Summary of Exploration Activities and Results for the Fort à la Corne Diamond Project, Saskatchewan

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1. Introduction

Kimberlites and associated diamonds have been the focus of extensive exploration in central Saskatchewan since 1988. During 1989, Uranerz Exploration and Mining Limited identified 71 shallow magnetic anomalies from detailed aeromagnetic surveys in the Fort à la Corne area. By the end of 1991, eighteen of these targets had been proven, by drilling, to be kimberlite bodies encased within Cretaceous sedimentary strata. The discoveries induced a considerable amount of competitive activity by both junior and senior exploration companies. In response to the level of industry activity, the Geological Survey of Canada and the Saskatchewan Geological Survey, under a Joint Partnership Agreement on Mineral Development and with industry co-funding, initiated large-scale aeromagnetic surveys covering the southern third of Saskatchewan, much of it flown for the first time. Kimberlite exploration activity resulted in various drilling programs between 1989 and 1995, including the following: peripheral to the Fort à la Corne occurrences; the Sturgeon Lake area, near Montreal Lake; Wapawekka Lake; Candle Lake; Tobin Lake; and south of the Saskatchewan River at Gronlid, Mistatim, and near Hudson Bay. Other than the Fort à la Corne kimberlites and some glacially rafted kimberlite material in the Sturgeon Lake area, the only significant additional kimberlite discoveries during this period were near Candle Lake.

At the Fort à la Corne project, from 1991 to 1997, the number of drill-confirmed kimberlite bodies has increased to 69. Our current view, drawing on an integration of geophysical and geological information, is that the kimberlites are composed of individual bodies and multi-vent clusters of coalesced bodies, all apparently constructed of stacked, temporally distinct layers of pyroclastic "crater-facies" kimberlite. Diamond recoveries and geochemical results from associated heavy minerals at Fort à la Corne remain highly variable, although continued minibulk sampling is expected to improve the estimation of diamond grades for the most prospective bodies.

Prior to its acquisition by Cameco Corporation in 1998, Uranerz Exploration and Mining Limited operated the Fort à la Corne Diamond Project Joint Venture with a 10 percent interest. The remaining interest was held by partners Cameco Corporation (30 percent), Monopros Limited (30 percent) and Kensington Resources Limited (30 percent). The project land holdings consist of 144 claims in seven groups having a total area of 25 488 hectares. The main group of kimberlites is located approximately 60 km east of the city of Prince Albert and extends for 32 km in a narrow northwest corridor (Figure 1). Distinct smaller clusters of kimberlite also are located towards the west, north, and northeast. All outlying clusters are within a radius of approximately 28 km from the centre of the main trend (Figure 2).

An earlier paper by Lehnert-Thiel *et al.* (1992) detailed the discovery and early exploration activity at Fort à la Corne. This paper presents an update on activities conducted since 1992, with additional reference to the regional stratigraphic context, petrography, emplacement character, and economic potential of the Fort à la Corne kimberlite bodies.

2. Regional Geology

a) Basement Geology

The project area lies near the northeastern rim of the Interior Platform of North America. Little is known of the metamorphic basement underlying the kimberlite area except from 1950s and 1960s era exploration work at the nearby Choiceland banded iron formation deposit. Aeromagnetic and gravity data suggest that crystalline basement in the Fort à la Corne area is geologically similar to the Glennie Domain which is exposed farther north in the vicinity of Lac La Ronge (Lewry, 1981; Green *et al.*, 1985 Collerson *et al.*, 1989; Kjarsgaard, 1995; Leclair and Lucas, 1995). The Glennie Domain is part of the Reindeer Zone of the 1.8 Ga Trans-Hudson Orogen (Lewry *et al.*, 1994) and is composed of Paleoproterozoic island arc volcanogenic-plutonic successions and isolated windows of reworked Archean granitoids and granitic

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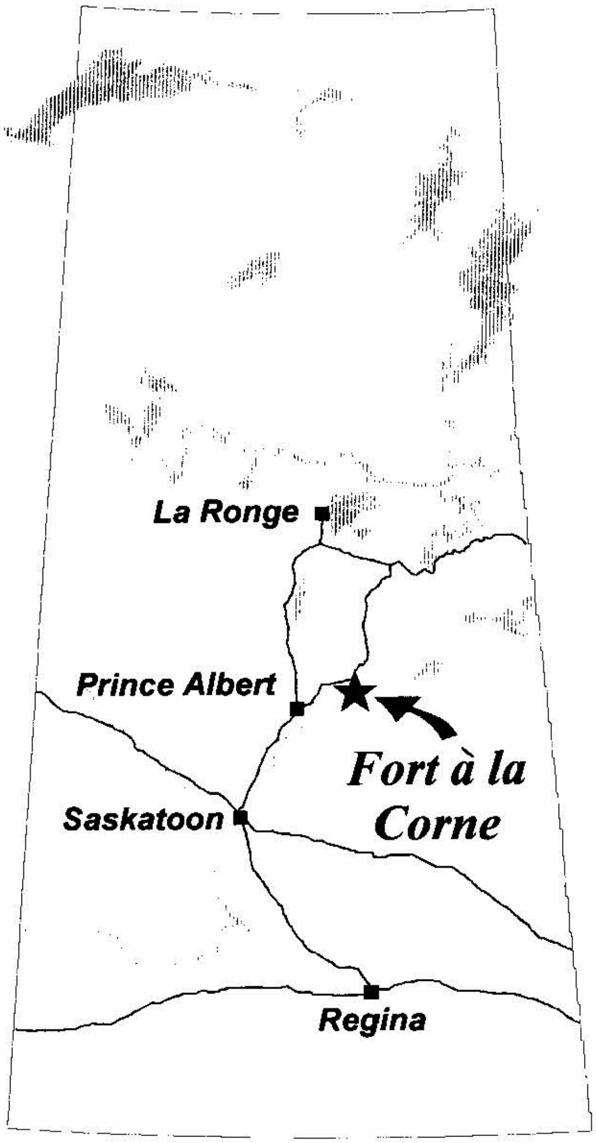

Figure 1 - Map of Saskatchewan showing the location of the Fort à la Corne kimberlite clusters.

gneisses (McNichol *et al.*, 1992). Recent integration of field mapping, radiometric dating, and LITHOPROBE seismic investigations, summarized by Chiarenzelli *et al.* (1996), indicates that the Glennie Domain blankets the apex of a largely buried Archean microcontinent (see also Ashton *et al.*, 1997; Ansdell *et al.*, 1995) which has recently been named the Saskatchewan Craton (Chiarenzelli *et al.* 1996).

The shape and size of the Saskatchewan Craton is still poorly understood; however, it has been defined as a roughly 500 km long by 200 km wide "westward convex bow" bounded on the west by (and dipping under) the La Ronge belt and on the east by the Flin Flon belt and Caisson Domain (Chiarenzelli *et al.* 1996; Green *et al.*, 1985). The inferred outline of the Saskatchewan Craton and the southward extension of the Glennie Domain under the Phanerozoic sedimentary cover is shown in Figure 3. It is suggested that the Saskatchewan Craton probably provided a thick lithospheric keel, a characteristic feature of diamondiferous kimberlite provinces elsewhere. A recent teleseismic study of south-central Saskatchewan (Bank *et al.*, 1997) supports this model.

b) Phanerozoic Geology

Throughout much of Phanerozoic time, most of Saskatchewan was the site of episodic marine deposition, with periodic intervals of erosion brought about by both craton uplift and regression of marginal and epeiric seas which once extended over much of the North American continent. The central Saskatchewan region is underlain by over 700 m of Phanerozoic sedimentary rocks (Figure 4). The basal 440 m comprises Cambro-Ordovician to Devonian sandstones and carbonates, overlain by 150 to 170 m of Cretaceous shale and sandstone, in turn overlain by up to 130 m of unconsolidated Quaternary deposits. Paleozoic and Mesozoic strata dip gently toward the southwest, which in central Saskatchewan, results in successively lower strata being exposed at the sub-Quaternary interface towards the northeast. Within the project area, subcrops of Cretaceous Colorado Group and Mannville Group strata underlie the topographically irregular basal Tertiary/Quaternary unconformity. The regional Quaternary section consists of several glacial till sheets of variable areal continuity, derived from diverse bedrock origins, and comprising alternating layers of predominantly fine-grained till with subordinate sandy to gravelly beds (Schreiner, 1990; Christiansen and Sauer, 1993).

The kimberlite host rocks in the Fort à la Corne area are dominantly of Cretaceous age and were deposited near the northeastern margin of the broad Western Canada Sedimentary Basin. Regional deposition of sands and mudstones was strongly influenced by oscillating sea levels. Periods of shallow marine conditions with terrestrial erosion were dominant during intervals of regression, whereas inundation culminated within the confluence of a peak transgressive north-south-trending seaway through the Prairie region. In Saskatchewan, fluvio-deltaic and nearshore marine silts and sands of the Mannville Group were deposited prior to a thick sequence of laterally continuous Colorado Group mudstones punctuated by thin sandstones. Mudstones and white-speckled calcareous shales were deposited in the eastern portion of the seaway distal from the tectonically active western Cordillera, which was the major clastic source to the basin. In central Saskatchewan, some fine-grained sands derive from eroding sedimentary precursors and from exposed basement located somewhere north and east of the seaway.

During Cretaceous time, kimberlite volcanoes erupted into the sedimentary basin in the Weirdale, Foxford, White Fox, Snowden, and Fort à la Corne areas. In general, episodes or pulses of kimberlite volcanism occurred during intervals of sand and mudstone

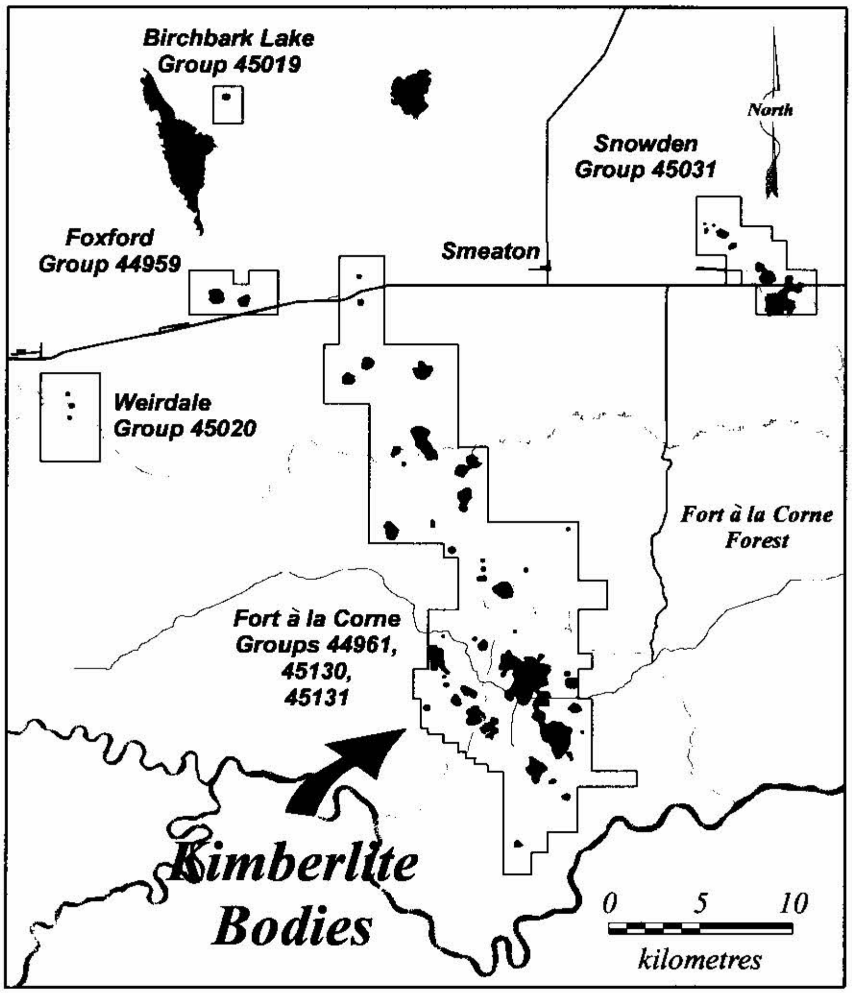

Figure 2 - Fort à la Corne location map showing the distribution of kimberlite bodies and assessment groups.

deposition spanning approximately 14 million years and corresponding to Lower Cretaceous Albian time (98.3 to 112 Ma). A few sporadic eruptions appear outside of this time frame including older, distinct kimberlites possibly emplaced during latest Aptian time (112 to 114 Ma) and younger kimberlites erupted during Cenomanian and early Turonian time (90 to 98.3 Ma). Figure 5 shows the broad ranges of kimberlite occurrence interpreted for the Fort à la Corne area. Periodically during the main times of eruption, particularly from 103 Ma onwards, transgressive pulses of the shallow epeiric sea promoted rapid deposition of fine-grained sediments (often kimberlitic, in part) which enhanced preservation of beveled volcanic masses within their shallow craters.

Since the exact time of each kimberlite eruption is loosely constrained, only broad interpretations of the prevalent depositional environments can be made. Older crater-facies kimberlites are encased within brownish-grey sands and muddy siltstones of the Cantuar Formation of the Mannville Group, which were deposited in fluvial/deltaic to shallow marine sedimentary regimes. Kimberlite is also found sporadically as thinly bedded extra-crater ashfalls throughout much of the Mannville Group stratigraphic section. Slightly younger kimberlites are quite common throughout the area and were emplaced during and after deposition of Pense Formation (Mannville Group) mudstone and silty sandstones. Perhaps the most widespread and abundant kimberlites were emplaced during deposition of the Lower Colorado Group mudstones and intervening thin sandstones. Similar to those in the Pense Formation, these younger kimberlites formed lensoidal masses with margins characterized by tapering aprons of water-lain kimberlitic material, and in many other cases, relatively sharp boundaries with the encasing fine-grained sediments.

3. Summary of Drilling and Sampling

From 1989 to 1997, the Fort à la Corne joint venture targeted 183 drill holes on or near 71 geophysical anomalies, resulting in 172 significant kimberlite intersections and two stratigraphic control holes. Nine holes were abandoned either in overlying glacial till or Cretaceous sediments, or at a point just within the top of kimberlite. Drilling has intersected and sampled kimberlite in 69 of the 71 kimberlite-type geophysical anomalies. One anomaly was found to have a non-kimberlite source (magnetite in till). A number of different drilling methods were employed predicated by the stage of investigation for the specific kimberlite bodies, and in a few cases, by the current focus on drilling method.

Of the 174 completed drill holes, 85 were by reverse circulation air blast (RCA) drilling methods with borehole diameters ranging from 152 to 305 mm. Fifteen of the large diameter RCA drill holes were augmented by underreaming which expanded the borehole diameters to as wide as 457 mm. Large diameter drill holes were utilized in most cases to obtain large masses of kimberlite for macrodiamond recovery. The initial underreaming program was conducted during 1991 with the goal of providing flexibility in both testing for the presence of kimberlite and to obtain larger kimberlite samples from one transit through thick overburden. Underreamming

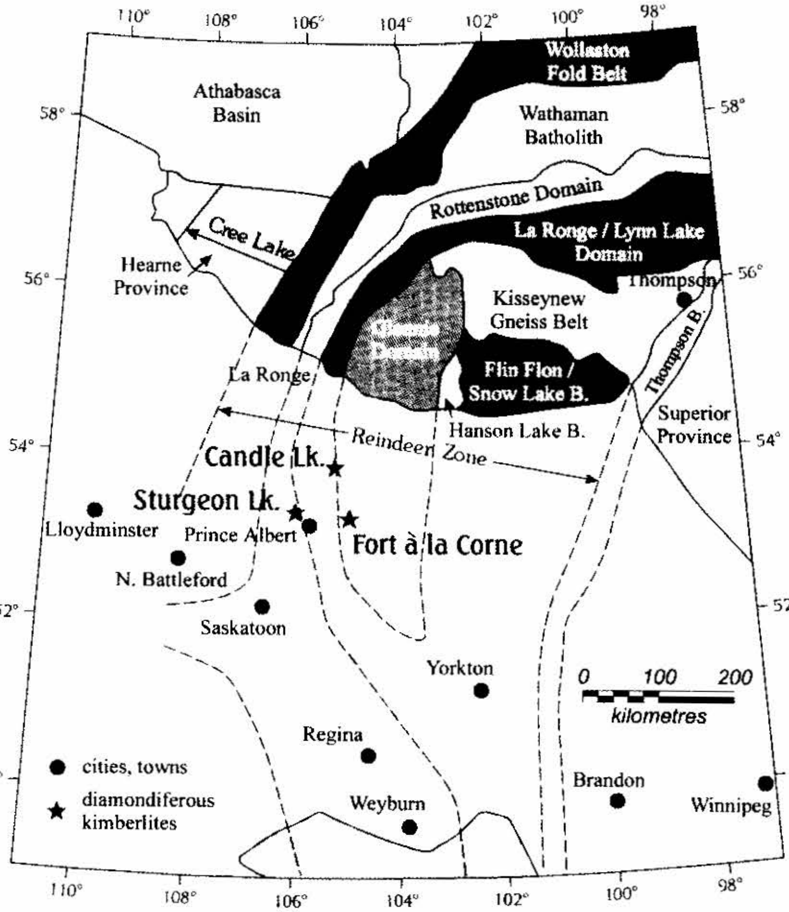

Figure 3 - Tectonic map of Saskatchewan and eastern Manitoba showing the extent of Phanerozoic sedimentary cover and estimated sub-Phanerozoic tectonic boundaries (modified from Green et al., 1985; Lewry et al., 1994; and Bank et al., 1997).

during the 1997 program was designed to provide ultra-large tonnage samples for macrodiamond testing at a lower cost per tonne of kimberlite. The use of underreaming has been abandoned due to problems associated with mud circulation and difficulties in lifting cuttings to the surface in very wide boreholes.

Reverse circulation air blast drilling methods provided a very positive and immediate return of cuttings characterized by large chip sizes and minimized fines production. Typically, for large diameter drill holes, a carbide insert bit with a 300 mm diameter would cut a theoretical mass of 17.7 tonnes from a 100 m thick intersection of kimberlite, compared to only 4.5 tonnes cut by a 152 mm diameter bit. Of the 17.7 tonnes of kimberlite cut by the bit, 35 to 50 percent would be chips and fines having diameters less than 0.8 mm that would be lost during dewatering over the shaker table screen. Diamonds possessing at least one dimension nominally greater than 1 mm are considered to be macrodiamonds by the joint venture partners, and if liberated, these stones should traverse the screen to the sample bag. Hence, in this example, the actual mass of kimberlite would be on the order of 10 tonnes, although grades would be calculated based on recovery of stones from the theoretical mass cut. Large diameter RCA drilling gives the best sample quality and is the most economic means to recover kimberlite when the cost per tonne is compared to coring or small diameter, conventional mud circulation, water well-style drilling (test holes).

Forty rotary test holes ranging from 120 to 160 mm in diameter were used to test for the presence of kimberlite in early drilling programs and then, more recently, to obtain samples from numerous bodies thought to be less than 20 hectares in area. Samples from these drill holes were submitted for indicator mineral, microdiamond, and macrodiamond recoveries. The remaining 49 drill holes were core holes with diameters ranging from 64 to 76 mm. Core holes were utilized during 1991-1993 to collect continuous records of the kimberlites for petrographic and stratigraphic studies, microdiamond recoveries, indicator mineral studies, as well as for macrodiamond recovery from small minibulk samples.

Including all drill holes, approximately 19 960 m of overburden were penetrated above 19 235 m of kimberlite intersection. These intersections produced 1005 tonnes of core and screened kimberlite chip samples representative of 1645 tonnes of theoretical, *in situ* kimberlite. Bulk kimberlite chip samples were collected as screened product without fine fragments (variably <0.4 mm to <0.8 mm during 1989-1997), whereas core was split, described, and then consigned for diamond recovery. Representative core and chip samples from many of the kimberlites were collected and archived for further investigations. Well over 1,000 microdiamond samples have been tested in most cases by caustic dissolution procedures, commonly in conjunction with separation of indicator mineral concentrates. A total of 380 samples have been submitted for heavy mineral analyses and indicator mineral chemistry. An average of 500 mineral grains including garnets, picroilmenites, and chrome spinels were collected from each sample and analyzed. Approximately 3,000 petrographic samples were examined macroscopically and described. In addition, thin sections from core samples, and multi-disciplinary studies were conducted by several consultants (for example, see Scott-Smith *et al.*, 1994 and Leckie *et al.*, 1997, respectively). After 1992, sampling methods were modified to reflect stratigraphic zonation based on the major lithological units, whereby samples were composited over reduced

Period	Epoch	Basal Age (Ma)	Group / Formation	Approx Depth (m)
Quaternary	Holocene	0.011	post-glacial sediments	
	Pleistocene		Saskatoon Group	
			Sutherland Group	
		1.6	Empress Group	100
Cretaceous	Late		Montana Group	
		82	Upper Colorado Subgroup	
		97	Lower Colorado Subgroup	
	Early	103	Mannville Group	
		114		200
Devonian	Middle		Manitoba Group	300
	Early	387	Elk Point Group	400
Silurian	Early	438	Interlake Group	500
Ordovician	Late	458	Big Horn Group	
	Middle	478		600
	Early	505	Winnipeg Formation	700
Cambrian	Late	523	Deadwood Formation	720
Precambrian	Paleo-Proterozoic	2100-1800	Glennie Domain	

Figure 4 - Phanerozoic stratigraphic table for the Fort à la Corne area in east-central Saskatchewan. Ages refer to the best estimate for the base of epochs represented by strata.

depth intervals and then submitted for macro- and microdiamond recoveries.

4. Geophysical Exploration

The Fort à la Corne kimberlite bodies lie beneath 75 to 150 m of cover, including Cretaceous sediments and overlying glacial overburden, and have no surface expression. Since the known kimberlite bodies were discovered from aeromagnetics, all are magnetic to some degree. Apparent magnetite contents for the kimberlites range from 0.1 to 4 percent, in contrast to the non-magnetic Phanerozoic sediments which host the kimberlites. Magnetic responses from crystalline basement, which is greater than 600 m below the ground surface, are sufficiently longer in wavelength to be clearly differentiated from the sharper signatures of the kimberlite bodies. The cost effectiveness of magnetic surveys in delineating the kimberlites was recognized at an early stage, although some refinements in interpretation and modelling have been necessary to comply with the unusual geometry of these bodies as subsequently revealed by drilling.

a) 3D Models from Magnetics

A working model for the Fort à la Corne kimberlite bodies, up until late 1990, consisted of a vertical, near-circular pipe based on the published and widely accepted diatreme-type occurrences of Southern Africa (Gerryts, 1970; Macnae, 1979). Magnetic signatures, particularly over some smaller bodies, were found to be reasonably consistent with this model, (Figure 6, model a). The larger magnetic features were assumed to be aggregates of coalesced pipes. More intensive drilling soon revealed that many of the kimberlite bodies were limited to ±100 m in thickness. Revised geophysical modelling confirmed that the typical pipe-like magnetic signatures could also be caused by lensoid magnetic bodies, which would be somewhat larger in footprint area and also more irregular in shape than the pipe-type models. More extensive and detailed ground magnetic coverage was required to map this geometry.

A further refinement to the model was the recognition that many bodies appear to have a residual, weakly magnetic halo which commonly seems to be developed more extensively towards the south or southwest of the main magnetic feature. This could represent a reworked peripheral apron of kimberlite, or perhaps distally deposited material which might be down-current or down-wind from a volcanic centre. The working geophysical model at this point could be described in terms of a central thick kimberlite block, 100 to 200 m in thickness, with an irregular, peripheral apron perhaps 30 to 50 m in thickness. The apron areas of many of the kimberlite bodies can be quite large and contribute significantly to overall footprint areas, consequently additional detailed ground magnetic coverage was required to assess them. Ultimately, in support of mapping these bodies in detail, almost 1000 km of ground magnetic profiles were completed over the 71 kimberlite targets, a job which, with present day GPS equipment, could have been performed just as effectively from the air. The sizes of the kimberlite bodies, estimated according to current geophysical models for each body, fall in the range 2.7 to 184 hectares. The mass of kimberlite at each body has also been estimated, using a conservative density value of 2.5 g/cm^3, and ranges from 3 to 675 million tonnes. The total kimberlite footprint area for the 71 bodies is estimated to be 2818 ha. The total mass of kimberlite is 9.5 billion tonnes.

The "puck and apron" model (Figure 6, model b) is recognized to be inadequate for many of the larger kimberlite bodies, where kimberlite thicknesses are difficult to predict from magnetics due to uneven distribution of magnetite. Many bodies contain multiple magnetic peaks which do not correspond to thick kimberlite segments but which are more likely caused by zones of strongly magnetic kimberlite near the top of the kimberlite section. A more complex but probably more realistic working model is to simulate each kimberlite body by a stack of horizontal disks of varying dimensions, corresponding to stratigraphically discrete kimberlite layers. This is supported by geological evidence of sub-horizontal stratification which is thought to be caused by sequences of kimberlite deposition separated by erosional intervals. Models of this complexity (Figure 6, model c) need control from drilling and detailed stratigraphic input.

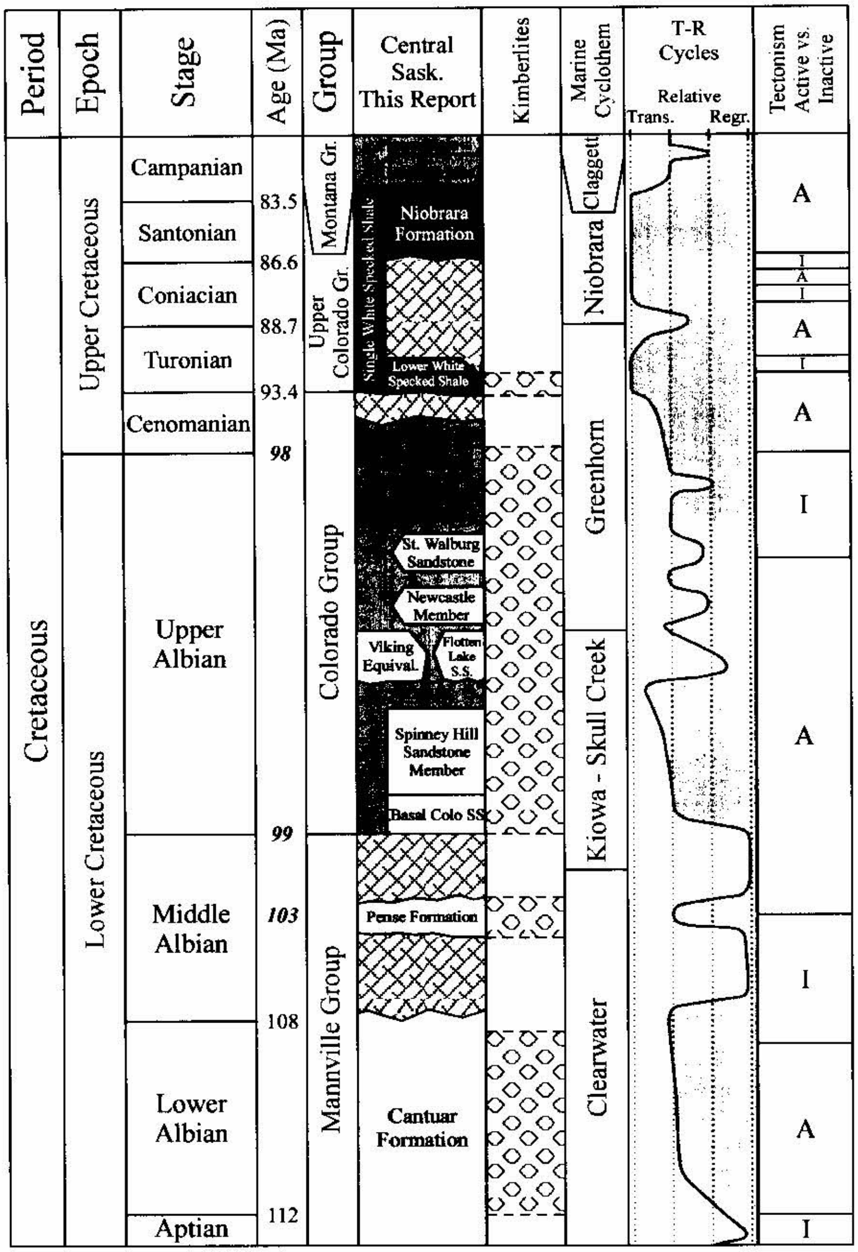

Figure 5 - Cretaceous stratigraphic table showing a summary of preserved kimberlite sections, marine cycles of the Western Interior Seaway and local expression of transgressive-regressive cycles. The stratigraphic section is a compilation incorporating suitable nomenclature from Simpson (1982), Bloch et al. (1993), Banerjee et al. (1994), and McNeil (1984). Lightly shaded blocks represent dominantly coarser-grained clastic lithologies such as sandstones in the Mannville Group and sandy siltstones of the Viking equivalent, moderate shading is non-calcareous mudstones and siltstones, and dark shading is calcareous mudstones and speckled shales. The cross-hach pattern represents times of significant erosion or non-deposition. Ages refer to the best estimate for the base of epochs represented by strata. Columns showing marine cyclothems transgressive-regressive (T-R) cycles, and tectonism were modified from Kauffman and Caldwell (1993).

Several of the Fort à la Corne kimberlites are already at this stage of exploration.

b) Gravity Coverage

As kimberlite can be of a significantly higher density than the surrounding Phanerozoic sediments (i.e. perhaps 2.6 g/cm^3 vs. 2.4g/cm^3), gravity surveys have proved to be effective. Gravity surveys were completed in 1989, 1990, 1991, and 1993 with a total of 219 km of profiles. The surveys provided positive peak anomalies ranging from 0.1 to over 1.0 milliGals in amplitude for 29 of the kimberlites. These data provided assistance in modelling some of the larger kimberlite bodies, where kimberlite thicknesses were difficult to predict from magnetics. Also, some weak magnetic anomalies have been screened by gravity to ascertain their cause, since magnetite concentrations in till or within the Phanerozoic sediments are possible sources of false anomalies. Three large bodies in the central Fort à la Corne Forest area provided the highest amplitude gravity signatures (1.0 milliGal), and drilling has confirmed that thick (>200 m) kimberlite segments are present.

While the geophysical emphasis has been on magnetics and gravity, several other methods have been tested. Outlines or locations for the test surveys are shown in Figure 7. These surveys included: galvanic resistivity, GEOTEM, TEM in-loop, seismic, borehole logging and magnetic susceptibility logging.

c) Galvanic Resistivity Surveys

In comparison to the enclosing Phanerozoic sediments, which are largely mudstones and shales, the kimberlite bodies should tend to be more highly resistive. The 100 m thick overburden comprises various interbedded sands and sandy tills grading to clayey tills that average between 10 to 20 ohm-metres in resistivity. Bedrock is composed of the Phanerozoic Colorado

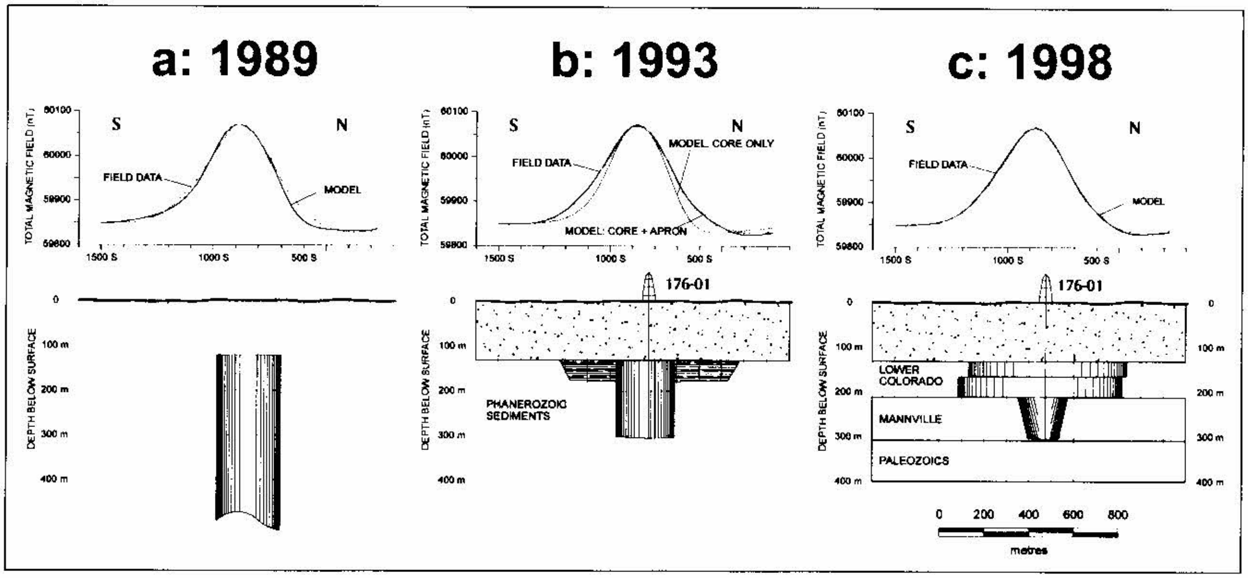

Figure 6 - Evolution of the geophysical model showing three approaches to modelling a north-south ground magnetic profile at target 176. a) The 1989 model, prior to drilling, assumed a diatreme-type target and comprises a pipe-like, magnetic body; b) The 1993 model, after drilling, is limited in thickness and has a peripheral, weakly magnetic apron zone; and c) The 1998 model uses flat, stacked disks with differing magnetic properties to simulate stratigraphic layering within the kimberlite body.

Group shales, with resistivity of perhaps 5 ohm-metres, overlying Mannville Group sandstone units which might have resistivities in the 100 ohm-metre range. Kimberlite resistivities can be highly variable, depending on the degree of alteration and porosity. Test survey data over a small number of bodies indicated that most kimberlites fall in the range 20 to 100 ohm-metres. Attempts at ground DC resistivity surveys were made at four sites in 1990. Dipole-dipole array tests were not successful due to the highly conductive overburden. A gradient array survey provided clear, high-resistivity anomaly signatures at two of the four sites.

d) GEOTEM Test Survey

Resistivity mapping can also be performed from the air using electromagnetics. A time domain EM and aeromagnetic survey (GEOTEM) was flown over a 12 km by 4 km block in 1996 and provided an opportunity to test the effects of different EM system parameters. The survey area contained 11 kimberlite bodies defined by magnetics and confirmed by drilling (Figure 7). The processed EM data detected 10 of the 11 kimberlites as high-resistivity anomalies, and one as a low-resistivity anomaly. The low-resistivity anomaly is also one of the most strongly magnetic features at Fort à la Corne, with an estimated magnetite content of 4 percent. Analysis of borehole logging data from a nearby target by the GSC noted the strong correlation of lower kimberlite resistivities with higher magnetic responses (Richardson *et al.*, 1995), presumably due to the high-metallic magnetite content. Overall, the resistivity background of the GEOTEM test area is quite active, which might tend to mask kimberlite signatures. For example, a probable glacial drainage feature, which correlates with drilled overburden depths of 130 m, produces a prominent, broad resistivity low south of the town of Shipman. The combination of aeromagnetics and coincident EM data, which the GEOTEM system provides, is, nevertheless, a powerful exploration tool in this environment.

e) TEM In-loop Soundings

As a follow-up to the GEOTEM survey, three profiles of in-loop TEM depth soundings were obtained at one site. It confirmed that a resistivity anomaly caused by a kimberlite body, in this case a high-resistivity feature, can be detected by this method. A benefit of in-loop TEM soundings is that simple one dimensional inversions may be performed to image the ground resistivity in a pseudo-depth section format, providing information on kimberlite thickness as well as location.

f) Seismic Test

During 1992 and 1993, high-resolution reflection seismic data were obtained over a kimberlite body (target 169) in farm land near Smeaton. This work was performed under the supervision of Don Gendzwill of the University of Saskatchewan in collaboration with the Geological Survey of Canada (reported in Matieshin, 1998; Gendzwill and Matieshin, 1996). Seismic data complemented a suite of studies including multi-parameter borehole logging also conducted by the GSC on a core hole at the same kimberlite target. The strong velocity and density contrasts between kimberlite and host sediments, and the normally horizontal stratification of the Phanerozoic sediments provided a favourable setting for seismic imaging. After suitable processing, the upper kimberlite surface and two possible intra-kimberlite horizons were resolved. The base of kimberlite is not distinctly

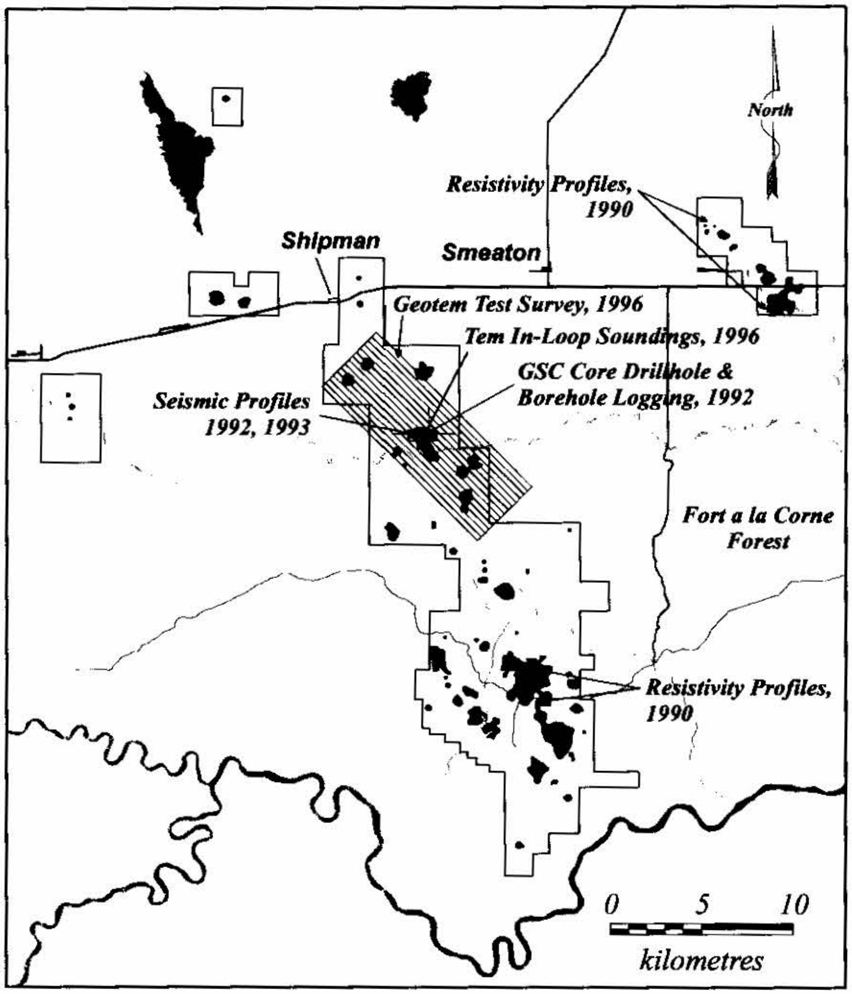

Figure 7 - Locations of geophysical test surveys.

geophysical parameters investigated assisted in characterization of the physical properties of the kimberlites and in the interpretation of other, geophysical measurements (Richardson *et al.*, 1995; Mwenifumbo *et al.*, 1996).

h) Magnetic Susceptibility Logging

Over 7,500 magnetic susceptibility measurements were collected on core from 16 drill holes targeted on 11 different kimberlites. The data were used to establish reasonable average magnetic susceptibility values for the kimberlites for comparison with model-derived values from ground magnetic data and to assess the variability of magnetic properties within each body. Magnetic susceptibility logging indicates that some segments of some kimberlites are essentially non-magnetic. Whether wholly non-magnetic kimberlites might exist is conjectural, as none have been detected, thus far. Gravity, resistivity (airborne and ground surveys), and seismics might be employed if such targets were suspected.

imaged and diverges from drill-indicated data in some regions. The overall size of the kimberlite body indicated by the seismic coverage is considerably larger than that from magnetic modelling, apparently due to an extensively developed, thin apron zone which is not fully identified in magnetics. The 169 body is enclosed and overlain by Colorado Group sediments and has a dome-shaped upper surface. Many other kimberlite bodies seem to have been eroded to a flat upper surface, which is commonly at subcrop level. The sub-horizontal intra-kimberlite reflectors lend support to the multi-temporal, multi-erosional genetic model.

g) GSC Borehole Logging

During 1992, the GSC funded drilling of a 242 m vertical core hole near the centre of the 169 kimberlite, which intersected approximately 100 m of kimberlite. Borehole geophysical measurements were obtained in the drill hole with a near comprehensive suite of logs acquired including seismic velocity and magnetic susceptibility which complemented ground geophysical surveys in the area. The wide range of

5. Kimberlite Geology

The Fort à la Corne kimberlites are dominated by olivine lapilli pyroclastics of variable composition with rare to common country rock and mantle xenoliths, minor very fine-grained inter-clast matrix, and rare garnet, ilmenite, and chromite. Texturally, these rocks are classified as pyroclastic kimberlites which may have accumulated within shallow blast-excavated craters that built upwards into low-relief tuff cones. Reworked kimberlite and intervening fine-grained sediments occur locally and provide time markers within the pyroclastic pile that help record times of erosion, transgression, and/or shallow marine deposition.

a) Petrographic Characteristics

The Fort à la Corne bodies are classified as Group 1 kimberlites based upon a composition including two generations of olivine (phenocrysts and macrocrysts) and a groundmass of monticellite, spinel, perovskite, mica, primary serpentine and carbonate (Scott-Smith *et al.*, 1994). Most bodies also contain rare amounts of mantle-derived, xenocrystic/xenolithic constituents including garnet, ilmenite, and olivine macro- and

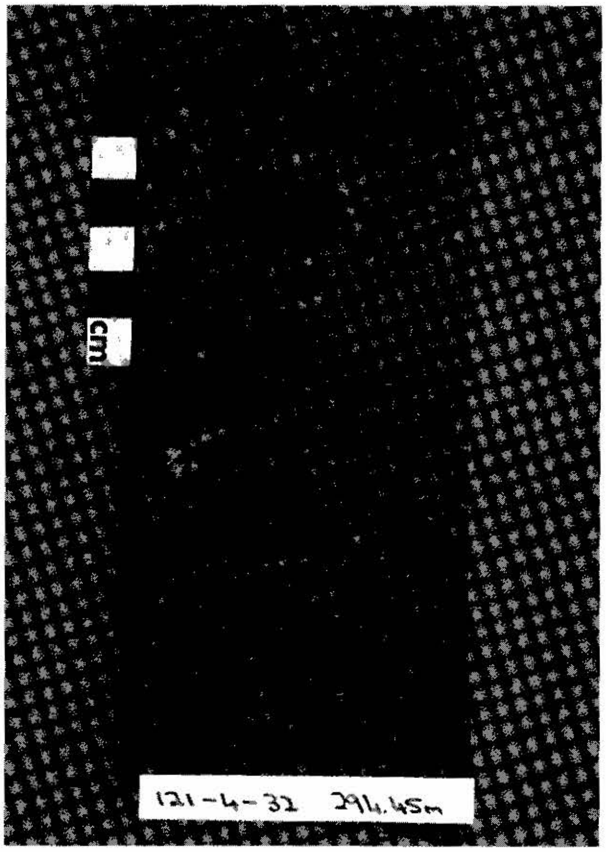

Figure 8 – Core sample of xenolithic breccia from Fort à la Corne composed of massive, densely-packed, medium- to coarse-grained olivine with common garnet and distinct xenoliths of mantle, basement, and country rock material.

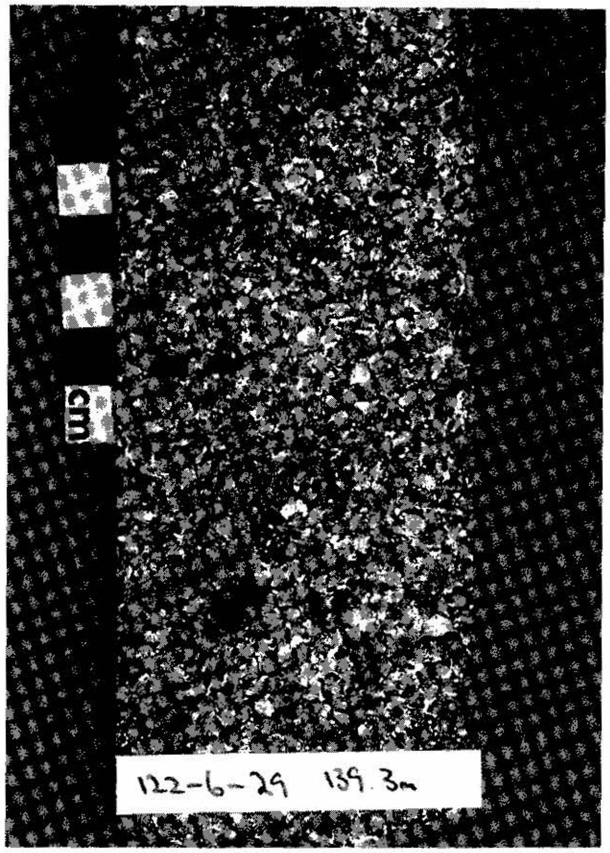

Figure 9 - Fort à la Corne core sample of massive, partially carbonatized, medium- to coarse-grained, lapilli-dominated pyroclastic kimberlite with macrocrysts of phlogopite, garnet, and ilmenite.

megacrysts, as well as eclogites and coarse-grained, garnet-bearing peridotites (Figure 8). Basement rocks, Paleozoic carbonates, and Cretaceous terrigenous and marine lithologies may also be found as fine to very coarse xenolithic fragments within the kimberlites.

The main rock-type end members are juvenile lapilli-dominated kimberlites and olivine-dominated crystal tuffs. Although pure end member rock types do occur, they are rare; the olivine lapilli kimberlite of variable composition is most common. Clast sizes range from <1 mm to 10 cm, although most rocks are dominated by fine to medium-grained textures ranging from 0.5 to 5 mm with a notable paucity of "fines" or material less than 0.2 mm in size. The pyroclastic components are dominated by juvenile lapilli and single olivine crystals of varying sizes and proportions. Lapilli vary in shape from spherical to ovoid, to more fluidal, irregular amoeboid forms. An example of lapilli-dominated kimberlite is shown in Figure 9.

Olivines occur in two significantly different populations which commonly coexist in varying proportions that were controlled by physical separation processes either prior to, or during eruption. A finer grained population, of euhedral to subhedral olivine phenocryts generally <2 mm in size, is expected to have crystallized from the precursor kimberlitic magma. A second, coarser-grained population of subhedral to anhedral macrocrysts typically >2 mm in size, is xenolithic in nature, having been derived from either the kimberlite magma source or from mantle wallrocks during ascent. Figure 10 shows a core sample of distinctively bedded kimberlite with a range of olivine sizes from 0.2 to 5 mm.

The inter-clast matrix of the rock and intra-lapilli matrix are composed of dense, commonly massive serpentine, carbonate, magnetite, and a highly variable assortment of very fine grains including spinel, apatite, monticellite, perovskite, mica, primary carbonate, and coarse ash-sized olivine microphenocrysts (Scott-Smith *et al.*, 1994). Inter-clast matrix or cement may form through the crystallization of minerals from kimberlitic fluids derived from subsequent eruptions, or may be the alteration product of fine ash deposited coevally with the coarser grains. Multiple and sequential phases of identifiable cementation show that lithification occurred early on, but with modification of the cementing components during subsequent eruptive pulses, subsidence, and compaction (Scott-Smith *et al.*, 1994).

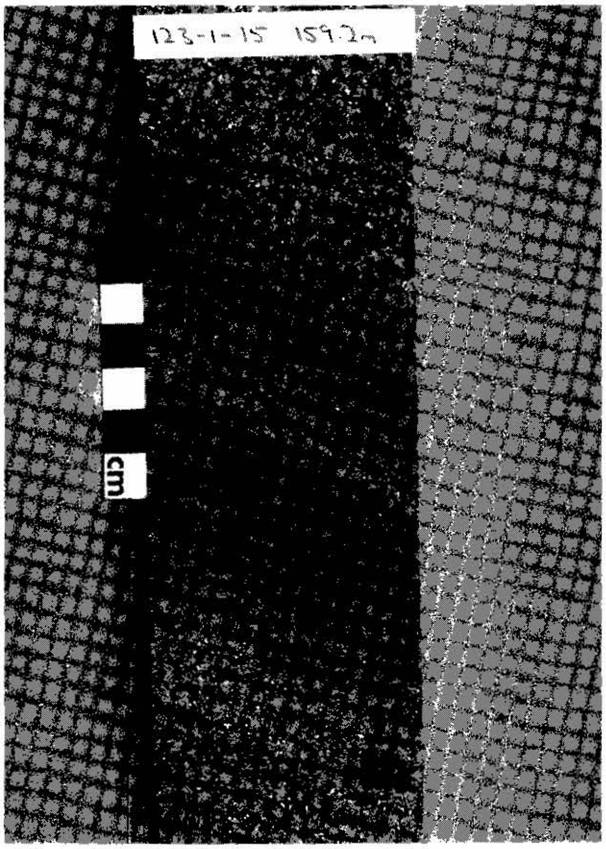

Figure 10 - Horizontally bedded kimberlite core from Fort à la Corne with 0.5 to 1.5 cm thick beds composed of very fine- to fine-grained olivine (0.2 to 1 mm) in the groundmass (<0.2 mm) separated by 1 to 3 cm thick beds of fine- to medium-grained olivine lapilli pyroclastic kimberlite. Three generations of olivine are present including very fine-grained microphenocrysts (<0.2 mm; possibly resedimented), fine-grained olivine phenocrysts (0.5 to 2 mm), and medium-grained olivine macrocrysts (2 to 5 mm).

b) Kimberlite Emplacement and Post-depositional Modification

Geologically, the Fort à la Corne kimberlites are somewhat unique in that they apparently consist only of crater-facies material (Scott-Smith, 1996); however, internally, each kimberlite body varies considerably. Pyroclastic airfall and lava spattering are interpreted as the principle modes of kimberlite accumulation and are likely the result of several styles of eruption due to variations in volatile content and degree of interaction with groundwater. Feeders for the kimberlite bodies are probably small in area. Some drill holes penetrate what are thought to be feeder zones, although a specific kimberlite type indigenous to a pipe or diatreme-facies, has not been identified.

Pyroclastic airfall kimberlites composed of variable proportions of olivine and lapilli formed subtly graded beds resulting from physical separation of grain components within high energy eruptive columns. These columns were the product of rapid degassing of a volatile-rich magma at the vent and may be considered to be the extrusive equivalent of intrusive diatremes in other kimberlites (Scott-Smith *et al.*, 1994). The fine ash component of these eruptive columns may have reached up to 15 km high and been effectively removed by wind action, allowing concentration of distinct grain size and density populations dependent on local weather conditions and proximity to the vent (Scott-Smith *et al.*, 1994). Olivine-dominated crystal tuffs with absent to rare lapilli are thought to have formed through extreme examples of this process or possibly by the disintegration of lapilli followed by winnowing of fines in a sedimentary environment. Juvenile lapilli form as the result of fragmentation of fluidal magmas in explosive to relatively passive eruptive conditions, and may be most concentrated in areas proximal to eruptive vents in which lava spatter and fountaining are dominant. Up to four distinct generations of lapilli have been observed to coexist in the same rock type in some Fort à la Corne kimberlites, indicating that material from old eruptions is recycled to a limited extent during later eruptions in some bodies (Scott-Smith *et al.*, 1994). Some lapilli are vesicular, but scoriaceous clasts are extremely rare.

Different eruptive styles ranging from explosive Strombolian-type ash columns to more passive Hawaiian-style lava fountaining (Leckie *et al.*, 1997; Scott-Smith *et al.*, 1994), ultimately resulted in complex layering of stratigraphically distinct kimberlite lithotypes during late Mannville time and throughout much of Lower Colorado time. Changing eruptive centres, physical properties of the erupting kimberlite magma, and morphology of the crater-cone development affected the formation of graded and massive bedded lapilli tuffs and olivine-dominated crystal tuffs. The progressive loss of abundant volatile content (CO_2 and H_2O vapour ?) and increasing magma viscosity would have dampened the escape velocity of pyroclastic material from the vent, allowing the formation of thicker mega-graded beds and lapilli-rich lithotypes characteristic of lava-spattering. Collectively, these deposits may have overfilled the shallow crater allowing a period of cone development dependent on the volume of material extruded and the size of the crater. Cone-margin deposits probably formed which consisted of coarse-grained xenolith-rich base surge and airfall deposits overlain by distal, finer-grained, xenolith-poor, airfall facies (Leckie *et al.*, 1997). Subsequent to each eruption, terrestrial or marine depositional and erosional processes may have affected the exposed portions of the body causing truncation of beds and accumulation of reworked kimberlites. Furthermore, continued eruption from the current vent or proximal new vents may have locally truncated existing beds.

The bulk of petrographic evidence suggests that most of the kimberlites accumulated in dominantly subaerial conditions as crater-fill pyroclastic deposits (Scott-Smith *et al.*, 1994); however, it is not known to what extent positive-relief cone building occurred above the plane of the surrounding surface. Some vent-distal deposits indicate deposition of water-lain kimberlite but drill hole control is typically poor away from the centres of the kimberlite bodies. Lower Colorado Group sediments preserved above the top of the main kimberlites are often sand- and silt-dominated facies which were associated with one of several regressive seaway episodes coeval with deposition of the St. Walburg, Newcastle, or Viking/Flotten Lake coarser terrigenous units (Figure 5). Some kimberlite bodies however have a preserved upper transitional sequence of interbedded kimberlitic siltstones, marine mudstones, and ashfall tuffs. Furthermore, interbedded marine mudstones and kimberlitic mudstones are common towards the margins of some kimberlite bodies. These younger kimberlites are thought to have erupted into nearshore terrestrial to shallow marine conditions subject to periodic strandline migration and erosion.

Synthesis of petrographic information, body geometry, and internal correlation of kimberlite and marker strata indicate kimberlite body architectures that range from simple, mono-eruptive, essentially stratiform bodies to stratigraphically complex, temporally diverse, multi-centered, multi-eruptive edifices marked by stacking of lensoidal to pancake shaped eruptive deposits (Figure 11). Correlation of marker beds and erosive horizons indicate the very common occurrence of severely beveled kimberlite masses at several stratigraphic levels. Coalescence of proximal, expanding kimberlite bodies or eruptive centres produced clusters of intercalated kimberlites.

6. Indicator Mineral Geochemistry

Major and trace element geochemistry of garnets can be used in conjunction with garnet Ni-thermometry to synthesize an interpretation of the mantle source rocks for kimberlite. Garnet geochemical data from Fort à la Corne kimberlites indicate a predominantly lherzolitic population with lesser harzburgitic, websteritic, megacrystic, and eclogitic components. Ni-thermometry data are trimodal, which is a strong indication that mantle material at three separate depths was sampled by the ascending kimberlitic magma. Geochemical analyses of ilmenite and chromite also have provided clues to the potential for diamonds and the magmatic history of the kimberlites.

The main mantle sampling interval or depth straddles the lower threshold of the "diamond window" based on application of a cratonic geotherm of 40 mWm^{-2}. Most of the kimberlites are dominated by G9 lherzolitic garnets, but also include other peridotitic, eclogitic, and macrocrystic garnets. Garnet Ni-thermometry data indicates a common triple sampling pattern or entrainment of lithospheric mantle material variably split between the 700°-800°C, 950°C, and 1150° to 1200°C temperature regimes. The middle sampling interval (950°C) is the dominant peak in the temperature distributions and it lies just within the lower threshold of the diamond stability field. The abundance of high-TiO_2 lherzolitic garnets formed at close to 1200°C suggests that this temperature marks the base of the lithosphere and the lower depth of diamond entrainment.

Prospective harzburgitic G10 garnets are present in most of the kimberlites, but generally in low abundance (<7 percent of total garnet, averaging 3.4 percent) and are usually associated with sampling in the 950°C range. Sampling of the mantle was

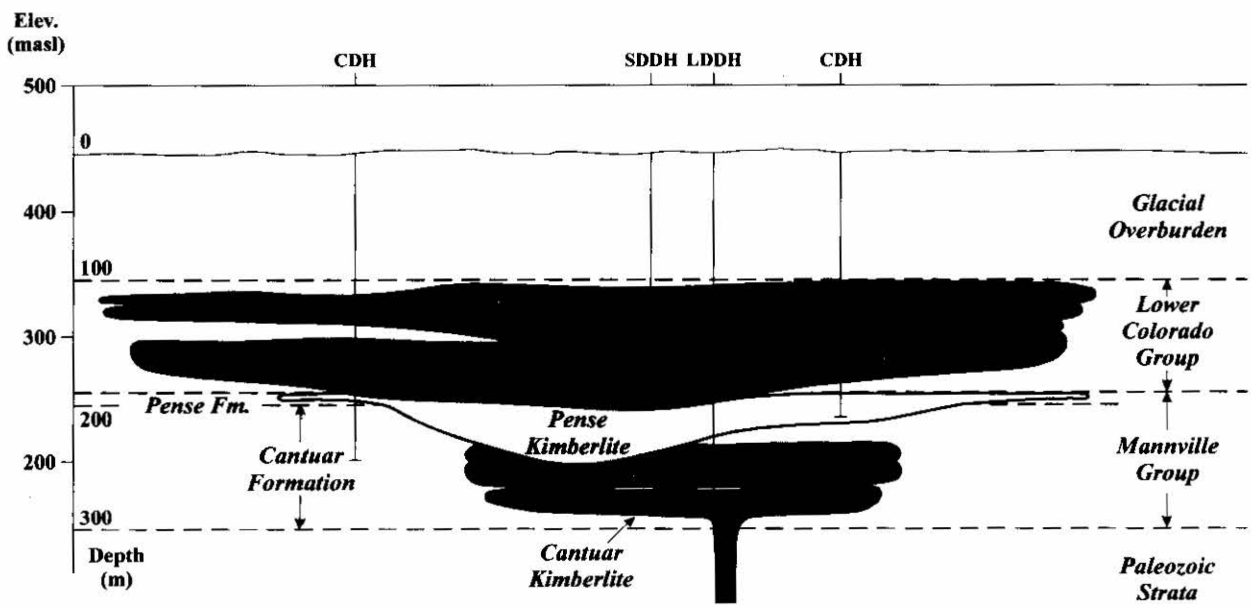

Figure 11 - Schematic cross-section showing generalized kimberlite body architecture within the framework of Cretaceous stratigraphy preserved at Fort à la Corne. Lensoidal bodies, in solid outlines, are preferentially preserved crater-facies kimberlites, which were deposited during chronologically discrete eruptive events. Short dashed lines within the bodies represent changes in lithology between associated pulses of kimberlite included within an eruptive event. Long dashed lines represent an average depth of intersection for major Cretaceous lithological groups and the top of the Paleozoic strata.

dominantly at or near 950°C, however, the source rocks seem to have been not melt-fractionated lherzolites, thus diamond grades could be low. Where material was entrained over the lower temperature interval (700° to 800°C), the mantle was also fertile and consequently of low diamond potential. Mantle material from the upper temperature interval (1200° to 1400°C) was enriched by melt-metasomatic processes and is considered to have low diamond preservation potential.

Chrome spinel is common in most of the kimberlites tested. On a plot of weight percent MgO vs. Cr_2O_3, chrome spinels often plot in an inverted "U" pattern or portion thereof, interpreted to represent entrainment of material from a number of different mantle sources. High interest spinels have very high chromium contents (>61 percent), which place them within the "diamond inclusion field" at MgO contents of 11.5 to 16.5 wt.%. Generally, Fort à la Corne kimberlites contain only a few percent chrome spinel grains that plot in the diamond inclusion window, but a few bodies range up to 8 percent. Ilmenite (picroilmenite) is also common in most of the kimberlite bodies Most of the ilmenites have major chemistry signatures indicative of the megacryst suite, although distinct populations are seen in some Cr_2O_3 vs. MgO plots that probably reflect sampling from several different sources in the lithosphere. Some kimberlite bodies have ilmenite subpopulations characterized by low MgO contents (<7 wt.%). In general, Gurney *et al.* (1993) consider the presence of picroilmenites with low MgO compositions to be indicative of exposure to conditions promoting low diamond preservation potential. In the past, De Beers considered these low MgO and low Cr_2O_3 ilmenites simply to be non-kimberlitic. Recently, Schulze *et al.* (in press) found no evidence to support the hypothesis that oxidized ilmenite populations were indicative of increased potential for diamond resorption in kimberlites.

Although many Fort à la Corne kimberlites incorporated mantle material from within the diamond stability field, the contribution of diamonds from depleted, harzburgitic mantle appears to have been diluted by potentially diamond-poor, fertile, and enriched lherzolites. An understanding of the highly variable contribution of xenocrysts (including picroilmenite, chrome spinel, and diamonds) to the kimberlite magma from distinct mantle lithosphere sources including harzburgite, lherzolite, websterite, and eclogite, from within distinct temperature ranges, contributes to the explanation of why the diamond contents of the Fort à la Corne kimberlites are highly variable. However, for many of the Fort à la Corne kimberlites, major and minor element chemistry have identified abundant peridotitic garnets, potentially from diamondiferous mantle source rocks (G1, G9, G10, and G11), which justifies continued exploration interest.

7. Diamond Recovery and Economic Potential

Microdiamond recovery, primarily by caustic dissolution methods, has produced 4,426 stones dominantly in the size range from 0.074 to 0.8 mm. Determination of the size distribution of these stones on a per body basis has allowed estimation of preliminary grade forecasts for commercial-sized stones using statistical methods. A total of 705 macrodiamonds (1 axis >1.0 mm) collectively weighing 35.5 carats were recovered by a variety of methods from 34 of the 69 tested bodies. Close to 70 percent of the macrodiamonds recovered thus far, are considered to be of gem quality; a few of these macrodiamonds are shown in Figure 12. The largest macrodiamond recovered to-date weighs just less than one carat. Ongoing recovery of minibulk samples from large diameter drill holes targeted on selected diamondiferous kimberlites remains a priority of the project. Acquisition of sufficient kimberlite bulk samples (5000 to 10 000 tonnes) will allow more confident determination of diamond grades, stone values, and size frequencies. In consideration of preliminary grades, currently based on very low levels of testing, the higher priority Fort à la Corne kimberlites with the greatest economic potential are best categorized as very large tonnage, lower grade diamond deposits. Open-pit mining methods, conducted on a large scale, could facilitate mining the Fort à la Corne kimberlites, particularly in light of the proximity of population centres, existing means of ground transportation, and utility infrastructure.

8. Acknowledgments

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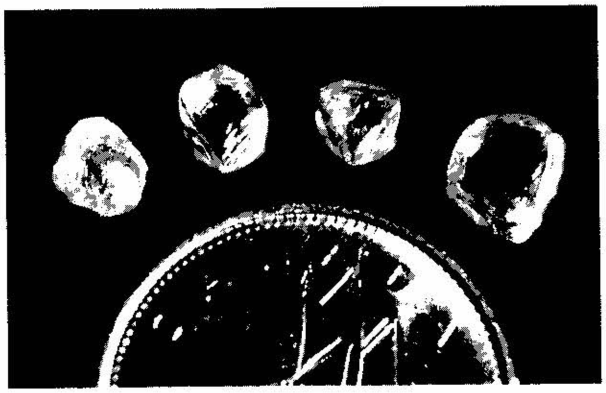

Figure 12 - Four macrodiamonds recovered from Fort à la Corne kimberlite. Shown beside a dime for scale.

operated the project until the completion of the acquisition of Uranerz by Cameco Corporation in August 1998.

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