrust sheets, but instead are extensional faults related to the Hudsonian basement below.	McGugan (1987)
F-13@@ (Turner Valley Fault)	Twp. 21,@@R.3W5	Transverse fault.	Approximately 7 km in strike length.	N37°E	Post-Cretaceous	None	None	Hume (1931)
F-14@@ (Near Moose Mountain)	Twp. 21, R.8W5@@Twp. 22, R.7W5	Transverse fault.	Approximately 7 km in strike length.	N45°E	Cretaceous to Post-Cretaceous	None	None	Beach (1942)
F-15@@ (Canmore Area)	Twp. 10-13,@@R.23-26W5	Several (8 or more) transcurrent "tear" faults.	Up to about 10 km long, with variable amounts of both dextral and sinistral displacement.	Between N40°E and N60°E	Post-Cretaceous, syn-Laramide Orogeny.	None	These faults have been proven to be directly related to folding and thrusting in the area.	Moffat and Spang (1984); Verrall (1968)
F-16@@ (Indianhead Creek Area)	Twp. 33-34,@@R.14-15W5	Four large normal faults, with numerous smaller associated faults.	Up to about 6 km long, with variable displacement ranging from 0 m to 500 m, NW side down, along each fault.	Strike between N15°E and N45°E. Dips from 45° to 90° to the NW, becoming progressively shallower with depth and to the NW.	Syn-Laramide Orogeny, with possibly some pre-Laramide movement.	None	Movement on these faults appears to both pre-date and post-date the movement along the Third Range Thrust Fault.	Birnie (1961); Verrall (1968)
F-17@@ (Bighorn Tear)	Twp. 39,@@R.16W5	Transcurrent fault, with significant vertical movement.	Up to about 5 km long, with vertical displacement to the S along entire length.	Strikes about N30°E, dips nearly vertical.	Pre- or syn-Laramide Orogeny. Cuts entire Bighorn thrust sheet, but is overridden by McConnell Thrust.	None	None	Verrall (1968)
F-18@@ (Worsley)	Twp. 86-87,@@R.11-13W6	Two normal faults.	At least 25 km long, each with vertical displacements up to 30 m.	One fault strikes about N40°E, and terminates in the other, which strikes N80°E. Both faults dip 60°-70°N, with N-side-down.	Post-Cretaceous, cutting Baldonnel Fm. May be reactivation of basement faults.	Silver occurs in fault zone. Anomaly 83M-M-02 in Olson et al. (1994)	None	Baykal (1968a)
F-19@@ (Steen River Structure)	Twp. 120-122,@@R.20-23W5	Possible meteorite impact feature, with associated normal and reverse faults.	About 25 km across, with surrounding area uplifted and disturbed up to 30 km away.	Circular. Associated faults are radial in nature.	Mid-Cretaceous, about 95 + 7 Ma.	Adjacent to Great Slave Lake Shear Zone (F-20) and NW-striking basement fault (F-21).	Same approximate age as Fort à la Corne kimberlites in Sask., and Fish Scales unit.	Winzer (1972) and others (eg., Wilson et al, 1989)

Anomaly # (General Area)	Location	GEOLOGICAL FEATURES						Source
		Nature of Anomaly	Approximate Size	Orientation	Relative Age or Horizons Affected	Associated Anomalies	Comments	
F-20@@ (Hay River Fault and Great Slave Lake Shear Zone)	Strikes SW from Twp. 126, R.13W5 to Twp. 103,R.12W6	Transcurrent fault, with vertical component. Has > 300 km dextral displacement, as well as substantial S-side-up movement.	In Alberta, about 320 km long, extends NE into N.W.T. and SW into B.C.	About N40°E. Dip near vertical.	Precambrian in origin. Continued movement through Cretaceous (?)	Fault F-22 is a splay off this fault.	Extends for >1,000 km to the NE, past the East Arm of Great Slave Lake. SW extension of McDonald Fault System and Great Slave Lake Shear Zone.	Haites (1960); Wilson et al. (1989)
F-21	Strikes NW from Twp. 118, R.19W5 to Twp. 124, R.3W6	Transcurrent fault, possibly with some vertical component.	100 km or more long. Sinistral displacement of > 3 km across Great Slave Lake Shear Zone (F-20). Unknown vertical displacement.	About N45°W. Dip likely near vertical.	Precambrian in origin? Movement through Cretaceous?	Cuts through F-19 (Steen River Structure).	None	Wilson et al. (1989);
F-22	Strikes SW from Twp. 116, R.1W6 to Twp. 99, R.13W6	Transcurrent fault, possible with some vertical component.	In Alberta, about 200 km long. Extends SW into B.C.	About N40°E. Dip likely near vertical.	Precambrian in origin? Movement through Cretaceous.	Great Salve Lake Shear Zone (F-20).	Splay off at fault F-20.	Haites (1960); Wilson et al. (1989)
F-23	Strikes NNW from Twp. 80, R.1W4 to Twp. 103, R.8W4	Transcurrent fault, inferred from aeromagnetic data.	In Alberta, about 230 km long. Extends SE into Saskatchewan.	About N25°W. Dip likely near vertical.	Basement structure. May be younger movement affecting overlying units.	Intersects anomalies F-9 and F-24.	No data.	Dubord (1987); Garland and Bower (1959)
F-24	Strikes NE from Twp. 66, R.18W4 to Twp. 81, R.2W4	Transcurrent Fault, inferred from aeromagnetic data.	About 220 km long.	About N°40E. Dip likely near vertical.	Basement structure. May be younger movement affecting overlying units.	Intersects anomalies F-23, F-25 and F-26.	No data.	Dubord (1987); Garland and Bower (1959)
F-25	Strikes NNW from Twp. 72, R.10W4 to Twp. 94, R.16W4.	Transcurrent fault, inferred from aeromagnetic data.	About 210 km long.	About N25°W. Dip likely near vertical.	Basement structure. May be younger movement affecting overlying units.	Intersects anomalies F-9, F-24, and F-27.	No data.	Dubord (1987); Garland and Bower (1959)
F-26	Strikes NNW from Twp. 69, R.14W4 to Twp. 84, R.19W4	Transcurrent fault, inferred from aeromagnetic data.	About 160 km long.	About N25°W. Dip likely near vertical.	Basement structure. May be younger movement affecting overlying units.	Intersects anomalies F-9 and F-24.	No data.	Dubord (1987); Garland and Bower (1959)
F-27	Strikes NE from Twp. 94, R.17W4 to Twp. 96, R.12W4	Transcurrent fault, inferred from aeromagnetic data.	About 60 km long.	About N55°E. Dip likely near vertical.	Basement structure. May be younger movement affecting overlying units.	Intersects anomalies F-25 and F-28.	No data.	Dubord (1987); Garland and Bower (1959)
F-28	Strikes N-S from Twp. 96, R.14W4 to Twp. 104, R.13W4	Transcurrent fault, inferred from aeromagnetic data.	About 80 km long.	About N00°E. Dip likely near vertical.	Basement structure. May be younger movement affecting overlying units.	Intersects anomaly @@F-27.	No data.	Dubord (1987); Garland and Bower (1959)
INTRUSIONS IN SE AND SW ALBERTA								
I-29@@ (LaCoulotte Peak & Ridge)	Twp. 2-3,@@R.2-3W5	Series of syenitic intrusives.	Dykes occur within an area about 10 km E-W and 5 km @@N-S.	Dykes generally strike northeasterly.	Dykes cut Mississippian rocks, and are believed to be Late Cretaceous or Early Tertiary.	None	Equivalent to Anomalies 82G-G6 and equivalent others in SW Alberta (see Olson et al. 1994).	Baykal (1968b);@@Goble (1974a)
I-30@@ (Sweetgrass Hills, Deadhorse Coulee)	5-18-1-11W4 and@@20,28,29,32,3-3-1-11W4	Minette intrusive and anticlinal structure.	Small dyke < 100 m long. Anticline is > 5 km long and about 1.5 km wide.	Dyke strikes NNE, dips vertically. Anticline trends N to NNE, plunges gently N.	Eocene: ca. 48 Ma - postdates Sweetgrass Arch.	Extends SW towards West Butte intrusion of Sweetgrass Hills in Montana.	Anticline and dyke are probably both related to emplacement of West Butte intrusion. Anticline may be cored by intrusive?	Williams and Dyer (1930); Russell and Landes (1940)

Anomaly # (General Area)	Location	GEOLOGICAL FEATURES						Source
		Nature of Anomaly	Approximate Size	Orientation	Relative Age or Horizons Affected	Associated Anomalies	Comments	
I-31@@ (Sweetgrass Hills at Pinhorn area)	5,8,9-1-9W4 and@@Twp. 1, R.9W4	Minette intrusive and domal structure.	Intrusive is about 30 m long in exposure, and up to 1.5 m thick. Domal structure is > @@5 km across.	N05°E strike dips vertically. Dome is semicircular, slightly steeper on W and N sides.	As for F-30.	Dyke extends S towards East Butte intrusion of Sweetgrass Hills in Montana.	Dyke and dome are probably both related to emplacement of East Butte intrusion. Dome may be cored by intrusive?	As for F-30.
I-32@@ (Sweetgrass Hills)	NE-13-2-9W4 and@@16-19-2-8W4	Two minette intrusives about 2 km apart.	Small intrusive mass about 20 m x 15 m, and about 15 m high (16-19-2-8W4). Other intrusion is similar.	Semicircular, vertical bodies.	As for F-30.	None	Has inclusions of sulphurous limestone, indicating that it pierced Mississippian carbonates which are about 1,000 m below. Therefore deep in origin.	As for F-30.
I-33@@ (Sweetgrass Hills)	NE-30-1-8W4	Minette intrusive.	Small dyke.	Approximately N-S. Vertical dip.	As for F-30.	None	None	As for F-30.
I-34@@ (Sweetgrass Hills, Black Butte)	13-10-1-8W4	Minette intrusive.	About 400 m long x 100 m wide, up to 30 m high. Oval in shape.	Generally NE-SW. Vertical body.	As for F-30.	None	Has inclusions of dioritic rock and limestone, indicating that it originated at great depth.	As for F-30.
I-35@@ (Sweetgrass Hills,@@Comrey area)	SW-5-1-5W4 and@@Twp. 1, R.5W4	Minette intrusive and domal structure	At least 100 m long in exposure, and up to 1.5 m thick. Domal structure is > 4 km across.	Strikes N58°E, dips vertically. Dome is elongated slightly E-W.	As for F-30.	Dyke extends SW towards East Bluff intrusion of Sweetgrass Hills.	Dyke and dome are probably related to emplacement of East Butte intrusion. Dome may be cored by intrusive?	As for F-30.
FOLD STRUCTURES								
F-36@@ (Erickson Coulee)	Twp. 1, R.12-13W4	Asymmetrical anticline.	> 4 km long, and about 1 km across.	Trend is N15°W. Plunge to the N.	Tertiary (Ecocene) Postdates Sweetgrass Arch.	Extends SE to West Butte intrusion of the Sweetgrass Hills.	Structure is steeper on W side than on E, which indicates that it postdates Sweetgrass Arch. May be cored by intrusive?	Russell and Landes (1940).
F-37@@ (Sage Creek)	Twp. 4, R.3-4W4	Anticlinal to domal structure.	> 7 km E-W, and > 5 km N- S.	Axis is oriented ENE, closure is steep to N, moderate to E and S, and gentle to the W.	Tertiary? Related to or postdates Sweetgrass Arch.	None	Anomalous structure relative to gentle W dip in region. Possibly cored by intrusive?	As for F-36.
F-38@@ (Foremost area)	Twp. 5-6, @@R.10-11W4	Anticlinal structure.	About 15 km long and 8 km wide.	Trend is about N20°W. Plunge is moderate to NW.	Tertiary? Post-Sweetgrass Arch?	None	Cuts across trend of Sweetgrass Arch. Possibly related to intrusive activity?	AAas for F-36.
F-39@@ (Skiff area)	Twp. 5-6,@@R.13-14W4	Anticlinal or domal structure.	Broad structure, about 20 km N-S and 15 km E-W.	Trends generally N-S, plunges gently to N, E and W; possibly also to S.	As for F-38.	None	As for F-38.	As for F-38.
F-40@@ (Bow Island area)	Twp. 10-11,@@R.10-12W4	Series of fold noses (complex anticline); at least 4 separate noses.	> 25 km long and 15 km across.	Trends generally NW. Plunges to NW.	As for F-38.	None	As for F-38.	As for F-38; also Williams and Dyer (1930)
F-41@@ (Medicine Hat)	Twp. 12,@@R.5-6W4	Synclinal structure, possibly with anticlinal noses on flanks.	_ 10 km long and 3 km across.	Trends generally E-W, plunges moderately E.	Tertiary. Syn- or post-Sweetgress Arch.	Close proximity to bentonite occurrence #B3-7.	Part of structure which forms a saddle across the Sweetgrass-North Battleford Arch. Plunge of this arch(s) reverses direction here.	As for F-38; also Meyboom (1960)

Anomaly # (General Area)	Location	GEOLOGICAL FEATURES						Source
		Nature of Anomaly	Approximate Size	Orientation	Relative Age or Horizons Affected	Associated Anomalies	Comments	
FAULTS CUTTING PRECAMBRIAN ROCKS								
F-42@@ (Johnson Lake)	Twp. 98-100,@@R.3-5W4	Two basement faults, transcurrent in nature. One fault has _ 7 km dextral displacement.	One fault is _ 25 km long, the other is _ 15 km long.	Strike about N45°E and N10°W.	Basement structures; may affect overlying units.	The longer, western fault has coincident EM and weak negative magnetic anomalies.	A pre-Cretaceous and post-Cretaceous (glacial) erosional channels are in the same area as the faults.	Meyboom (1960); Dufresne et al. (1994)
F-43@@ (South shore of @@Lake Athabasca)	Strikes SW from Twp. 115, R.1W4 to Twp. 111, R.4W4	Normal fault, with some possible strike-slip movement.	_ 60 km long in Alberta. Has NW-side-up movement.	Strikes almost N40°E. Dips nearly vertically.	Basement structure. Cuts Helikian Athabasca Group. Some possible movement since Proterozoic time.	None	S.W. extensions of Black Bay Fault in Saskatchewan.	King (1969)
F-44@@ (Richardson River)	Twp. 103-108@@R.6-12W4	Normal or strike-slip faults.	Faults _ 5 km long. Two faults are _ 50 km long.	Two sets:@@- N45°E to N80°E@@- N10°E to N30°W	Basement structures. Some later movement?	None	None	Walker (1981); McWilliams et al. (1979)
ULTRABASIC DIATREMES AND INTRUSIONS								
I-45@@ ("Larry Diatremes" near Golden, B.C.)	117°23', 35"W and 52°04', 23" N; approx. 76 km NW of Golden, B.C. and 3 km SSW of Columbia Icefield	Lamproite@@Dykes & diatremes	1,185 m dyke and diatreme system trending N-S.	Strikes Nrly.	< 60 Ma, post Laramide Orogeny.	None	Abundant chromites (100 - 200 grains), some low Cr- garnets and low-Cr clinopyroxenes from bulk sample.	Fipke (1990)
I-46@@ ("Jack Diatremes" near Golden, B.C.)	117° 07'20" W and 51° 54'16" N. Approximately 60 km NW of Golden B.C. and 4.5 km west of BC/AB border.	Tuffisitic breccia diatreme with lamprophyre-lamproite clasts.	About 700 m long in NW-SE direction	NE-SW	Between 98 and 60 Ma (late Laramide Orogeny).	None	76 Chromites, 47 high-Cr garnets, 63 low-Cr garnets, 82 picroilmenites, 7 high-Cr clinopyroxenes and 31 low-Cr clinopyroxenes from bulk sample.	Fipke (1990)
I-47@@ ("Mike diatremes" near Goldon, B.C.)	Immediately West of BC/AB border at 117°00'33"W and 51° 49'27"N. @@46.5 km NW of Golden, B.C.; 5.5 km NW of Mark diatremes.	Diatreme facies tuffisitic breccia of possible lamproite affinity.	100 to 400 m long	WNW-ESE	Diatremes are post-thrusting on Mons Fault; also are post folding of sedimentary rocks. Therefore, probably post Laramide and <60Ma).	None	5 discreet bodies of diatreme breccia. Got >100 chromites and 1 high-Cr clinopyroxene from bulk sample.	Fipke (1990)
I-48@@ ("Mark diatremes" near Golden, B.C.)	Astride BC/AB border; 41 km NW of Golden, B.C.@@116° 57'50"W and 51° 46'48"N	Diatreme facies@@tuffisitic breccia	250 x 550 m+ (Mark 1); is one of the largest known diatremes in the Canadian Rockies. Other diatremes (Mark 2 to 5) are about 65 x 220 m.	N E-W	At least post-Columbian Orogeny (<98 Ma). Emplacement probably occurred at end of or just after Laramide Orogeny (<60 Ma).	None	Diatreme cluster definitely extends across divide into Alberta, but is mostly covered by the Niverville Glacier. Bulk sample: chromites, high-Cr and low-Cr garnets and 1 low-Cr clinopyroxene.	Fipke (1990)

Anomaly # (General Area)	Location	GEOLOGICAL FEATURES						Source
		Nature of Anomaly	Approximate Size	Orientation	Relative Age or Horizons Affected	Associated Anomalies	Comments	
I-50@@ ("Joff diatremes" near Joffrey Cr., B.C.)	55 km east of Invermere, B.C.; south of Palliser Range on ridges west of Joffrey Creek; no exact location given.	Breccia: hypabyssal facies; phlogopite-bearing kimberlite.	About 500 m x 130 m	Circular	Unknown	None	Bulk sample: 82 chromites, plus low-Cr- garnet, ilmente, and high-Cr and low-Cr clinopyroxene.	Fipke (1990)
I-51@@ ("Russ diatremes")	UTM coordinates are 553700N, 625950E; near Fairmont Hot Springs	Tuffisitic box:@@alkaline lamprophyre or possible olivine melilite.	About 50 m x 50 m		Unknown	None	Pipe exposed on surface and face of cliff (good cross-section).	Pell (1987a, b)
I-52@@ ("Cross diatreme")	N side of Crossing Creek, 88 km NW of Elkford, B.C.@@114° 59'30"W and 50° 05'25"N	Kimberlite @@diatreme@@(Group I kimberlite)	70 m x 15 m	E-W@@(flattened)	240 - 250 Ma from Rb-Sr age on phlogopite.	None	Bulk sample: abundant chromite, high-Cr and garnets, ilmenite, and high-Cr clinopyroxenes.	Fipke (1990)
I-53@@ Geike siding west of Jasper	On old Yellowhead Rd, 5/8 mile NW of Geike Siding	Igneous intrusive rock; only known occurrence in Jasper region	About 3 m long	Unknown	Intrudes Old Fort Point Fm, hence emplaced prior to Laramide Orogeny.	None	Green, fine-grained igneous rock, probably altered diabase. Intrusion is highly altered, veined and fractured.	Charlesworth et al. (1967)
MISCELLANEOUS STRUCTURES								
C-54 and C-55	3-30-33-19W4 and@@10-24-33-20-W4	Salt removal causing drop in known geologic contacts	Unknown	Unknown	Late Cretaceous; salt dissolved in Devonian Wabamun Group	Possibly F-8	Devonian Wabamun Group was likely thinned during Late Cretaceous then compensated by thickening of Upper Cretaceous shales.	Oliver and Couper (1983)
F-56	Twp. 32-37, @@R1-7W5M	Caroline Arch - discovered through lineament analysis	About 60 km x 20 km	Approx. E-W		None	The Caroline Arch rose by 61 m in late Paleozoic and early Mesozoic times.	Haman (1975)
F-57@@ (Del Bonita Structure)	Twp. 1-2,@@R.21-22W4M	Asymmetrical syncline-anticline pair.	About 10 km long by 10 km wide.	Fold axes trend and plunge NW.	Post-Cretaceous	None	None	Russell and Landes (1940)
F-58@@ (Kevin Sunburst Dome)	Twp. 1,@@R.17W4M	Broad NW - plunging anticline.	About 10 km long.	About N40°W, plunge is to NW.	Post-Cretaceous	None	None	Meyboom (1960)
C-59@@ (Berry Field)	Twp. 26-27,@@R.13W4M	Anomalous sedimentary structure, area of local subsidence.	About 8 km long by 2 km wide.	Approximately NE-SW.	Upper Cretaceous or Tertiary.	None	Possibly a product of local salt dissolution from Devonian horizons.	Hopkins (1987)
C-60@@ (Suffield)	Twp. 18-22,@@R.6-10W4M	Faulting and juxtaposition of sandstone beds.	Roughly circular area about 40 km across.	Roughly circular.	Affects Lower Cretaceous Mannville Group.	None	Possibly related to salt dissolution, or more likely to uplift associated with the Sweetgrass-North Battleford Arch.	Tilley and Longstaffe (1984)
C-61	10-16-75-6W4M	Paleo-low, unrelated to salt solution.	Unknown.	Unknown.	Cretaceous	None	Abnormally thickened Cretaceous section, with no evidence of salt removal.	D. McPhee (Pers. Comm., 1994)

Anomaly # (General Area)	Location	GEOLOGICAL FEATURES						Source
		Nature of Anomaly	Approximate Size	Orientation	Relative Age or Horizons Affected	Associated Anomalies	Comments	
C-61	10-16-75-6W4M	Paleo-low, unrelated to salt solution.	Unknown.	Unknown.	Cretaceous	None	Abnormally thickened Cretaceous section, with no evidence of salt removal.	D. McPhee (Pers. Comm., 1994)
C-62	7-34-73-4W4M	Paleo-low, unrelated to salt solution.	Unknown.	Unknown.	Cretaceous	None	Abnormally thickened Cretaceous section, with no evidence of salt removal.	D. McPhee (Pers. Comm., 1994
C-63	Sec. 17-18, Twp. 68, R.2W4M	Bedrock low, possibly related to salt solution collapse.	Unknown.	Unknown.	Cretaceous or younger?	None	No data.	R. Stein (Pers. Comm., 1994)
C-64	Sec. 4-5, Twp. 70, R.2W4M	Bedrock low, possibly related to salt solution collapse.	Unknown.	Unknown.	Cretaceous or younger?	None	No data	R. Stein (Pers. Comm., 1994)
C-65	Sec. 3, Twp. 70,@@R.3W4M	Bedrock low, possibly related to salt solution collapse.	Unknown.	Unknown.	Cretaceous or younger?	None	No Data.	R. Stein (Pers. Comm., 1994)

Appendix 2. Reported bentonite occurrences in Alberta

OCCURRENCE NUMBER	STRATIGRAPHIC HORIZON	THICKNESS (Feet)	UNUSUAL FEATURES	LOCATION(s)	SOURCE
B-1 (Bullshead)	KBp	2		N1/2 2-8-7W4, NE 3-8-7W4, NW 14-8-7W4	Babet (1966), Scafe (1975)
B-2A (GrosVentre)	KBp (100' above base)	8.7		SW 25-10-5W4	Babet (1966), Scafe (1975)
B-2B (GrosVentre)	KBp (25' below 12A)	4.5		SW 25-10-5W4	Babet (1966), Scafe (1975)
B-3 (Irvine)	KBp	up to 10.9		NE 12-11-4W4, 17-11-3W4	Babet (1966), Scafe (1975)
B-4 (Irvine)	KBp	greater than or equal to13.0		SE 17-11-4W4	Babet (1966), Scafe (1975)
B-5 (Irvine)	KBp	up to 10		NW 1-11-3W4	Babet (1966), Scafe (1975)
B-6 (Irvine)	KBp	up to 11		E1/2 23-11-3W4, NE 25-11-3W4, 20-11-2W4, NW 30-11-2W4	Babet (1966), Scafe (1975)
B-7 (Irvine)	KBp	10 to 11		4-12-2W4, 15-12-2W4	Babet (1966), Scafe (1975)
B-8 (Dorothy-Trefoil)	KBp	up to 33	About 10 miles in extent	Sections 3-5,7-10 T27-17W4; Sections 12-14,22-24,26-27,33--34 T26-17W4; Sections 4-8,18 T26-16W4	Scafe (1975)
B-9 (Drumheller-Newcastle)	KHC	3 to 15		NW 2-29-20W4, NW 14-29-20W4, NE 34-28-20W4, SE 9-29-20W4	Babet (1966), Scafe (1975)
B-10 (Morrin)	KHC	3 to 15	Grades laterally into silty bentonite	NE 32-31-21W4	Babet (1966), Scafe (1975)11 (Sheerness)KHC4.5-W1/2 13-29-13W4Babet (1966), Scafe (1975)
B-12A (Rosalind)	KHC	5 to 8		Sections 31-32 T42-17W4; 25-43-18; Sections 5-8,18-19 T43-17W4	Scafe (1975)
B-12B (Rosalind)	KHC (10' below 12A)	8 to 10.5		as above	Babet (1966), Scafe (1975)
B-12C (Rosalind)	KHC (80' below 12B)	6 to 8		as above	Babet (1966), Scafe (1975)
B-12D (Rosalind)	KHC (80' below 12C)	4 to 6		as above	Babet (1966), Scafe (1975)
B-13 (Onoway)	KHC	up to 22.7		6-56-2W5, 7-56-2W5, W1/2 8-56-2W5, N1/2 18-56-2W5	Babet (1966), Scafe (1975)
B-14 (Onoway)	KHC	0.3 to 1		NE 27 -56-2W5	Babet (1966), Scafe (1975)

OCCURRENCE NUMBER	STRATIGRAPHIC HORIZON	THICKNESS (Feet)	UNUSUAL FEATURES	LOCATION(s)	SOURCE
B-15 (Onoway)	KHC	up to 31		NE 8-56-1W5, N1/2 9-56-1W5, NW 10-56-1W5, SW 15-56-1W5, E1/2 16-56-1W5	Babet (1966), Scafe (1975)
B-16 (Busby)	KHC	up to 52		Sections 19-22,27,29-30,36 T57-1W5; 25-57-2W5	Babet (1966), Scafe (1975)
B-17 (Lac la Nonne)	KHC	1.3 to 5.3		SW 11-57-2W5	Babet (1966), Scafe (1975)18 (Lac la Nonne)KHCno dataVery poor qualitySW 28-57-3W5Babet (1966), Scafe (1975)
B-19 (Busby)	KHC	2 to 14	Lens shaped and highly variable	NE 3-58-2W5, SE 7-58-2W5, SE 11-58-2W5	Babet (1966), Scafe (1975)
B-20 (Mcleod River)	TKP	6 to 8		NE 6-52-18W5	Scafe (1975)
B-21 (Kleskun Hills)	KWT	up to 4		Sections 15,21-23,27 T72-4W6	Babet(1966), Scafe (1975)
B-22 (Milk River Ridge)	KBp	1.5 to 2.0		9-4-19W4	Babet (1966)
B-23 (Walsh)	KBp	4 to 5		SW 28-11-1W4	Babet (1966)
B-24 (Little Bow River)	KBp	15		NW 14-12-20W4	Babet (1966)
B-25 (Rosebud)	KHC	3.5	Lens shaped deposit	SE 32-27-2-W4	Babet (1966)
B-26 (Rosedale)	KHC	0.5 to 1.0		SE 22-28-19W4	Babet (1966)
B-27 (Horseshoe Canyon)	KHC	20		26-28-21W4	Babet (1966)
B-28 (Bow River)	KBR	no data	High K2O (~4.65%) High Al2O3 (~ 27%) ;Low CaO (~ 0.85%)	T28-4W5	Babet (1966)
B-29 (Nevis)	KHC	no data	Very poor quality	SW 22-39-22W4, NW 15-39-22W4	Babet (1966)
B-30 (Camrose)	KHC	2 to 3		SE 21-46-20W4	Babet (1966)
B-31 (Smokey River)	KHC	no data		SW 35-69-4W6	Babet (1966)
B-32 (Smokey River)	KHC	no data		SW 2-70-3W6	Babet (1966)33 (Milk River)KBRup to 42-2-17W4ARC Min. Comm. Files
B-34 (St. Mary River)	KBp	less than 1.5		T6,7 R 22W4	ARC Min. Comm. Files
B-35 (Standard)	KHC?	2.5		T 24 R 2W4	ARC Min. Comm. Files
B-36 (Black Diamond)	TKP?	no data		T 20 R2W5	ARC Min. Comm. Files
B-37 (Keephills)	KHC	up to 1		31-50-3W5	ARC Min. Comm. Files
B-38 (Camrose)	KHC	up to 2		T 47 R 20W4	ARC Min. Comm. Files
B-39 (Edmonton)	KHC	up to 0.7		T 53 R 24W4	ARC Min. Comm. Files

OCCURRENCE NUMBER	STRATIGRAPHIC HORIZON	THICKNESS (Feet)	UNUSUAL FEATURES	LOCATION(s)	SOURCE
B-40 (Coalspur)	TKP? or KHC?	up to 16	about 20 miles in extent	33-48-21W5	Sanderson (1965)
B-41 (Nanton)	TKP?	up to 2	Volcanic glass or pumice	SE 36-13-2W5	Rutherford (1943) Allen (1944)
B-42 (Stavely)	TKP?	no data	Volcanic glass or pumice	T 14 R 27W4	Kelso (1944)
B-43 (Bickerdike)	TKP	100		6-52-18W5	Byrne (1955)
B-44 (Raley Creek	KHC?	15		21-4-23W4	Ower (1960)
B-45 (Well 10-20-36-16)	KBp	13		10-20-16-36	Habib (1981)
B-46 (Embarass River)	KC	?	K2O/Na2O = 2.5	33-48-21W5	Ritchie (1957)
B-47 (Strawberry Creek)	KB	?	Fe Montmorillonite Tuff	SW1/4 5-50-1W5	Ritchie (1957)
B-48 (Oldman River)	KB	?	K2O/Na2O = 1.92	T 7 R 28W4	Ritchie (1957)
B-49 (St. Mary River)	KBp	0.6	Garnet bearing Tuff	4-1-9-22W4	Nascimbene (1963)

Appendix 3. Reported bentonite marker beds greater than 3 metres thick (AGS coal database)

AGS Coal Database ID No.	ERCB Id No.	Company ID	Top	Base	Thickness (meters)	Meridian	Township	Range	Section	Marker Type
1004190	419515	21-82	55.25	58.4	3.15	4	14	23	22	FIRST BENTONITE
1004269	419523	24-82	185.2	188.7	3.5	4	15	23	5	FIRST BENTONITE
1004329	419531	27-82	288.5	292.3	3.8	4	15	24	36	FIRST BENTONITE
1004565	388827	13-81	184.65	189.3	4.65	4	16	23	32	FIRST BENTONITE
1004970	419499	14-82	141	145	4	4	17	22	31	FIRST BENTONITE
1004971	388793	08-81	94	97.7	3.7	4	17	23	1	FIRST BENTONITE
1004973	419390	04-81	152.6	157.4	4.8	4	17	23	9	FIRST BENTONITE
1004975	463828	36-82	82.9	91.8	8.9	4	17	23	11	FIRST BENTONITE
1004976	419416	VU6-82	91.3	96.7	5.4	4	17	23	12	FIRST BENTONITE
1004977	463794	32-82	103.8	107	3.2	4	17	23	12	FIRST BENTONITE
1004978	419408	VU5-82	103.3	108.6	5.3	4	17	23	14	FIRST BENTONITE
1004979	463810	35-82	122.7	126.4	3.7	4	17	23	16	FIRST BENTONITE
1004980	463844	39-82	125.3	128.7	3.4	4	17	23	16	FIRST BENTONITE
1004982	419457	10-82	207.2	210.8	3.6	4	17	23	19	FIRST BENTONITE
1004984	419440	VU9-82	170.5	174.3	3.8	4	17	23	20	FIRST BENTONITE
1004985	463851	40-82	146.4	150.6	4.2	4	17	23	21	FIRST BENTONITE
1004987	463836	38-82	114.7	118.3	3.6	4	17	23	23	FIRST BENTONITE
1004988	463869	41-82	114.3	117.5	3.2	4	17	23	23	FIRST BENTONITE
1004990	463885	43-82	131	134.9	3.9	4	17	23	26	FIRST BENTONITE
1004992	419473	12-82	211	215	4	4	17	23	32	FIRST BENTONITE
1004994	463901	45-82	163.4	167.4	4	4	17	23	33	FIRST BENTONITE
1004995	419481	13-82	153.2	156.3	3.1	4	17	23	34	FIRST BENTONITE
1004996	463893	44-82	169.9	173.2	3.3	4	17	23	34	FIRST BENTONITE
1050001	463919	46-82	138.8	144.3	5.5	4	17	23	35	FIRST BENTONITE
1050003	388785	SH7-81	235.3	238.7	3.4	4	17	24	1	FIRST BENTONITE
1050004	463729	26-82	299.8	304.6	4.8	4	17	24	3	FIRST BENTONITE
1004997	388777	SH6-81	319.5	323.7	4.2	4	17	24	9	FIRST BENTONITE
1004998	419382	VU3-82	198.2	202.3	4.1	4	17	24	12	FIRST BENTONITE
1004999	423541	20-81	236.8	240.8	4	4	17	24	14	FIRST BENTONITE
1005000	463711	24-82	297	300.5	3.5	4	17	24	15	FIRST BENTONITE
1005001	463778	34-83	289.2	293.2	4	4	17	24	15	FIRST BENTONITE
1005002	463703	23-82	319.7	322.8	3.1	4	17	24	18	FIRST BENTONITE
1005003	463760	33-83	341.4	347	5.6	4	17	24	18	FIRST BENTONITE
1005004	463786	35-83	308	312.8	4.8	4	17	24	20	FIRST BENTONITE
1005005	423558	18-81	276	279.5	3.5	4	17	24	22	FIRST BENTONITE
1005006	463745	28-82	270.4	275	4.6	4	17	24	27	FIRST BENTONITE
1005007	463695	22-82	297.6	301.9	4.3	4	17	24	29	FIRST BENTONITE
1005008	388769	SH4-81	286.7	291	4.3	4	17	24	30	FIRST BENTONITE
1005010	463752	30-82	299.1	303	3.9	4	17	24	32	FIRST BENTONITE
1005011	423566	17-81	255.8	260.1	4.3	4	17	24	35	FIRST BENTONITE
1005012	423574	19-81	356.6	361	4.4	4	17	25	12	FIRST BENTONITE
1005013	423582	16-81	310.8	315.4	4.6	4	17	25	36	FIRST BENTONITE
1005014	463687	21-82	338.6	343.2	4.6	4	17	25	36	FIRST BENTONITE
1005136	36590	18	82.3	86.7	4.4	4	18	22	4	FIRST BENTONITE
1005137	370353	11-80	122.3	126.7	4.6	4	18	22	7	FIRST BENTONITE
1005139	36608	17	17.4	23.5	6.1	4	18	22	14	FIRST BENTONITE
1005140	36616	14	152.5	157.1	4.6	4	18	22	19	FIRST BENTONITE
1005141	370361	10A-80	130.4	133.7	3.3	4	18	22	19	FIRST BENTONITE
1005143	36582	19	91.2	94.8	3.6	4	18	22	21	FIRST BENTONITE
1005144	464198	117-82	167.1	173.6	6.5	4	18	22	30	FIRST BENTONITE
1005145	370379	09-80	145	149.6	4.6	4	18	22	31	FIRST BENTONITE
1005150	463935	50-82	196.4	200.5	4.1	4	18	23	5	FIRST BENTONITE
1005151	419465	11-82	201.1	208.4	7.3	4	18	23	6	FIRST BENTONITE
1005152	463943	52-82	253	257.6	4.6	4	18	23	7	FIRST BENTONITE
1005154	380162	81-45	193.2	197.6	4.4	4	18	23	8	FIRST BENTONITE
1005157	380147	81-35	137	142	5	4	18	23	14	FIRST BENTONITE
1005158	463950	53-82	186.4	190.5	4.1	4	18	23	16	FIRST BENTONITE

AGS Coal Database ID No.	ERCB Id No.	Company ID	Top	Base	Thickness (meters)	Meridian	Township	Range	Section	Marker Type
1005159	464172	82-84	221.2	224.7	3.5	4	18	23	16	FIRST BENTONITE
1005160	463976	57-82	193.9	197.6	3.7	4	18	23	17	FIRST BENTONITE
1005164	463984	58-82	219.7	224.8	5.1	4	18	23	19	FIRST BENTONITE
1005166	464149	82-70	196.2	199.8	3.6	4	18	23	21	FIRST BENTONITE
1005167	464164	82-78	174.8	180	5.2	4	18	23	22	FIRST BENTONITE
1005168	463968	54-82	171.4	175.6	4.2	4	18	23	23	FIRST BENTONITE
1005169	464180	82-86	186.6	191.9	5.3	4	18	23	23	FIRST BENTONITE
1005172	464123	82-65	215.8	219.1	3.3	4	18	23	27	FIRST BENTONITE
1005173	464156	82-72	190.6	195.2	4.6	4	18	23	27	FIRST BENTONITE
1005174	464131	82-68	210.4	216.4	6	4	18	23	28	FIRST BENTONITE
1005175	380071	81-20	246.8	250.5	3.7	4	18	23	31	FIRST BENTONITE
1005176	464024	82-43	208.2	212	3.8	4	18	23	33	FIRST BENTONITE
1005177	464099	82-55	224.8	229.9	5.1	4	18	23	33	FIRST BENTONITE
1005179	464032	82-45	186	189.2	3.2	4	18	23	34	FIRST BENTONITE
1005180	464073	82-51	189.1	193.8	4.7	4	18	23	34	FIRST BENTONITE
1005181	380097	81-23C	180	184.4	4.4	4	18	23	35	FIRST BENTONITE
1005183	380139	81-32	234	239.5	5.5	4	18	24	12	FIRST BENTONITE
1005184	388744	SH1-81	320.7	325.7	5	4	18	24	16	FIRST BENTONITE
1005185	380154	81-44	326.2	333	6.8	4	18	24	24	FIRST BENTONITE
1005186	380089	81-22	279.3	284	4.7	4	18	24	35	FIRST BENTONITE
1005424	38919	30-77	32.61	35.81	3.2	4	19	21	10	FIRST BENTONITE
1005446	38901	17-77	44.2	47.24	3.04	4	19	21	35	FIRST BENTONITE
1005448	39115	9	108.2	112.9	4.7	4	19	22	3	FIRST BENTONITE
1005449	39123	9-A	108	113.2	5.2	4	19	22	3	FIRST BENTONITE
1005451	370346	13-80	119.1	123.4	4.3	4	19	22	4	FIRST BENTONITE
1005452	39107	16	170.6	175.3	4.7	4	19	22	5	FIRST BENTONITE
1005454	380022	81-11	235.4	239	3.6	4	19	22	7	FIRST BENTONITE
1005456	370395	06-80	160.9	165.4	4.5	4	19	22	8	FIRST BENTONITE
1005457	464206	118-82	189.2	193.5	4.3	4	19	22	8	FIRST BENTONITE
1005458	39164	1	120.5	126.3	5.8	4	19	22	10	FIRST BENTONITE
1005459	380170	81-46	160.7	164.8	4.1	4	19	22	16	FIRST BENTONITE
1005460	39099	20	209	213.2	4.2	4	19	22	18	FIRST BENTONITE
1005461	370387	07-80	210.7	215.2	4.5	4	19	22	18	FIRST BENTONITE
1005462	370403	5A-80	164.2	167.8	3.6	4	19	22	20	FIRST BENTONITE
1005464	39024	50-76	109.42	117.65	8.23	4	19	22	21	FIRST BENTONITE
1005467	370338	3	221.6	227	5.4	4	19	22	30	FIRST BENTONITE
1005468	39156	2	123.7	128	4.3	4	19	22	33	FIRST BENTONITE
1005470	39149	3	61.4	65.8	4.4	4	19	22	35	FIRST BENTONITE
1005472	39180	BH79-3	231.5	236	4.5	4	19	23	3	FIRST BENTONITE
1005474	380048	81-13	282.4	286.7	4.3	4	19	23	9	FIRST BENTONITE
1005476	380220	81-17C	236.4	240	3.6	4	19	23	10	FIRST BENTONITE
1005477	380030	81-12	275.4	280.7	5.3	4	19	23	14	FIRST BENTONITE
1005478	464040	82-46	274	277.7	3.7	4	19	23	18	FIRST BENTONITE
1005480	39198	BH79-2	376	382	6	4	19	23	20	FIRST BENTONITE
1005482	379990	81-06	343.9	349	5.1	4	19	23	23	FIRST BENTONITE
1005483	370320	4	268.5	273.2	4.7	4	19	23	24	FIRST BENTONITE
1005484	380006	81-07	279.8	284	4.2	4	19	23	24	FIRST BENTONITE
1005485	379982	81-05	345	349.2	4.2	4	19	23	28	FIRST BENTONITE
1005487	39206	BH79-1	301.8	306.7	4.9	4	19	23	35	FIRST BENTONITE
1005491	380055	81-14	312.6	316.6	4	4	19	24	7	FIRST BENTONITE
1005492	380063	81-16	279.5	283.1	3.6	4	19	24	12	FIRST BENTONITE
1005493	464065	82-48	273.6	280.2	6.6	4	19	24	13	FIRST BENTONITE
1005494	380212	19-81	394.7	398.7	4	4	19	24	20	FIRST BENTONITE
1005566	423806	10-82	32.9	36.7	3.8	4	20	21	8	FIRST BENTONITE
1005569	423814	11-82	19.75	23.5	3.75	4	20	21	12	FIRST BENTONITE
1005571	423822	13-82	46.5	50.8	4.3	4	20	21	16	FIRST BENTONITE
1005953	424085	97-82C	75.6	79	3.4	4	21	21	33	FIRST BENTONITE
1005954	461657	109-83	56.24	59.4	3.16	4	21	21	33	FIRST BENTONITE
1005955	464628	134-84	63.7	68.3	4.6	4	21	21	33	FIRST BENTONITE
1005958	464602	13584C	62	66.2	4.2	4	21	21	34	FIRST BENTONITE
1005960	464610	136-84	64.4	69.4	5	4	21	21	35	FIRST BENTONITE
1005993	385054	48-80	10	14	4	4	22	20	7	FIRST BENTONITE
1005994	385062	48-80C	10.6	14.5	3.9	4	22	20	7	FIRST BENTONITE
1006012	423855	96-82	68.9	73.1	4.2	4	22	20	19	FIRST BENTONITE

AGS Coal Database ID No.	ERCB Id No.	Company ID	Top	Base	Thickness (meters)	Meridian	Township	Range	Section	Marker Type
1006013	461889	132-83	72.8	77.4	4.6	4	22	20	19	FIRST BENTONITE
1006014	512517	174-85	64.2	69	4.8	4	22	20	19	FIRST BENTONITE
1006038	464644	14084C	92.2	96	3.8	4	22	20	30	FIRST BENTONITE
1006041	464669	142-84	90.5	94.4	3.9	4	22	20	31	FIRST BENTONITE
1006048	512558	178-85	53.8	59.2	5.4	4	22	21	1	FIRST BENTONITE
1006049	423871	98-82	43.9	49	5.1	4	22	21	2	FIRST BENTONITE
1006050	464677	144-84	76.5	82	5.5	4	22	21	2	FIRST BENTONITE
1006051	464685	14584C	70.2	74.4	4.2	4	22	21	2	FIRST BENTONITE
1006052	464693	14684C	91	96	5	4	22	21	2	FIRST BENTONITE
1006053	464719	148-84	79.4	93.8	4.4	4	22	21	2	FIRST BENTONITE
1006054	423897	100-82	90.85	94	3.15	4	22	21	3	FIRST BENTONITE
1006055	461665	110-83	71.6	75.2	3.6	4	22	21	3	FIRST BENTONITE
1006056	512541	177-85	87.4	91.4	4	4	22	21	3	FIRST BENTONITE
1006057	512566	179-85	104.2	109	4.8	4	22	21	3	FIRST BENTONITE
1006058	461673	111-83	134	138.6	4.6	4	22	21	4	FIRST BENTONITE
1006059	464727	149-84	109.4	115.4	6	4	22	21	4	FIRST BENTONITE
1006061	423921	101-82	158.3	161.5	3.2	4	22	21	9	FIRST BENTONITE
1006062	461681	112-83	112.2	116.2	4	4	22	21	9	FIRST BENTONITE
1006063	464735	150-84	152.2	157.4	5.2	4	22	21	9	FIRST BENTONITE
1006064	464743	152-84	150	155.8	5.8	4	22	21	9	FIRST BENTONITE
1006065	461707	11483C	138.8	142.6	3.8	4	22	21	10	FIRST BENTONITE
1006066	464701	147-84	119.4	124	4.6	4	22	21	10	FIRST BENTONITE
1006067	464750	153-84	119	122	3	4	22	21	10	FIRST BENTONITE
1006068	464768	154-84	147.8	153.2	5.4	4	22	21	10	FIRST BENTONITE
1006069	423889	99-82	71.15	74.85	3.7	4	22	21	11	FIRST BENTONITE
1006070	423913	102-82	121.1	124.4	3.3	4	22	21	11	FIRST BENTONITE
1006072	461723	116-83	65	69.5	4.5	4	22	21	11	FIRST BENTONITE
1006073	464776	155-84	111	115.4	4.4	4	22	21	11	FIRST BENTONITE
1006074	385104	51-80	28.5	34	5.5	4	22	21	12	FIRST BENTONITE
1006075	385112	51-80C	29.8	33.25	3.45	4	22	21	12	FIRST BENTONITE
1006077	423905	103-82	78.59	82.5	3.91	4	22	21	12	FIRST BENTONITE
1006078	461731	117-83	66.8	70.2	3.4	4	22	21	12	FIRST BENTONITE
1006080	464792	157-84	52.6	60.8	8.2	4	22	21	12	FIRST BENTONITE
1006081	461749	11883C	75	80.6	5.6	4	22	21	13	FIRST BENTONITE
1006082	423830	105-82	113.9	117.25	3.35	4	22	21	14	FIRST BENTONITE
1006083	461756	11983C	129.4	133.2	0.8	4	22	21	14	FIRST BENTONITE
1006084	464800	15884C	114.2	118	3.8	4	22	21	14	FIRST BENTONITE
1006085	464818	159-84	92.4	97.2	4.8	4	22	21	14	FIRST BENTONITE
1006086	512574	180-85	126	130	4	4	22	21	14	FIRST BENTONITE
1006087	512582	181-85	144	148.4	4.4	4	22	21	14	FIRST BENTONITE
1006088	423954	106-82	143.6	147.5	3.9	4	22	21	15	FIRST BENTONITE
1006089	461764	120-83	153.6	158	4.4	4	22	21	15	FIRST BENTONITE
1006090	464826	160-84	156.8	161.2	4.4	4	22	21	15	FIRST BENTONITE
1006091	464834	161-84	156.4	161	4.6	4	22	21	15	FIRST BENTONITE
1006092	461699	113-83	162.6	167.8	5.2	4	22	21	17	FIRST BENTONITE
1006093	461772	121-83	157.4	162	4.6	4	22	21	17	FIRST BENTONITE
1006094	461780	122-83	141.4	146.2	4.8	4	22	21	18	FIRST BENTONITE
1006096	461798	123-83	147.2	152	4.8	4	22	21	22	FIRST BENTONITE
1006097	464859	164-84	149.4	153.6	4.2	4	22	21	22	FIRST BENTONITE
1006099	512590	182-85	129.2	134.8	5.6	4	22	21	23	FIRST BENTONITE
1006100	514968	183-85	140	144	4	4	22	21	23	FIRST BENTONITE
1006101	514976	184-85	107.4	122.2	4.8	4	22	21	23	FIRST BENTONITE
1006104	423947	107-82	82	85.3	3.3	4	22	21	24	FIRST BENTONITE
1006106	514984	185-85	94.2	98.2	4	4	22	21	24	FIRST BENTONITE
1006107	461814	125-83	125.8	131	5.2	4	22	21	25	FIRST BENTONITE
1006108	461830	127-83	106.4	111	4.6	4	22	21	25	FIRST BENTONITE
1006110	464883	167-84	98.3	104.3	6	4	22	21	25	FIRST BENTONITE
1006111	514992	186-85	100.6	105.8	5.2	4	22	21	25	FIRST BENTONITE
1006112	464891	169-84	123.6	129.2	5.6	4	22	21	26	FIRST BENTONITE
1006113	461806	12483C	134.6	138.8	4.2	4	22	21	27	FIRST BENTONITE
1006114	461855	129-83	140.6	144.9	4.3	4	22	21	27	FIRST BENTONITE
1006115	464842	163-84	145.8	152.2	6.4	4	22	21	27	FIRST BENTONITE
1006117	461863	130-83	140.6	145	4.4	4	22	21	33	FIRST BENTONITE
1006118	464917	171-84	103.6	107.2	3.6	4	22	21	34	FIRST BENTONITE

AGS Coal Database ID No.	ERCB Id No.	Company ID	Top	Base	Thickness (meters)	Meridian	Township	Range	Section	Marker Type
1006120	461848	128-83	128.4	132.9	4.5	4	22	21	35	FIRST BENTONITE
1006121	464925	172-84	108.1	111.4	3.3	4	22	21	36	FIRST BENTONITE
1006164	464933	173-84	119	124.2	0.2	4	23	20	6	FIRST BENTONITE
1006173	41202	065-76	35.97	41.61	5.64	4	23	20	20	FIRST BENTONITE
1006175	41236	09-77	39.01	42.06	3.05	4	23	20	20	FIRST BENTONITE
1006182	41228	H4-77	49.53	54.89	5.36	4	23	20	30	FIRST BENTONITE
1006183	41277	H4-77C	49.83	55.47	5.64	4	23	20	30	FIRST BENTONITE
1006185	41269	H12-77	42.67	48.59	5.92	4	23	20	31	FIRST BENTONITE
1006187	463398	H22-83	49.8	53.2	3.4	4	23	20	32	FIRST BENTONITE
1006190	41251	H11-77	79.25	82.3	3.05	4	23	20	34	FIRST BENTONITE
1006192	463406	H23-83	103.2	106.2	3	4	23	20	34	FIRST BENTONITE
1006194	41285	18-78	82.7	86.5	3.8	4	23	20	36	FIRST BENTONITE
1006202	41418	H5-77	39.47	42.67	3.2	4	23	21	24	FIRST BENTONITE
1006204	463430	H27-83	64.4	69	4.6	4	23	21	30	FIRST BENTONITE
1006205	463422	H26-83	71.2	76.3	5.1	4	23	21	33	FIRST BENTONITE
1006206	41434	H7-77	57.91	63.58	5.67	4	23	21	34	FIRST BENTONITE
1006208	41442	H13-77	62.79	67.67	4.88	4	23	21	35	FIRST BENTONITE
1006209	41459	21778C	56.75	61	4.25	4	23	21	36	FIRST BENTONITE
1006227	41749	H17-77	92.96	96.62	3.66	4	24	19	7	FIRST BENTONITE
1006243	41772	S-216	51.05	56.69	5.64	4	24	20	4	FIRST BENTONITE
1006246	41939	218C78	79	82.1	3.1	4	24	20	9	FIRST BENTONITE
1006251	41905	H3-77	63.25	67.42	4.17	4	24	20	18	FIRST BENTONITE
1006257	41855	S-220	82.3	85.34	3.04	4	24	20	30	FIRST BENTONITE
1006259	42044	H14-77	63.09	68.12	5.03	4	24	21	1	FIRST BENTONITE
1006260	42036	H-8-77	68.88	73.46	4.58	4	24	21	2	FIRST BENTONITE
1006261	463455	H29-83	70.6	76.6	6	4	24	21	9	FIRST BENTONITE
1006264	42051	H15-77	82.42	85.5	3.08	4	24	21	13	FIRST BENTONITE
1006294	463521	RF2-83	143.8	149	5.2	4	24	22	34	FIRST BENTONITE
1006297	468496	R32-84	171.5	175.1	3.6	4	24	23	14	FIRST BENTONITE
1006301	463539	RF4-83	189.2	193.2	4	4	24	23	23	FIRST BENTONITE
1006385	463513	RF1-83	177.5	180.5	3	4	25	22	5	FIRST BENTONITE
1006408	463547	R8-83C	155	158.8	3.8	4	25	22	12	FIRST BENTONITE
1006422	468520	R36-84	227	233.4	6.4	4	25	22	18	FIRST BENTONITE
1006423	468504	R38-84	219.3	224.3	5	4	25	22	20	FIRST BENTONITE
1006424	463554	R10-83	243.8	249.6	5.8	4	25	22	23	FIRST BENTONITE
1006426	517557	3-85C	260.8	266.9	6.1	4	25	22	27	FIRST BENTONITE
1006483	517623	16-85	147.6	150.6	3	4	26	21	7	FIRST BENTONITE
1006499	517755	45-85	124.8	129.8	5	4	26	21	31	FIRST BENTONITE
1006505	517649	23-85	140.6	144.4	3.8	4	26	22	13	FIRST BENTONITE
1006510	517664	25-85	182.2	186.8	4.6	4	26	22	21	FIRST BENTONITE
1006512	517656	24-85	183	186.6	3.6	4	26	22	23	FIRST BENTONITE
1006514	517631	18-85	110	113.8	3.8	4	26	22	24	FIRST BENTONITE
1006517	468553	R43-84	184.2	187.2	3	4	26	22	27	FIRST BENTONITE
1006518	468546	R42-84	159.8	162.8	3	4	26	22	29	FIRST BENTONITE
1006525	463588	R19-83	171.8	178.3	6.5	4	26	23	11	FIRST BENTONITE
1006528	468561	R46-84	157.4	162.4	5	4	26	23	25	FIRST BENTONITE
1006829	517789	55-85	140.4	144	3.6	4	27	21	5	FIRST BENTONITE
1006830	468579	R47-84	87.8	92	4.2	4	27	21	6	FIRST BENTONITE
1006840	463596	R20-83	136.2	139.8	3.6	4	27	22	2	FIRST BENTONITE
1006841	468488	20-84C	136.7	140.5	3.8	4	27	22	2	FIRST BENTONITE
1006844	517722	40-85	161.8	164.8	3	4	27	22	5	FIRST BENTONITE
1006848	463604	R21-83	193.6	197	3.4	4	27	22	8	FIRST BENTONITE
1006849	468587	R48-84	111	114.6	3.6	4	27	22	9	FIRST BENTONITE
1006851	463612	R22-83	175.6	180	4.4	4	27	22	15	FIRST BENTONITE
1007866	463620	R26-83	183	188	5	4	28	22	4	FIRST BENTONITE
1025673	428011	82-46	12.19	17.13	4.94	5	46	19	13	FIRST BENTONITE
1025675	428037	82-48	64.92	68.37	3.45	5	46	19	13	FIRST BENTONITE
1025876	246298	1746	97.48	103.85	6.37	5	46	19	33	FIRST BENTONITE
1026341	448316	3039	61.26	65.38	4.12	5	47	19	3	FIRST BENTONITE
1026864	447318	2346	40.54	44.2	3.66	5	47	19	7	FIRST BENTONITE
1026888	449090	3253	51.36	54.68	3.32	5	47	19	7	FIRST BENTONITE
1027410	456871	994	69.49	70.57	3.5	5	47	19	9	FIRST BENTONITE
1028630	460840	3742	15.33	18.38	3.05	5	47	20	24	FIRST BENTONITE

Appendix 4. Summary of indicator mineral analyses for Alberta

Table A. southern Alberta

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
1	'91TCA-3019'	1641	CD1	CPX_05_UNKNOWN	0.07	0.88	2.17	17.93	23.44	52.68	0.88	0.12	0.06	0.01	98.23	n/a	n/a		
1	'91TCA-3019'	1621	'Garnet'	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.12	18.09	12.54	6.43	39.06	22.12	0.00	0.44	0.01	98.95	n/a	n/a		
1	'91TCA-3019'	1606	'Almandine'	G_05_MAGNESIAN_ALMANDINE	0.06	0.04	25.06	7.43	6.12	37.30	21.11	0.00	1.10	0.01	98.22	n/a	n/a		
1	'91TCA-3019'	1614	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.15	0.03	23.59	7.89	7.61	37.58	21.28	0.00	0.39	0.01	98.52	n/a	n/a		
1	'91TCA-3019'	1622	'Almandine'	G_05_MAGNESIAN_ALMANDINE	0.15	0.10	25.12	7.37	6.37	37.81	21.32	0.00	0.79	0.00	99.03	n/a	n/a		
1	'91TCA-3019'	1623	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.11	0.03	23.06	13.02	1.35	38.71	22.28	0.00	0.29	0.01	98.85	n/a	n/a		
1	'91TCA-3019'	1636	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.10	0.05	23.90	12.32	1.36	38.54	22.03	0.00	0.63	0.00	98.93	n/a	n/a		
2	'91TCA-3020'	327		CPX_02_UNKNOWN	0.06	0.74	5.65	15.47	22.54	51.60	1.72	0.64	0.17	0.00	98.59	n/a	n/a		
2	'91TCA-3020'	328		CPX_05_UNKNOWN	0.12	0.94	3.51	16.15	23.18	51.78	2.04	0.67	0.12	0.00	98.51	n/a	n/a		
2	'91TCA-3020'	306	G3	G_03_CALCIC_PYROPE_ALMANDINE	0.36	0.10	20.21	7.32	11.30	37.84	21.55	0.04	0.57	0.01	99.29	n/a	n/a		
2	'91TCA-3020'	343	'Chromite'	PICRO_CHROMITE	0.04	48.60	18.62	11.89	0.02	0.07	19.46	0.00	0.29	0.01	99.25	707	1366	0.09	0.17
2	'91TCA-3020'	360	'Chromite'	PICRO_CHROMITE	0.05	52.42	18.70	11.78	0.01	0.11	15.59	0.00	0.29	0.01	99.18	786	1044	0.10	0.13
2	'91TCA-3020'	363	'Chromite'	PICRO_CHROMITE	0.04	45.18	19.56	11.96	0.05	0.07	21.47	0.00	0.25	0.01	98.87	786	1526	0.10	0.19
2	'91TCA-3020'	370	'Chromite'	PICRO_CHROMITE	3.09	40.79	29.42	11.59	0.01	0.12	13.32	0.00	0.24	0.00	98.93	1965	803	0.25	0.10
2	'91TCA-3020'	372	'Chromite'	PICRO_CHROMITE	0.10	51.41	21.92	10.05	0.00	0.09	15.48	0.00	0.34	0.01	99.64	393	1607	0.05	0.20
2	'91TCA-3020'	325	'Cr-grossular'	UNKNOWN	0.12	7.44	20.43	0.06	33.65	34.23	0.40	0.00	0.04	n/a	96.37	n/a	n/a		
2	'91TCA-3020'	366	'Magnesiochromite'	UNKNOWN	0.08	45.38	13.72	14.55	0.00	0.11	24.68	0.00	0.24	0.01	99.01	864	1125	0.11	0.14
3	'91TCA-3021'	1648	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.07	0.03	21.68	12.11	3.71	38.57	22.00	0.00	0.33	0.00	98.50	n/a	n/a		
4	'91TCA-3022'	1680	CD1	CPX_02_UNKNOWN	0.09	0.68	4.49	15.03	22.34	51.10	3.41	0.68	0.13	0.01	97.95	n/a	n/a		
4	'91TCA-3022'	1676	G1	G_02_HIGH_TITANIUM_PYROPE	0.90	1.35	7.95	21.63	4.74	40.61	20.92	0.05	0.29	0.01	98.44	n/a	n/a		
4	'91TCA-3022'	1673	G3	G_03_CALCIC_PYROPE_ALMANDINE	0.27	0.09	23.35	8.94	6.10	37.21	20.96	0.02	0.58	0.00	97.52	n/a	n/a		
5	'91TCA-3023'	1744	CD1	CPX_02_UNKNOWN	0.07	0.70	3.59	16.82	22.43	52.63	1.26	0.50	0.10	0.01	98.10	n/a	n/a		
5	'91TCA-3023'	1736	'Garnet'	G_03_CALCIC_PYROPE_ALMANDINE	0.13	0.09	22.35	9.20	6.21	37.82	21.68	0.00	0.79	0.00	98.27	n/a	n/a		
5	'91TCA-3023'	1746	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.08	0.10	24.54	8.03	5.92	37.20	21.33	0.00	0.67	0.00	97.87	n/a	n/a		
8	'91TCA-3026'	1709	'Garnet'	G_03_CALCIC_PYROPE_ALMANDINE	0.10	0.05	22.64	7.94	7.84	37.67	21.54	0.00	0.49	0.00	98.27	n/a	n/a		
8	'91TCA-3026'	1712	G9	G_09_CHROME_PYROPE	0.21	5.08	7.34	20.60	4.89	40.66	19.63	0.04	0.43	0.01	98.88	n/a	n/a		
9	'91TCA-3027'	1762	CD1	CPX_02_DIOPSIDE	0.10	0.90	4.82	15.11	20.73	52.07	1.60	1.91	0.12	0.01	97.36	n/a	n/a		
9	'91TCA-3027'	1758	G3	G_03_CALCIC_PYROPE_ALMANDINE	0.38	0.11	21.53	7.53	9.20	38.06	21.23	0.03	0.68	0.00	98.75	n/a	n/a		
9	'91TCA-3027'	1753	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.15	0.05	24.57	8.18	6.21	37.89	21.40	0.00	0.55	0.00	99.00	n/a	n/a		
9	'91TCA-3027'	1766	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.16	0.11	23.56	9.51	5.06	37.45	21.28	0.00	0.90	0.01	98.03	n/a	n/a		
10	'91TCA-3028'	1792	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.22	0.04	23.81	7.07	7.84	37.04	21.17	0.00	0.66	0.01	97.85	n/a	n/a		
11	'91TCA-3029'	1851	CD1	CPX_02_DIOPSIDE	0.08	0.64	4.66	16.25	20.22	51.68	1.60	0.56	0.12	0.06	95.81	n/a	n/a		
11	'91TCA-3029'	1849	'Diopside'	CPX_02_UNKNOWN	0.05	0.22	5.82	17.69	19.94	52.40	0.90	0.36	0.17	0.01	97.55	n/a	n/a		
11	'91TCA-3029'	1850	'Diopside'	CPX_02_UNKNOWN	0.05	0.04	4.43	15.50	23.96	52.04	0.65	0.70	0.17	0.00	97.54	n/a	n/a		
11	'91TCA-3029'	1871	'Diopside'	CPX_02_UNKNOWN	0.04	0.03	4.91	14.83	23.71	52.03	1.35	0.89	0.55	0.01	98.34	n/a	n/a		
11	'91TCA-3029'	1852	'Na-diopside'	CPX_04_UNKNOWN	0.39	0.06	5.92	14.12	22.33	49.73	2.56	1.59	0.03	0.00	96.73	n/a	n/a		
11	'91TCA-3029'	1820	'Garnet'	G_03_CALCIC_PYROPE_ALMANDINE	0.09	0.07	17.16	13.86	5.51	38.97	22.46	0.00	0.43	0.00	98.55	n/a	n/a		
11	'91TCA-3029'	1844	'Garnet'	G_03_CALCIC_PYROPE_ALMANDINE	0.11	0.04	20.87	6.36	11.30	37.51	21.45	0.00	0.52	0.00	98.16	n/a	n/a		
11	'91TCA-3029'	1816	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.08	0.03	23.29	10.02	4.76	36.07	20.90	0.00	0.70	0.01	95.85	n/a	n/a		
11	'91TCA-3029'	1831	'Garnet'	G_05_MAGNESIAN_ALMANDINE	0.15	0.09	23.63	8.37	6.68	37.19	21.29	0.00	0.54	0.01	97.94	n/a	n/a		

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
11	'91TCA-3029'	1846	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.08	0.06	23.81	8.23	6.43	37.58	21.36	0.00	0.56	0.01	98.11	n/a	n/a		
11	'91TCA-3029'	1857	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.11	0.08	22.87	13.06	1.38	37.12	21.81	0.00	0.65	0.01	97.08	n/a	n/a		
11	'91TCA-3029'	1859	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.08	0.04	22.21	13.20	1.45	38.21	22.11	0.00	0.56	0.00	97.86	n/a	n/a		
12	'91TCA-3030'	585	‘Chromite’	CHROMITE	0.31	51.41	31.96	5.35	0.02	0.08	8.16	0.03	0.48	0.01	98.33	786	3455	0.10	0.43
12	'91TCA-3030'	661		CPX_01_UNKNOWN	0.09	0.69	6.69	18.64	11.70	49.81	8.02	0.96	0.12	0.00	96.72	n/a	n/a		
12	'91TCA-3030'	665	‘Diopside’	CPX_02_UNKNOWN	0.05	0.05	5.84	15.11	23.23	51.84	1.09	0.82	0.27	0.00	98.30	n/a	n/a		
12	'91TCA-3030'	667	‘Diopside’	CPX_02_UNKNOWN	0.07	0.23	5.08	15.56	23.10	53.40	0.51	0.97	0.21	0.00	99.13	n/a	n/a		
12	'91TCA-3030'	473	G3	G_03_CALCIC_PYROPE_ALMANDINE	0.28	0.06	22.85	9.16	7.03	37.44	21.39	0.01	0.47	0.01	98.69	n/a	n/a		
12	'91TCA-3030'	375	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.16	0.05	21.34	8.64	8.78	38.01	21.93	0.02	0.59	0.00	99.52	n/a	n/a		
12	'91TCA-3030'	377	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.08	22.36	8.24	8.38	37.68	21.60	0.00	0.59	0.01	99.08	n/a	n/a		
12	'91TCA-3030'	380	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.19	0.06	22.52	8.34	8.16	37.82	21.65	0.00	0.57	0.00	99.31	n/a	n/a		
12	'91TCA-3030'	389	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.14	0.04	24.10	8.49	6.67	37.69	21.65	0.00	0.54	0.00	99.32	n/a	n/a		
12	'91TCA-3030'	437	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.14	0.04	24.39	8.11	6.80	37.76	21.36	0.01	0.73	0.00	99.34	n/a	n/a		
12	'91TCA-3030'	443	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.09	0.06	24.26	8.34	6.63	37.48	21.43	0.00	0.62	0.00	98.91	n/a	n/a		
12	'91TCA-3030'	446	‘Almandine’	G_05_MAGNESIAN_ALMANDINE	0.14	0.05	25.32	7.45	7.09	37.62	21.29	0.00	0.55	0.00	99.51	n/a	n/a		
12	'91TCA-3030'	448	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.18	0.09	24.90	8.41	5.96	37.83	21.35	0.00	0.60	0.00	99.32	n/a	n/a		
12	'91TCA-3030'	481	‘Almandine’	G_05_MAGNESIAN_ALMANDINE	0.13	0.03	25.76	7.30	6.84	37.12	21.24	0.00	0.62	0.01	99.04	n/a	n/a		
12	'91TCA-3030'	543	‘Chromite’	PICRO_CHROMITE	1.14	46.17	22.88	11.65	0.03	0.16	16.23	0.00	0.27	0.01	98.82	1650	643	0.21	0.08
12	'91TCA-3030'	581	‘Chromite’	PICRO_CHROMITE	0.11	46.32	17.95	11.49	0.01	0.08	22.12	0.01	0.32	0.00	98.76	550	2250	0.07	0.28
12	'91TCA-3030'	411	‘Jadeite’	UNKNOWN	0.03	0.01	0.14	0.02	7.92	57.18	25.64	6.67	0.01	0.48	97.62	n/a	n/a		
12	'91TCA-3030'	4118	‘Mg-ilmenite’	UNKNOWN	51.59	0.82	27.20	13.79	0.03	0.09	0.55	0.00	0.27	0.01	94.34	n/a	n/a		
12	'91TCA-3030'	4137	‘Chromite’	UNKNOWN	0.12	38.97	22.33	8.80	0.02	0.11	24.37	0.01	0.34	n/a	95.49	393	2973	0.05	0.37
13	'91TCA-3031'	1959	‘Diopside’	CPX_02_UNKNOWN	0.04	0.17	5.59	15.67	22.88	52.01	0.95	0.36	0.18	0.00	97.85	n/a	n/a		
13	'91TCA-3031'	1960	‘Diopside’	CPX_02_UNKNOWN	0.07	0.25	3.95	15.76	24.26	52.27	0.65	0.39	0.19	0.00	97.79	n/a	n/a		
13	'91TCA-3031'	1967	‘Diopside’	CPX_02_UNKNOWN	0.05	0.12	5.54	15.73	22.30	52.07	1.20	0.70	0.16	0.00	97.87	n/a	n/a		
13	'91TCA-3031'	1961	CD1	CPX_05_UNKNOWN	0.11	0.83	3.33	16.40	22.86	52.18	1.26	0.60	0.17	0.00	97.74	n/a	n/a		
13	'91TCA-3031'	1885	G2	G_02_HIGH_TITANIUM_PYROPE	0.94	2.06	8.75	20.51	4.89	39.86	20.31	0.05	0.33	0.00	97.70	n/a	n/a		
13	'91TCA-3031'	1908	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.21	0.05	21.16	8.02	8.99	37.44	21.18	0.00	0.56	0.01	97.61	n/a	n/a		
13	'91TCA-3031'	1913	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.18	0.06	22.60	9.73	5.92	37.42	21.22	0.00	0.50	0.01	97.63	n/a	n/a		
13	'91TCA-3031'	1924	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.08	0.03	20.98	6.96	10.23	37.53	21.67	0.00	0.82	0.01	98.30	n/a	n/a		
13	'91TCA-3031'	1932	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.08	0.04	21.73	6.64	10.45	37.28	21.40	0.00	0.57	0.01	98.19	n/a	n/a		
13	'91TCA-3031'	1950	‘Garnet’	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.07	22.57	6.85	9.32	37.36	21.13	0.00	0.77	0.00	98.22	n/a	n/a		
13	'91TCA-3031'	1883	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.07	0.06	21.70	13.98	1.15	37.18	21.95	0.00	0.68	0.00	96.77	n/a	n/a		
13	'91TCA-3031'	1917	‘Almandine’	G_05_MAGNESIAN_ALMANDINE	0.09	0.04	26.56	10.05	1.94	37.47	21.57	0.00	0.43	0.00	98.15	n/a	n/a		
13	'91TCA-3031'	1925	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.07	0.05	23.00	13.25	0.94	38.51	22.13	0.00	0.62	0.01	98.57	n/a	n/a		
13	'91TCA-3031'	1928	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.08	0.06	23.33	13.03	1.16	38.33	21.98	0.00	0.44	0.00	98.41	n/a	n/a		
13	'91TCA-3031'	1943	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.11	0.08	24.68	8.00	5.96	37.00	21.20	0.00	0.64	0.01	97.67	n/a	n/a		
13	'91TCA-3031'	1947	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.19	0.04	24.40	8.03	5.73	37.34	21.49	0.00	0.81	0.00	98.03	n/a	n/a		
14	'91TCA-3032'	2044	‘Diopside’	CPX_02_UNKNOWN	0.03	0.49	5.73	15.54	22.24	51.63	1.00	0.55	0.25	0.01	97.46	n/a	n/a		
14	'91TCA-3032'	2047	‘Na-diopside’	CPX_02_UNKNOWN	0.13	0.03	5.49	16.08	21.98	54.75	1.78	1.69	0.09	0.01	102.02	n/a	n/a		
14	'91TCA-3032'	2048	‘Diopside’	CPX_02_UNKNOWN	0.06	0.06	3.99	14.71	22.89	48.81	0.86	0.49	0.02	0.04	91.89	n/a	n/a		
14	'91TCA-3032'	1984	‘Almandine’	G_05_MAGNESIAN_ALMANDINE	0.08	0.05	26.90	10.46	1.09	37.34	21.73	0.00	0.64	0.00	98.29	n/a	n/a		
14	'91TCA-3032'	1996	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.11	0.04	23.55	8.76	6.03	37.66	21.65	0.00	0.79	0.00	98.59	n/a	n/a		
14	'91TCA-3032'	2005	‘Garnet’	G_05_MAGNESIAN_ALMANDINE	0.08	0.07	22.28	13.25	1.58	38.05	22.06	0.00	0.62	0.00	97.99	n/a	n/a		
14	'91TCA-3032'	2015	‘Almandine’	G_05_MAGNESIAN_ALMANDINE	0.05	0.05	25.44	7.09	6.09	36.81	21.40	0.00	0.83	0.00	97.76	n/a	n/a		
14	'91TCA-3032'	2034	‘Almandine’	G_05_MAGNESIAN_ALMANDINE	0.05	0.03	25.98	8.24	4.02	37.18	21.41	0.00	1.40	0.01	98.31	n/a	n/a		
15	1-3-1-T	QH	MGI	PICRO_ILMENITE	50.64	0.23	36.44	11.28	0.04	0.01	0.58	0.01	0.31	0.02	99.54	n/a	n/a		

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
22	15-3-2-T	553	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.04	0.05	21.80	9.54	5.90	36.84	20.89	0.00	1.09	0.00	96.15	n/a	n/a		
23	15-4-2-T	GH	G2	G_02_HIGH_TITANIUM_PYROPE	0.99	3.61	7.38	21.41	5.00	40.87	19.01	0.06	0.29	0.01	98.62	n/a	n/a		
23	15-4-2-T	QH	G9	G_09_CHROME_PYROPE	0.26	4.34	7.79	20.73	5.01	42.56	19.34	0.05	0.39	0.00	100.47	n/a	n/a		
23	15-4-2-T	4842	Chromite	PICRO_CHROMITE	0.04	41.07	21.47	11.75	0.01	0.00	23.21	0.01	0.35	0.01	97.91	n/a	n/a		
23	15-4-2-T	4840	Chromite	SUB_PICRO_CHROMITE	0.86	45.79	33.33	6.11	0.02	0.00	11.62	0.00	0.55	0.02	98.28	n/a	n/a		
24	16-3-1-T	QH	G9	G_09_CHROME_PYROPE	0.03	4.95	7.70	19.58	6.05	42.13	19.15	0.03	0.43	0.01	100.05	n/a	n/a		
24	16-3-1-T	QH	G9	G_09_CHROME_PYROPE	0.03	4.97	7.64	19.62	6.09	42.25	19.37	0.03	0.43	0.01	100.43	n/a	n/a		
25	16-3-2-T	3152	Garnet	G_05_MAGNESIAN_ALMANDINE	0.00	0.00	22.63	11.50	3.91	39.75	21.81	0.00	0.31	0.00	99.91	n/a	n/a		
26	16-4-1-T	GH	CD1	CPX_02_UNKNOWN	0.23	0.64	3.67	15.74	23.11	52.21	3.35	0.42	0.13	0.00	99.50	n/a	n/a		
26	16-4-1-T	QH	CD1	CPX_05_UNKNOWN	0.07	0.90	3.71	16.70	22.82	54.58	1.35	0.47	0.08	0.00	100.68	n/a	n/a		
26	16-4-1-T	6488	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.13	0.00	23.27	6.77	9.21	39.40	21.00	0.03	0.80	0.00	100.61	n/a	n/a		
26	16-4-1-T	QH	MGI	PICRO_ILMENITE	54.01	0.44	33.66	12.39	0.04	0.04	0.56	0.05	0.26	0.02	101.45	n/a	n/a		
28	17-1-2-T	QH	CD2	CPX_02_DIOPSIDE	0.26	1.23	4.70	17.39	20.61	52.13	3.09	0.17	0.12	0.00	99.70	n/a	n/a		
28	17-1-2-T	QH	MGI	PICRO_ILMENITE	54.00	0.83	29.33	14.12	0.05	0.01	0.43	0.02	0.36	0.02	99.15	n/a	n/a		
30	17-3-1-T	QH	CD1	CPX_05_UNKNOWN	0.14	0.66	2.94	16.60	23.34	53.53	2.20	0.48	0.09	0.00	99.98	n/a	n/a		
30	17-3-1-T	QH	CD2	CPX_05_UNKNOWN	0.04	1.06	3.83	16.47	22.59	53.99	1.08	0.66	0.17	0.00	99.89	n/a	n/a		
30	17-3-1-T	6598	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.19	0.03	22.63	9.31	6.93	39.84	21.13	0.01	0.62	0.00	100.69	n/a	n/a		
30	17-3-1-T	6599	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.10	0.03	22.17	10.14	6.61	39.80	21.76	0.00	0.28	0.00	100.89	n/a	n/a		
32	17-4-1-T	738	Almandine	G_05_MAGNESIAN_ALMANDINE	0.05	0.03	25.79	7.96	3.89	36.77	20.90	0.00	1.63	0.00	97.02	n/a	n/a		
36	18-3-2-T	QH	CD1	CPX_02_UNKNOWN	0.20	0.69	4.72	15.69	23.25	53.64	1.62	0.32	0.16	0.00	100.29	n/a	n/a		
38	18-4-2-T	5220	Diopside	CPX_02_UNKNOWN	0.06	0.36	4.27	15.55	23.46	54.65	1.22	0.64	0.20	0.01	100.41	n/a	n/a		
40	19-2-2-T	GH	CD1	CPX_02_UNKNOWN	0.08	0.70	3.76	19.07	19.97	55.01	0.81	0.40	0.10	0.01	99.90	n/a	n/a		
42	19-3-2-T	6698	Almandine	G_05_MAGNESIAN_ALMANDINE	0.10	0.03	25.45	7.32	6.48	39.11	20.76	0.00	0.88	0.00	100.13	n/a	n/a		
43	19-4-1-T	QH	G9	G_09_CHROME_PYROPE	0.20	4.61	8.06	19.93	5.09	41.99	19.20	0.05	0.40	0.01	99.53	n/a	n/a		
46	2-3-1-T	4861	Almandine	G_05_MAGNESIAN_ALMANDINE	0.18	0.01	25.60	7.42	6.56	39.59	21.03	0.01	0.89	0.00	101.29	n/a	n/a		
46	2-3-1-T	4862	Chromite	PICRO_CHROMITE	1.11	43.99	20.03	15.00	0.01	0.06	18.05	0.00	0.28	0.01	98.53	n/a	n/a		
49	2-4-2-T	537	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.07	0.13	18.86	11.04	7.05	38.52	21.57	0.00	0.41	0.01	97.65	n/a	n/a		
49	2-4-2-T	536	Garnet	G_05_MAGNESIAN_ALMANDINE	0.07	0.11	22.95	8.47	6.19	37.27	21.05	0.00	0.81	0.01	96.92	n/a	n/a		
49	2-4-2-T	538	Garnet	G_05_MAGNESIAN_ALMANDINE	0.05	0.05	23.89	10.61	3.33	38.05	21.54	0.00	0.70	0.00	98.22	n/a	n/a		
51	20-3-1-T	QH	G9	G_09_CHROME_PYROPE	0.01	2.46	7.72	20.66	4.84	42.30	21.06	0.02	0.53	0.02	99.60	n/a	n/a		
52	20-3-2-T	QH	MGI	PICRO_ILMENITE	52.32	0.72	31.64	12.90	0.04	0.01	0.36	0.02	0.30	0.01	98.31	n/a	n/a		
54	20-4-2-T	782	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.22	0.02	23.16	6.51	8.33	36.90	20.83	0.00	0.63	0.00	96.60	n/a	n/a		
54	20-4-2-T	781	Garnet	G_05_MAGNESIAN_ALMANDINE	0.20	0.09	24.52	7.13	6.40	36.92	20.84	0.00	0.73	0.00	96.83	n/a	n/a		
56	21-3-1-T	6819	Diopside	CPX_02_UNKNOWN	0.00	0.31	5.95	15.86	22.36	53.50	1.34	0.30	0.26	0.00	99.88	n/a	n/a		
56	21-3-1-T	6818	Diopside	CPX_05_UNKNOWN	0.00	0.00	4.16	15.41	25.20	54.15	0.65	0.33	0.41	0.00	100.31	n/a	n/a		
56	21-3-1-T	GH	G1	G_01_TITANIAN_PYROPE	0.77	2.21	8.23	20.50	4.97	42.01	20.06	0.05	0.30	0.00	99.10	n/a	n/a		
56	21-3-1-T	QH	G1	G_01_TITANIAN_PYROPE	0.71	2.15	8.02	21.26	4.77	42.84	19.78	0.06	0.26	0.00	99.85	n/a	n/a		
56	21-3-1-T	6816	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.13	0.02	18.04	11.32	8.28	40.10	22.29	0.01	0.32	0.00	100.51	n/a	n/a		
56	21-3-1-T	QH	G9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.04	7.28	7.26	19.78	5.82	42.09	17.57	0.02	0.45	0.01	100.31	n/a	n/a		
58	21-4-1-T	1994	Garnet	G_05_MAGNESIAN_ALMANDINE	0.01	0.00	22.79	8.40	7.31	38.73	21.51	0.01	0.77	0.00	99.53	n/a	n/a		
60	23-1-1-T	QH	G2	G_02_HIGH_TITANIUM_PYROPE	0.96	3.04	7.45	21.60	4.86	42.57	19.57	0.09	0.25	0.00	100.39	n/a	n/a		
60	23-1-1-T	QH	MGI	PICRO_ILMENITE	52.73	0.23	34.85	11.59	0.04	0.02	0.54	0.03	0.29	0.02	100.32	n/a	n/a		
62	23-3-1-T	QH	CD1	CPX_05_CHROME_DIOPSIDE	0.28	0.73	2.53	14.70	21.11	52.17	6.52	1.46	0.00	0.00	99.50	n/a	n/a		
62	23-3-1-T	6530	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.01	0.08	19.81	9.30	8.94	39.99	21.74	0.02	0.54	0.00	100.43	n/a	n/a		
63	23-3-2-T	2369	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.19	0.00	22.11	4.04	12.50	38.59	21.47	0.03	1.74	0.01	100.67	n/a	n/a		
66	24-2-1-T	5637	Chromite	SUB_PICRO_CHROMITE	0.52	39.04	27.67	9.41	0.02	0.00	21.62	0.00	0.46	0.03	98.74	n/a	n/a		
67	24-2-2-T	QH	G9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.07	5.94	7.50	19.92	5.75	41.89	18.54	0.01	0.42	0.01	100.04	n/a	n/a		

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
68	24-3-1-T	QH	CD1	CPX_02_UNKNOWN	0.16	0.70	4.06	15.18	22.63	53.70	2.36	0.91	0.11	0.00	99.81	n/a	n/a		
69	24-3-2-T	4678	Diopside	CPX_02_UNKNOWN	0.04	0.48	4.48	16.29	22.97	53.66	1.76	0.32	0.16	0.00	100.16	n/a	n/a		
71	24-4-2-T	5193	Chromite	CHROMITE	0.63	46.60	29.22	4.98	0.05	0.07	15.52	0.01	0.60	0.03	97.68	n/a	n/a		
71	24-4-2-T	5196	Diopside	CPX_02_UNKNOWN	0.07	0.38	5.34	15.42	23.04	54.03	1.40	0.44	0.15	0.01	100.27	n/a	n/a		
71	24-4-2-T	2087	Garnet	G_05_MAGNESIAN_ALMANDINE	0.07	0.03	23.49	12.17	1.60	38.76	22.08	0.00	1.29	0.02	99.49	n/a	n/a		
71	24-4-2-T	QH	G9	G_09_CHROME_PYROPE	0.22	5.44	6.74	20.75	5.44	42.37	18.33	0.03	0.36	0.00	99.68	n/a	n/a		
72	25-1-1-T	QH	G1	G_01_TITANIAN_PYROPE	0.60	4.10	6.72	21.46	5.00	42.21	18.84	0.05	0.29	0.02	99.27	n/a	n/a		
74	25-2-1-T	5128	Diopside	CPX_02_UNKNOWN	0.04	0.34	4.70	15.51	23.21	53.67	2.23	0.45	0.21	0.00	100.36	n/a	n/a		
74	25-2-1-T	5130	Diopside	CPX_05_UNKNOWN	0.01	0.46	3.33	16.16	24.69	54.71	0.60	0.43	0.14	0.01	100.53	n/a	n/a		
74	25-2-1-T	1947	Garnet	G_05_MAGNESIAN_ALMANDINE	0.06	0.05	22.66	9.49	6.28	39.04	21.87	0.00	0.59	0.00	100.04	n/a	n/a		
75	25-2-2-T	QH	CD2	CPX_02_UNKNOWN	0.00	1.03	4.26	14.47	22.33	52.08	3.69	0.82	0.02	0.00	98.70	n/a	n/a		
77	25-3-2-T	4889	Chromite	SUB_PICRO_CHROMITE	0.26	49.46	32.32	6.77	0.02	0.00	8.12	0.01	0.57	0.02	97.53	n/a	n/a		
85	26-3-2-T	5312	Garnet	G_05_MAGNESIAN_ALMANDINE	0.10	0.00	22.67	9.26	6.79	39.71	20.68	0.01	0.36	0.00	99.58	n/a	n/a		
87	26-4-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.36	3.46	6.46	21.91	4.79	42.68	19.56	0.05	0.19	0.00	99.46	n/a	n/a		
88	27-1-1-T	1774	Chromite	CHROMITE	0.21	43.38	33.45	3.97	0.00	0.00	16.12	0.03	0.56	0.09	97.72	n/a	n/a		
88	27-1-1-T	4999	Diopside	CPX_02_UNKNOWN	0.00	0.00	6.10	15.10	22.28	53.39	0.47	1.02	0.17	0.00	98.53	n/a	n/a		
88	27-1-1-T	5000	Diopside	CPX_05_UNKNOWN	0.00	0.41	4.20	15.36	23.90	52.38	0.94	0.57	0.08	0.00	97.84	n/a	n/a		
89	27-1-2-T	7039	Diopside	CPX_02_UNKNOWN	0.08	0.31	3.92	15.83	23.24	53.35	2.18	0.62	0.09	0.00	99.62	n/a	n/a		
89	27-1-2-T	7038	Diopside	CPX_05_CHROME_DIOPSIDE	0.12	0.48	3.23	16.07	23.39	53.35	1.64	0.60	0.09	0.00	98.97	n/a	n/a		
89	27-1-2-T	7037	Almandine	G_05_MAGNESIAN_ALMANDINE	0.05	0.24	25.30	7.57	6.78	38.74	21.51	0.01	0.69	0.00	100.89	n/a	n/a		
89	27-1-2-T	GH	MGI	PICRO_ILMENITE	54.14	0.95	28.41	14.66	0.01	0.00	0.53	0.03	0.26	0.00	98.99	n/a	n/a		
90	27-2-1-T	QH	G2	G_02_HIGH_TITANIUM_PYROPE	0.94	2.15	8.26	20.71	4.89	41.69	19.36	0.05	0.26	0.00	98.31	n/a	n/a		
90	27-2-1-T	GH	G11	G_11_UVAROVITE_PYROPE	0.45	7.99	7.76	19.01	6.20	41.26	16.42	0.07	0.42	0.00	99.58	n/a	n/a		
90	27-2-1-T	GH	MGI	PICRO_ILMENITE	51.93	0.93	29.25	12.91	0.02	0.20	0.39	0.00	0.29	0.00	95.92	n/a	n/a		
91	27-2-2-T	QH	MGI	PICRO_ILMENITE	54.30	1.89	30.63	13.64	0.04	0.04	0.56	0.03	0.27	0.02	101.40	n/a	n/a		
91	27-2-2-T	GH	MGI	PICRO_ILMENITE	44.12	0.41	44.64	7.38	0.04	0.03	0.24	0.00	0.35	0.02	97.21	n/a	n/a		
93	27-3-2-T	4476	Chromite	PICRO_CHROMITE	0.34	40.48	18.13	14.14	0.01	0.01	25.19	0.00	0.34	0.01	98.64	n/a	n/a		
96	28-1-1-T	4510	Almandine	G_05_MAGNESIAN_ALMANDINE	0.18	0.01	25.12	7.67	6.85	39.52	21.01	0.01	0.70	0.00	101.07	n/a	n/a		
98	28-2-1-T	QH	CD1	CPX_02_UNKNOWN	0.18	0.58	4.39	17.54	21.83	54.03	0.66	0.20	0.16	0.00	99.57	n/a	n/a		
98	28-2-1-T	QH	CD1	CPX_02_UNKNOWN	0.04	0.81	3.94	16.52	22.41	54.41	1.82	0.66	0.14	0.00	100.75	n/a	n/a		
98	28-2-1-T	QH	CD1	CPX_02_UNKNOWN	0.15	0.63	3.47	17.76	22.66	54.25	0.68	0.17	0.15	0.00	99.92	n/a	n/a		
98	28-2-1-T	QH	CD2	CPX_05_UNKNOWN	0.15	1.32	3.45	15.59	21.81	53.46	1.96	1.06	0.10	0.00	98.90	n/a	n/a		
99	28-2-2-T	QH	G6	G_03_CALCIC_PYROPE_ALMANDINE	0.31	0.03	20.73	6.42	12.43	39.60	21.17	0.01	0.45	0.01	101.15	n/a	n/a		
99	28-2-2-T	5646	Chromite	PICRO_CHROMITE	0.26	47.40	16.98	12.91	0.02	0.02	19.82	0.02	0.70	0.02	98.13	n/a	n/a		
104	29-1-1-T	QH	CD2	CPX_05_CHROME_DIOPSIDE	0.06	1.20	2.51	16.75	23.34	54.70	1.09	0.50	0.09	0.00	100.24	n/a	n/a		
104	29-1-1-T	QH	MGI	PICRO_ILMENITE	55.44	1.06	28.46	14.62	0.04	0.03	0.50	0.01	0.32	0.02	100.48	n/a	n/a		
106	29-2-1-T	QH	CD1	CPX_02_DIOPSIDE	0.14	0.80	3.66	17.16	21.35	53.95	2.56	0.36	0.12	0.00	100.10	n/a	n/a		
106	29-2-1-T	4624	Diopside	CPX_02_UNKNOWN	0.05	0.34	4.69	16.23	22.06	54.94	0.99	0.72	0.14	0.00	100.16	n/a	n/a		
106	29-2-1-T	4625	Diopside	CPX_02_UNKNOWN	0.08	0.47	3.88	15.73	22.89	54.65	2.00	0.76	0.11	0.00	100.57	n/a	n/a		
107	29-2-2-T	5175	Chromite	PICRO_CHROMITE	0.59	45.60	28.82	12.92	0.02	0.02	9.79	0.00	0.39	0.02	98.15	n/a	n/a		
107	29-2-2-T	5174	Chromite	SUB_PICRO_CHROMITE	0.68	36.41	35.80	6.66	0.02	0.00	18.15	0.00	0.57	0.02	98.29	n/a	n/a		
108	29-3-1-T	5020	Garnet	G_05_MAGNESIAN_ALMANDINE	0.00	0.03	24.57	8.57	5.53	39.21	21.46	0.01	0.56	0.00	99.94	n/a	n/a		
109	29-3-2-T	217	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.07	21.14	8.40	7.85	37.60	21.09	0.02	0.59	0.01	96.91	n/a	n/a		
109	29-3-2-T	219	Garnet	G_05_MAGNESIAN_ALMANDINE	0.08	0.05	22.92	12.66	1.35	37.92	21.65	0.00	0.52	0.00	97.15	n/a	n/a		
109	29-3-2-T	GH	MGI	PICRO_ILMENITE	43.02	2.05	40.37	7.50	0.02	0.20	0.05	0.00	0.46	0.00	93.67	n/a	n/a		
109	29-3-2-T	QH	MGI	PICRO_ILMENITE	47.22	3.85	36.22	10.18	0.04	0.01	0.34	0.00	0.34	0.02	98.20	n/a	n/a		
110	29-4-1-T	3395	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.11	0.16	21.00	6.05	11.69	39.57	21.23	0.01	0.79	0.00	100.61	n/a	n/a		

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
115	30-1-2-T	QH	G11	G_01_TITANIAN_PYROPE	0.78	6.39	6.73	20.60	5.90	42.04	16.73	0.06	0.22	0.00	99.45	n/a	n/a		
117	30-2-2-T	6904	Chromite	CHROMITE	0.15	48.74	40.74	0.49	0.00	0.00	5.41	0.05	1.82	0.00	97.40	n/a	n/a		
121	30-4-2-T	QH	G9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.17	7.79	6.77	19.85	6.20	41.88	16.90	0.04	0.40	0.01	100.00	n/a	n/a		
124	31-2-2-T	2297	Garnet	G_05_MAGNESIAN_ALMANDINE	0.10	0.06	23.46	13.15	1.39	39.87	22.47	0.01	0.56	0.04	101.07	n/a	n/a		
125	31-3-1-T	QH	G2	G_02_HIGH_TITANIUM_PYROPE	1.04	5.12	7.26	20.69	5.61	41.98	17.58	0.06	0.32	0.01	99.66	n/a	n/a		
125	31-3-1-T	QH	MGI	PICRO_ILMENITE	53.11	0.32	34.30	12.04	0.05	0.04	0.57	0.00	0.32	0.02	100.75	n/a	n/a		
125	31-3-1-T	5095	Chromite	SUB_PICRO_CHROMITE	4.36	38.26	33.94	13.44	0.03	0.06	7.99	0.00	0.42	0.02	98.50	n/a	n/a		
126	31-3-2-T	QH	CD1	CPX_05_CHROME_DIOPSIDE	0.25	0.83	3.03	15.88	23.32	53.14	2.20	0.55	0.08	0.00	99.28	n/a	n/a		
126	31-3-2-T	4995	Diopside	CPX_05_UNKNOWN	0.05	0.47	2.84	16.74	23.68	53.82	1.07	0.48	0.07	0.00	99.22	n/a	n/a		
126	31-3-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.57	4.24	6.76	21.66	5.09	42.59	18.51	0.05	0.29	0.00	99.76	n/a	n/a		
126	31-3-2-T	QH	G9	G_09_CHROME_PYROPE	0.03	3.43	7.85	20.33	5.42	42.55	20.38	0.01	0.49	0.00	100.49	n/a	n/a		
127	31-4-1-T	6367	Garnet	G_05_MAGNESIAN_ALMANDINE	0.22	0.03	24.38	7.41	7.77	39.45	21.00	0.01	0.73	0.01	101.00	n/a	n/a		
129	33-1-1-T	QH	G1	G_02_HIGH_TITANIUM_PYROPE	0.90	4.30	7.10	21.27	5.22	42.43	18.42	0.07	0.28	0.01	99.99	n/a	n/a		
129	33-1-1-T	QH	G2	G_02_HIGH_TITANIUM_PYROPE	0.91	4.96	7.52	20.99	5.47	42.33	17.90	0.07	0.29	0.00	100.44	n/a	n/a		
130	34-1-1-T	6706	Diopside	CPX_02_UNKNOWN	0.02	0.18	5.40	15.77	22.95	53.60	1.66	0.37	0.15	0.00	100.10	n/a	n/a		
130	34-1-1-T	QH	CD1	CPX_05_UNKNOWN	0.03	0.57	2.68	17.03	23.85	54.87	1.20	0.44	0.15	0.00	100.82	n/a	n/a		
130	34-1-1-T	QH	G3	G_03_CALCIC_PYROPE_ALMANDINE	0.25	0.02	23.22	9.56	6.09	39.62	21.39	0.01	0.60	0.00	100.76	n/a	n/a		
130	34-1-1-T	GH	G4	G_04_TITANIAN,_CALCIC, MAGNESIAN_ALMANDINE	0.75	0.00	21.22	7.55	9.40	39.56	21.09	0.03	0.64	0.00	100.24	n/a	n/a		
131	34-1-2-T	3521	Diopside	CPX_02_UNKNOWN	0.02	0.09	4.22	15.94	24.17	54.78	0.57	0.36	0.13	0.00	100.28	n/a	n/a		
132	34-2-1-T	QH	CD1	CPX_02_DIOPSIDE	0.13	0.56	5.63	17.24	19.56	54.37	1.95	0.73	0.12	0.00	100.29	n/a	n/a		
133	34-2-2-T	47	Diopside	CPX_05_UNKNOWN	0.15	0.02	2.23	16.07	24.17	51.49	2.42	0.66	0.01	0.01	97.22	n/a	n/a		
133	34-2-2-T	GH	G9	G_09_CHROME_PYROPE	0.21	2.67	8.37	20.61	4.23	40.37	20.55	0.02	0.32	0.01	97.35	n/a	n/a		
134	34-3-1-T	QH	CD1	CPX_05_UNKNOWN	0.03	0.56	2.98	16.28	23.68	54.05	1.71	0.37	0.04	0.00	99.70	n/a	n/a		
134	34-3-1-T	QH	CD1	CPX_05_UNKNOWN	0.00	0.73	3.53	15.08	24.53	54.42	1.13	0.43	0.00	0.00	99.85	n/a	n/a		
134	34-3-1-T	QH	G9	G_09_CHROME_PYROPE	0.25	6.08	7.33	20.12	5.69	41.85	18.02	0.05	0.42	0.01	99.81	n/a	n/a		
137	34-4-2-T	6930	Diopside	CPX_02_UNKNOWN	0.00	0.31	4.10	14.83	23.01	51.93	1.80	0.57	0.05	0.00	96.60	n/a	n/a		
137	34-4-2-T	QH	G9	G_09_CHROME_PYROPE	0.19	2.79	7.74	21.27	4.57	42.66	20.64	0.05	0.34	0.00	100.25	n/a	n/a		
137	34-4-2-T	QH	G9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.14	5.72	7.14	20.76	5.07	42.39	18.75	0.03	0.41	0.00	100.41	n/a	n/a		
139	35-1-2-T	5591	Almandine	G_05_MAGNESIAN_ALMANDINE	0.03	0.00	25.14	6.96	7.42	39.69	21.17	0.02	0.93	0.00	101.36	n/a	n/a		
140	35-2-1-T	2411	Garnet	G_05_MAGNESIAN_ALMANDINE	0.00	0.00	23.74	8.23	4.81	39.03	21.85	0.00	3.45	0.02	101.11	n/a	n/a		
141	35-2-2-T	QH	CD2	CPX_02_DIOPSIDE	0.19	1.11	2.91	16.18	20.16	52.13	5.89	1.12	0.10	0.00	99.79	n/a	n/a		
141	35-2-2-T	1274	Jadeite	UNKNOWN	0.02	0.02	0.13	0.01	10.82	52.89	27.04	5.34	0.03	0.17	96.30	n/a	n/a		
145	35-4-2-T	QH	CD1	CPX_05_UNKNOWN	0.03	0.63	3.47	16.23	22.33	53.60	2.35	0.61	0.07	0.00	99.32	n/a	n/a		
147	36-1-2-T	7030	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.11	0.02	20.33	10.21	7.62	39.44	22.23	0.05	0.43	0.00	100.44	n/a	n/a		
148	36-2-1-T	QH	CD1	CPX_05_CHROME_DIOPSIDE	0.30	0.90	2.91	15.92	20.26	51.73	6.48	1.08	0.11	0.00	99.69	n/a	n/a		
148	36-2-1-T	5274	Andradite	G_07_FERRO-MAGNESIAN UVAROVITE_GROSSULAR	0.37	12.49	6.16	0.31	30.87	37.77	9.64	0.00	0.90	0.01	98.51	n/a	n/a		
150	36-3-1-T	QH	CD2	CPX_05_CHROME_DIOPSIDE	0.28	1.20	2.38	15.38	20.48	52.03	6.37	1.31	0.04	0.01	99.47	n/a	n/a		
150	36-3-1-T	6450	Diopside	CPX_05_UNKNOWN	0.06	0.37	3.21	16.80	23.51	54.55	1.05	0.52	0.06	0.00	100.13	n/a	n/a		
151	36-3-2-T	QH	CD1	CPX_02_DIOPSIDE	0.09	0.58	4.01	18.26	21.07	54.04	2.46	0.25	0.05	0.00	100.81	n/a	n/a		
151	36-3-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.77	3.31	7.91	20.98	5.08	42.60	19.13	0.07	0.28	0.01	100.13	n/a	n/a		
151	36-3-2-T	5557	Garnet	G_05_MAGNESIAN_ALMANDINE	0.06	0.00	24.66	7.30	6.68	39.42	21.01	0.01	2.02	0.00	101.16	n/a	n/a		
155	37-1-2-T	QH	G9	G_09_CHROME_PYROPE	0.17	4.82	8.06	20.22	4.88	42.11	19.32	0.05	0.45	0.00	100.08	n/a	n/a		
158	37-3-1-T	1287	Almandine	G_05_MAGNESIAN_ALMANDINE	0.09	0.12	26.52	10.23	1.66	37.51	21.31	0.00	0.84	0.01	98.28	n/a	n/a		
158	37-3-1-T	QH	G9	G_09_CHROME_PYROPE	0.08	3.02	8.88	20.01	4.61	42.11	20.95	0.04	0.52	0.00	100.22	n/a	n/a		
159	37-3-2-T	6595	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.23	0.03	22.54	8.25	8.28	39.77	21.27	0.01	0.52	0.00	100.90	n/a	n/a		
160	37-4-1-T	QH	MGI	PICRO_ILMENITE	49.26	0.13	38.84	10.41	0.01	0.00	0.41	0.00	0.24	0.00	99.30	n/a	n/a		

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
164	38-2-1-T	1625	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.18	0.09	22.76	9.72	6.12	39.41	21.54	0.01	0.80	0.01	100.63	n/a	n/a		
164	38-2-1-T	1627	Pyrope G3?	G_09_CHROME_PYROPE	0.12	0.11	11.01	19.98	3.71	41.82	22.98	0.04	0.34	0.00	100.11	n/a	n/a		
165	38-2-2-T	710	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.21	0.07	22.17	8.63	6.57	37.26	20.73	0.00	0.49	0.01	96.13	n/a	n/a		
165	38-2-2-T	709	Almandine	G_05_MAGNESIAN_ALMANDINE	0.07	0.05	25.59	8.78	3.26	37.10	20.89	0.00	0.59	0.00	96.33	n/a	n/a		
166	38-3-1-T	6502	Diopside	CPX_02_UNKNOWN	0.00	0.20	4.86	16.34	22.82	54.25	0.58	0.34	0.08	0.00	99.47	n/a	n/a		
166	38-3-1-T	QH	G9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.06	7.39	6.96	19.51	6.43	41.93	17.29	0.02	0.43	0.01	100.02	n/a	n/a		
166	38-3-1-T	GH	MGI	PICRO_ILMENITE	46.71	0.27	41.44	8.72	0.03	0.03	0.35	0.02	0.33	0.01	97.90	n/a	n/a		
167	38-3-2-T	GH	MGI	PICRO_ILMENITE	55.65	0.98	28.08	14.56	0.03	0.04	0.47	0.01	0.34	0.01	100.16	n/a	n/a		
167	38-3-2-T	GH	MGI	PICRO_ILMENITE	55.21	0.96	29.06	14.37	0.03	0.04	0.44	0.02	0.31	0.01	100.44	n/a	n/a		
168	38-4-1-T	QH	G9	G_09_CHROME_PYROPE	0.30	2.51	7.20	21.03	4.60	42.53	20.83	0.03	0.30	0.00	99.33	n/a	n/a		
168	38-4-1-T	4314	Chromite	UNKNOWN	0.19	31.36	28.74	10.20	0.01	0.00	26.49	0.00	0.40	0.02	97.39	n/a	n/a		
169	38-4-2-T	4272	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.01	0.00	20.40	10.46	6.65	39.82	21.28	0.03	0.31	0.00	98.96	n/a	n/a		
170	39-1-1-T	QH	CD1	CPX_02_UNKNOWN	0.02	0.65	4.81	15.49	23.07	52.86	1.70	0.47	0.17	0.00	99.24	n/a	n/a		
170	39-1-1-T	6257	Chromite	PICRO_CHROMITE	0.08	46.30	18.32	13.15	0.03	0.00	21.17	0.01	0.35	0.01	99.41	n/a	n/a		
172	39-2-1-T	4735	Diopside	CPX_02_UNKNOWN	0.05	0.29	5.40	15.29	22.50	53.82	1.25	0.62	0.26	0.00	99.48	n/a	n/a		
174	39-3-1-T	507	Almandine	G_05_MAGNESIAN_ALMANDINE	0.04	0.04	25.39	10.58	1.85	37.24	21.21	0.00	0.51	0.00	96.86	n/a	n/a		
174	39-3-1-T	GH	MGI	PICRO_ILMENITE	50.30	0.50	33.15	10.83	0.03	0.19	0.32	0.00	0.30	0.01	95.62	n/a	n/a		
178	40-1-1-T	QH	G9	G_09_CHROME_PYROPE	0.08	3.87	7.68	19.98	5.28	41.81	19.83	0.03	0.43	0.01	98.99	n/a	n/a		
180	40-2-1-T	QH	CD1	CPX_02_DIOPSIDE	0.17	0.82	5.62	15.17	21.62	54.38	1.48	1.07	0.15	0.01	100.48	n/a	n/a		
181	40-2-2-T	3045	Diopside	CPX_05_UNKNOWN	0.00	0.00	2.08	17.25	25.50	54.49	0.26	0.11	0.09	0.00	99.78	n/a	n/a		
184	40-4-1-T	6249	Chromite	SUB_PICRO_CHROMITE	0.28	38.88	21.61	12.61	0.02	0.00	25.51	0.01	0.37	0.01	99.29	n/a	n/a		
186	41-1-1-T	QH	CD2	CPX_05_UNKNOWN	0.15	1.07	3.36	16.07	22.97	52.88	1.53	0.66	0.11	0.00	98.80	n/a	n/a		
187	41-1-2-T	3582	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.01	21.87	7.85	8.90	39.82	21.30	0.02	0.50	0.00	100.42	n/a	n/a		
188	41-2-1-T	4950	Diopside	CPX_02_UNKNOWN	0.05	0.00	4.59	15.39	23.74	54.05	1.36	0.85	0.02	0.00	100.05	n/a	n/a		
188	41-2-1-T	4951	Diopside	CPX_02_UNKNOWN	0.04	0.14	4.53	15.52	24.33	54.53	0.72	0.47	0.16	0.00	100.44	n/a	n/a		
188	41-2-1-T	QH	G9	G_09_CHROME_PYROPE	0.04	2.89	8.62	19.88	5.36	42.46	20.81	0.02	0.54	0.00	100.62	n/a	n/a		
189	41-2-2-T	QH	CD1	CPX_02_DIOPSIDE	0.15	0.51	4.37	18.48	19.98	53.55	2.83	0.26	0.11	0.00	100.24	n/a	n/a		
189	41-2-2-T	6654	Diopside	CPX_02_UNKNOWN	0.10	0.23	5.70	16.14	21.92	54.00	1.44	0.46	0.39	0.06	100.38	n/a	n/a		
189	41-2-2-T	QH	G1	G_02_HIGH_TITANIUM_PYROPE	0.85	5.12	7.16	21.04	5.56	42.42	17.85	0.06	0.27	0.00	100.33	n/a	n/a		
189	41-2-2-T	QH	G1	G_02_HIGH_TITANIUM_PYROPE	0.86	5.31	7.11	20.95	5.68	42.56	17.82	0.05	0.30	0.00	100.64	n/a	n/a		
189	41-2-2-T	GH	MGI	PICRO_ILMENITE	52.30	0.52	33.07	12.31	0.05	0.11	0.67	0.09	0.29	0.02	99.41	n/a	n/a		
192	41-4-2-T	QH	G9	G_09_CHROME_PYROPE	0.24	6.56	7.15	20.11	5.97	42.01	17.73	0.05	0.31	0.00	100.13	n/a	n/a		
194	43-1-2-T	5515	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.18	0.01	20.41	10.10	7.72	40.29	21.49	0.01	0.44	0.00	100.65	n/a	n/a		
195	43-2-1-T	5561	Almandine	G_05_MAGNESIAN_ALMANDINE	0.04	0.00	26.10	9.69	3.08	39.90	21.43	0.01	1.14	0.00	101.39	n/a	n/a		
196	43-2-2-T	QH	CD2	CPX_02_UNKNOWN	0.14	1.02	3.16	17.47	21.89	53.11	2.35	0.42	0.11	0.01	99.67	n/a	n/a		
198	43-4-1-T	QH	G1	G_02_HIGH_TITANIUM_PYROPE	0.86	1.61	9.19	19.96	4.89	41.63	20.16	0.07	0.28	0.00	98.65	n/a	n/a		
198	43-4-1-T	QH	G2	G_02_HIGH_TITANIUM_PYROPE	1.02	5.25	7.31	20.92	5.67	42.23	17.33	0.06	0.30	0.01	100.09	n/a	n/a		
199	44-1-1-T	QH	CD1	CPX_03_UNKNOWN	0.55	0.71	2.60	14.65	21.48	52.29	6.59	1.36	0.07	0.01	100.30	n/a	n/a		
199	44-1-1-T	QH	G9	G_09_CHROME_PYROPE	0.07	5.46	7.73	20.13	5.63	41.73	18.64	0.03	0.42	0.01	99.84	n/a	n/a		
199	44-1-1-T	QH	MGI	PICRO_ILMENITE	55.33	1.17	28.10	14.74	0.04	0.03	0.51	0.00	0.32	0.02	100.24	n/a	n/a		
200	44-1-2-T	6642	Garnet	G_05_MAGNESIAN_ALMANDINE	0.20	0.03	23.72	7.49	8.23	38.85	21.00	0.01	0.65	0.01	100.18	n/a	n/a		
201	44-2-1-T	6713	Diopside	CPX_02_UNKNOWN	0.09	0.24	4.82	14.84	22.80	53.24	3.15	0.76	0.25	0.00	100.19	n/a	n/a		
201	44-2-1-T	6711	Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.10	0.05	22.27	9.56	6.80	40.01	21.31	0.00	0.53	0.00	100.63	n/a	n/a		
202	44-2-2-T	GH	CD1	CPX_05_UNKNOWN	0.11	0.85	3.50	15.15	23.00	52.20	1.96	0.58	0.11	0.00	97.46	n/a	n/a		
202	44-2-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.79	4.36	7.16	20.85	5.40	41.96	18.54	0.06	0.31	0.01	99.43	n/a	n/a		
202	44-2-2-T	QH	G9	G_09_CHROME_PYROPE	0.00	3.73	8.50	19.85	4.79	42.13	19.93	0.01	0.50	0.00	99.44	n/a	n/a		
203	44-3-2-T	92	Diopside	CPX_05_UNKNOWN	0.10	0.03	2.00	16.02	23.84	52.11	2.21	0.86	0.11	0.01	97.28	n/a	n/a		

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
205	44-4-2-T	QH	G9	G_09_CHROME_PYROPE	0.22	2.67	7.85	20.65	4.52	42.49	20.83	0.04	0.40	0.00	99.67	n/a	n/a		
207	45-1-2-T	QH	CD1	CPX_05_CHROME_DIOPSIDE	0.08	0.99	2.51	16.34	23.12	54.23	2.25	0.67	0.07	0.00	100.26	n/a	n/a		
208	45-2-1-T	5023	Diopside	CPX_02_UNKNOWN	0.00	0.00	4.99	14.66	24.20	53.54	0.94	0.56	0.62	0.00	99.51	n/a	n/a		
209	45-2-2-T	749	Garnet	G_05_MAGNESIAN_ALMANDINE	0.11	0.06	22.77	11.92	1.16	37.74	21.42	0.00	1.96	0.00	97.14	n/a	n/a		
211	45-4-1-T	QH	CD2	CPX_02_UNKNOWN	0.13	1.02	3.68	15.90	22.86	53.57	1.82	0.56	0.11	0.00	99.65	n/a	n/a		
212	46-1-1-T	740	Almandine	G_05_MAGNESIAN_ALMANDINE	0.07	0.04	25.99	10.92	0.86	37.24	21.30	0.00	0.60	0.00	97.02	n/a	n/a		
214	46-2-1-T	3092	Diopside	CPX_05_UNKNOWN	0.01	0.01	2.83	16.26	25.07	53.47	0.78	0.44	0.16	0.00	99.03	n/a	n/a		
215	46-2-2-T	5612	Garnet	G_05_MAGNESIAN_ALMANDINE	0.13	0.03	23.38	8.89	6.50	40.01	20.92	0.03	0.63	0.00	100.52	n/a	n/a		
216	46-3-1-T	QH	CD1	CPX_05_UNKNOWN	0.03	0.59	2.34	16.48	23.83	54.87	1.73	0.57	0.04	0.00	100.48	n/a	n/a		
216	46-3-1-T	5627	Diopside	CPX_05_UNKNOWN	0.00	0.00	2.35	17.26	25.33	55.82	0.20	0.06	0.26	0.00	101.28	n/a	n/a		
217	46-3-2-T	QH	G10	G_10_LOW_CALCIUM_CHROME_PYROPE	0.01	6.56	6.93	21.11	4.68	42.37	18.23	0.01	0.41	0.00	100.31	n/a	n/a		
217	46-3-2-T	QH	MGI	PICRO_ILMENITE	50.81	0.39	36.03	10.90	0.03	0.00	0.19	0.02	0.32	0.02	98.69	n/a	n/a		
217	46-3-2-T	QH	MGI	PICRO_ILMENITE	52.94	0.46	31.66	13.50	0.04	0.03	0.55	0.01	0.26	0.02	99.45	n/a	n/a		
218	47-1-1-T	QH	G11	G_02_HIGH_TITANIUM_PYROPE	0.86	6.95	7.07	20.52	6.14	41.89	16.48	0.07	0.34	0.02	100.32	n/a	n/a		
218	47-1-1-T	QH	G11	G_02_HIGH_TITANIUM_PYROPE	0.86	6.39	6.99	20.65	5.87	41.93	16.89	0.05	0.33	0.01	99.96	n/a	n/a		
220	47-2-1-T	QH	CD1	CPX_02_UNKNOWN	0.06	0.64	5.02	15.28	23.00	53.57	1.27	0.68	0.20	0.00	99.72	n/a	n/a		
221	47-2-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.64	5.09	6.89	21.14	5.41	42.49	18.03	0.04	0.31	0.01	100.04	n/a	n/a		
222	47-3-1-T	2227	Almandine	G_05_MAGNESIAN_ALMANDINE	0.00	0.08	25.50	7.10	6.64	38.63	21.71	0.00	0.68	0.00	100.34	n/a	n/a		
223	47-3-2-T	QH	CD1	CPX_02_UNKNOWN	0.16	0.82	3.96	16.10	23.06	53.45	1.44	0.63	0.15	0.00	99.77	n/a	n/a		
224	47-4-1-T	QH	CD1	CPX_05_CHROME_DIOPSIDE	0.02	0.99	2.70	16.02	23.18	53.92	1.77	0.83	0.01	0.00	99.44	n/a	n/a		
224	47-4-1-T	QH	G9	G_09_CHROME_PYROPE	0.13	4.03	8.02	20.58	5.00	42.46	19.97	0.04	0.46	0.01	100.69	n/a	n/a		
225	47-4-2-T	QH	CD2	CPX_05_CHROME_DIOPSIDE	0.16	1.89	3.14	14.75	20.98	53.98	3.25	1.78	0.08	0.00	100.01	n/a	n/a		
225	47-4-2-T	QH	G3	G_03_CALCIC_PYROPE_ALMANDINE	0.27	0.06	22.95	9.89	6.06	39.94	21.17	0.01	0.61	0.01	100.96	n/a	n/a		
225	47-4-2-T	QH	G7	G_09_CHROME_PYROPE	0.18	6.11	11.10	15.97	7.35	41.40	17.50	0.00	0.54	0.01	100.15	n/a	n/a		
226	48-1-1-T	QH	CD1	CPX_02_DIOPSIDE	0.12	0.89	3.75	17.28	21.34	54.68	1.63	0.68	0.10	0.00	100.47	n/a	n/a		
226	48-1-1-T	GH	CD1	CPX_05_CHROME_DIOPSIDE	0.15	0.69	2.87	15.52	22.33	53.20	1.91	0.77	0.01	0.00	97.45	n/a	n/a		
226	48-1-1-T	QH	G1	G_01_TITANIAN_PYROPE	0.68	4.36	6.81	21.43	5.21	42.82	18.73	0.06	0.28	0.01	100.38	n/a	n/a		
226	48-1-1-T	QH	G9	G_09_CHROME_PYROPE	0.18	3.78	7.39	20.92	4.83	42.67	20.31	0.04	0.40	0.01	100.52	n/a	n/a		
230	48-3-1-T	QH	CD1	CPX_05_CHROME_DIOPSIDE	0.07	0.94	2.75	16.25	23.22	54.50	2.16	0.76	0.05	0.00	100.70	n/a	n/a		
230	48-3-1-T	QH	CD2	CPX_05_CHROME_DIOPSIDE	0.07	1.15	3.20	16.09	23.09	53.88	1.76	0.62	0.10	0.00	99.96	n/a	n/a		
230	48-3-1-T	QH	G1	G_02_HIGH_TITANIUM_PYROPE	0.87	1.93	8.94	20.74	4.88	42.56	19.87	0.06	0.33	0.01	100.18	n/a	n/a		
230	48-3-1-T	QH	G1	G_02_HIGH_TITANIUM_PYROPE	0.90	3.59	7.74	21.15	5.18	42.54	18.80	0.06	0.31	0.01	100.27	n/a	n/a		
230	48-3-1-T	QH	G11	G_02_HIGH_TITANIUM_PYROPE	0.89	6.09	7.00	20.97	5.92	42.33	16.78	0.05	0.32	0.02	100.35	n/a	n/a		
230	48-3-1-T	6477	Garnet	G_05_MAGNESIAN_ALMANDINE	0.03	0.03	24.97	7.81	6.39	39.69	21.52	0.02	0.78	0.01	101.24	n/a	n/a		
230	48-3-1-T	QH	G9	G_09_CHROME_PYROPE	0.18	3.08	7.95	20.80	4.53	42.41	20.50	0.03	0.45	0.01	99.93	n/a	n/a		
231	48-3-2-T	QH	CD1	CPX_05_UNKNOWN	0.00	0.84	3.75	15.71	22.42	54.20	2.14	0.76	0.04	0.00	99.86	n/a	n/a		
231	48-3-2-T	2022	Garnet	G_05_MAGNESIAN_ALMANDINE	0.00	0.00	23.01	9.22	6.21	39.35	21.84	0.01	0.63	0.00	100.27	n/a	n/a		
231	48-3-2-T	5155	Garnet	G_05_MAGNESIAN_ALMANDINE	0.11	0.03	24.08	8.48	7.23	39.38	20.78	0.01	0.48	0.01	100.58	n/a	n/a		
231	48-3-2-T	5158	Garnet	G_05_MAGNESIAN_ALMANDINE	0.10	0.05	23.27	8.95	6.88	39.85	21.27	0.00	0.59	0.01	100.96	n/a	n/a		
231	48-3-2-T	QH	G9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.08	7.89	7.88	18.93	6.39	41.82	17.13	0.02	0.51	0.01	100.65	n/a	n/a		
232	48-4-1-T	QH	G1	G_01_TITANIAN_PYROPE	0.46	3.75	6.69	21.76	5.09	42.86	19.10	0.04	0.27	0.01	100.02	n/a	n/a		
232	48-4-1-T	QH	MGI	PICRO_ILMENITE	52.22	0.24	35.94	11.10	0.04	0.03	0.53	0.02	0.30	0.01	100.42	n/a	n/a		
233	48-4-2-T	QH	CD1	CPX_02_UNKNOWN	0.17	0.52	3.58	15.78	22.94	53.02	1.99	0.73	0.08	0.00	98.81	n/a	n/a		
234	49-1-1-T	6686	Diopside	CPX_05_UNKNOWN	0.01	0.44	3.49	17.00	23.26	54.67	1.15	0.37	0.10	0.00	100.49	n/a	n/a		
234	49-1-1-T	QH	G9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.22	6.24	7.48	20.40	5.19	42.34	18.11	0.05	0.42	0.00	100.45	n/a	n/a		
234	49-1-1-T	6687	Chromite	SUB_PICRO_CHROMITE	0.05	61.26	24.05	7.27	0.04	0.01	6.36	0.04	0.54	0.02	99.62	n/a	n/a		
236	49-2-1-T	QH	CD2	CPX_05_CHROME_DIOPSIDE	0.04	1.11	2.36	16.11	23.08	54.38	1.98	0.90	0.09	0.00	100.05	n/a	n/a		

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
236	49-2-1-T	QH	CD2	CPX_05_CHROME_DIOPSIDE	0.05	1.12	2.48	16.00	22.92	54.46	2.09	0.97	0.10	0.00	100.19	n/a	n/a		
236	49-2-1-T	QH	G1	G_01_TITANIAN_PYROPE	0.43	2.09	7.29	21.80	4.45	43.16	20.26	0.05	0.26	0.00	99.79	n/a	n/a		
237	49-2-2-T	3057	Diopside	CPX_02_UNKNOWN	0.02	0.11	5.09	15.23	23.48	53.13	2.03	0.41	0.16	0.00	99.66	n/a	n/a		
237	49-2-2-T	QH	CD1	CPX_05_CHROME_DIOPSIDE	0.07	0.96	2.20	16.30	23.07	54.66	2.39	0.82	0.07	0.01	100.54	n/a	n/a		
240	5-1-1-T	QH	CD1	CPX_02_UNKNOWN	0.16	0.94	4.70	14.59	22.05	52.95	3.09	0.79	0.07	0.00	99.34	n/a	n/a		
242	5-2-1-T	QH	CD1	CPX_05_UNKNOWN	0.11	0.82	3.43	16.39	22.86	54.81	1.22	0.58	0.14	0.00	100.36	n/a	n/a		
242	50-2-1-T	QH	G9	G_09_CHROME_PYROPE	0.03	4.27	7.33	20.77	5.00	42.62	19.74	0.05	0.31	0.00	100.12	n/a	n/a		
243	50-2-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.72	5.61	6.64	20.75	5.62	42.17	17.64	0.07	0.35	0.00	99.57	n/a	n/a		
243	5-2-2-T	380	Almandine	G_05_MAGNESIAN_ALMANDINE	0.07	0.03	25.63	9.52	2.89	37.38	21.22	0.00	0.70	0.00	97.44	n/a	n/a		
243	5-2-2-T	QH	G9	G_09_CHROME_PYROPE	0.23	5.34	8.08	19.64	5.72	41.72	18.68	0.02	0.44	0.01	99.87	n/a	n/a		
243	50-2-2-T	GH	MGI	PICRO_ILMENITE	51.33	0.16	34.92	11.04	0.00	0.00	0.54	0.00	0.21	0.00	98.20	n/a	n/a		
245	50-1-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.59	4.61	6.94	21.41	5.13	42.37	18.46	0.06	0.29	0.00	99.86	n/a	n/a		
249	50-3-2-T	QH	G9	G_09_CHROME_PYROPE	0.22	3.46	7.80	20.88	4.55	42.54	19.89	0.05	0.38	0.01	99.77	n/a	n/a		
249	50-3-2-T	QH	G9	G_09_CHROME_PYROPE	0.24	3.48	7.84	20.87	4.66	42.58	20.08	0.04	0.38	0.01	100.17	n/a	n/a		
249	50-3-2-T	QH	G11	G_11_UVAROVITE_PYROPE	0.43	7.58	8.37	19.21	5.83	41.85	16.71	0.06	0.47	0.01	100.51	n/a	n/a		
250	6-1-1-T	206	Pyrope G3?	G_05_MAGNESIAN_ALMANDINE	0.06	0.04	20.77	14.29	1.10	37.91	21.57	0.00	0.62	0.00	96.36	n/a	n/a		
251	6-1-2-T	4870	Diopside	CPX_02_UNKNOWN	0.12	0.00	3.93	16.00	23.42	54.05	1.01	0.72	0.00	0.00	99.25	n/a	n/a		
251	6-1-2-T	QH	G1	G_01_TITANIAN_PYROPE	0.76	5.33	6.21	21.50	5.36	42.45	17.78	0.07	0.29	0.00	99.75	n/a	n/a		
258	8-2-1-T	6387	Chromite	PICRO_CHROMITE	2.36	44.16	25.98	12.87	0.03	0.06	12.94	0.00	0.37	0.02	98.77	n/a	n/a		
258	8-2-1-T	QH	MGI	PICRO_ILMENITE	48.84	3.27	36.95	10.36	0.03	0.02	0.32	0.01	0.34	0.02	100.14	n/a	n/a		
259	8-2-2-T	5176	Chromite	CHROMITE	0.18	45.33	39.20	2.04	0.03	0.00	10.73	0.01	0.63	0.03	98.15	n/a	n/a		
263	9-1-2-T	QH	MGI	PICRO_ILMENITE	53.88	0.96	29.40	13.91	0.03	0.03	0.47	0.03	0.27	0.01	98.98	n/a	n/a		
374	B-3	3		SUB_PICRO_CHROMITE	0.19	54.93	27.40	7.17	0.00	0.00	7.09	0.00	0.44	n/a	97.55	550	2089	0.07	0.26
376	B-5	9		PICRO_CHROMITE	1.47	45.26	20.60	14.45	0.00	0.00	17.11	0.00	0.21	n/a	99.43	1965	643	0.25	0.08
377	B-6	10		PICRO_CHROMITE	0.85	47.29	19.10	14.03	0.00	0.00	17.34	0.00	0.22	n/a	99.15	1965	562	0.25	0.07
378	B-7	12		PICRO_CHROMITE	0.29	50.88	25.60	9.52	0.00	0.00	12.52	0.00	0.36	n/a	99.45	943	1285	0.12	0.16
379	B-8	13		PICRO_CHROMITE	0.59	46.31	34.10	8.48	0.00	0.00	9.27	0.00	0.49	n/a	99.56	1179	1366	0.15	0.17
379	B-8	14		PICRO_CHROMITE	1.12	46.55	19.70	14.37	0.00	0.00	16.82	0.00	0.20	n/a	99.10	2043	643	0.26	0.08
380	B-9	15		PICRO_CHROMITE	1.79	41.44	24.10	13.43	0.00	0.00	18.06	0.00	0.20	n/a	99.35	1965	643	0.25	0.08
380	B-9	17		PICRO_CHROMITE	1.30	41.50	27.60	10.24	0.00	0.00	18.29	0.00	0.27	n/a	99.57	1886	1044	0.24	0.13
380	B-9	18		PICRO_CHROMITE	0.11	53.01	23.20	8.36	0.00	0.00	10.86	0.00	0.34	n/a	96.16	550	1687	0.07	0.21
381	B-10	19		PICRO_CHROMITE	0.34	51.14	27.60	12.84	0.00	0.00	6.71	0.00	0.31	n/a	99.19	1336	643	0.17	0.08
381	B-10	20		PICRO_CHROMITE	0.15	52.78	24.40	8.61	0.00	0.00	12.35	0.00	0.36	n/a	98.94	550	1767	0.07	0.22
382	B-11	21		SUB_PICRO_CHROMITE	0.15	50.84	22.80	7.43	0.00	0.00	16.89	0.00	0.28	n/a	98.99	157	4660	0.02	0.58
382	B-11	23		UNKNOWN	0.17	29.59	22.80	12.79	0.00	0.00	33.50	0.00	0.24	n/a	99.51	1414	1928	0.18	0.24
383	B-12	27		PICRO_CHROMITE	0.32	51.34	20.20	12.48	0.00	0.00	14.77	0.00	0.28	n/a	99.64	1414	562	0.18	0.07
383	B-12	28		PICRO_CHROMITE	0.05	44.61	20.20	11.62	0.00	0.00	22.25	0.00	0.29	n/a	99.34	707	1848	0.09	0.23
383	B-12	30		PICRO_CHROMITE	1.30	43.75	21.50	14.23	0.00	0.00	18.80	0.00	0.21	n/a	100.11	2043	482	0.26	0.06
383	B-12	31		PICRO_CHROMITE	1.08	47.15	19.00	14.68	0.00	0.00	17.77	0.00	0.19	n/a	100.19	1965	562	0.25	0.07
383	B-12	33		PICRO_CHROMITE	0.11	45.49	18.10	12.18	0.00	0.00	22.96	0.00	0.25	n/a	99.39	707	1687	0.09	0.21
383	B-12	34		PICRO_CHROMITE	0.07	44.43	23.40	10.02	0.00	0.00	21.11	0.00	0.34	n/a	99.96	629	4097	0.08	0.51
383	B-12	35		PICRO_CHROMITE	0.75	49.91	16.40	15.48	0.00	0.00	16.33	0.00	0.20	n/a	99.28	1257	402	0.16	0.05
383	B-12	37		PICRO_CHROMITE	0.06	47.31	20.60	10.96	0.00	0.00	19.83	0.00	0.31	n/a	99.39	629	1928	0.08	0.24
383	B-12	38		PICRO_CHROMITE	1.29	42.19	22.40	13.35	0.00	0.00	19.85	0.00	0.21	n/a	99.61	1886	643	0.24	0.08
383	B-12	40		PICRO_CHROMITE	1.42	46.09	20.40	14.64	0.00	0.00	16.74	0.00	0.18	n/a	99.78	1886	562	0.24	0.07
383	B-12	41		PICRO_CHROMITE	1.29	44.69	21.60	13.46	0.00	0.00	17.46	0.00	0.24	n/a	99.07	1965	643	0.25	0.08
383	B-12	42		PICRO_CHROMITE	1.36	45.20	21.90	13.58	0.00	0.00	17.24	0.00	0.25	n/a	99.85	1886	643	0.24	0.08

Site #	Sample #	Grain	Mineral (GSC ID)	Mineral (Min-ID.ASC)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
383	B-12	24		SUB_PICRO_CHROMITE	0.47	49.47	32.90	6.94	0.00	0.00	8.39	0.00	0.62	n/a	99.27	864	2973	0.11	0.37
383	B-12	25		SUB_PICRO_CHROMITE	0.44	38.99	15.00	16.92	0.00	0.00	27.45	0.00	0.20	n/a	99.29	1807	482	0.23	0.06
383	B-12	26		SUB_PICRO_CHROMITE	0.21	55.07	26.70	7.76	0.00	0.00	8.67	0.00	0.38	n/a	99.02	1022	803	0.13	0.1
383	B-12	29		SUB_PICRO_CHROMITE	0.92	37.71	36.80	13.59	0.00	0.00	10.52	0.00	0.25	n/a	100.10	2043	402	0.26	0.05
383	B-12	32		UNKNOWN	0.36	31.57	15.60	16.75	0.00	0.00	35.18	0.00	0.17	n/a	99.91	1572	643	0.2	0.08
386	B-15	43		PICRO_CHROMITE	0.43	52.04	22.10	15.30	0.00	0.00	9.35	0.00	0.22	n/a	99.69	1493	482	0.19	0.06
386	B-15	44		UNKNOWN	0.40	31.17	18.40	14.32	0.00	0.00	34.64	0.00	0.22	n/a	99.54	1414	1687	0.18	0.21
387	B-16	45		PICRO_CHROMITE	0.10	47.73	24.20	9.19	0.00	0.00	17.70	0.00	0.35	n/a	99.58	393	2089	0.05	0.26
392	B-21	46		PICRO_CHROMITE	0.54	47.27	33.80	8.07	0.00	0.00	9.18	0.00	0.40	n/a	99.53	786	1366	0.1	0.17
392	B-21	48		PICRO_CHROMITE	0.32	41.62	25.30	10.63	0.00	0.00	21.28	0.00	0.30	n/a	99.80	1022	1767	0.13	0.22
393	B-22	50		PICRO_CHROMITE	0.73	50.65	15.20	15.69	0.00	0.00	16.87	0.00	0.22	n/a	99.61	1572	402	0.2	0.05
394	B-23	52		PICRO_CHROMITE	0.90	50.63	17.50	14.54	0.00	0.00	15.86	0.00	0.22	n/a	99.87	1179	562	0.15	0.07
411	5570	38	G3 Garnet	G_03_CALCIC_PYROPE_ALMANDINE	0.09	0.00	22.35	7.86	9.39	39.34	22.54	0.03	0.29	n/a	101.89	n/a	n/a		
412	6424	a		PICRO_CHROMITE	0.64	48.88	18.23	14.64	0.00	0.16	16.53	0.00	0.31	n/a	99.62	1257	562	0.16	0.07
412	6424	b		PICRO_CHROMITE	0.22	53.96	25.66	8.98	0.00	0.05	11.31	0.00	0.43	n/a	100.83	943	803	0.12	0.10
412	6424	d		PICRO_CHROMITE	1.16	50.03	19.53	14.50	0.00	0.23	14.83	0.00	0.28	n/a	100.78	1336	402	0.17	0.05
412	6424	f		PICRO_CHROMITE	0.08	59.15	22.10	8.40	0.00	0.05	10.36	0.00	0.51	n/a	101.00	707	2089	0.09	0.26
417	6422	a		PICRO_CHROMITE	0.30	51.55	27.65	12.59	0.00	0.17	6.86	0.00	0.33	n/a	99.64	1493	0	0.19	0.00
417	6422	c		PICRO_CHROMITE	0.69	45.35	30.08	13.87	0.00	0.15	10.11	0.00	0.23	n/a	100.76	1493	723	0.19	0.09
417	6422	d		PICRO_CHROMITE	0.26	51.49	18.91	10.72	0.03	0.00	16.46	0.00	0.31	n/a	98.18	n/a	n/a		
417	6422	e		PICRO_CHROMITE	0.11	52.05	18.93	11.75	0.00	0.00	16.46	0.00	0.35	n/a	99.65	n/a	n/a		
426	3975	a		G_01_TITANIAN_PYROPE	0.72	4.10	7.91	21.27	5.02	42.31	19.68	0.03	0.00	n/a	101.04	n/a	n/a		
426	3975	e		G_02_HIGH_TITANIUM_PYROPE	1.16	5.07	7.53	19.89	6.44	41.23	18.30	0.00	0.25	n/a	99.87	n/a	n/a		
426	3975	c		G_09_CHROME_PYROPE	0.28	6.12	6.56	20.78	5.67	41.82	18.76	0.00	0.31	n/a	100.30	n/a	n/a		
426	3975	b		G_10_LOW_CALCIUM_CHROME_PYROPE	0.01	5.96	7.08	20.07	5.86	41.14	19.04	0.00	0.48	n/a	99.64	n/a	n/a		
426	3975	d		G_10_LOW_CALCIUM_CHROME_PYROPE	0.06	6.54	5.87	23.10	2.36	42.63	18.83	0.00	0.31	n/a	99.70	n/a	n/a		
426	3975	f		SUB_PICRO_CHROMITE	0.56	38.91	21.37	14.53	0.00	0.24	23.36	0.00	0.07	n/a	99.04	n/a	n/a		
430	6424T	h(till)		G_10_LOW_CALCIUM_CHROME_PYROPE	0.00	7.96	7.03	18.66	7.00	40.74	17.89	0.05	0.43	n/a	99.76	n/a	n/a		
431	3WGK001	1	G9 Garnet	G_11_UVAROVITE_PYROPE	0.06	7.68	6.62	19.26	6.56	41.82	17.28	0.45	0.24	0.03	100.00	n/a	n/a	0.00	0.00
432	3WGK004	2	Picroilmenite	PICRO_ILMENITE	48.23	2.94	38.06	9.78	0.00	0.00	0.42	0.00	0.26	n/a	100.00	n/a	n/a	0.25	0.00
491	3958	8	G4 Garnet	UNKNOWN (G4 Garnet)	2.78	0.08	26.96	0.24	32.07	34.05	2.57	0.17	2.20	n/a	101.12	n/a	n/a		
492	3964	16	Chromite	PICRO_CHROMITE	0.95	44.01	26.55	10.58	n/a	0.19	17.29	n/a	0.31	n/a	100.12	629	1285		
493	5855	47	Chromite	PICRO_CHROMITE	2.55	47.52	25.54	12.41	n/a	0.11	11.67	n/a	0.17	n/a	100.48	2279	1767		

n/a = Not Analysed

▨ = Those sites with indicator mineral grains of favourable chemistry

Appendix 4. Summary of indicator mineral analyses for Alberta

Table B. northern Alberta

Site#	Sample #	Grain	Mineral (minclass/garclass)	Mineral (min-id.asc)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
268	NAT92-1	3		CPX_04_UNKNOWN	0.40	0.21	9.82	15.74	12.10	49.64	6.38	1.07	0.15	0.54	96.05	n/a	n/a		
269	NAT92-10	2	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.00	0.06	14.23	15.84	5.21	40.88	22.30	0.00	0.55	0.00	99.08	n/a	n/a		
276	NAT92-17	1		PICRO_CHROMITE	1.18	43.11	21.12	15.01	0.00	0.08	18.04	n/a	0.22	n/a	98.98	1730	0	0.2202	0.0000
278	NAT92-19	4	G-9	G_09_CHROME_PYROPE	0.01	3.94	8.04	18.72	5.52	41.29	20.55	0.00	0.62	0.00	98.69	n/a	n/a		
279	NAT92-2	1	G-11	GROSSULAR	0.47	4.62	3.30	0.16	35.40	38.36	15.62	0.00	0.31	n/a	98.24	n/a	n/a		
283	NAT92-23	6	G-9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.10	7.78	8.33	19.53	7.13	40.88	17.08	0.00	0.44	n/a	101.27	n/a	n/a		
285	NAT92-25	9	G-5	G_05_MAGNESIAN_ALMANDINE	0.05	0.04	25.16	9.62	2.61	38.70	21.74	0.00	0.61	0.00	98.53	n/a	n/a		
287	NAT92-27	1		PICRO_CHROMITE	0.66	48.19	26.20	13.22	0.00	0.06	10.27	n/a	0.28	n/a	98.99	830	0	0.1056	0.0000
288	NAT92-28	2	C-4 Low-Cr-diopside	CPX_04_UNKNOWN	0.71	0.03	11.69	15.90	12.74	49.60	7.69	0.75	0.26	n/a	99.38	n/a	n/a		
290	NAT92-3	12	G-2	G_02_HIGH_TITANIUM_PYROPE	1.02	0.96	10.30	21.41	5.03	41.24	20.86	0.01	0.30	n/a	101.12	n/a	n/a		
291	NAT92-30	8		UNKNOWN	0.86	30.55	16.04	19.76	0.00	0.00	33.81	0.00	0.17	n/a	101.20	n/a	n/a		
293	NAT92-32	6		G_07_FERRO-MAGNESIAN UVAROVITE_GROSSULAR	0.42	15.87	1.31	0.54	32.79	36.97	8.04	0.00	0.76	n/a	96.71	n/a	n/a		
295	NAT92-34	10	C-4 Low-Cr-diopside	CPX_04_UNKNOWN	1.15	0.08	13.34	15.82	11.18	49.44	7.64	1.14	0.18	n/a	99.96	n/a	n/a		
297	NAT92-5	1		SUB_PICRO_CHROMITE	0.12	37.28	25.68	10.69	0.00	0.00	25.07	0.00	0.31	n/a	99.13	n/a	n/a		
310	NAT93-37	1	G-3	G_05_MAGNESIAN_ALMANDINE	0.21	0.06	23.89	10.91	3.13	38.36	22.70	0.02	0.37	0.00	99.65	n/a	n/a		
310	NAT93-37	2	G-5	G_05_MAGNESIAN_ALMANDINE	0.07	0.03	25.00	8.97	4.36	38.13	22.30	0.03	0.32	0.00	99.21	n/a	n/a		
310	NAT93-37	3	G-5	G_05_MAGNESIAN_ALMANDINE	0.02	0.12	24.37	11.76	1.96	39.29	22.44	0.02	0.28	0.00	100.26	n/a	n/a		
310	NAT93-37	3	G-5	G_05_MAGNESIAN_ALMANDINE	0.14	0.11	24.20	7.83	6.48	38.68	21.60	0.02	0.59	0.00	99.65	n/a	n/a		
310	NAT93-37	2		UNKNOWN (Jaedite?)	0.83	0.06	13.86	14.78	11.94	46.90	7.49	1.48	0.15	0.69	98.17	n/a	n/a		
311	NAT93-38	1	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.10	0.00	22.32	6.29	10.65	39.62	21.29	0.00	0.39	0.00	100.66	n/a	n/a		
312	NAT93-39	197	G-5	G_05_MAGNESIAN_ALMANDINE	0.00	0.07	25.54	9.59	2.99	39.26	22.77	0.01	0.49	0.00	100.72	n/a	n/a		
312	NAT93-39	198	G-5	G_05_MAGNESIAN_ALMANDINE	0.05	0.08	25.67	9.29	2.46	37.87	22.23	0.03	0.49	0.00	98.17	n/a	n/a		
312	NAT93-39	200	G-5	G_05_MAGNESIAN_ALMANDINE	0.01	0.07	25.77	9.60	2.94	39.40	23.06	0.00	0.44	0.00	101.29	n/a	n/a		
313	NAT93-40	64		CPX_01_UNKNOWN	0.00	1.16	4.15	20.72	12.86	54.15	3.76	0.76	0.12	0.19	97.87	n/a	n/a		
314	NAT93-41	1	G-9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.02	5.66	7.82	18.13	5.70	41.96	20.12	0.03	0.38	0.00	99.82	n/a	n/a		
317	NAT93-44	208	G-9	G_09_CHROME_PYROPE	0.02	4.67	7.66	18.77	5.88	40.75	20.99	0.00	0.46	0.00	99.20	n/a	n/a		
317	NAT93-44	209	G-9	G_09_CHROME_PYROPE	0.00	4.12	7.53	18.71	5.62	41.23	20.89	0.01	0.52	0.00	98.63	n/a	n/a		
317	NAT93-44	210	G-9	G_09_CHROME_PYROPE	0.11	6.27	7.96	18.89	6.10	41.97	19.62	0.03	0.48	0.00	101.43	n/a	n/a		
317	NAT93-44	211	G-9	G_09_CHROME_PYROPE	0.13	6.14	7.91	18.06	5.94	41.12	18.93	0.01	0.48	0.00	98.72	n/a	n/a		
317	NAT93-44	212	G-9	G_09_CHROME_PYROPE	0.00	4.05	8.16	19.74	4.59	41.89	21.52	0.03	0.49	0.00	100.47	n/a	n/a		
317	NAT93-44	6		PICRO_CHROMITE	0.19	48.15	35.12	10.54	0.03	0.00	3.39	0.00	0.42	n/a	98.11	1865	295		
318	NAT93-45	1	G-5	G_05_MAGNESIAN_ALMANDINE	0.08	0.14	25.51	11.53	1.08	38.50	22.21	0.02	0.47	0.00	99.54	n/a	n/a		
318	NAT93-45	2	G-9	G_11_UVAROVITE_PYROPE	0.34	6.47	7.31	19.21	5.65	40.71	18.80	0.07	0.44	0.00	99.01	n/a	n/a		
319	NAT93-46	206	G-9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.02	8.31	7.08	18.00	6.89	40.65	17.77	0.02	0.40	0.00	99.14	n/a	n/a		
319	NAT93-46	207	G-11	G_11_UVAROVITE_PYROPE	0.59	7.18	7.42	19.50	6.30	41.35	16.96	0.06	0.27	0.00	99.63	n/a	n/a		
328	NAT93-51	2		CPX_04_UNKNOWN	0.23	0.60	11.60	14.97	10.84	49.58	6.88	1.04	0.36	0.46	96.56	n/a	n/a		
328	NAT93-51	1		UNKNOWN (Chromite?)	0.29	34.68	31.65	13.38	0.00	0.03	16.65	n/a	0.28	n/a	97.24	1971	84	0.2508	0.0104
330	NAT93-53	1	G-9	G_09_CHROME_PYROPE	0.16	1.78	9.72	18.46	5.07	42.06	21.45	0.02	0.57	0.00	99.28	n/a	n/a		
332	NAT93-55	1	C-5 Chrome-diopside	CPX_05_CHROME_DIOPSIDE	0.05	1.73	2.42	15.60	21.32	54.65	1.35	1.72	0.11	0.00	98.94	n/a	n/a		

Site#	Sample #	Grain	Mineral (minclass/garclass)	Mineral (min-id.asc)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
336	NAT93-59	1	C-2 Diopside	CPX_02_DIOPSIDE_>ONE_S.D.	0.23	0.83	4.55	17.88	20.82	53.42	2.26	0.53	0.14	0.00	100.66	n/a	n/a		
337	NAT93-60	7		PICRO_CHROMITE	0.09	52.82	20.02	12.78	0.00	0.02	13.24	0.00	0.33	n/a	99.58	792	1462		
341	NAT93-64	2	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.08	0.06	22.62	7.29	8.63	39.28	22.21	0.00	0.47	0.00	100.64	n/a	n/a		
348	NAT93-71	1		CPX_01_UNKNOWN	0.12	0.19	9.74	18.95	11.22	50.94	3.25	1.02	0.42	0.38	96.22	n/a	n/a		
350	NAT93-73	1		SUB_PICRO_CHROMITE	1.43	36.87	22.96	13.69	0.00	0.08	21.94	n/a	0.27	n/a	97.43	1535	0	0.1954	0.0000
350	NAT93-73	2		SUB_PICRO_CHROMITE	0.13	58.27	22.64	7.09	0.00	0.03	8.09	n/a	0.38	n/a	96.90	441	1780	0.0561	0.2215
351	NAT93-74	1	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.11	0.06	20.25	8.72	9.06	40.30	21.58	0.00	0.46	0.00	100.54	n/a	n/a		
351	NAT93-74	2	G-3	G_05_MAGNESIAN_ALMANDINE	0.02	0.22	23.31	12.84	1.06	40.26	22.30	0.01	0.33	0.00	100.35	n/a	n/a		
351	NAT93-74	6	G-5	G_05_MAGNESIAN_ALMANDINE	0.10	0.00	24.68	6.07	9.00	36.96	21.23	0.03	0.58	0.00	98.64	n/a	n/a		
352	NAT93-75	1	G-9	G_09_CHROME_PYROPE	0.12	5.17	8.47	18.76	5.48	41.93	18.86	0.03	0.48	0.00	99.29	n/a	n/a		
353	NAT93-76	3		CPX_04_UNKNOWN	0.29	1.01	12.01	15.79	11.81	49.37	5.83	0.96	0.31	0.57	97.96	n/a	n/a		
353	NAT93-76	2	G-5	G_05_MAGNESIAN_ALMANDINE	0.06	0.01	24.53	11.23	2.72	39.48	22.05	0.00	0.27	0.00	100.35	n/a	n/a		
353	NAT93-76	3	G-5	G_05_MAGNESIAN_ALMANDINE	0.05	0.00	25.11	10.70	2.87	39.43	21.83	0.02	0.29	0.00	100.31	n/a	n/a		
355	NAT93-78	9	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.09	0.07	22.93	6.50	9.16	38.91	21.50	0.01	0.64	0.00	99.81	n/a	n/a		
355	NAT93-78	1	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.07	0.00	22.13	9.25	6.12	40.03	21.35	0.00	0.44	0.00	99.39	n/a	n/a		
355	NAT93-78	3	G-5	G_05_MAGNESIAN_ALMANDINE	0.02	0.09	24.42	12.29	1.33	39.37	22.32	0.00	0.28	0.00	100.12	n/a	n/a		
355	NAT93-78	8	G-5	G_05_MAGNESIAN_ALMANDINE	0.14	0.00	25.60	6.84	7.00	38.86	21.47	0.02	0.97	0.00	100.89	n/a	n/a		
359	NAT93-82	3	C-2 Diopside	CPX_02_UNKNOWN	0.10	0.58	3.93	16.48	22.66	53.75	1.65	0.60	0.13	0.00	99.88	n/a	n/a		
359	NAT93-82	1	C-2 Diopside	CPX_02_UNKNOWN	0.05	0.65	4.11	15.87	22.90	53.58	1.55	0.59	0.10	0.00	99.39	n/a	n/a		
360	NAT93-83	1	C-4 Low-Cr-diopside	CPX_04_UNKNOWN	0.11	0.77	8.17	15.71	18.01	52.39	2.65	0.77	0.04	0.00	98.63	n/a	n/a		
360	NAT93-83	1	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.13	0.22	20.32	12.50	4.43	39.71	21.62	0.05	0.70	0.00	99.69	n/a	n/a		
362	NAT93-85	4	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.19	0.00	21.91	5.51	12.01	38.48	21.00	0.01	0.69	0.00	99.80	n/a	n/a		
362	NAT93-85	2	G-5	G_05_MAGNESIAN_ALMANDINE	0.06	0.00	25.30	8.35	5.70	39.78	21.19	0.01	0.49	0.00	100.88	n/a	n/a		
364	NAT93-87	3	G-5	G_05_MAGNESIAN_ALMANDINE	0.08	0.00	25.88	11.39	1.04	40.52	21.86	0.03	0.46	0.00	101.26	n/a	n/a		
364	NAT93-87	4	G-5	G_05_MAGNESIAN_ALMANDINE	0.04	0.00	25.56	11.02	1.44	40.17	21.66	0.00	0.86	0.00	100.75	n/a	n/a		
364	NAT93-87	5	G-5	G_05_MAGNESIAN_ALMANDINE	0.01	0.04	25.11	11.45	1.30	39.99	21.70	0.00	0.48	0.00	100.09	n/a	n/a		
364	NAT93-87	6	G-5	G_05_MAGNESIAN_ALMANDINE	0.07	0.00	24.88	11.96	1.32	40.15	21.55	0.01	0.52	0.00	100.47	n/a	n/a		
364	NAT93-87	7	G-5	G_05_MAGNESIAN_ALMANDINE	0.01	0.00	24.11	12.10	1.15	40.07	21.79	0.00	0.87	0.00	100.10	n/a	n/a		
364	NAT93-87	8	G-3	G_05_MAGNESIAN_ALMANDINE	0.06	0.00	23.49	6.73	8.37	39.52	21.17	0.03	0.67	0.00	100.03	n/a	n/a		
364	NAT93-87	11	G-5	G_05_MAGNESIAN_ALMANDINE	0.16	0.00	25.49	11.15	1.38	39.58	21.74	0.06	0.94	0.00	100.50	n/a	n/a		
364	NAT93-87	12	G-5	G_05_MAGNESIAN_ALMANDINE	0.07	0.00	25.10	11.63	0.68	40.73	21.51	0.01	1.42	0.00	101.14	n/a	n/a		
366	NAT93-89	3	G-5	G_05_MAGNESIAN_ALMANDINE	0.11	0.00	23.90	6.50	8.65	39.01	21.88	0.03	0.72	0.00	100.80	n/a	n/a		
367	PR93-10	1	C-2 Diopside	CPX_02_DIOPSIDE_>ONE_S.D.	0.11	0.64	5.35	15.04	21.48	53.94	1.39	1.26	0.19	0.00	99.39	n/a	n/a		
369	PR93-3	1	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.20	0.00	19.17	7.92	10.35	39.88	21.30	0.07	0.57	0.00	99.46	n/a	n/a		
369	PR93-3	1	G-9	G_09_CHROME_PYROPE	0.17	4.12	7.89	19.30	5.36	42.26	19.60	0.00	0.42	0.00	99.13	n/a	n/a		
370	PR93-6A	1	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.19	0.00	21.83	9.84	6.01	40.05	21.25	0.05	0.54	0.00	99.76	n/a	n/a		
371	PR93-6B	1	G-5	G_05_MAGNESIAN_ALMANDINE	0.16	0.00	24.97	6.56	7.69	39.29	20.95	0.00	0.63	0.00	100.25	n/a	n/a		
371	PR93-6B	1	G-9	G_09_CHROME_PYROPE	0.22	3.34	8.24	19.36	4.98	42.58	20.08	0.03	0.63	0.00	99.46	n/a	n/a		
371	PR93-6B	2	G-9	G_09_CHROME_PYROPE	0.26	4.00	8.61	19.17	4.89	42.75	19.73	0.00	0.42	0.00	99.82	n/a	n/a		
371	PR93-6B	3	G-9	G_09_CHROME_PYROPE	0.19	4.22	8.29	19.01	5.04	42.23	19.97	0.02	0.30	0.00	99.28	n/a	n/a		
371	PR93-6B	4	G-9	G_09_CHROME_PYROPE	0.31	3.55	8.47	19.40	4.93	41.98	19.83	0.04	0.50	0.00	99.02	n/a	n/a		
413	6692	a	C-3 Ti-Cr-diopside	CPX_03_UNKNOWN	0.55	0.78	2.99	14.93	19.59	50.99	7.09	2.08	0.06	n/a	99.06	n/a	n/a		
413	6692	d	C-3 Ti-Cr-diopside	CPX_03_UNKNOWN	0.52	1.07	2.79	14.73	19.50	51.24	6.63	2.07	0.04	n/a	98.61	n/a	n/a		
413	6692	h	C-5 Chrome-diopside	CPX_05_CHROME_DIOPSIDE	0.14	1.03	2.30	15.18	19.94	52.39	5.85	2.11	0.06	n/a	99.00	n/a	n/a		
413	6692	75		PICRO_CHROMITE	0.17	43.10	27.52	8.95	n/a	0.05	18.35	n/a	0.41	n/a	99.07	1022	3133		
413	6692	74		SUB_PICRO_CHROMITE	1.91	35.26	30.84	9.48	n/a	0.08	21.51	n/a	0.40	n/a	99.85	707	2250		

Site#	Sample #	Grain	Mineral (minclass/garclass)	Mineral (min-id.asc)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
413	6692	76		SUB_PICRO_CHROMITE	0.67	35.49	19.86	15.56	n/a	0.16	28.37	n/a	0.24	n/a	100.49	864	241		
414	6815	86		CHROMITE	0.19	55.90	27.90	2.97	n/a	0.13	9.15	n/a	1.35	n/a	98.37	786	5463		
414	6815	85		PICRO_CHROMITE	0.71	45.25	27.17	10.05	n/a	0.08	16.14	n/a	0.30	n/a	99.94	236	1687		
414	6815	87		PICRO_CHROMITE	0.53	50.02	25.62	8.43	n/a	0.08	13.20	n/a	0.34	n/a	98.52	1336	1044		
427	4212	23		G_03_CALCIC_PYROPE_ALMANDINE	0.08	0.00	22.15	9.12	8.81	37.94	24.33	0.01	0.53	n/a	102.97	n/a	n/a		
427	4212	27		PICRO_CHROMITE	1.23	44.50	23.23	12.86	n/a	0.08	18.40	n/a	0.29	n/a	100.92	1257	1366		
427	4212	30		PICRO_CHROMITE	0.04	43.65	20.20	11.91	n/a	0.08	23.83	n/a	0.41	n/a	100.35	707	1125		
427	4212	31		PICRO_CHROMITE	0.54	40.37	36.20	12.84	n/a	0.08	8.72	n/a	0.29	n/a	99.44	1886	1285		
427	4212	32		PICRO_CHROMITE	1.05	45.93	20.11	14.27	n/a	0.09	18.34	n/a	0.31	n/a	100.45	1493	1285		
427	4212	33		PICRO_CHROMITE	1.26	40.09	22.88	12.39	n/a	0.11	18.07	n/a	0.25	n/a	95.32	864	1285		
427	4212	34		PICRO_CHROMITE	3.09	42.64	29.96	11.40	n/a	0.16	12.46	n/a	0.31	n/a	100.27	1336	643		
427	4212	35		UNKNOWN (Chromite)	0.32	30.40	16.81	15.82	n/a	0.14	33.75	n/a	0.21	n/a	97.74	2279	0		
446	93BJB0101			PICRO_CHROMITE	0.11	40.31	16.46	13.82	0.00	0.00	27.72	0.00	n/a	n/a	98.42	n/a	n/a		
449	NAT94-92	213	G-5	G_05_MAGNESIAN_ALMANDINE	0.05	0.00	24.45	6.12	8.29	39.30	22.14	0.00	0.85	0.00	101.20	n/a	n/a		
450	NAT94-93	53	C-1 Sub-calcic diopside	CPX_01_UNKNOWN	0.01	0.12	6.74	20.52	12.77	55.72	1.90	0.63	0.34	0.23	98.98	n/a	n/a		
450	NAT94-93	52	C-2 Diopside	CPX_02_UNKNOWN	0.18	0.50	5.59	14.89	23.69	50.33	3.43	0.73	0.17	0.00	99.51	n/a	n/a		
450	NAT94-93	16	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.08	0.06	21.62	4.75	11.83	38.39	22.06	0.06	0.63	0.00	99.48	n/a	n/a		
450	NAT94-93	15	G-5	G_05_MAGNESIAN_ALMANDINE	0.11	0.05	24.89	6.49	7.20	38.61	22.05	0.00	0.62	0.00	100.02	n/a	n/a		
450	NAT94-93	17	G-5	G_05_MAGNESIAN_ALMANDINE	0.02	0.07	24.55	11.85	0.96	39.58	23.46	0.00	0.47	0.00	100.96	n/a	n/a		
451	NAT94-94	214	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.05	22.69	8.28	6.49	38.68	22.16	0.00	0.58	0.00	99.08	n/a	n/a		
451	NAT94-94	215	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.04	19.80	8.02	9.55	39.25	22.43	0.04	0.41	0.00	99.69	n/a	n/a		
453	NAT94-96	32	G-5	G_05_MAGNESIAN_ALMANDINE	0.04	0.13	24.15	12.59	0.94	40.02	23.14	0.02	0.17	0.00	101.20	n/a	n/a		
454	NAT94-97	40	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.03	0.09	13.49	12.98	9.58	41.11	23.57	0.00	0.27	0.00	101.12	n/a	n/a		
454	NAT94-97	38	G-5	G_05_MAGNESIAN_ALMANDINE	0.04	0.03	24.04	12.67	1.08	40.29	23.27	0.00	0.34	0.00	101.76	n/a	n/a		
455	NAT94-98	60	C-2 Diopside	CPX_02_UNKNOWN	0.10	0.68	5.77	16.09	22.72	54.30	0.83	0.80	0.13	0.00	101.43	n/a	n/a		
455	NAT94-98	205	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.24	0.05	21.79	6.13	9.90	39.14	21.95	0.04	0.84	0.00	100.08	n/a	n/a		
455	NAT94-98	45	G-5	G_05_MAGNESIAN_ALMANDINE	0.03	0.06	25.09	10.90	2.02	39.34	22.97	0.02	0.00	0.00	100.43	n/a	n/a		
457	NAT94-100	216	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.07	0.04	22.63	5.96	9.33	38.73	22.31	0.00	0.69	0.00	99.76	n/a	n/a		
459	NAT94-102	41	C-4 Low-Cr-diopside	CPX_04_UNKNOWN	0.03	0.67	8.51	15.04	22.11	52.59	1.78	0.55	0.36	0.00	101.64	n/a	n/a		
459	NAT94-102	62	G-5	G_05_MAGNESIAN_ALMANDINE	0.05	0.11	24.33	11.66	0.93	39.18	23.15	0.01	0.31	0.00	99.73	n/a	n/a		
460	NAT94-103	58	C-5 Chrome-diopside	CPX_05_UNKNOWN	0.24	1.47	3.91	15.73	24.23	52.60	2.37	1.18	0.07	0.00	101.81	n/a	n/a		
460	NAT94-103	59	C-5 Chrome-diopside	CPX_05_UNKNOWN	0.20	1.33	3.65	15.45	23.51	50.97	2.23	1.02	0.11	0.02	98.49	n/a	n/a		
460	NAT94-103	67	G-3	G_05_MAGNESIAN_ALMANDINE	0.01	0.16	22.90	9.39	5.58	38.03	22.88	0.00	0.31	0.00	99.26	n/a	n/a		
460	NAT94-103	204	G-9	G_09_CHROME_PYROPE	0.01	4.34	7.33	18.58	6.39	41.48	20.89	0.00	0.53	0.00	99.55	n/a	n/a		
461	NAT94-104	37	C-4 Low-Cr-diopside	CPX_04_UNKNOWN	0.44	1.09	8.55	17.34	12.54	48.45	8.44	1.27	0.13	0.73	98.98	n/a	n/a		
461	NAT94-104	71	G-5	G_05_MAGNESIAN_ALMANDINE	0.02	0.12	24.57	11.54	1.04	39.59	22.46	0.02	0.25	0.00	99.61	n/a	n/a		
462	NAT94-105	35	C-4 Low-Cr-diopside	CPX_04_UNKNOWN	0.19	0.09	12.33	16.09	12.45	50.36	6.23	0.74	0.28	0.16	98.92	n/a	n/a		
462	NAT94-105	77	G-5	G_05_MAGNESIAN_ALMANDINE	0.01	0.05	25.13	11.38	1.27	39.88	23.42	0.02	0.26	0.00	101.42	n/a	n/a		
462	NAT94-105	2		PICRO_ILMENITE	51.86	0.68	31.28	14.31	0.10	0.02	0.41	0.00	0.38	n/a	99.14	747	60		
463	NAT94-106	34		CPX_01_UNKNOWN	0.28	0.60	5.09	19.57	13.08	49.33	6.96	1.41	0.12	0.76	97.20	n/a	n/a		
463	NAT94-106	79	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.15	0.00	20.08	10.84	5.44	40.18	22.69	0.05	0.53	0.00	99.96	n/a	n/a		
463	NAT94-106	3		PICRO_CHROMITE	2.09	45.56	25.40	15.03	0.00	0.04	11.08	0.00	0.22	n/a	99.60	1330	55		
465	NAT94-108	31	C-1 Sub-calcic diopside	CPX_01_UNKNOWN	0.02	0.12	8.60	18.68	12.88	52.84	4.04	0.84	0.32	0.29	98.63	n/a	n/a		
465	NAT94-108	202	G-7	GROSSULAR	0.55	12.01	3.90	0.31	33.73	37.20	10.03	0.00	0.60	0.00	98.33	n/a	n/a		
466	NAT94-109	28	C-1 Sub-calcic diopside	CPX_01_UNKNOWN	0.27	0.19	10.58	18.46	11.57	52.98	3.40	0.82	0.26	0.28	98.81	n/a	n/a		
466	NAT94-109	95	G-3	G_05_MAGNESIAN_ALMANDINE	0.05	0.08	23.01	10.34	4.05	39.53	23.18	0.04	0.22	0.00	100.50	n/a	n/a		

Site#	Sample #	Grain	Mineral (minclass/garclass)	Mineral (min-id.asc)	% TiO2	% Cr2O3	% FeO	% MgO	% CaO	% SiO2	% Al2O3	% Na2O	% MnO	% K2O	% Total	ppm Ni	ppm Zn	NiO	ZnO
466	NAT94-109	4		PICRO_ILMENITE	48.30	0.37	39.65	9.59	0.05	0.01	0.39	0.00	0.24	n/a	98.67	420	153		
467	NAT94-110	100	G-6	G_06_PYROPE_GROSSULAR_ALMANDINE	0.29	0.02	16.44	5.24	17.67	38.65	22.63	0.03	0.31	0.00	101.28	n/a	n/a		
468	NAT94-111	26	C-4 Low-Cr-diopside	CPX_04_UNKNOWN	0.16	0.37	11.77	15.86	12.67	49.22	7.63	0.94	0.22	0.29	99.13	n/a	n/a		
474	NAT94-117	5		SUB_PICRO_CHROMITE	2.05	39.06	28.40	13.26	0.00	0.06	17.54	0.00	0.29	n/a	100.95	1513	782		
476	NAT94-119	19		CPX_01_UNKNOWN	0.04	0.42	6.60	20.06	11.94	51.73	4.59	0.95	0.16	0.23	96.72	n/a	n/a		
476	NAT94-119	20		CPX_01_UNKNOWN	0.01	0.12	5.84	21.09	12.06	53.46	4.17	0.81	0.19	0.37	98.12	n/a	n/a		
476	NAT94-119	57		CPX_05_UNKNOWN	0.12	1.35	3.58	16.69	24.36	54.26	1.42	0.56	0.16	0.00	102.51	n/a	n/a		
476	NAT94-119	143	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.30	0.03	18.12	8.49	10.99	39.92	22.60	0.06	0.47	0.00	100.98	n/a	n/a		
477	NAT94-120	147	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.05	0.08	21.48	9.50	6.27	37.10	22.41	0.00	0.66	0.00	97.55	n/a	n/a		
477	NAT94-120	144	G-3	G_05_MAGNESIAN_ALMANDINE	0.09	0.03	23.36	11.83	1.76	39.74	23.04	0.00	0.50	0.00	100.35	n/a	n/a		
478	LL94-27	16	C-2 Diopside	CPX_05_CHROME_DIOPSIDE	0.43	0.94	2.86	15.34	22.60	51.94	6.26	1.51	0.11	0.00	101.99	n/a	n/a		
478	LL94-27	154	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.06	0.00	21.96	8.05	7.62	39.61	22.67	0.00	0.47	0.00	100.44	n/a	n/a		
479	LL94-34	218	G-3	G_03_CALCIC_PYROPE_ALMANDINE	0.04	0.12	19.40	10.82	6.42	39.45	22.64	0.01	0.54	0.00	99.44	n/a	n/a		
480	LL94-35	63	C-5 Chrome-diopside	CPX_05_CHROME_DIOPSIDE	0.26	1.18	2.60	15.56	22.68	52.06	6.07	1.39	0.06	0.02	101.88	n/a	n/a		
481	LL94-40	62	G-9	G_09_CHROME_PYROPE	0.17	5.05	9.14	19.83	5.60	41.83	18.73	0.03	0.54	0.00	100.92	n/a	n/a		
481	LL94-40	10		UNKNOWN (Chromite)	0.31	60.57	25.71	10.23	0.00	0.00	1.75	0.00	0.37	n/a	99.13	853	678		
482	LL94-42	219	G-9	G_10_LOW_CALCIUM_CHROME_PYROPE	0.03	7.10	7.71	18.45	6.67	40.73	18.78	0.00	0.42	0.00	99.89	n/a	n/a		
483	94SAB-14	8		PICRO_CHROMITE	0.10	55.39	19.99	10.30	0.00	0.00	13.27	0.00	0.29	n/a	99.60	395	1669		
485	94SAB-39	9		PICRO_CHROMITE	0.05	55.89	20.10	11.60	0.02	0.01	13.63	0.00	0.28	n/a	101.83	468	1520		
487	94SAB-35	173	G-5	G_05_MAGNESIAN_ALMANDINE	0.01	0.00	24.38	11.45	1.04	39.93	23.66	0.02	0.23	0.00	100.72	n/a	n/a		
488	94SAB-76	11		PICRO_CHROMITE	1.52	43.96	24.74	13.72	0.02	0.06	16.53	0.00	0.24	n/a	101.04	1518	494		
497	T 7 G	128	G-9	G_09_CHROME_PYROPE	0.03	2.88	8.24	19.55	4.74	42.51	22.08	0.01	0.52	0.00	100.56	n/a	n/a		
498	T 8 H	1	C-5 Chrome-diopside	CPX_05_CHROME_DIOPSIDE	0.23	1.44	2.45	15.65	21.35	52.73	5.59	1.51	0.07	0.00	101.02	n/a	n/a		
498	T 8 H	2	C-5 Chrome-diopside	CPX_05_CHROME_DIOPSIDE	0.23	1.52	2.69	15.75	18.97	53.45	5.23	2.09	0.07	0.00	100.00	n/a	n/a		

n/a = Not Analysed

▨ = Those sites with indicator mineral grains of favourable chemistry

Appendix 5. Summary of indicator minerals for Alberta

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
1	91TCA-3019	110.482618	49.974459	72L	Medicine Hat	GSC/Thorleifson	Till	91TCA-3019			0	1	5	6	1			7	
2	91TCA-3020	111.133141	50.212083	72L	Suffield	GSC/Thorleifson	Till	91TCA-3020		1	1	1		1	2	6		10	3 jadeite, 3 kyanite
3	91TCA-3021	111.995606	50.641376	72L	Brooks	GSC/Thorleifson	Till	91TCA-3021			0		1	1				1	
4	91TCA-3022	113.072479	50.911406	82I	Gleichen	GSC/Thorleifson	Till	91TCA-3022	1		1	1		1	1			3	
5	91TCA-3023	113.724499	51.041018	82I	Calgary	GSC/Thorleifson	Till	91TCA-3023			0	1	1	2	1			3	
6	91TCA-3024	114.000208	51.282528	82O	Airdrie	GSC/Thorleifson	Till				0			0				0	
7	91TCA-3025	114.020485	51.721074	82O	Olds	GSC/Thorleifson	Till				0			0				0	
8	91TCA-3026	113.906378	52.316490	83A	Red Deer	GSC/Thorleifson	Till	91TCA-3026		1	1	1		1				2	
9	91TCA-3027	113.642677	52.838858	83A	Ponoka	GSC/Thorleifson	Till	91TCA-3027			0	1	2	3	1			4	
10	91TCA-3028	113.548995	53.291394	83H	Leduc	GSC/Thorleifson	Till	91TCA-3028					1	1				1	
11	91TCA-3029	113.177713	53.572967	83H	Edmonton	GSC/Thorleifson	Till	91TCA-3029			0	2	5	7	1			8	
12	91TCA-3030	112.275724	53.561718	83H	Vegreville	GSC/Thorleifson	Till	91TCA-3030			0	4	6	10	1	4	1	16	1 jadeite; 3 kyanite
13	91TCA-3031	111.229755	53.334595	73E	Mannville	GSC/Thorleifson	Till	91TCA-3031	1		1	5	6	11	1			13	
14	91TCA-3032	110.349661	53.342037	73E	Kitscoty	GSC/Thorleifson	Till	91TCA-3032			0		5	5				5	
15	1-3-1-T	114.973516	54.009835	83J	Mayerthorpe	GSC/Thorleifson	Till	1-3-1-T			0			0			1	1	
16	10-2-2-T	114.174442	50.919886	82J	Calgary	GSC/Thorleifson	Till				0			0				0	
17	10-3-1-T	114.003055	50.396573	82J	Nanton	GSC/Thorleifson	Till				0			0				0	
18	13-3-2-T	113.586360	54.910684	83I	Grosmont	GSC/Thorleifson	Till				0			0				0	
19	14-3-2-T	113.574480	53.961582	83H	Morinville	GSC/Thorleifson	Till				0			0				0	
20	14-4-1-T	113.751049	54.349667	83I	Westlock	GSC/Thorleifson	Till				0			0				0	
21	15-3-1-T	113.419206	53.410983	83H	Edmonton	GSC/Thorleifson	Till				0			0				0	
22	15-3-2-T	113.426939	53.335301	83H	Beaumont	GSC/Thorleifson	Till	15-3-2-T			0	1		1				1	
23	15-4-2-T	113.944395	53.628477	83H	Spruce Grove	GSC/Thorleifson	Till	15-4-2-T	1	1	2			0		2		4	
24	16-3-1-T	113.710031	52.704251	83A	Ponoka	GSC/Thorleifson	Till	16-3-1-T		2	2			0				2	
25	16-3-2-T	113.897522	52.718699	83A	Gull Lake	GSC/Thorleifson	Till	16-3-2-T			0		1	1				1	
26	16-4-1-T	113.402242	53.136196	83H	Leduc	GSC/Thorleifson	Till	16-4-1-T			0	1		1	1		1	3	
27	16-4-2-T	113.798421	52.882048	83A	Ponoka	GSC/Thorleifson	Till	16-4-2-T			0			0	1			1	
28	17-1-2-T	113.931122	52.002003	83A	Innisfail	GSC/Thorleifson	Till	17-1-2-T			0			0	1		1	2	
29	17-2-2-T	113.976587	52.378594	83A	Gull Lake	GSC/Thorleifson	Till				0			0				0	
30	17-3-1-T	113.505812	52.108949	83A	Pine Lake	GSC/Thorleifson	Till	17-3-1-T			0	2		2	2			4	
31	17-3-2-T	113.630924	52.026182	83A	Innisfail	GSC/Thorleifson	Till				0			0				0	
32	17-4-1-T	113.409615	52.166709	83A	Pine Lake	GSC/Thorleifson	Till	17-4-1-T			0		1	1				1	
33	17-4-2-T	113.921387	52.410549	83A	Lacombe	GSC/Thorleifson	Till				0			0				0	
34	18-1-2-T	113.983408	51.162418	82P	McDonald Lake	GSC/Thorleifson	Till				0			0				0	
35	18-3-1-T	113.541584	51.139581	82P	Strathmore	GSC/Thorleifson	Till				0			0				0	
36	18-3-2-T	113.784880	51.357098	82P	Airdrie	GSC/Thorleifson	Till	18-3-2-T			0			0	1			1	1 corundum
37	18-4-1-T	113.551010	51.774333	82P	Three Hills	GSC/Thorleifson	Till				0			0				0	
38	18-4-2-T	113.821012	51.663831	82P	Olds	GSC/Thorleifson	Till				0			0				0	
39	19-1-2-T	113.973555	50.651746	82I	Okotoks	GSC/Thorleifson	Till				0			0				0	
40	19-2-2-T	113.955918	50.821306	82I	Calgary	GSC/Thorleifson	Till	19-2-2-T			0			0	1			1	
41	19-3-1-T	113.787266	50.396394	82I	Nanton	GSC/Thorleifson	Till				0			0				0	
42	19-3-2-T	113.534874	50.571275	82I	Vulcan	GSC/Thorleifson	Till	19-3-2-T			0		1	1				1	
43	19-4-1-T	113.530810	50.863689	82I	Carseland	GSC/Thorleifson	Till	19-4-1-T		1	1			0				1	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
44	19-4-2-T	113.761278	50.963699	82I	Calgary	GSC/Thorleifson	Till				0			0				0	
45	2-1-2-T	115.305178	53.583483	83G	Chip Lake	GSC/Thorleifson	Till				0			0				0	
46	2-3-1-T	114.676142	53.456034	83G	Wabamun Lake	GSC/Thorleifson	Till	2-3-1-T			0		1	1		1		2	
47	2-3-2-T	114.908833	53.533157	83G	Wabamun Lake	GSC/Thorleifson	Till				0								
48	2-4-1-T	114.970879	53.718523	83G	Wabamun Lake	GSC/Thorleifson	Till				0			0				0	
49	2-4-2-T	114.639229	53.632429	83G	Wabamun Lake	GSC/Thorleifson	Till	2-4-2-T			0	1	2	3				3	
50	20-1-1-T	113.870727	49.959865	82H	Claresholm	GSC/Thorleifson	Till				0			0				0	
51	20-3-1-T	113.618358	49.883079	82H	Ft. Macleod	GSC/Thorleifson	Till	20-3-1-T		1	1			0				1	
52	20-3-2-T	113.705464	49.722749	82H	Ft. Macleod	GSC/Thorleifson	Till	20-3-2-T			0			0			1	1	
53	20-4-1-T	113.759358	50.133490	82I	Stavely	GSC/Thorleifson	Till				0			0				0	
54	20-4-2-T	113.392774	50.246871	82I	Stavely	GSC/Thorleifson	Till	20-4-2-T			0	1	1	2				2	
55	21-2-2-T	113.968438	49.438307	82H	Pincher Creek	GSC/Thorleifson	Till				0			0				0	
56	21-3-1-T	113.290555	49.129867	82H	Cardston	GSC/Thorleifson	Till	21-3-1-T	2	1	3	1		1				4	
57	21-3-2-T	113.638861	49.234885	82H	Waterton	GSC/Thorleifson	Till				0			0				0	
58	21-4-1-T	113.595359	49.322239	82H	Waterton	GSC/Thorleifson	Till	21-4-1-T			0		1	1				1	
59	21-4-2-T	113.459386	49.548319	82H	Ft. Macleod	GSC/Thorleifson	Till	21-4-2-T			0		1	1				1	
60	23-1-1-T	113.433824	54.709779	83I	Athabasca	GSC/Thorleifson	Till	23-1-1-T	1		1			0			1	2	
61	23-1-2-T	112.875845	54.896770	83I	Alpac	GSC/Thorleifson	Till				0			0				0	
62	23-3-1-T	112.803187	54.841244	83I	Grassland	GSC/Thorleifson	Till	23-3-1-T			0	1		1	1			2	
63	23-3-2-T	112.297317	54.751540	83I	Plamondon	GSC/Thorleifson	Till	23-3-2-T			0	1		1				1	
64	24-1-1-T	113.177236	54.207667	83I	Elbridge	GSC/Thorleifson	Till				0			0				0	1 corundum
65	24-1-2-T	112.980632	54.264997	83I	Abee	GSC/Thorleifson	Till				0			0				0	
66	24-2-1-T	113.014969	54.496345	83I	Ellscott	GSC/Thorleifson	Till	24-2-1-T			0			0		1		1	
67	24-2-2-T	113.401949	54.511747	83I	Perryvale	GSC/Thorleifson	Till	24-2-2-T		1	1			0				1	
68	24-3-1-T	112.259110	54.017627	83I	Kahwin	GSC/Thorleifson	Till				0			0				0	
69	24-3-2-T	112.324041	54.187710	83I	Edwand	GSC/Thorleifson	Till	24-3-2-T			0			0				0	
70	24-4-1-T	112.794752	54.615766	83I	Boyle	GSC/Thorleifson	Till				0			0				0	
71	24-4-2-T	112.798801	54.320881	83I	Valley Lake	GSC/Thorleifson	Till	24-4-2-T		1	1		1	1		1		3	
72	25-1-1-T	113.385931	53.354111	83H	Beaumont	GSC/Thorleifson	Till				0			0				0	
73	25-1-2-T	112.877368	53.338924	83H	Cooking Lake	GSC/Thorleifson	Till				0			0				0	
74	25-2-1-T	113.118034	53.919257	83H	Redwater	GSC/Thorleifson	Till	25-2-1-T			0		1	1				1	
75	25-2-2-T	113.125194	53.670107	83H	Ft Saskatchewan	GSC/Thorleifson	Till	25-2-2-T			0			0	1			1	
76	25-3-1-T	112.754627	53.495420	83H	Elk Island	GSC/Thorleifson	Till				0			0				0	
77	25-3-2-T	112.221350	53.351038	83H	Vegreville	GSC/Thorleifson	Till	25-3-2-T			0			0		1		1	
78	25-4-1-T	112.723489	53.656787	83H	Chipman	GSC/Thorleifson	Till				0			0				0	
79	25-4-2-T	112.434890	53.669583	83H	Hilliard	GSC/Thorleifson	Till				0			0				0	
80	26-1-1-T	113.015289	52.757665	83A	Stettler	GSC/Thorleifson	Till				0			0				0	
81	26-1-2-T	113.176962	52.671184	83A	Samson Lake	GSC/Thorleifson	Till				0			0				0	1 corundum
82	26-2-1-T	113.119390	53.069640	83H	Bittern Lake	GSC/Thorleifson	Till				0			0				0	
83	26-2-2-T	112.911928	53.171154	83H	Miquelon Lake	GSC/Thorleifson	Till				0			0				0	
84	26-3-1-T	112.305981	52.576997	83A	Stettler	GSC/Thorleifson	Till				0			0				0	1 corundum
85	26-3-2-T	112.579983	52.727400	83A	Driedmeat Lake	GSC/Thorleifson	Till	26-3-2-T			0		1	1				1	
86	26-4-1-T	112.193431	53.158046	83H	Holden	GSC/Thorleifson	Till				0			0				0	
87	26-4-2-T	112.656594	53.106654	83H	Camrose	GSC/Thorleifson	Till	26-4-2-T	1		1			0				1	
88	27-1-1-T	113.078572	51.903241	82P	Trochu	GSC/Thorleifson	Till	27-1-1-T			0			0		1		1	
89	27-1-2-T	113.273845	52.142429	83A	Delburne	GSC/Thorleifson	Till	27-1-2-T			0		1	1			1	2	
90	27-2-1-T	112.859892	52.414040	83A	Buffalo Lake	GSC/Thorleifson	Till	27-2-1-T	1	1	2			0			1	3	1 olivine; MgO

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
91	27-2-2-T	113.262207	52.402528	83A	Buffalo Lake	GSC/Thorleifson	Till	27-2-2-T			0			0			2	2	
92	27-3-1-T	112.203325	52.114156	83A	Sullivan Lake	GSC/Thorleifson	Till				0			0				0	
93	27-3-2-T	112.500349	51.825713	82P	Farrell Lake	GSC/Thorleifson	Till	27-3-2-T			0			0		1		1	
94	27-4-1-T	112.499909	52.291482	83A	Stettler	GSC/Thorleifson	Till				0			0				0	
95	27-4-2-T	112.175562	52.279871	83A	Halkirk	GSC/Thorleifson	Till				0			0				0	
96	28-1-1-T	113.056386	51.383848	82P	Drumheller	GSC/Thorleifson	Till	28-1-1-T			0		1	1				1	
97	28-1-2-T	112.772189	51.132192	82P	Standard	GSC/Thorleifson	Till				0			0				0	
98	28-2-1-T	113.241396	51.757266	82P	Three Hills	GSC/Thorleifson	Till	28-2-1-T			0			0	4			4	
99	28-2-2-T	112.878453	51.565792	82P	Munson	GSC/Thorleifson	Till	28-2-2-T			0	1		1		1		2	
100	28-3-1-T	112.345706	51.358196	82P	Littlefish Lake	GSC/Thorleifson	Till				0			0				0	
101	28-3-2-T	112.186811	51.267293	82P	Littlefish Lake	GSC/Thorleifson	Till				0			0				0	
102	28-4-1-T	112.507201	51.639490	82P	Drumheller	GSC/Thorleifson	Till				0			0				0	
103	28-4-2-T	112.389057	51.792911	82P	Drumheller	GSC/Thorleifson	Till				0			0				0	
104	29-1-1-T	112.848941	50.510439	82I	McGregor Lake	GSC/Thorleifson	Till	29-1-1-T			0			0	1		1	2	
105	29-1-2-T	112.705758	50.568388	82I	Blackfoot Res.	GSC/Thorleifson	Till				0			0				0	
106	29-2-1-T	112.728416	50.839664	82I	Blackfoot Res.	GSC/Thorleifson	Till	29-2-1-T			0			0	1			1	
107	29-2-2-T	113.121571	51.021147	82I	Blackfoot Res.	GSC/Thorleifson	Till	29-2-2-T			0			0		2		2	
108	29-3-1-T	112.292921	50.601584	82I	Bassano/BIR	GSC/Thorleifson	Till	29-3-1-T			0		1	1				1	
109	29-3-2-T	112.535459	50.629217	82I	Blackfoot Res.	GSC/Thorleifson	Till	29-3-2-T			0	1	1	2			2	4	
110	29-4-1-T	112.309811	51.005191	82P	Wolf Lake	GSC/Thorleifson	Till	29-4-1-T			0	1		1				1	
111	29-4-2-T	112.366960	50.864244	82I	Barkenhouse Lake	GSC/Thorleifson	Till				0			0				0	
112	3-4-1-T	114.950613	53.198536	83G	Drayton Valley	GSC/Thorleifson	Till				0			0				0	
113	3-4-2-T	114.942338	52.964633	83B	Buck Lake	GSC/Thorleifson	Till				0			0				0	
114	30-1-1-T	112.782958	49.954711	82H	Keho Lake	GSC/Thorleifson	Till				0			0				0	1 olivine; MgO
115	30-1-2-T	112.866812	49.815768	82H	Lethbridge	GSC/Thorleifson	Till	30-1-2-T		1	1			0				1	
116	30-2-1-T	112.970465	50.312366	82I	Vulcan	GSC/Thorleifson	Till				0			0				0	
117	30-2-2-T	112.822919	50.016155	82I	Traverse Res.	GSC/Thorleifson	Till	30-2-2-T			0			0		1		1	
118	30-3-1-T	112.620021	49.668365	82H	Coaldale	GSC/Thorleifson	Till				0			0				0	
119	30-3-2-T	112.301606	49.991693	82H	Vauxhall	GSC/Thorleifson	Till				0			0				0	
120	30-4-1-T	112.183804	50.023536	82I	Vauxhall	GSC/Thorleifson	Till				0			0				0	
121	30-4-2-T	112.474328	50.165018	82I	Enchant	GSC/Thorleifson	Till	30-4-2-T		1	1			0				1	
122	31-1-2-T	112.714355	49.275702	82H	Raymond	GSC/Thorleifson	Till				0			0				0	
123	31-2-1-T	112.768061	49.354955	82H	Raymond	GSC/Thorleifson	Till				0			0				0	
124	31-2-2-T	112.779295	49.589565	82H	Cardston	GSC/Thorleifson	Till	31-2-2-T			0		1	1				1	
125	31-3-1-T	112.189977	49.137464	82H	Mackie Creek	GSC/Thorleifson	Till	31-3-1-T	1		1			0		1	1	3	
126	31-3-2-T	112.542634	49.279921	82H	Raymond	GSC/Thorleifson	Till	31-3-2-T	1	1	2			0	1			3	
127	31-4-1-T	112.252862	49.293322	82H	Warner	GSC/Thorleifson	Till	31-4-1-T			0		1	1				1	
128	31-4-2-T	112.588447	49.464609	82H	Raymond	GSC/Thorleifson	Till				0			0				0	
129	33-1-1-T	111.886622	54.870270	83I	Lac la Biche	GSC/Thorleifson	Till	33-1-1-T	2		2			0				2	
130	34-1-1-T	111.973190	54.126341	73L	Vilna	GSC/Thorleifson	Till	34-1-1-T			0	2		2	1			3	
131	34-1-2-T	112.134626	54.042237	83I	Kahwin E.	GSC/Thorleifson	Till				0			0				0	
132	34-2-1-T	111.829584	54.520176	73L	Grandeur Lake	GSC/Thorleifson	Till	34-2-1-T			0			0	1			1	
133	34-2-2-T	112.030574	54.280457	73L	Whitefish Lake	GSC/Thorleifson	Till	34-2-2-T		1	1			0				1	
134	34-3-1-T	111.275422	54.125466	73L	Vincent Lake	GSC/Thorleifson	Till	34-3-1-T		1	1			0	2			3	
135	34-3-2-T	111.307167	54.073263	73L	Owlseye	GSC/Thorleifson	Till				0			0				0	1 kyanite
136	34-4-1-T	111.104568	54.331550	73L	Franchere	GSC/Thorleifson	Till				0			0				0	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
137	34-4-2-T	111.385866	54.483766	73L	Frenchman Lake	GSC/Thorleifson	Till	34-4-2-T		2	2			0				2	
138	35-1-1-T	111.732947	53.429653	73E	Ranfurly	GSC/Thorleifson	Till				0			0				0	
139	35-1-2-T	112.170876	53.263447	83H	Holden	GSC/Thorleifson	Till	35-1-2-T			0		1	1				1	
140	35-2-1-T	111.985501	53.741540	73E	Hairy Hill	GSC/Thorleifson	Till	35-2-1-T			0		1	1				1	
141	35-2-2-T	112.214320	53.947078	83H	Shandro	GSC/Thorleifson	Till	35-2-2-T			0			0	1			1	1 jadeite
142	35-3-1-T	111.034562	53.363578	73E	Mannville	GSC/Thorleifson	Till				0			0				0	
143	35-3-2-T	111.550280	53.386581	73E	Innisfree	GSC/Thorleifson	Till				0			0				0	
144	35-4-1-T	111.567837	53.800879	73E	Lac Sante	GSC/Thorleifson	Till				0			0				0	
145	35-4-2-T	111.155740	53.627752	73E	Myrnam	GSC/Thorleifson	Till	35-4-2-T			0			0	1			1	
146	36-1-1-T	111.613562	52.871186	73D	Sedgewick	GSC/Thorleifson	Till				0			0				0	
147	36-1-2-T	112.095838	52.671730	83A	Stettler	GSC/Thorleifson	Till	36-1-2-T			0	1		1				1	
148	36-2-1-T	112.076556	53.149272	83H	Holden	GSC/Thorleifson	Till	36-2-1-T		1	1			0	1			2	
149	36-2-2-T	111.911409	52.976252	73D	Killam	GSC/Thorleifson	Till				0			0				0	
150	36-3-1-T	111.526960	52.712483	73D	Hardisty	GSC/Thorleifson	Till	36-3-1-T			0			0	1			1	
151	36-3-2-T	111.040112	52.871870	73D	Wainwright	GSC/Thorleifson	Till	36-3-2-T	1		1		1	1	1			3	
152	36-4-1-T	111.568275	52.929844	73D	Sedgewick	GSC/Thorleifson	Till				0			0				0	
153	36-4-2-T	111.540230	53.186175	73E	Birch Lake	GSC/Thorleifson	Till				0			0				0	
154	37-1-1-T	111.861656	52.117148	72M	Sullivan Lake	GSC/Thorleifson	Till							0					
155	37-1-2-T	112.142284	52.011364	83A	Sullivan Lake	GSC/Thorleifson	Till	37-1-2-T		1	1			0				1	
156	37-2-1-T	111.931993	52.198431	73D	Castor	GSC/Thorleifson	Till				0			0				0	
157	37-2-2-T	111.754903	52.367829	73D	Alliance	GSC/Thorleifson	Till				0			0				0	
158	37-3-1-T	111.279104	52.143344	73D	Coronation	GSC/Thorleifson	Till	37-3-1-T		1	1		1	1				2	
159	37-3-2-T	111.574074	52.126998	73D	Coronation	GSC/Thorleifson	Till	37-3-2-T			0	1		1				1	
160	37-4-1-T	111.112665	52.201167	73D	Coronation	GSC/Thorleifson	Till	37-4-1-T			0			0			1	1	
161	37-4-2-T	111.363052	52.224030	73D	Talbot	GSC/Thorleifson	Till				0			0				0	
162	38-1-1-T	112.066536	51.272946	82P	East Coulee	GSC/Thorleifson	Till				0			0				0	
163	38-1-2-T	111.643197	51.240968	72M	Drumheller	GSC/Thorleifson	Till				0			0				0	
164	38-2-1-T	111.913988	51.747212	72M	Hanna	GSC/Thorleifson	Till	38-2-1-T			0	2		2				2	
165	38-2-2-T	111.855834	51.735960	72M	Hanna	GSC/Thorleifson	Till	38-2-2-T			0	1	1	2				2	
166	38-3-1-T	111.040185	51.326353	72M	Oyen	GSC/Thorleifson	Till	38-3-1-T		1	1			0			1	2	
167	38-3-2-T	111.149074	51.269622	72M	Oyen	GSC/Thorleifson	Till	38-3-2-T			0			0			2	2	
168	38-4-1-T	111.430968	51.676254	72M	Hanna	GSC/Thorleifson	Till	38-4-1-T		1	1			0		1		2	
169	38-4-2-T	111.089835	51.763326	72M	Coronation	GSC/Thorleifson	Till	38-4-2-T			0	1		1				1	
170	39-1-1-T	111.696270	50.386343	72L	Tilley	GSC/Thorleifson	Till	39-1-1-T			0			0	1	1		2	
171	39-1-2-T	111.990791	50.479536	72L	Newell Lake W.	GSC/Thorleifson	Till				0			0				0	
172	39-2-1-T	111.627655	50.834595	72L	Dinosaur Park	GSC/Thorleifson	Till				0			0				0	
173	39-2-2-T	112.129259	50.730090	82I	Rosemary	GSC/Thorleifson	Till				0			0				0	
174	39-3-1-T	111.293301	50.731597	72L	Iddesleigh	GSC/Thorleifson	Till	39-3-1-T			0		1	1			1	2	1 corundum
175	39-3-2-T	111.187954	50.607708	72L	Suffield	GSC/Thorleifson	Till				0			0				0	
176	39-4-1-T	111.342552	50.878943	72L	Dinosaur Park	GSC/Thorleifson	Till				0			0				0	
177	39-4-2-T	111.399362	51.039727	72M	Dinosaur Park	GSC/Thorleifson	Till				0			0				0	
178	40-1-1-T	111.844250	49.845718	72E	Purple Springs	GSC/Thorleifson	Till	40-1-1-T		1	1			0				1	
179	40-1-2-T	111.775639	50.077355	72L	Hays	GSC/Thorleifson	Till				0			0					
180	40-2-1-T	112.015006	50.359712	82I	Vauxhall North	GSC/Thorleifson	Till	40-2-1-T			0			0	1			1	
181	40-2-2-T	112.069796	50.107389	82I	Vauxhall	GSC/Thorleifson	Till				0			0				0	
182	40-3-1-T	111.530438	49.893458	72E	Burdett	GSC/Thorleifson	Till				0			0				0	
183	40-3-2-T	111.052693	49.697674	72E	Maleb	GSC/Thorleifson	Till				0			0				0	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
184	40-4-1-T	111.518065	50.167824	72L	12 Mile Coulee	GSC/Thorleifson	Till	40-4-1-T			0			0		1		1	
185	40-4-2-T	111.558245	50.251288	72L	12 Mile Coulee	GSC/Thorleifson	Till				0			0				0	
186	41-1-1-T	111.564519	49.110733	72E	Writing on Stone	GSC/Thorleifson	Till	41-1-1-T			0			0	1			1	
187	41-1-2-T	111.952446	49.118978	72E	Red Creek	GSC/Thorleifson	Till	41-1-2-T			0	1		1				1	
188	41-2-1-T	112.048257	49.502250	82H	Wrentham	GSC/Thorleifson	Till	41-2-1-T		1	1			0				1	
189	41-2-2-T	111.645704	49.347784	72E	Crow Indian Lake	GSC/Thorleifson	Till	41-2-2-T	2		2			0	1		1	4	
190	41-3-1-T	111.255009	49.140621	72E	Milk River	GSC/Thorleifson	Till				0			0				0	
191	41-4-1-T	111.110609	49.556421	72E	North Pakowki	GSC/Thorleifson	Till				0			0				0	
192	41-4-2-T	111.301596	49.361796	72E	Foremost	GSC/Thorleifson	Till	41-4-2-T		1	1			0				1	
193	43-1-1-T	110.705004	54.296182	73L	Bonnyville	GSC/Thorleifson	Till				0			0				0	
194	43-1-2-T	110.518435	54.220993	73L	Muriel Lake	GSC/Thorleifson	Till	43-1-2-T			0	1		1				1	
195	43-2-1-T	110.701516	54.353695	73L	Fort Kent	GSC/Thorleifson	Till	43-2-1-T			0		1	1				1	
196	43-2-2-T	110.775965	54.526414	73L	LaCorey	GSC/Thorleifson	Till	43-2-2-T			0			0	1			1	
197	43-3-1-T	110.351797	54.186951	73L	Angling Lake	GSC/Thorleifson	Till				0			0				0	
198	43-4-1-T	110.200957	54.459270	73L	Cold Lake	GSC/Thorleifson	Till	43-4-1-T	2		2			0				2	
199	44-1-1-T	110.951844	53.425594	73E	Vermilion	GSC/Thorleifson	Till	44-1-1-T		1	1			0	1		1	3	
200	44-1-2-T	110.731778	53.481935	73E	Vermilion N.	GSC/Thorleifson	Till	44-1-2-T			0		1	1				1	
201	44-2-1-T	110.720834	53.771330	73E	Northern Val	GSC/Thorleifson	Till	44-2-1-T			0	1		1				1	
202	44-2-2-T	110.898081	53.881270	73E	Elk Point	GSC/Thorleifson	Till	44-2-2-T	1	1	2			0	1			3	
203	44-3-2-T	110.348147	53.342923	73E	Kitscoty	GSC/Thorleifson	Till				0			0				0	
204	44-4-1-T	110.052356	53.743644	73E	John Lake	GSC/Thorleifson	Till				0			0				0	
205	44-4-2-T	110.369679	53.715176	73E	Heinsburg	GSC/Thorleifson	Till	44-4-2-T		1	1			0				1	
206	45-1-1-T	110.493503	52.735051	73D	Wainwright	GSC/Thorleifson	Till				0			0				0	
207	45-1-2-T	110.827970	52.795336	73D	Wainwright	GSC/Thorleifson	Till	45-1-2-T			0			0	1			1	
208	45-2-1-T	110.564018	53.236039	73E	Vermillion	GSC/Thorleifson	Till				0			0				0	
209	45-2-2-T	110.953609	53.187388	73E	Vermillion	GSC/Thorleifson	Till	45-2-2-T			0		1	1				1	
210	45-3-1-T	110.249710	52.874000	73D	Wainwright	GSC/Thorleifson	Till				0			0				0	
211	45-4-1-T	110.278453	52.932610	73D	Wainwright	GSC/Thorleifson	Till	46-1-1-T			0			0	1			1	
212	46-1-1-T	110.949088	51.939576	72M	Consort	GSC/Thorleifson	Till	45-4-1-T			0		1	1				1	
213	46-1-2-T	110.425063	51.966948	72M	Consort	GSC/Thorleifson	Till				0			0				0	
214	46-2-1-T	110.517388	52.314409	73D	Provost	GSC/Thorleifson	Till				0			0				0	
215	46-2-2-T	110.963207	52.461036	73D	Hardisty	GSC/Thorleifson	Till	46-2-2-T			0		1	1				1	
216	46-3-1-T	110.147367	51.873550	72M	Altario	GSC/Thorleifson	Till	46-3-1-T			0			0	1			1	
217	46-3-2-T	110.053335	52.062556	73D	Provost	GSC/Thorleifson	Till	46-3-2-T		1	1			0			2	3	
218	47-1-1-T	110.564197	51.426262	72M	Oyen	GSC/Thorleifson	Till	47-1-1-T		2	2			0				2	
219	47-1-2-T	110.847614	51.404495	72M	Oyen	GSC/Thorleifson	Till				0			0				0	
220	47-2-1-T	110.471513	51.605720	72M	Oyen	GSC/Thorleifson	Till	47-2-1-T			0			0	1			1	
221	47-2-2-T	110.971034	51.743577	72M	Coronation	GSC/Thorleifson	Till	47-2-2-T	1		1			0				1	
222	47-3-1-T	110.423557	51.401377	72M	Oyen	GSC/Thorleifson	Till	47-3-1-T			0		1	1				1	
223	47-3-2-T	110.038202	51.474379	72M	Oyen	GSC/Thorleifson	Till	47-3-2-T			0			0	1			1	
224	47-4-1-T	110.290610	51.631736	72M	Oyen	GSC/Thorleifson	Till	47-4-1-T		1	1			0	1			2	
225	47-4-2-T	110.382793	51.759039	72M	Oyen	GSC/Thorleifson	Till	47-4-2-T		1	1	1		1	1			3	
226	48-1-1-T	110.507696	50.385578	72L	Suffield East	GSC/Thorleifson	Till	48-1-1-T	1	1	2		1	1	2			5	
227	48-1-2-T	110.842810	50.705784	72L	Suffield North	GSC/Thorleifson	Till				0			0				0	
228	48-2-1-T	110.559235	50.742819	72L	Suffield North	GSC/Thorleifson	Till				0			0				0	1 olivine; MgO
229	48-2-2-T	110.763202	50.765899	72L	Suffield North	GSC/Thorleifson	Till				0			0				0	
230	48-3-1-T	110.115049	50.396753	72L	Schuler	GSC/Thorleifson	Till	48-3-1-T	2	2	4		1	1	2			7	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	Anomalous Samples	G1,G2	G7,9,10,11	Kimberlitic Garnets	G3,G4,G6	G5	Eclogitic Garnets	Chrome Diopsides	Chromites	Picro-ilmenites	Total Indicators	Other
231	48-3-2-T	110.264585	50.461639	72L	Suffield East	GSC/Thorleifson	Till	48-3-2-T		1	1		3	3	1			5	
232	48-4-1-T	110.404223	51.007416	72L	Empress	GSC/Thorleifson	Till	48-4-1-T	1		1			0			1	2	
233	48-4-2-T	110.134267	51.038108	72L	Empress	GSC/Thorleifson	Till	48-4-2-T			0			0	1			1	
234	49-1-1-T	110.530015	49.689537	72E	Cypress Hills	GSC/Thorleifson	Till	49-1-1-T		1	1			0		1		2	
235	49-1-2-T	110.758806	49.961868	72E	Seven Persons	GSC/Thorleifson	Till				0			0				0	
236	49-2-1-T	110.483269	50.303644	72L	Bowmanton	GSC/Thorleifson	Till	49-2-1-T	1		1			0	2			3	
237	49-2-2-T	110.956563	50.202251	72L	Redcliff	GSC/Thorleifson	Till	49-2-2-T			0			0	1			1	
238	49-4-1-T	110.310044	50.047309	72L	Medicine Hat	GSC/Thorleifson	Till				0			0				0	
240	5-1-1-T	114.435861	54.289057	83J	Barrhead	GSC/Thorleifson	Till	5-1-1-T			0			0	1			1	
241	5-1-2-T	114.271288	53.965368	83G	Barrhead	GSC/Thorleifson	Till				0			0				0	
242	5-2-1-T	114.005257	54.504803	83J	Fawcett	GSC/Thorleifson	Till	5-2-1-T						0	1			1	
243	5-2-2-T	114.379163	54.407407	83J	Vega	GSC/Thorleifson	Till	5-2-2-T		1	1		1	1				2	
244	50-1-1-T	110.807744	49.221697	72E	Pakowki Lake	GSC/Thorleifson	Till				0			0				0	
245	50-1-2-T	110.498470	49.114628	72E	Onefour	GSC/Thorleifson	Till	50-1-2-T	1		1			0				1	
246	50-2-1-T	110.902073	49.436801	72E	Pakowki Lake	GSC/Thorleifson	Till	50-2-1-T		1	1			0				1	
247	50-2-2-T	110.615029	49.633194	72E	Cypress Hills	GSC/Thorleifson	Till	50-2-2-T	1		1			0			1	2	
248	50-3-1-T	110.148368	49.073893	72E	Wildhorse	GSC/Thorleifson	Till				0			0				0	
249	50-3-2-T	110.243283	49.044866	72E	Wildhorse	GSC/Thorleifson	Till	50-3-2-T		3	3			0				3	
250	6-1-1-T	114.430090	53.564281	83G	Wabamun	GSC/Thorleifson	Till	6-1-1-T			0	1		1				1	
251	6-1-2-T	114.267158	53.561566	83G	Wabamun	GSC/Thorleifson	Till	6-1-2-T	1		1			0				1	1 corundum
252	6-2-1-T	114.494171	53.909991	83G	Barrhead	GSC/Thorleifson	Till				0			0				0	
253	6-2-2-T	114.074890	53.743146	83G	Spruce Grove	GSC/Thorleifson	Till				0			0				0	
254	7-1-2-T	114.555356	52.670459	83B	Rimbey	GSC/Thorleifson	Till				0			0				0	
255	7-2-1-T	114.233837	52.959239	83B	Pigeon Lake	GSC/Thorleifson	Till				0			0				0	
256	8-1-1-T	114.384278	52.090373	83B	Innisfail	GSC/Thorleifson	Till				0			0				0	
257	8-1-2-T	114.529724	51.941531	82O	Garrington	GSC/Thorleifson	Till				0			0				0	
258	8-2-1-T	114.431864	52.303650	83B	Sylvan Lake	GSC/Thorleifson	Till	8-2-1-T			0			0		1	1	2	
259	8-2-2-T	114.347539	52.290994	83B	Sylvan Lake	GSC/Thorleifson	Till	8-2-2-T			0			0		1		1	
260	8-3-1-T	114.048572	52.111218	83B	Innisfail	GSC/Thorleifson	Till				0			0				0	
261	8-4-2-T	114.045513	52.355767	83B	Gull Lake	GSC/Thorleifson	Till				0			0				0	
262	9-1-1-T	114.208422	51.159961	82O	Bowness	GSC/Thorleifson	Till				0			0				0	
263	9-1-2-T	114.283447	51.294844	82O	Airdrie	GSC/Thorleifson	Till	9-1-2-T			0			0			1	1	
264	9-2-1-T	114.589260	51.590235	82O	Cremona	GSC/Thorleifson	Till				0			0				0	
265	9-2-2-T	114.285115	51.630358	82O	Didsbury	GSC/Thorleifson	Till				0			0				0	
266	9-4-1-T	114.069342	51.435388	82O	Crossfield	GSC/Thorleifson	Till				0			0				0	
267	9-4-2-T	114.084851	51.710997	82O	Olds	GSC/Thorleifson	Till				0			0				0	
268	NAT92-1	115.045494	55.655777	83O	Lesser Slave Lk	AGS/Fenton	Till				0			0				0	1 Na-diopside
269	NAT92-10	117.482651	58.907486	84K	Meander River	AGS/Fenton	Till	92-10			0	1		1				1	
270	NAT92-11	119.435425	58.494476	84L	Rainbow Lake	AGS/Fenton	Till				0			0				0	
271	NAT92-12	117.922272	58.573204	84K	High Level W.	AGS/Fenton	Till				0			0				0	
272	NAT92-13	117.470474	57.573986	84F	Kemp R	AGS/Fenton	Till				0			0				0	2 corundum
273	NAT92-14	117.542633	57.226784	84F	Hawk Hills	AGS/Fenton	Till				0			0				0	
274	NAT92-15	117.626968	56.930439	84C	Manning	AGS/Fenton	Till				0			0				0	
275	NAT92-16	117.797569	56.479240	84C	Smithmill	AGS/Fenton	Till				0			0				0	
276	NAT92-17	117.902939	56.179340	84C	Brownvale	AGS/Fenton	Till	92-17			0			0		1		1	
277	NAT92-18	119.869659	56.300076	84D	Boundary Lake	AGS/Fenton	Till				0			0				0	
278	NAT92-19	117.902969	56.179340	84C	Brownvale	AGS/Fenton	Till	92-19		1	1			0				1	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
279	NAT92-2	115.311295	56.241127	84B	Cranberry Lake	AGS/Fenton	Till	92-2		1	1			0				1	
280	NAT92-20	116.914932	56.379333	84C	Peace River E.	AGS/Fenton	Till				0			0				0	
281	NAT92-21	118.050995	55.685005	83M	Birch Hills	AGS/Fenton	Till				0			0				0	
282	NAT92-22	119.880760	55.257896	83M	Goodfare	AGS/Fenton	Till				0			0				0	
283	NAT92-23	117.177483	55.179489	83N	Valley View	AGS/Fenton	Till	92-23		1	1			0				1	
284	NAT92-24	111.057915	57.249889	74E	Kearl Lake E.	AGS/Fenton	Till							0					
285	NAT92-25	111.403374	57.249889	74E	Kearl Lake W.	AGS/Fenton	Till	92-25			0		1	1				1	
286	NAT92-26	110.861938	55.799088	73M	Chard	AGS/Fenton	Till				0			0				0	
287	NAT92-27	110.903915	56.246296	74D	Cheecham	AGS/Fenton	Till	92-27			0			0		1		1	
288	NAT92-28	111.877754	56.077339	74D	SW 1/4	AGS/Fenton	Till				0			0				0	1 jadeitic diopside
289	NAT92-29	112.187798	55.797279	83P	Crow Lake	AGS/Fenton	Till				0			0				0	
290	NAT92-3	115.104530	57.128601	84G	Wabasca River	AGS/Fenton	Till	92-3	1		1			0				1	
291	NAT92-30	111.666733	55.009575	73M	Heart Lake	AGS/Fenton	Till	92-30			0			0		1		1	
292	NAT92-31	111.647591	55.038666	73M	Heart Lake	AGS/Fenton	Till				0			0				0	
293	NAT92-32	110.329117	54.422314	73L	Cold Lake	AGS/Fenton	Till	92-32		1	1			0				1	
294	NAT92-33	110.329137	54.422314	73L	Cold Lake	AGS/Fenton	Till				0			0				0	
295	NAT92-34	116.234718	54.977757	83K	Swan Hills	AGS/Fenton	Till				0			0				0	1 jadeitic diopside
296	NAT92-4	115.392570	57.388626	84G	Wabasca River	AGS/Fenton	Till				0			0				0	
297	NAT92-5	115.552650	57.855755	84G	Wadlin Lake	AGS/Fenton	Till	92-5			0			0		1		1	
298	NAT92-6	116.482430	58.542141	84K	High Level east	AGS/Fenton	Till				0			0				0	
299	NAT92-7	114.554718	58.589458	84J	Wentzil River	AGS/Fenton	Till				0			0				0	
300	NAT92-8	115.496025	58.556770	84J	Beaver Creek	AGS/Fenton	Till				0			0				0	
301	NAT92-9	116.740000	60.100000	85A	N.W.T.	AGS/Fenton	Till				0			0				0	
302	HL93-10	117.914995	58.574983	84K	High Level West	AGS/Fenton	Till				0			0				0	
303	HL93-11	117.427913	58.545908	84K	High Level West	AGS/Fenton	Till				0			0				0	
304	HL93-4	115.159492	58.593159	84J	Lawrence Creek	AGS/Fenton	Till				0			0				0	
305	HL93-6	116.599871	58.520458	84K	High Level East	AGS/Fenton	Till				0			0				0	
306	HL93-8	117.469041	58.902094	84K	High Level North	AGS/Fenton	Till				0			0				0	
307	HL93-9	117.237134	58.716729	84K	High Level North	AGS/Fenton	Till				0			0				0	
308	NAT93-35	118.502798	55.259612	83M	Kleskun Hill	AGS/Fenton	Till				0			0				0	
309	NAT93-36	118.791573	55.434174	83M	S. Saddle Hills	AGS/Fenton	Till				0			0				0	
310	NAT93-37	118.380879	55.455982	83M	Teepee Creek	AGS/Fenton	Till	93-37			0		4	4				4	1 jadeite
311	NAT93-38	119.256644	55.895966	83M	Grand Prairie	AGS/Fenton	Till	93-38			0	1		1				1	
312	NAT93-39	114.797688	55.444968	83 O	Martin Mtn	AGS/Fenton	Till	93-39			0		3	3				3	
313	NAT93-40	115.202941	55.943092	83 O	E. Utikuma Lake	AGS/Fenton	Till	93-40			0			0	1			1	
314	NAT93-41	115.391913	56.033980	84B	N. Utikuma Lake	AGS/Fenton	Till	93-41		1	1			0				1	
315	NAT93-42	116.012510	55.714038	83N	Salt Prairie	AGS/Fenton	Till				0			0				0	
316	NAT93-43	116.477531	55.626762	83N	E. Winagami Lk	AGS/Fenton	Till				0			0				0	
317	NAT93-44	116.981889	55.852193	83N	N. Kimiwan Lk	AGS/Fenton	Till	93-44		5	5			0		1		6	
318	NAT93-45	116.825499	55.986723	83N	Springburn	AGS/Fenton	Till	93-45		1	1		1	1				2	
319	NAT93-46	116.812466	56.121254	84C	Harmon Valley	AGS/Fenton	Till	93-46		2	2			0				2	
320	NAT93-47	119.485239	56.074121	84D	Silver Valley	AGS/Fenton	Till				0			0				0	
321	NAT93-48	119.700771	55.819606	83M	Saddle Hills W.	AGS/Fenton	Till				0			0				0	
322	NAT93-49	118.883613	57.404592	84E	Chinchaga River	AGS/Fenton	Till				0			0				0	
323	NAT93-50	118.422845	57.284647	84E	Chinchaga Rd.	AGS/Fenton	Till				0			0				0	
324	NAT93-500	114.976950	55.339521	83O	Lesser Slave Lake	AGS/Fenton	Till				0			0				0	
325	NAT93-501	115.342733	57.273683	84G	Wabasca River	AGS/Fenton	Till				0			0				0	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	Anomalous Samples	G1,G2	G7,9,10,11	Kimberlitic Garnets	G3,G4,G6	G5	Eclogitic Garnets	Chrome Diopsides	Chromites	Picro-ilmenites	Total Indicators	Other
326	NAT93-502	116.266790	56.659318	84C	Haig Lake	AGS/Fenton	Till				0			0				0	
327	NAT93-503	116.326510	56.542986	84C	Golden Lake	AGS/Fenton	Till				0			0				0	
328	NAT93-51	114.541601	55.237706	83 O	E. Lesser Slave. Lk	AGS/Fenton	Till	93-51			0			0	1	1		2	
329	NAT93-52	115.220233	55.339513	83 O	S.Lesser Slave Lk	AGS/Fenton	Till				0			0				0	
330	NAT93-53	116.865597	55.332242	83N	N. Snipe Lake	AGS/Fenton	Till	93-53		1	1			0				1	
331	NAT93-54	116.802771	55.110438	83N	S. Snipe Lake	AGS/Fenton	Till				0			0				0	
332	NAT93-55	118.740789	56.361331	84D	Montagneuse R.	AGS/Fenton	Till	93-55			0			0	1			1	
333	NAT93-56	118.997814	56.426774	84D	Clear Hills	AGS/Fenton	Till				0			0				0	
334	NAT93-57	119.006968	56.583099	84D	Clear Hills	AGS/Fenton	Till				0			0				0	
335	NAT93-58	119.026920	56.670345	84D	Clear Hills	AGS/Fenton	Till				0			0				0	
336	NAT93-59	119.046873	56.608542	84D	Clear Hills	AGS/Fenton	Till	93-59			0			0	1			1	
337	NAT93-60	116.403975	56.506631	84C	Cadotte Lake	AGS/Fenton	Till	93-60			0			0		1		1	
338	NAT93-61	116.101513	56.452093	84C	Little Buffalo	AGS/Fenton	Till				0			0				0	
339	NAT93-62	115.772750	56.459370	84B	Lubicon Lake	AGS/Fenton	Till				0			0				0	
340	NAT93-63	115.555767	56.470267	84B	Loon Lake	AGS/Fenton	Till				0			0				0	
341	NAT93-64	115.118842	56.655675	84B	Red Earth	AGS/Fenton	Till	93-64			0	1		1				1	
342	NAT93-65	114.826878	56.742928	84B	Peerless Lake	AGS/Fenton	Till				0			0				0	
343	NAT93-66	117.105189	57.975252	84F	La Crete Ferry	AGS/Fenton	Till				0			0				0	
344	NAT93-67	114.512365	58.585885	84J	Wentzil River	AGS/Fenton	Till				0			0				0	
345	NAT93-68	113.973608	55.538768	83P	Pelican Mtn	AGS/Fenton	Till				0			0				0	
346	NAT93-69	118.646443	57.306452	84E	Chinchaga Rd. Pit	AGS/Fenton	Till				0			0				0	
347	NAT93-70	115.349313	54.764969	83J	Swan Hills	AGS/Fenton	Till				0			0				0	
348	NAT93-71	118.022858	57.171979	84E	Chinchaga Rd.	AGS/Fenton	Till				0			0				0	1 Na - diopside
349	NAT93-72	117.727772	57.121012	84F	Chinchaga Rd.	AGS/Fenton	Till				0			0				0	
350	NAT93-73	118.215513	56.633992	84D	Sulphur Lake	AGS/Fenton	Till	93-73			0			0		2		2	
351	NAT93-74	116.147238	56.862901	84C	Haig Lake	AGS/Fenton	Till	93-74			0	1	2	3				3	
352	NAT93-75	116.260155	56.659316	84C	Otter Lakes	AGS/Fenton	Till	93-75		1	1			0				1	
353	NAT93-76	115.244917	56.826557	84B	Loon River	AGS/Fenton	Till	93-76			0		2	2	1			3	
354	NAT93-77	115.089082	57.175534	84G	Wabasca River	AGS/Fenton	Till				0			0				0	
355	NAT93-78	115.335099	57.622666	84G	Senex Creek	AGS/Fenton	Till	93-78			0	2	2	4				4	
356	NAT93-79	116.257624	57.982514	84F	Buffalo Hd Hills	AGS/Fenton	Till				0			0				0	
357	NAT93-80	111.096795	57.531475	74E	Firebag River	AGS/Fenton	Riv S&G				0			0				0	
358	NAT93-81	111.029191	57.462403	74E	Firebag River	AGS/Fenton	Till				0			0				0	
359	NAT93-82	110.454578	57.338768	74E	Firebag River	AGS/Fenton	Till	93-82			0			0	2			2	
360	NAT93-83	110.745265	57.404221	74E	Firebag River	AGS/Fenton	Till	93-83			0	1		1	1			2	
361	NAT93-84	111.202795	57.647831	74E	Firebag River	AGS/Fenton	Till				0			0				0	
362	NAT93-85	111.004878	57.622381	74E	Marguerite R	AGS/Fenton	Riv S&G	93-85			0	1	1	2				2	
363	NAT93-86	111.496257	57.564205	74E	Fort McKay	AGS/Fenton	Till				0			0				0	
364	NAT93-87	111.562086	57.182424	74E	Muskeg River	AGS/Fenton	Riv S&G	93-87			0		8	8				8	
365	NAT93-88	111.501796	57.076978	74E	Saline Lake	AGS/Fenton	Till				0			0				0	
366	NAT93-89	110.677291	57.629659	74E	Johnson Lake	AGS/Fenton	Till	93-89			0		1	1				1	
367	PR93-10	117.959329	56.015809	84C	Peace River S.	AGS/Fenton	Till	93-10			0			0	1			1	
368	PR93-13	117.881135	55.899470	83N	Winagami North	AGS/Fenton	Till				0			0				0	
369	PR93-3	117.153553	56.452093	84C	Peace River S.	AGS/Fenton	Till	93-3		1	1	1		1				2	
370	PR93-6A	117.330067	55.615856	83N	Peavine	AGS/Fenton	Till	93-6A			0	1		1				1	
371	PR93-6B	117.330097	55.615856	83N	Peavine	AGS/Fenton	Till	93-6B		4	4		1	1				5	
372	B-1	113.800640	53.691129	83H	Villineuve	GSC/Ballantyne	Riv S&G				0			0				0	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
373	B-2	114.163087	53.633880	83G	Eden Lake	GSC/Ballantyne	Riv S&G				0			0				0	
374	B-3	114.875051	53.604795	83G	Evansburg	GSC/Ballantyne	Riv S&G	3			0			0		1		1	
375	B-4	114.924141	53.590245	83G	Pembina River	GSC/Ballantyne	Riv S&G				0			0				0	
376	B-5	116.543000	53.381000	83F	McLeod River	GSC/Ballantyne	Riv S&G	5			0			0		1		1	
377	B-6	116.618096	53.459293	83F	Embarras River	GSC/Ballantyne	Riv S&G	6			0			0		1		1	
378	B-7	117.278713	53.284697	83F	McLeod River	GSC/Ballantyne	Riv S&G	7			0			0		1		1	
379	B-8	117.497887	53.197386	83F	Gregg River	GSC/Ballantyne	Riv S&G	8			0			0		2		2	
380	B-9	117.108255	53.139182	83F	McLeod River	GSC/Ballantyne	Riv S&G	9			0			0		3		3	
381	B-10	117.010851	53.168290	83F	Embarras River	GSC/Ballantyne	Riv S&G	10			0			0		2		2	
382	B-11	116.816040	53.066430	83F	Lovett River	GSC/Ballantyne	Riv S&G	11			0			0		2		2	
383	B-12	116.576097	52.935477	83C	Pembina River	GSC/Ballantyne	Riv S&G	12			0			0		17		17	
384	B-13	116.551941	52.877280	83C	Brazeau River	GSC/Ballantyne	Riv S&G				0			0				0	
385	B-14	116.547000	52.788000	83C	Cardinal River	GSC/Ballantyne	Riv S&G				0			0				0	
386	B-15	116.310373	52.702651	83C	Blackstone River	GSC/Ballantyne	Riv S&G	15			0			0		2		2	
387	B-16	116.012643	52.280634	83C	North Ram River	GSC/Ballantyne	Riv S&G	16			0			0		1		1	
388	B-17	116.340043	52.382510	83C	Crescent Falls	GSC/Ballantyne	Riv S&G				0			0				0	
389	B-18	115.965084	52.207858	83B	Cripple Creek	GSC/Ballantyne	Riv S&G				0			0				0	
390	B-19	115.846186	52.076873	83B	Ram River	GSC/Ballantyne	Riv S&G				0			0				0	
391	B-20	115.275479	52.251520	83B	Prairie Creek	GSC/Ballantyne	Riv S&G				0			0				0	
392	B-21	115.410000	52.280000	83B	Main Ram River	GSC/Ballantyne	Riv S&G	21			0			0		2		2	
393	B-22	115.429327	52.367953	83B	N.Saskatchewan R	GSC/Ballantyne	Riv S&G	22			0			0		1		1	
394	B-23	115.573124	52.557134	83B	Baptiste Creek	GSC/Ballantyne	Riv S&G	23			0			0		1		1	
395	B-24	112.805693	51.479347	82P	Red Deer River	GSC/Ballantyne	Riv S&G				0			0				0	
396	B-25	112.477858	51.333829	82P	E. Coulee Beach Sd	GSC/Ballantyne	Riv S&G				0			0				0	
397	B-26	110.339150	53.662031	73E	N.Saskatchewan R	GSC/Ballantyne	Riv S&G				0			0				0	
398	B-27	110.539977	53.778430	73E	Heinsburg Bridge	GSC/Ballantyne	Riv S&G				0			0				0	
399	B-28	110.911260	53.851168	73E	Outwash Gravel Pit	GSC/Ballantyne	Riv S&G				0			0				0	
400	B-29	111.072000	53.817000	73E	N.Saskatchewan R	GSC/Ballantyne	Riv S&G				0			0				0	
401	B-30	111.233038	53.749325	73E	N.Saskatchewan R	GSC/Ballantyne	Riv S&G				0			0				0	
402	B-31	111.703332	53.792967	73E	N.Saskatchewan R	GSC/Ballantyne	Riv S&G				0			0				0	
403	B-32	112.198378	53.982118	83H	N.Saskatchewan R	GSC/Ballantyne	Riv S&G				0			0				0	
404	B-33	112.520160	53.982119	83H	N.Saskatchewan R	GSC/Ballantyne	Riv S&G				0			0				0	
405	B-34	112.792437	54.054862	83I	N.Saskatchewan R	GSC/Ballantyne	Riv S&G				0			0				0	
406	B-35	112.990456	53.880264	83H	Vinca Bridge	GSC/Ballantyne	Riv S&G				0			0				0	
407	B-36	113.236000	53.705678	83H	Ft. Saskatchewan	GSC/Ballantyne	Riv S&G				0			0				0	
408	5854	113.202302	50.678920	82I	Arrowwood	AGS/Edwards	Ter S&G				0			0				0	
409	3913	112.833202	50.853577	82I	Cluny	AGS/Edwards	Ter S&G				0			0				0	
410	4213	110.221554	49.587365	72E	Cypress Hills	AGS/Edwards	Ter S&G				0			0				0	
411	5570	112.777942	49.034274	82H	Del Bonita	AGS/Edwards	Ter S&G	5570			0	1		1				1	
412	6424	114.973241	53.590233	83G	Entwhistle	AGS/Edwards	Ter S&G	6424			0			0		4		4	
413	6692	117.594093	56.237591	84C	Grimshaw	AGS/Edwards	Ter S&G	6692			0			0	3	3		6	
414	6815	118.639683	57.313717	84E	Halverson Ridge	AGS/Edwards	Ter S&G	6815			0			0		3		3	
415	6808	112.360778	51.523008	82P	Hand Hills	AGS/Edwards	Ter S&G				0			0				0	
416	6106	113.830098	52.497986	83A	Lacombe	AGS/Edwards	Ter S&G				0			0				0	
417	6422	114.875041	53.604783	83G	Magnolia	AGS/Edwards	Ter S&G	6422			0			0		4		4	
418	5669	112.819853	49.354485	82H	Magrath	AGS/Edwards	Ter S&G				0			0				0	
419	5812	113.980350	50.475179	82I	Nanton	AGS/Edwards	Ter S&G				0			0				0	

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	Anomalous Samples	G1,G2	G7,9,10,11	Kimberlitic Garnets	G3,G4,G6	G5	Eclogitic Garnets	Chrome Diopsides	Chromites	Picro-ilmenites	Total Indicators	Other
420	3915	117.501901	53.575679	83F	Obed Mtn.	AGS/Edwards	Ter S&G				0			0				0	
421	6824	113.973608	55.538768	83P	Pelican Mtn.	AGS/Edwards	Ter S&G				0			0				0	
422	5566	112.955994	49.077932	82H	Peters Ck.	AGS/Edwards	Ter S&G				0			0				0	
423	4028	118.169123	55.132343	83M	Simonette R	AGS/Edwards	Ter S&G				0			0				0	
424	3914	118.289900	54.404946	83L	Smoky Tower	AGS/Edwards	Ter S&G				0			0				0	
425	3973	115.375553	54.754055	83J	Swan Hills	AGS/Edwards	Ter S&G				0			0				0	
426	3975	113.800640	53.676584	83H	Villeneuve	AGS/Edwards	Ter S&G	3975	2	3	5			0		1		6	
427	4212	117.633621	55.714031	83N	Watino	AGS/Edwards	Ter S&G	4212			0	1		1		7		8	
428	6573	115.723903	54.026694	83J	Whitecourt Mtn.	AGS/Edwards	Ter S&G				0			0				0	
429	6811	112.459265	51.231953	82P	Wintering Hills	AGS/Edwards	Ter S&G				0			0				0	
430	6424T	114.973241	53.590333	83G	Entwhistle	AGS/Edwards	Till	6424T		1	1			0				1	
431	3WGK001	114.128069	49.285278	82G	Pincher Creek	S AlbtaRiftProj	Riv S&G	3WGK001		1	1			0				1	
432	3WGK004	114.104997	49.299740	82G	Pincher Creek	S AlbtaRiftProj	Riv S&G	3WGK004			0			0			1	1	
433	3WGK005	114.082762	49.309164	82G	Pincher Creek	S AlbtaRiftProj	Riv S&G				0			0				0	
434	3WGK006	114.340466	49.314620	82G	Grizzly Creek	S AlbtaRiftProj	Riv S&G				0			0				0	
435	3WGK009	114.672038	50.124045	82J	Oldman R trib.	S AlbtaRiftProj	Riv S&G				0			0				0	
436	3WGK010	114.675202	50.119949	82J	Oldman River	S AlbtaRiftProj	Riv S&G				0			0				0	
437	3WGK011	114.662992	50.117569	82J	Oldman River	S AlbtaRiftProj	Riv S&G				0			0				0	
438	3WGK012	114.335130	49.298765	82G	Grizzly Creek	S AlbtaRiftProj	Riv S&G				0			0				0	
439	92BJB0108	111.101776	59.749129	74M	Shield NE Alta	GSC/Bednarsky	Till				0			0				0	
440	92BJB0109	110.600227	59.998906	74M	Shield NE Alta	GSC/Bednarsky	Till				0			0				0	
441	92BJB0110	110.563016	59.693389	74M	Shield NE Alta	GSC/Bednarsky	Till				0			0				0	
442	92BJB0111	110.135478	59.891433	74M	Shield NE Alta	GSC/Bednarsky	Till				0			0				0	
443	93BJB0031	111.143836	59.470471	74M	Shield NE Alta	GSC/Bednarsky	Till				0			0				0	
444	93BJB0068	110.174288	59.677470	74M	Shield NE Alta	GSC/Bednarsky	Till				0			0				0	
445	93BJB0077	110.414121	59.348885	74M	Shield NE Alta	GSC/Bednarsky	Till				0			0				0	
446	93BJB0101	110.312348	59.551247	74M	Shield NE Alta	GSC/Bednarsky	Till	BJB0101								1		1	
447	NAT94-90	111.890228	56.967898	74D	UTF	AGS/Fenton	Till												
448	NAT94-91	111.142938	56.640626	74D	Clearwater River	AGS/Fenton	Till												
449	NAT94-92	111.250917	56.371549	74D	Waterways	AGS/Fenton	Till	94-92					1	1				1	
450	NAT94-93	110.117666	57.589651	74E	Johnson Airstrip N.W.	AGS/Fenton	Till*	94-93				1	2	3	1			4	1 jadeitic diopside
451	NAT94-94	110.069247	57.226057	74E	Firebag - upstream	AGS/Fenton	Till*	94-94				2		2				2	
452	NAT94-95	110.461337	57.298775	74E	Firebag - tributary	AGS/Fenton	Till												
453	NAT94-96	112.313773	55.546048	83P	May Hill	AGS/Fenton	Till	94-96					1	1				1	
454	NAT94-97	110.562283	56.317700	74D	Christine River	AGS/Fenton	Till	94-97				1	1	2				2	
455	NAT94-98	110.459487	56.756991	74D	High Hill River	AGS/Fenton	Till	94-98				1	1	2	1			3	
456	NAT94-99	110.015038	57.033340	74E	High Hill River - east	AGS/Fenton	Till*												
457	NAT94-100	113.448695	56.018802	84A	Housetail Lake	AGS/Fenton	Till	94-100				1		1				1	
458	NAT94-101	111.010229	56.826091	74D	Waterways	AGS/Fenton	Till												
459	NAT94-102	110.373226	56.731539	74D	Waterways	AGS/Fenton	Till	94-102					1	1	1			2	
460	NAT94-103	110.593403	56.335169	74D	Christine River	AGS/Fenton	Till	94-103		1	1		1	1	2			4	
461	NAT94-104	112.490133	56.769817	84A	Mackay River	AGS/Fenton	Till	94-104					1	1	1			2	
462	NAT94-105	112.676483	56.389900	84A	Athabasca River	AGS/Fenton	Till	94-105					1	1			1	2	1 jadeitic diopside
463	NAT94-106	113.175833	56.736167	84A	Island Lake	AGS/Fenton	Till*	94-106				1		1	1	1		3	
464	NAT94-107	111.675921	57.051528	74E	Bitumont	AGS/Fenton	Till												
465	NAT94-108	111.651129	57.306055	74E	Bitumont	AGS/Fenton	Till	94-108		1	1							1	1 jadeitic diopside
466	NAT94-109	111.651129	57.306055	74E	Birch Mountain	AGS/Fenton	Till*	94-109					1	1			1	2	1 jadeitic diopside

Site#	Field Sample#	Longitude °	Latitude °	NTS	Location Name	DataSource	Lithology	**Anomalous Samples**	G1,G2	G7,9,10,11	**Kimberlitic Garnets**	G3,G4,G6	G5	**Eclogitic Garnets**	**Chrome Diopsides**	**Chromites**	**Picro-ilmenites**	**Total Indicators**	Other
467	NAT94-110	111.297000	55.935000	73M	Chard	AGS/Fenton	Till	94-110				1		1				1	
468	NAT94-111	112.402333	55.939167	83P	Dropoff Creek	AGS/Fenton	Till												1 jadeitic diopside
469	NAT94-112	111.740333	56.475833	74D	Horse River	AGS/Fenton	Till												
470	NAT94-113	110.201820	58.082764	74L	Fort Chip	AGS/Fenton	Till												
471	NAT94-114	112.145878	58.023569	84L	Lake Claire	AGS/Fenton	Till												
472	NAT94-115	114.488889	58.856667	84J	Vermilion Chutes	AGS/Fenton	Till												
473	NAT94-116	114.487778	59.451389	84O	Whitesand River	AGS/Fenton	Till												
474	NAT94-117	113.486167	57.771111	84H	Birch Mountain	AGS/Fenton	Till	94-117								1		1	
475	NAT94-118	113.876389	57.917500	84H	Birch River	AGS/Fenton	Till												
476	NAT94-119	114.325333	58.180278	84J	Lambert/Harper Creeks	AGS/Fenton	Till	94-119				1		1	1			2	2 jadeitic diopsides
477	NAT94-120	114.552862	55.648579	83O	Willow River	AGS/Fenton	Till	94-120					1	1				1	
478	LL94-27	117.408251	56.851336	84C		AGS/Fenton	Till	LL94-27				1		1	1			2	
479	LL94-34	117.306372	56.421310	84C		AGS/Fenton	Till	LL94-34				1		1				1	
480	LL94-35	117.942251	56.044324	84C		AGS/Fenton	Till	LL94-35							1			1	
481	LL94-40	117.052159	56.037577	84C		AGS/Fenton	Till	LL94-40		1	1					1		2	
482	LL94-42	117.402607	56.630811	84C		AGS/Fenton	Till	LL94-42		1	1							1	
483	94SAB-14	117.197239	55.055772	83N		AGS/Fenton	Till	94SAB-14								1		1	
484	94SAB-38	117.533317	55.869319	83N		AGS/Fenton	Till												
485	94SAB-39	117.956870	55.465537	83N		AGS/Fenton	Till	94SAB-39								1		1	
486	94SAB-52	117.181372	55.526886	83N		AGS/Fenton	Till												
487	94SAB-35	117.785900	55.099222	83N		AGS/Fenton	Till	94SAB-35					1	1				1	
488	94SAB-76	117.361808	55.424719	83N		AGS/Fenton	Till	94SAB-76								1		1	
489	94BJB0042	110.881600	59.217500	74M	Shield NE Alta	GSC/Bednarsky	Till												
490	94BJB0105	111.963400	59.818200	74M	Shield NE Alta	GSC/Bednarsky	Till												
491	3958	112.055167	51.568899	82P	Hand Hills Lake	AGS/Edwards	Ter S&G	3958				1		1				1	
492	3964	112.101997	51.539798	82P	Hand Hills Lake	AGS/Edwards	Ter S&G	3964								1		1	
493	5855	113.131617	50.696106	82I	Arrowwood	AGS/Edwards	Ter S&G	5855								1		1	
494	6050	114.175048	51.059575	82O	Calgary	AGS/Edwards	Ter S&G												
495	6118	113.159540	52.806905	83A	Wetaskiwin	AGS/Edwards	Ter S&G												
496	6119	113.304577	52.908873	83A	Wetaskiwin	AGS/Edwards	Ter S&G												
497	T7	118.894100	56.248200	84D	Montagneuse R.	AGS/Fenton	Riv S&G	T7		1	1							1	
498	T8	118.929300	56.247100	84D	Montagneuse R.	AGS/Fenton	Riv S&G	T8							2			2	

*Sample of glacial sand and gravel that may be till or fluvial.