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ASSESSMENT REPORT PART B

Calling Lake Project, Alberta

2005-2007 Mineral Exploration Summary

Metallic and Industrial Minerals Permit
No. 9305070817

Halmco Inc.

Submitted by Halmco Inc.

August 8, 2007

Submitted by P.A.R.Brown P. Geo and R.Haimila Consultant to Halmco

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SUMMARY

Halmco Inc's diamond exploration on its properties at Calling Lake, AB.

Previous exploration of the Calling Lake area of Alberta resulted in the discovery of anomalous diamond indicator sites located along the west and south shores of Calling Lake and along the Calling River East. These anomalous diamond indicator sites are significant in that they include high magnesium picroilmenites, diamond inclusion quality: chrome diopsides, eclogitic garnets, olivines, chromites, and a complete suite of pyrope garnets (G1 to G12)- including 65 Gurney G10 garnets. Also discovered was a gem quality macro-diamond.(Calling River East). Over 3000 indicator minerals have been identified in this east-west trend. The potential to discover a diamondiferous intrusive in this east-west trend is significantly high.

Previous exploration of the Calling Lake-Calling River area (up-ice drilling and sampling) appears to provide a Northern cut-off to the highly anomalous diamond indicator sites located along the Calling River as well as the south shore of Calling Lake.

An exploration program has been implemented by Halmco to find the source of the these anomalous high quality diamond indicator sites. This exploration program was designed to test what appears to be significant seismic and resistive/magnetic anomalies that are at or south of the Northern cut-off to the anomalous diamond indicator locations (Priority Areas 1, 2 and 3).

Priority anomalies are resistive/magnetic anomalies that are in the same east-west trend as the anomalous diamond indicator locations. More importantly, these anomalies are in the same drainage systems as the diamond indicator sites.

High Priority Anomalies are resistive/magnetic anomalies with geophysical signatures indicating vertical structure (electrical resistivity tomography (ERT), very low frequency electromagnetic (VLF) and/or seismic diffractions)

Eight High Priority Anomalies showing vertical structure have been discovered to date.

AREA 1.. (Calling River East) . 2 resistive/magnetic anomalies with ERT-VLF structure
AREA 2.. (West drainage into Calling Lake) ....3 resistive, all with significant seismic diffractions
AREA 3...(South drainage into Calling Lake)....3 resistive, 1 magnetic, all with ERT structure

A significant high priority seismic structure with a coincidental resistive signature was drilled in December 2006.(AREA 2..west drainage) The structure appears to be approximately 450 meters in diameter. Brecciated rock was encountered in said hole. Thin sections are being prepared for petrological identification i.e.contact breccia and/or pyroclastic or resedimented kimberlite.

Initial interpretation suggest the breccia is an explosive volcanic breccia. Garnet and phologopite have been identified in thin section. A small sample of core (matrix) sent to the Saskatchewan Research Centre for diamond indicator processing identified 3 pyrope garnets.

In the spring of 2007, Halmco retained WorleyParsons Komex to conduct an ERT (electric resistivity tomography) on mineral permit 9305070817. This geophysical survey identified 4 resistive anomalies. Vertical structure has been noted on each of the 4 anomalies.

Geophysical surveys and interpretations are ongoing.

The Halmco Calling Lake Diamond Exploration Project was designed according to "the theory of geological prospecting systems reliability which is based on the study of failure of the systems or elements". This exploration method is described in chapter 3- "Search For Diamond Deposits (page 75) of the " **Field Guide Book –Kimberlites of Yakutia"** (Novosibirsk, 1995) see appendix. 1.........

In summary, Maps are designed " as a basis for evaluation of prospecting reliability and for protecting a higher quality scheme of prospecting"- and is based on 5 types of failure.

1. failures of targets to be indicated in expected manner
(i.e. lower resistivity of target-crater fascies-10 to 20 ohm meter)
2. failures attributed to landscape geological surroundings
(i.e. basal till may actually be layered crater fascies lake deposits)
3. failures of technical type
(i.e. resistive anomalies interpreted as culture because of video failure at time of the resistive/magnetic survey)
4. failures of geological interpretation
(i.e. diamond indicator sites may be at source and/or on drainage systems from the south rather than from up-ice targets)
5. failures of evaluation and verification
(follow up ground and air surveys of cultural anomalies and indicator sampling of drainage systems associated with highly anomalous diamond indicator sites)

The Maps A & B (appendix. 6 .) are the result of the review of data bases of past exploration programs of the Calling Lake area using the evaluation of prospecting reliability which is based on the above mentioned failure of systems.

Map A is the result of reviewing geochemical data bases of kimberlitic indicators (approx. 2200 grains from past exploration projects, assessment reports, etc. between 1994 and 2004) and then filtering out single sample location sites that are of a lower quality/ quantity kimberlitic indicators in favour of higher quality/quantity diamond indicators. This provides Map A and shows area of multiple sites of higher quality/ quantity diamond indicators. This map is then interpreted to provide a Northern cut-off to the significant diamond indicator sites and provides the Major Trend and/or trends in diamond indicator data. (i.e. narrows the window for the source of the highly significant diamond indicator sites.)

Map B is the result of reviewing geotechnical data bases of seismic, magnetic, resisitive surveys and anomalies and their proximity to the significant diamond indicator site. Again, the anomalies are reviewed based on the 5 failure system of prospecting reliability.

Work Specific to Halmc Inc's mineral permit 930505070817 for the period July 2005 to July 2007

It was decided at a meeting at Calling Lake in November of 2006 to conduct a geophysical survey on mineral permit 9305070817. Those present at said meeting were: Leo Halonen/Halmco,and consultants P. Brown (geologist), S. Mlot (mining engineer), Dr. Yoshida and R. Haimila. The location of the area of the survey would be in priority area 3, the south drainage into Calling lake. This area is also the location of anomalous kimberlitic indicators (see Map A) as well as a number of resistive/magnetic anomalies identified by Dighem geophysical survey 1998 (see Map B in appendix 6 of Part B)

The specific geophysical survey to be used would be an electric resistivity tomography (ERT). The ERT can identify vertical structure by mapping the distribution of subsurface electrical resistivity (or its inverse conductivity) in a cross-sectional format. (see enclosed Part C)

Dr. Kjarsgaard of the GSC has identified the importance of resistivity,porosity and the level of kimberlite erosion in his papers in "Searching for Diamonds in Canada, GSC open file 3228 (1996). When consulted by R. Haimila, Dr. Kjarsgaard reiterated the importance of resistivity in identifying crater fascies, structure, etc. in an exploration program.(see appendix 3 of Part B)

December 15, 2006; a site inspection of the proposed geophysical survey area by L. Halonen, P. Brown (geologist) and consultants R. Haimila and DR. Yoshida.

May 2007, R. Haimila met with Paul Bauman of WorlyParsons Komex to plan the specifics and location of ERT survey. (see appendix 5 of Part B)

June 2007, R. Haimila reviewed seismic data from Target Data- seismic diffractions coincidental with resistive anomaly identified by Dighem geophysical survey (see location of diffraction- appendix 2, Part B) The majority of data ordered is not available for viewing or purchase.

June 26-29, ERT survey conducted in high priority area of permit 9305070817.
R. Haimila was Halmco's project coordinator. This geophysical survey identified 4
Vertical structures coincidental with Dighem resistive/magnetic anomalies.

June 30, 2007; because of the positive results from ERT survey- Halmco did an air survey over a magnetic low approximately 1.5 km west of the north end of the ERT survey. The purpose being to identify an access route for an ERT survey over said anomaly in the fall of 2007 (see air photos at the end of appendix 4, Part B)

One of the more important points in doing an electric resistivity tomography survey is the fact that data can be viewed in the field the same evening that the survey is being run. The array of cables and electrodes for this specific survey was to collect data over 3.6 kms , over and/or near a line of Dighem anomalies. The length of survey allowed for a penetration depth of over 300 meters. This choice was based on the resistivity research of Dr. B. Kjarsgaard of the GSC (see appendix 3 of Part B) and of the research done by P. Bauman of WorlyParsons Komex. (see ERT Survey for Kimberlite Exploration,Calling Lake, Alberta, which is Part C of Halmco Inc's Assessment Report for Metallic and Industrial Minerals Permit 9305070817.)

Geophysical surveys and interpretations are ongoing.

Introduction and Terms of Reference

The following report was prepared to describe exploration activities that took place on the Calling Lake Project's Mineral permit No. 9305070817 during 2005-2007. This report has been structured to meet the assessment requirements of Alberta Resource Development and was not written to National Instrument Policy 43-101.

Property Location and Description

Metallic and Industrial Mineral Permit No. 9305070817 is centered south of Calling lake and about 50 kms. north of the town of Athabasca within the Pelican River. 1:250,000 scale National Topographic System (NTS) map sheet 83P.

Metallic and Industrial Minerals Permit NO. 9305070817

Term Commencement Date: July 11. 2005

Aggregate Area: 9216 Hectares

Description of Location and Permitted Substances

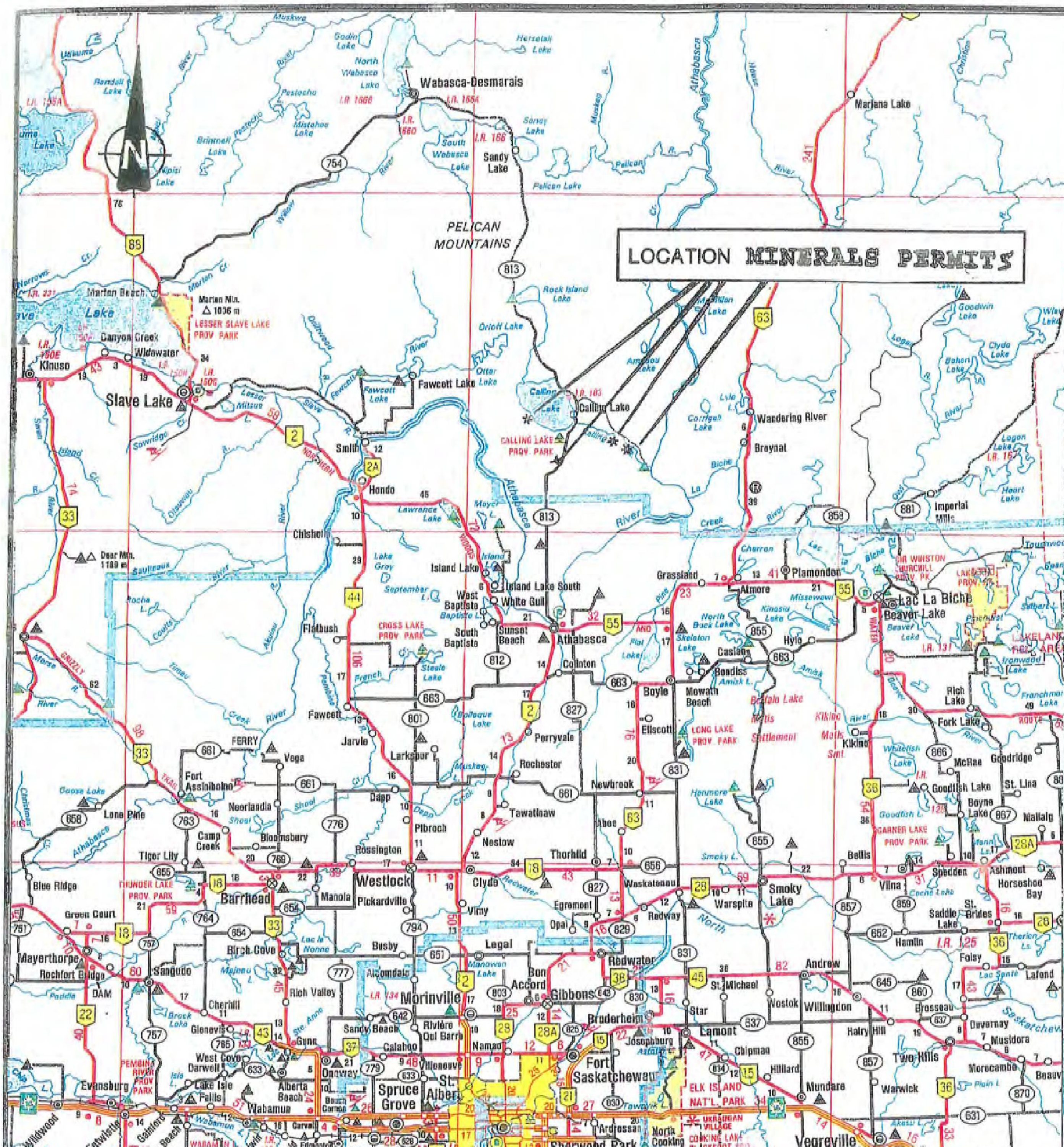
4-21-071: 6;7
4-22-070: 11-36
4-22-071: 1-4; 9-12

Descriptions and References that follow are from previous Calling Lake area Assessment Reports filed by: R. Haimila, 656405 Alberta Ltd., and Buffalo Diamonds, etc., (exploration periods 1994-2002)

Accessibility, Climate, Local Resources, Infrastructure and Physiography

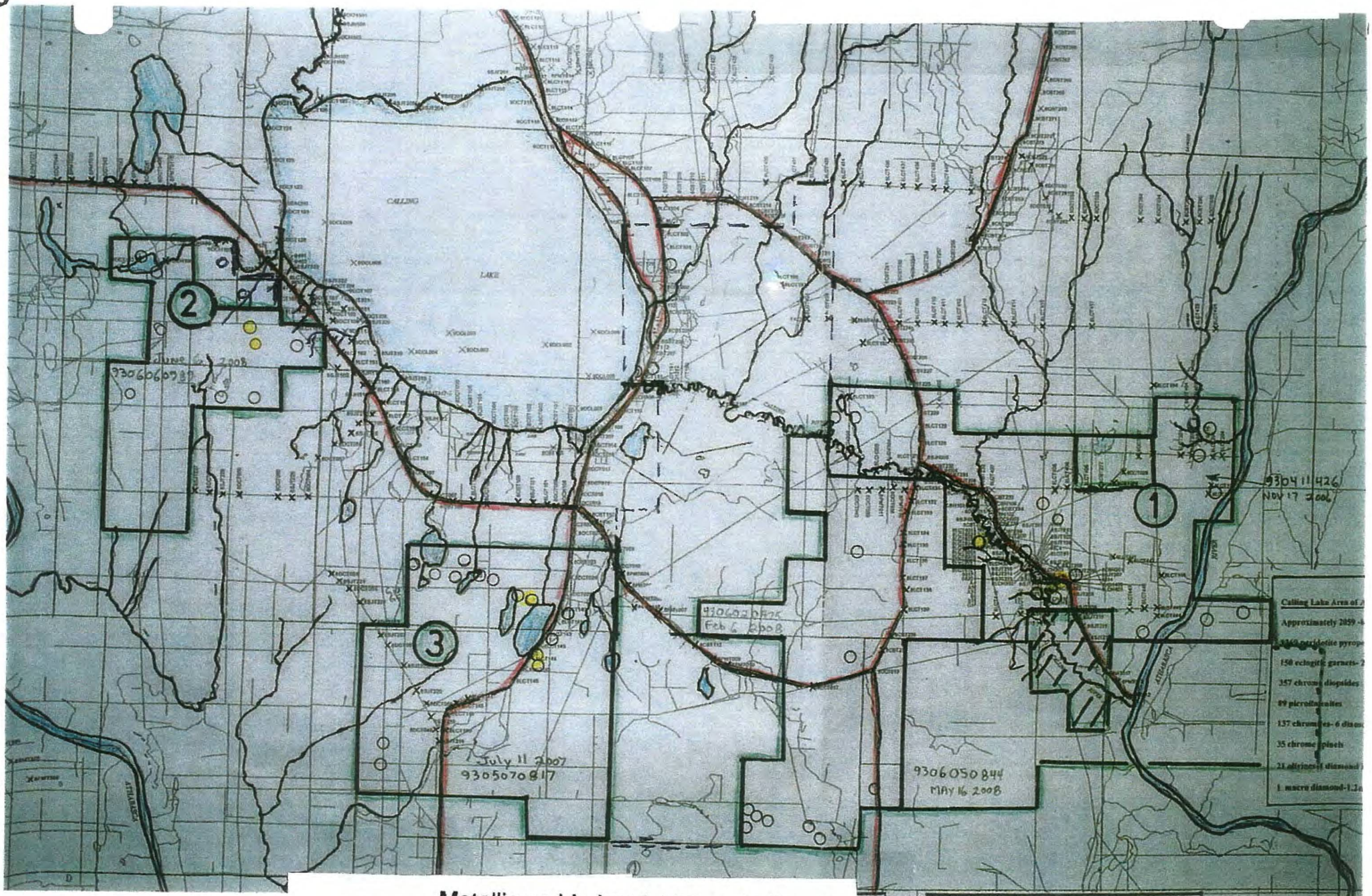
The Calling Lake property may be accessed via Provincial Highway 813, gravel roads, trails and seismic lines. Portions of the permit area may be accessed by four-wheel drive vehicles or Quads. There are two small airfields within the Calling Lake area, one near Orloff Lake and the second just north of Calling Lake. Accommodation and food can be obtained at Calling Lake Lodge but fuel and supplies are best obtained in Athabasca. Camping facilities may be available in Calling Lake Provincial Campground

The Calling Lake property is situated near the northern border of the Alberta Plain physiographic zone and the southern border of the Alberta Plateau (Klassen, 1989). Relief is low-lying. Elevation in the region generally varies from 590 to 700 m above sea level



HALMCO INC.

LOCATION MAP



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Metallic and Industrial Minerals Permit
No. 9305070817

(asl.), except along the Athabasca and Calling river valleys which drop steeply to approximately 480 m asl. Major topographic features in the region include: Calling Lake, situated in the centre of the property; Pelican Mountains to the northwest of the property; and the Athabasca and Calling rivers. Numerous streams and creeks drain the region, flowing into Calling Lake, which in turn drains into the Athabasca River via the Calling River or directly into the Athabasca River which wraps around the west, south and east borders of the property. In addition to the numerous small lakes and ponds, most of the property is covered by swamps, marshes and fens. A boreal forest containing mainly spruce and jack pine covers the property. Annual temperatures range from -40°C in January to 25°C in July.

Regional Geology

The Regional Geology description and references remains unchanged and has been reproduced from "Diamond Potential of Buffalo Diamonds Ltd's Calling Lake Property, Alberta" by Dufresne and Copeland (1999).

Precambrian

The Calling Lake permits lie in the Western Canadian Sedimentary Basin along the southern flank of the Peace River Arch (PRA). However, Precambrian rocks are not exposed within the Calling Lake area (NTS 83P). The basement underlying the PRA is comprised of several terranes including the Buffalo Head and the Chinchaga, both of which collectively form the Buffalo Head Craton (Ross *et al.*, 1991, 1998). The Buffalo Head Craton was accreted to the western edge of the Churchill Structural Province (Rae Subprovince) approximately 1.8 to 2.4 billion years ago (Ga). Due to their relatively stable history since accretion, the Buffalo Head and Chinchaga terranes are currently the focus of extensive diamond exploration in northern Alberta.

The basement underlying the Calling Lake permits borders the Buffalo Head Terrane (BHT), the Talston Magmatic Zone (TMZ) and an unnamed domain (Figure 3). Basement underlying the northeast portion of the Calling Lake Permits is part of the Talston Magmatic Zone (TMZ), a 2.0 to 1.8 Ga aged terrane that represents a magmatic arc related to collisional orogeny during the Proterozoic. The TMZ is characterised by a highly corrugated internal fabric comprised of extremely high relief, north-trending sinuous magnetic anomalies. The northwestern portion of the Calling Lake permits is underlain by basement of the BHT, an area of high positive magnetic relief with a north to northeasterly fabric (Villeneuve *et al.*, 1993). The area of Ashton Mining of Canada Inc.'s (Ashton) Buffalo Head Hills kimberlite discovery is underlain by basement of the BHT.

The bulk of the basement underlying the Calling Lake permits is part of an unnamed domain (Figure 3). The gravity and magnetic signatures of the unnamed domain are very similar to those of the BHT and Wabamun Terrane and, therefore, may in fact be an extension of either one of these terranes. The Wabamun Terrane is geologically and magnetically similar to the BHT and was likely accreted to the western edge of the Churchill Structural Province between 2.4 to 1.8 Ga. The BHT and the Wabamun Terrane are thought to represent either Archean crust that has been thermally reworked during the Hudsonian (Proterozoic) Orogeny (Burwash *et al.*, 1962; Burwash and Culbert, 1976; Burwash *et al.*, 1994) or accreted Proterozoic terranes that may or may not have an Archean component (Ross and Stephenson, 1989; Ross *et al.*, 1991; Villeneuve *et al.*, 1993). Precambrian rocks which have been intersected in drill core from the BHT and the Wabamun Terrane comprise felsic to intermediate metaplutonic rocks, felsic metavolcanic rocks and high-grade gneisses (Villeneuve *et al.*, 1993). The presence of a large number of eclogitic garnets and eclogitic pyroxenes in association with kimberlites or related intrusions in northern Alberta may indicate the presence of a significant volume of subducted basaltic and sedimentary protolith in the upper mantle and lower crust beneath the Buffalo Head Craton. The Calling Lake permits lie within an area with an intermediate to high residual gravity signature. Seismic refraction and reflection studies indicate that the crust in the Calling Lake region is likely around 35

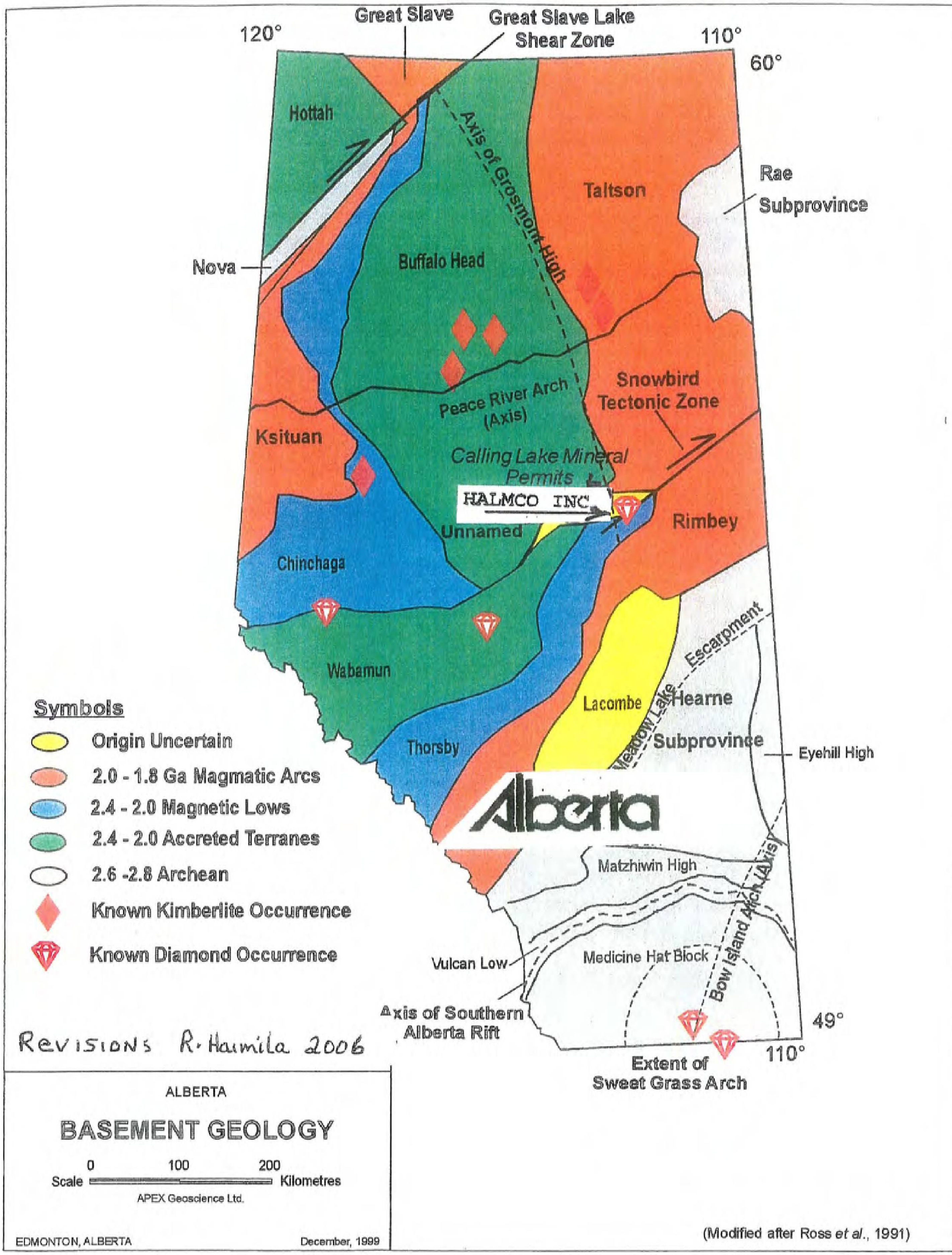
Great Slave
Great Slave Lake
Shear Zone
120°
110°
60°
Hottah
Axis of Grosmont High
Taltson
Rae
Subprovince
Nova
Buffalo Head
Snowbird
Tectonic Zone
Peace River Arch
(Axis)
Ksituan
Calling Lake Mineral
Permits
HALMCO INC
Unnamed
Rimbey
Chinchaga
Escarpment
Wabamun
Lacombe
Meadow Lake
Hearne
Subprovince
Eyehill High
Thorsby
Alberta
Matzhiwin High
Bow Island Arch (Axis)
Vulcan Low
Medicine Hat Block
Axis of Southern
Alberta Rift
49°
110°
Extent of
Sweet Grass Arch
Symbols
Origin Uncertain
2.0 - 1.8 Ga Magmatic Arcs
2.4 - 2.0 Magnetic Lows
2.4 - 2.0 Accreted Terranes
2.6 -2.8 Archean
Known Kimberlite Occurrence
Known Diamond Occurrence
Revisions R. Haimila 2006
ALBERTA
BASEMENT GEOLOGY
0
100
200
Scale
Kilometres
APEX Geoscience Ltd.
EDMONTON, ALBERTA
December, 1999
(Modified after Ross et al., 1991)

FIGURE 2.

to 40 km thick, a trait favourable for the formation and preservation of diamonds in the upper mantle (Dufresne *et al.,* 1996). In addition, studies by Lithoprobe have indicated that a deep mantle root, as illustrated by Figure 25 in Helmstaedt (1993), exists proximal to the area (Haimila, 1997).

Directly south of the Calling Lake permits, the basement is part of the Proterozoic Thorsby Magnetic Low (2.4 – 2.0 Ga), which merges into the Snowbird Tectonic Zone to the northeast (Figure 3). The Thorsby Low is a narrow northeasterly trending, curvilinear aeromagnetic low that is similar in character to the Chinchaga Low. It is collinear with a gravity gradient between the adjacent domains and contains numerous basement faults that extend into the overlying Paleozoic and Mesozoic succession (Edwards and Brown, 1994). The Snowbird Tectonic Zone (STZ) is a major northeast-trending crustal lineament that is a prominent lineament on both the aeromagnetic and the gravity maps of Canada (Geological Survey of Canada, 1990a, b). The STZ separates the Churchill Structural Province into two distinct basement domains, the Rae and Hearne Subprovinces, and extends to the northeast as far as Baker Lake, Nunavut (Ross *et al.*, 1991).

Phanerozoic

Overlying the basement in the Calling Lake region is a thick sequence of Phanerozoic rocks comprised mainly of Cretaceous sandstones and shales near surface and Mississippian to Devonian carbonates and salts at depth (Glass, 1990). Bedrock exposure within the permit blocks is limited primarily to river and stream cuts and topographic highs. Table 1 shows the upper units found in the region. Further information pertaining to the distribution and character of these and older units can be obtained from well log data in government databases and various geological and hydrogeological reports (Carrigy, 1971; Green *et al.*, 1970; Glass, 1990).

Underlying the near surface Cretaceous units in the Calling Lake area is a thick succession of Devonian to Mississippian carbonates, calcareous shales and salt horizons (Mossop and Shetson, 1994). Several of the Devonian carbonate units are part of the Grosmont Reef Complex, a large structure that extends in a northwesterly direction from the Calling Lake area to the N.W.T. (Bloy and Hadley, 1989). The Grosmont Reef Complex is likely the result of tectonic uplift during the Devonian along this trend (the Grosmont High on Figure 4). This structure in conjunction with the PRA could have played a significant role in the localisation of faults and other structures that could have provided favourable pathways for kimberlite volcanism.

In general, the Cretaceous strata underlying the Calling Lake permits is composed of alternating units of marine and nonmarine sandstones, shales, siltstones, mudstones and bentonites. The oldest documented units exposed in the permit area belong to the Smoky Group, a sequence of Upper Cretaceous calcareous and noncalcareous shales (Figure 4). However, older units from the base of the Fort St. John and/or the top of the Colorado groups may be exposed in river and stream cuts.

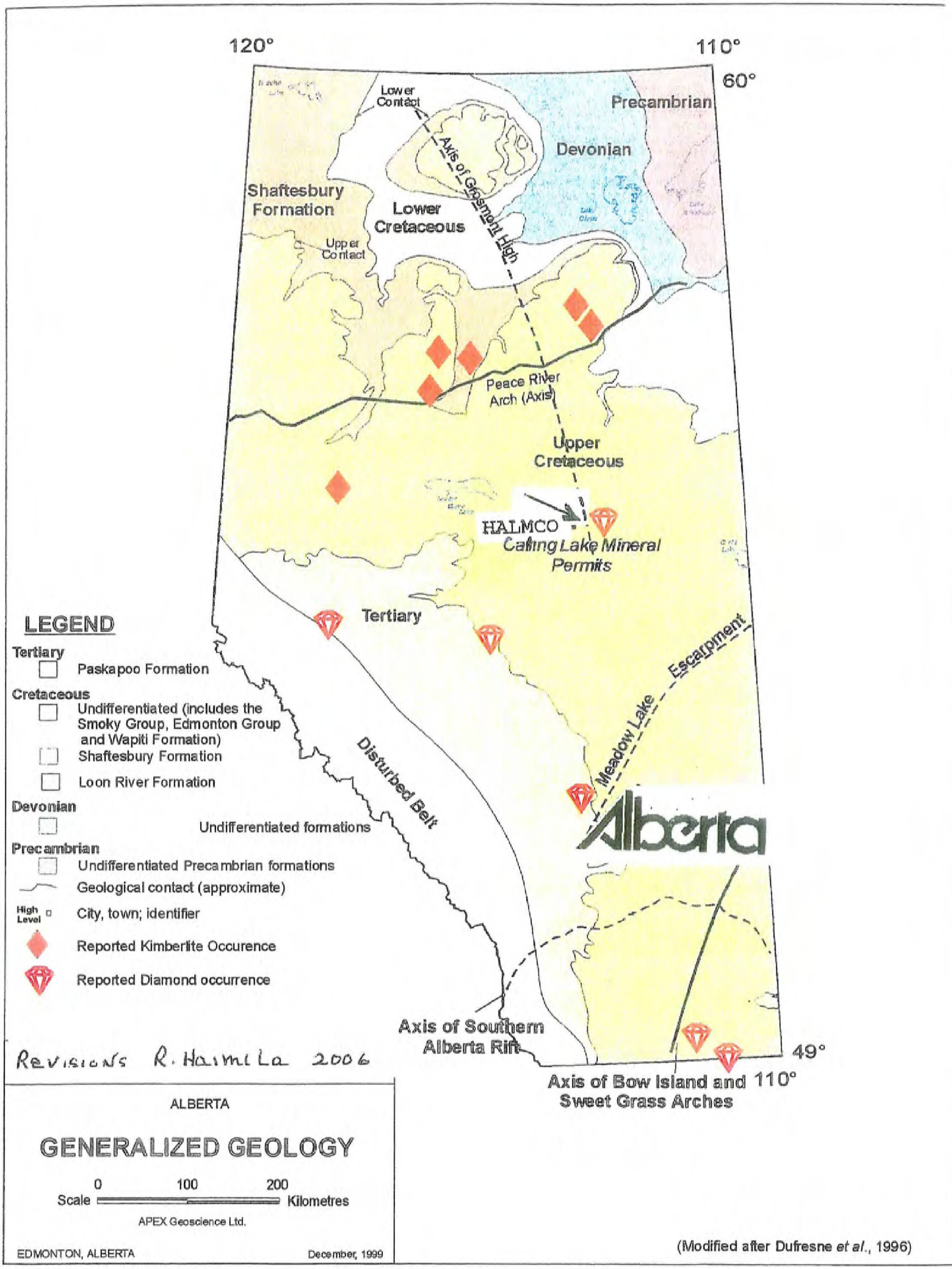
120°
110°
60°
Lower Contact
Precambrian
Axis of Grosmont High
Devonian
Shaftesbury Formation
Lower Cretaceous
Upper Contact
Peace River Arch (Axis)
Upper Cretaceous
HALMCO
Calling Lake Mineral Permits
Tertiary
Meadow Lake Escarpment
Disturbed Belt
Alberta
LEGEND
Tertiary
Paskapoo Formation
Cretaceous
Undifferentiated (includes the Smoky Group, Edmonton Group and Wapiti Formation)
Shaftesbury Formation
Loon River Formation
Devonian
Undifferentiated formations
Precambrian
Undifferentiated Precambrian formations
Geological contact (approximate)
High Level
City, town; identifier
Reported Kimberlite Occurence
Reported Diamond occurrence
Axis of Southern Alberta Rift
49°
Axis of Bow Island and Sweet Grass Arches
110°
Revisions R. Haimila 2006
ALBERTA
GENERALIZED GEOLOGY
0
100
200
Scale
Kilometres
APEX Geoscience Ltd.
EDMONTON, ALBERTA
December, 1999
(Modified after Dufresne et al., 1996)

FIGURE 3.

TABLE 2
GENERALIZED STRATIGRAPHY
CALLING LAKE PERMIT AREA

SYSTEM	GROUP	FORMATION	AGE* (MA)	DOMINANT LITHOLOGY
PLEISTOCENE			Recent	Glacial till and associated sediments
TERTIARY			6.5 to Recent	Preglacial sand and gravels
UPPER CRETACEOUS		Wapiti	70 to 80	Sandstone, minor coal seams and conglomerate lenses
	Smoky	Puskwaskau	75 to 86	Shale, silty-shale and ironstone, First White Specks
		Bad Heart	86 to 88	Sandstone
		Kaskapau	88 to 92	Shale, silty-shale and ironstone, Second White Specks
		Dunvegan	92 to 95	Sandstone and siltstone
	Fort St. John	Shaftesbury	95 to 98	Shale, bentonites, Fish-Scale Fm.
LOWER CRETACEOUS	Colorado	Pelican	98 to 100	Glauconitic sands, siltstone, mudstone and conglomerate
		Joli Fou	100 to 103	Shale, glauconitic sandstone and bentonite

*Ages approximated from Green *et al.* (1970), Glass (1990), Dufresne *et al.* (1996) and Leckie *et al.* (1997).

The Colorado Group is Lower Cretaceous in age and contains numerous formations, including the Joli Fou and the Pelican formations, which are correlative with the Peace River Formation of the Fort St. John Group further west (Dufresne *et al.*, 1996). The Joli Fou Formation is comprised of shale with interbedded, bioturbated to glauconitic sandstones and minor amounts of bentonite, pelecypod coquinas, nodular phosphorite and concretionary layers of calcite, siderite and pyrite (Glass, 1990). The Pelican Formation disconformably overlies the Joli Fou Formation and is gradational with the overlying Shaftesbury Formation (shales of the Colorado Group) and is correlative with the Cadotte and Paddy Sands of the Peace River area (Fort St. John Group). The Pelican Formation is comprised of glauconitic sands, interbedded siltstone and mudstone with minor amounts of conglomerate. Coalified plant fragments and bioturbated sandstones are locally abundant.

The La Biche Formation is a frequently incorrectly used term correlative to units of the Shaftesbury Formation and other formations within the Smoky and Colorado groups (Glass, 1990). In the Calling Lake permit area, the term Shaftesbury Formation (Fort St. John Group) is more commonly used. This unit is correlative with the shales overlying and underlying the Fish Scale unit in the Colorado Group. The Shaftesbury Formation is lower Upper Cretaceous in age and is comprised of marine shales with fish- scale bearing silts, thin bentonitic streaks and ironstones. The upper contact is conformable and transitional with the Dunvegan Formation, however, the Dunvegan Formation may be absent in the Calling Lake region. The Shaftesbury Formation may be exposed along deep river and stream cuts. Evidence of extensive volcanism during deposition of the Kaskapau and the Shaftesbury formations exists in the form of bentonites of variable thickness, distribution and composition. Numerous bentonitic horizons exist throughout the Shaftesbury Formation, especially within and near the Fish Scales horizon across much of Alberta (Leckie *et al.*, 1992; Bloch *et al.*, 1993). The time span of deposition of the Shaftesbury Formation is also chronologically correlative with the deposition of the Crowsnest Formation volcanics of southwest Alberta (Olson *et al.*, 1994; Dufresne *et al.*, 1995) and with kimberlitic volcanism near Fort à la Corne in Saskatchewan (Lehnert–Thiel *et al.*, 1992; Scott Smith *et al.*, 1994). In addition, there is documented igneous activity associated with the Steen River Anomaly, a possible impact structure, which formed in northwestern Alberta about this time (Carrigy, 1968; Dufresne *et al.*, 1995).

The Smoky Group is Upper Cretaceous in age and is comprised of thinly bedded, marine, silty shale with occasional ironstone and claystone nodules and thin bentonite streaks. The group is divided into three formations: (a) a lower shale unit, Kaskapau, which includes the Second White Specks marker unit; (b) a middle sandstone, named the Bad Heart; and, (c) an upper shale, Puskwaskau, which contains the First White Specks marker unit. The Smoky Group is conformably and transitionally overlain by the Wapiti Formation. Ammonite fossils and concretions are present in both the Puskwaskau and the Kaskapau formations. In addition, foraminifera are present in the lower arenaceous units (Glass, 1990). The upper formations of the Smoky Group are correlative with the Lea Park Formation. The lower portions of the Smoky Group are correlative with the middle to upper units of the Colorado Group, including the First and Second White Speckled Shale marker units (Glass, 1990). Bedrock exposures in the Calling Lake permits are likely comprised of the Kaskapau Formation, in particular, the Second White Specks unit or lower, since most of the upper portions of the Smoky Group have been eroded away by glacial and/or post-depositional processes. However, areas, where the Smoky Group is overlain by the Wapiti Formation, may still have most of the Bad Heart and/or Puskwaskau formations still intact with minimal erosion. In general, exposures of the Smoky Group are limited to river and stream cuts, topographic highs, and regions with thin drift veneer. There is strong evidence of volcanism associated within the depositional time span of the Smoky Group in the vicinity of the PRA (Auston, 1998; Carlson *et al.*, 1998). Ashton's recently discovered Buffalo Head Hills kimberlites intrude Kaskapau shale and yield emplacement ages of 86 to 88 Ma (Auston, 1998; Carlson *et al.*, 1998).

The youngest bedrock unit in the Calling Lake area is the Wapiti Formation of Upper Cretaceous age, comprised of non-marine, thinly bedded to massive sandstone with minor coal seams and thin conglomerate lenses. The upper surface of the Wapiti Formation is generally erosional. Thickness of the unit may exceed 100 m (Glass, 1990). The Wapiti Formation is exposed in the northwestern portions of the Calling Lake permits west of Calling Lake. In addition, smaller outliers or remnants of the Wapiti Formation are known to be present south and east of the permits (Green *et al.*, 1970). The Mountain Lake Kimberlite near Grande Prairie intrudes the Wapiti Formation sediments and yields an emplacement age of 75 Ma (Leckie *et al.*, 1997).

Quaternary

Data and information about the surficial geology in central to northern Alberta is sparse and regional in nature. Prior to continental glaciation during the Pleistocene, most of Alberta, including the Calling Lake region, had reached a mature stage of erosion. Large, broad paleochannels and their tributaries drained much of the region, flowing in an east to northeasterly direction (Dufresne *et al.*, 1996). In addition, Late Tertiary to Quaternary fluvial sand and gravel was deposited preglacially over much of the region.

During the Pleistocene, multiple southwesterly and southerly glacial advances of the Laurentide Ice Sheet across the region resulted in the deposition of ground moraine and associated sediments (Figure 5 in Dufresne *et al.*, 1996). In addition, the advance of glacial ice resulted in the erosion and glaciotectonism of the underlying bedrock. Ice thrusted bedrock has been documented just south of the Athabasca River (Klassen, 1989) and smaller occurrences of glaciotectonism within the Calling Lake permits are possible. Remnants of preglacial sands and gravel have been documented on topographic highs, including the Pelican Mountains just northwest of the Calling Lake permits (Dufresne *et al.*, 1996). Glacial sediments infilled low-lying and depressional areas, draped topographic highs and covered much of the Calling Lake area as veneers and/or blankets of till and diamict. Localised pockets of deposits from glacial meltwater and proglacial lakes infill the numerous spillway channels present near the area.

Glacial ice is believed to have receded from the area about 15,000 years ago. After the final glacial retreat, lacustrine clays and silts were deposited in low-lying regions along with organic sediments. Rivers previously re-routed due to glaciation, re-established easterly to northeasterly drainage regimes similar to that of the pre-Pleistocene. Extensive colluvial and alluvial sediments accompanied post-glacial river and stream incision.

The majority of area within the Calling Lake permits is underlain by drift of variable thickness, ranging from less than 2 m to likely over 45 m (Pawlowicz and Fenton, 1995a,b). Drift thickness decreases considerably outside of infilled depressions and meltwater channels and in areas of high topographic relief, in particular near the Pelican Mountains. However, local drift thicknesses can not be confirmed without detailed compilation of available drill hole data. Information regarding bedrock topography and drift thickness in northwest Alberta is available from the logs of holes drilled for petroleum, coal or groundwater exploration and from regional government compilations (Pawlowicz and Fenton, 1995a,b; Dufresne *et al.*, 1996).

Structural Geology

In north-central Alberta, the PRA is a region where the younger Phanerozoic rocks which overlie the Precambrian basement, have undergone periodic vertical and, possibly, compressive deformation from the Proterozoic into Tertiary time (Cant, 1988; O'Connell *et al.*, 1990; Dufresne *et al.*, 1995, 1996). This pattern of long-lived, periodic uplift and subsidence has imposed a structural control on the deposition patterns of the Phanerozoic strata in northern Alberta. In addition, this periodic movement has resulted in a rectilinear pattern of faults that not only is responsible for structurally controlled oil and gas pools, but may have provided potential pathways for later deep-seated intrusive kimberlitic magmas.

During the mid-Cretaceous and Early Tertiary, compressive deformation occurred as a result of the orogenic event that eventually led to the formation of the Rocky Mountains. The PRA was emergent during this period resulting in the reactivation of many prominent basement faults. The Phanerozoic rocks beneath the Calling Lake permits lie within the southeastern edge of the PRA and are underlain by and proximal to basement faults related to the STZ and the underlying Grosmont Reef Complex, which was formed over the Grosmont High (Bloy and Hadley, 1990; Dufresne *et al.*, 1996). Basement faults may have controlled the emplacement of the Mountain Lake Kimberlite and the Buffalo Head Hills kimberlites northwest of the Calling Lake permits (Dufresne *et al.*, 1996; Leckie *et al.*, 1997). Therefore, structures in the Calling Lake area resulting from tectonic activity associated with movement along the PRA, the Grosmont High, the STZ or even along contacts between different basement terranes could be pathways for kimberlitic volcanism.

Previous Exploration Excerpts are from Calling Lake assessment report 2002004 (June 27/02)

To date over $2,500,000 has been expended on exploration on the Calling Lake Property and immediate area. Several phases of surface and auger assisted indicator mineral sampling programs, airborne geophysical surveys and compilation of seismic and regional geological information led to the identification of numerous drill targets characteristic of kimberlite pipes. Details of previous work are well summarized by Dufresne and Copeland (1999).

The following page is from BHP Billiton's macroscopic drill core study (p2) of Buffalo Diamonds/New Claymore Resources 1999/2000 assessment report 2002004. Those comments of interest to Halmco's exploration program have been underlined

(type 5 failure)

bhpbilliton

BHP BILLITON DIAMONDS INC.

On 28 March , 2002 seventy-four (74) boxes of drill core were macroscopically examined for diamond potential at the BHP Billiton Diamonds Inc. Core Facility in Kelowna, BC, Canada.

Background

No information about the drill core was provided. This was not a concern because the goal of this study was to determine if any of any material recovered was of economic significance for diamonds or indicated the presence of a primary source for diamond bearing material (i.e. non-alluvial). The core was examined for similarities to the following primary diamond sources relevant to diamond exploration: kimberlite, group 2 kimberlite, lamproite, and melilitite. A macroscopic review of the core was possible for this study because the facility contains a relatively extensive world-wide library of samples mostly from primary diamond deposits for comparative studies of this nature.

The Buffalo Diamonds Ltd. web-site was reviewed before the study to provide a summary of public information on the project related to the drilling.

Drill Core

The following inventory was examined and consisted of 74, 4-run, five foot wooden core trays with plastic depth markers for depth and loss of core recovery. The box lids were fastened with nails and not sealed or made tamper-proof. Chain of custody and sample integrity can not be determined from this type of collection system. The trays are numbered in a series CLK-001 to CLK-010 with individual boxes marked with box number and from – to depths. Without accounting for empty rows, approximately 1 400 feet of core was studied. Except where the end of hole was encountered, the core trays were full and appear fully packed with complete drill cores. The core is mostly 7 cm diameter with some 4.5 cm intervals likely drilled due to hole squeezing. Most of the cores are dry and competent material, with minor intervals of sand sized material completely unconsolidated. Overall the core is in good condition and has been well handled.

Stratigraphy

It was decided after a detailed examination of every core interval not to undertake a detailed description and accompanying diamond drill log of the these cores for the following reasons:

1. Lack of background data on the drilling program.
2. Regional geology details have not been provided. This does not allow the a meaningful interpretation of the stratigraphy.
3. Target data on the anomalies are not available.
4. No primary diamond host rock types were macroscopically identified.

Interpretation and Recommendations

Given the world-wide variety of emplacement models, age relationships to host strata and genetic origins of primary diamondiferous source rocks, the core was reviewed to examine the potential of any known model as a source of the diamond geochemistry results in sampling to date. The most common exploration model used is a diamondiferous kimberlite pipe that has intruded to within the depths drilled by these holes.

If all of the holes are drilled vertically into discrete geophysical targets, them there is a possibility the relatively shallow holes were terminated too early if the deposit model is a pipe now completely capped by younger cover strata as seen at other localities (i.e. Saskatchewan). However, with increasing cover thickness, the probability of an economic deposit rapidly decreases and the generation of significant indicator grains at the present surface becomes more difficult to explain.

If the targets drilled are resolvable into anomalies within the depths drilled, no further work is recommended until improved target generation techniques are employed. (type 5 failuRE)

RAH

CONCLUSION

Early in 2006 the Halmco data base was reviewed by P. Brown (geologist) and S. Mlot (engineer) and input given to Halmco,s exploration team.

Four site visits have been made by P. Brown and three site visits by Steve Mlot. The first two visits were made to collect and verify indicator mineral geochemistry and spot several drillholes on mineral permit 9304110426 in the Calling River east area.

The third visit in November 2006 was to review data specific to mineral permit 9306060989 (Area 2-west drainage into Calling Lake) and a site visit to a high priority seismic/resistive anomaly nine(drill-site # 9). It was decided at this meeting to drill anomaly nine and to also plan a geophysical survey on mineral permit # 9305070817 (Area 3-south drainage into Calling Lake). Area # 3 is the location-anomalous kimberlitic indicators coincidental with resistive/magnetic anomalies.

The fourth visit by P. Brown in December 2006 was to be the onsite drill geologist (anomaly # 9). On December 15, 2006; P. Brown, R. Haimila, Dr. T. Yoshida and L. Halonen did a site inspection of the area picked for the proposed geophysical survey on Mineral permit #9305070817.

In May of 2007, R. Haimila began discussions with Paul Bauman of WorlyParsons Komex (Calgary) specific to running an electric resistivity tomography (ERT) on mineral permit 9305070817. Komex was given a $7500.oo retainer in June. R. Haimila was Halmco's onsite,project coordinator and the geophysical survey was completed on June 29, 2007.

The WorlyParsons Komex Geophysical results from the ERT geophysical survey (4 vertical structures identified) and their recommendation of "intrusive investigations in the form of drilling" is a recommendation agreed to by all of Halmco's Consultants.

Submitted by P.A.R.Brown P. Geo and R.Haimila Consultant to Halmco

[redacted]

GEOLOGIST'S CERTIFICATE:

I, Philip A. R. Brown P.Geo do certify that:

1. **I am a consulting geologist residing at 189, Astorville Road, Corbeil, Ontario, P0H1K0.**
2. **I am a graduate in Mining Geology from The Royal School of Mines, Imperial College, London University, England.**
3. **I am a practicing P.Geo registered in Ontario with APGO.**
4. **I have had many year's experience in diamond exploration for many companies in Canada, Sierra Leone and Brasil.**
5. **This report is for assessment purposes only and does not conform to National Instrument Policy 43-101.**
6. **I consent to the use of this report by Halmco Inc. for use of this report for assessment purposes only.**

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PROFESSIONAL GEOSCIENTIST
PHILIP A. R. BROWN
PRACTISING MEMBER
0200
ONTARIO

Background in Earth Sciences

1963-64: Integrated Velocity Services (Oil and Gas well-log interpretation).

1977 to present: Prospecting for Industrial and Metallic Minerals in Western Canada. This is a continuing project based on: Remote Sensing (Geotechnical Interpretations of Satellite Imagery) developed by Dr. N. Hamila. (Geologist – Geological Engineer): Reviewing and interpreting Seismic/Magnetic/Gravity data bases of Western Canada.

1991-92: Gained Intervenor Status between the Alberta Governments Natural Resources Conservation Board and Three Sisters Golf Resort. Presentation was an oral/visual presentation showing the Geotechnical Hazards associated with abandoned underground mining operations.

1993: Thesis Paper: (The Environmental Geology of the Canmore Mine Site) for Geology 1159, Mt. Royal College, Calgary.

1993: The Natural Resources-Conservation Board recommended the town of Canmore (3 Sisters Decision Report) utilize my geotechnical expertise. Appointed as a committee member of the town of Canmore Geotechnical Advisory Group. The mandate was to develop a set of undermining guidelines that would allow for safe development on undermined lands. The Province of Alberta adopted these guidelines in 1997.

1994-98: Co-owner operator of 656405 Alberta Ltd. (Alberta Diamond Exploration Company). Discovered the highly anomalous diamond indicator sites in Calling Lake Area in 1993-94 with partner Dr. Yoshida.

1996-98: Authored Alberta Mineral Assessment Reports for Dr. T. Yoshida, 656405 AB. Ltd. And co-authored assessment report for Buffalo Diamonds.
1998-2002: Co-founder and Director of Buffalo Diamonds (Public Diamond Exploration Company).

2003: Thesis Paper (Rheology and the Genesis of Diamonds) Theory demonstrates that the mechanics of rock and the rheological response of rock initiates a primary force that allows for a single species/element (carbon) to be converted to and/or deposited as the allotropic form of pure carbon-diamond.

2004 to present: Retained by Halmco Inc. to help design and implement a diamond exploration program for Halmco's Calling Lake project.

As co-author of this report, I consent to the use of this report by Halmco Inc. for assessment purposes only.

[redacted]

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REPRINTED FROM KIMBERLITES of YAKUTIA FIELD GUIDE BOOK

NOVOSIBIRSK 1995

UNDER LININGS + NOTATIONS HAIMILA 2004

SEARCH FOR DIAMOND DEPOSITS

to be applied to Halmco CALLING LAKE AREA

STAGES OF GEOLOGICAL PROSPECTING PROCESS AND RELIABILITY OF PROSPECTING SYSTEMS IN SEARCH FOR DIAMONDS

In searching for Middle Paleozoic kimberlites, the territory of Yakutia is divided into the following landscape/geological areas:

– wide distribution of Post-Middle Paleozoic formations of thickness 200 to 300 m (exploration is not expedient on economic grounds);

– wide distribution of Post-Middle Paleozoic formations of different lithologies and thickness from 10 to 300 m (extremely complicated conditions for exploration);

– a wide distribution of Post-Middle Paleozoic formations of a few meters, wide development of ancient and present-day crusts of weathering, and flat, smooth relief (complicated conditions for exploration); and

– a thin autochthonous cover of Quaternary sediments with weak development of weathering crusts and moderately smooth relief (favorable conditions for exploration).

Search for kimberlite bodies in Yakutia is divided into two stages that are distinguished by a changing geological and economic objective of diamond prospecting.

At first stage, the geological and economic objective was prospecting over a vast area with the aim of developing an economically viable mining complex or complexes for a long production period. At this stage, limited resources dictated the type of exploration model and what targets and what processes should be specified.

The objectives of prospecting at first stage were to findthat the kimberlite bodies be sufficiently large in size, have distinct indicating parameters, and occur in relatively favourable landscape and geological conditions for prospecting. Such targets were discovered by heavy mineral sampling and magnetic surveys and by conducting the prospecting work uniformly over vast areas (i.e. using a reduced or "prospector scheme" in the search process).

Searching for kimberlites by heavy mineral sampling within areas of favourable and complicated landscape-geological conditions proved to be highly effective in diamond prospecting. This method found virtually all the kimberlite bodies in the investigated areas.

Kimberlite bodies occurring in conditions less favourable for heavy mineral sampling were discovered firstly by airborne magnetics and later at investigations on the ground. In that case, it was observed that commercially valuable sites were often characterized by fairly weak magnetization in comparison to highly magnetic non-diamondiferous pipes situated nearby.

In the "prospector scheme" processes good results were obtained during experimental investigations using aerogamma spectrometry in combination with aeromagnetics.

Finally, in search for non-magnetic kimberlites in fairly complicated conditions for diamond prospecting, EM and geochemical methods were used to detect secondary dispersion haloes.

The "prospector scheme" of searching for diamonds recently gained recognition in Tsyganov's "theory of reliability of geological prospecting systems". From analysis of data for known kimberlite fields which exhibit the above-mentioned exponential distributions of indicating properties, and taking into account the typomorphism of pipes in different fields, the exploration models for predicting lower limits for economic pipes for particular mining and geological conditions are being developed.

The accuracy requirements of prospecting grids and the desired representativeness of sampling in the "prospecting scheme" are defined for of each prospective area separately, depending on the model of target and the landscape-geological conditions. It allowed to re-estimate the prospecting results for previously investigated areas and distinguish additional possibilities of primary diamond occurrences for them.

A combination of criteria for evaluation of any diamond mineralization found in each particular are is used in all stages of prospecting.

The great effectiveness of the "prospector scheme" led to attempts to apply it in complicated landscape-geological conditions. A substantial amount of drilling, seismic prospecting and EM prospecting with large depth penetration, was added to combination of diamond prospecting methods. Although some favourable results were obtained, a large portion of the investigated areas turned out to be practically untested, so that even some economic pipes were not found.

The above-mentioned difficulties and limited effectiveness of the "prospector scheme" under complicated conditions, despite a considerable increase in cost, showed a necessity to change the technology in search for diamonds under complicated conditions.

The second stage of prospecting involves working in a region containing an operating mine. It required firstly a different exploration model than that used in the "prospector scheme". Study showed that targets near operating mines are kimberlite bodies of small size, of low- contrast indicating parameters, or they occur in landscape-geological conditions unfavourable for prospecting. There, a discovering of such targets is virtually impossible or requires an extremely considerable increase in the cost.

Based on the available scientific data on regional and local controls of diamond deposit locations in the Siberian platform and world, the following hierarchical sequence of intermediate targets was developed by Tsyganov: subprovince of diamondiferous magmatism investigation – "mineragenic zone" – kimberlite field – cluster of kimberlite pipes – locally narrow kimberlite prospective site - kimberlite body – diamond deposit. Each on these items has its own corresponding field work and its own set parameters for modelling and data processing.

Schematically, the prospecting stages are combined into four groups:

– early stages with the target being a territory prospective for a kimberlite field;

– later stages with the target being a locally narrow kimberlite prospective site;

– a stage of verification work with the target being a kimberlite body; and

– evaluation stages with the final target being an economic diamond deposit developed for operation.

The prospecting-searching models for the targets of each stage are the most valuable developments of geologists and researchers of "Almazy-Rossii Sakha" Company which have already led the Company to the new positive geological results in Russia and now are being appcated in abroad.

To solve the problems of diamond deposit searching confidently "the theory of geological prospecting systems-reliability" or "the theory of geological prospecting mistakes" has been introduced into the geological prospecting practice of Almazy [Tsyganov, 1986, 1994].

This "theory of geological prospecting systems-reliability" is based on the study of failure of the systems or their elements. Here, a failure means any possible or real omission of only one deposit of minimum commercial grade.

During the investigations of geological prospecting systems reliability, two definitions of "target" are used, common and special. Common means any element of the above-mentioned hierarchical sequence. Depending on the stage of diamond prospecting, one element of the sequence is chosen as a "common target". While investigating reliability of the systems, tectonic, geophysical and mineralogical indicating parameters become "special targets" for study by one or other method.

As a result, every geological prospecting system is divided into simple components, for example "the target of prospecting - the exploration method". The reliability investigations are worked out separately for every target-method pair and finally, the results are united using common quantitative indices of geological-prospecting system reliability.

Further, for every target-method pair the possible failures of method are classified and five types of failures are as follows:

– failures of targets to be indicated in the expected manner (bound up with variability of indicator properties of prospecting targets);

– failures attributed to landscape geological surroundings (bound up with the masking effect of components on the environment surrounding a target);

– failures of technical type (bound up with equipment error and/or insufficient density and/or accuracy of observation);

– failures of geological interpretation (bound up with mistakes made during geological interpretation and forecasting); and

– failures of evaluation and verification (bound up with mistakes made during assessment of prospecting results).

The next stage of reliability investigations was classification of failures according to their frequency and their influence on effective prospecting. Then, for the more essential of them, specific quantitative and qualitative indices were assigned. On that basis, a conventional special legend for mapping according to changes of factors which determine the prospecting reliability was worked out. Maps were made which serve as a basis for evaluation of

MAPS A+B FOR Halmco INC.

prospecting reliability and for protecting a higher quality scheme of prospecting.

The main results of using the theory of geological prospecting systems reliability in diamond prospecting investigations in the Yakutian diamondiferous province are as follows:

In mining areas [Tsyganov et al., 1991, 1993], there are known minimal commercial parameters of targets (kimberlite bodies). However, indicated features of pipes for each kimberlite field were determined and methodical techniques for increasing reliability were recommended.

By investigation of failures attributed to geological surrounding and failures of technical type, special maps defining reliability methods were made. The ways of reserving under these circumstances were then worked out. Early investigations of geological interpretation and evaluation reliability [Tsyganov, 1985] in the time then available, led to recommended choices of local kimberlite prospective areas in difficult landscape-geological situations and the use of the radio shading method. As a result the Amakinskaya expedition discovered six new kimberlites in difficult landscape-geological setting of the Alakit-Marshinskoe kimberlite field.

The most important result that an appreciation of prospecting reliability has in mining regions is expansion of the resource base.

Early study of diamond prospecting-reliability by the Almazy geological enterprises achieved quantitative results for use in shortening prospecting schemes and in defining areas where it would be effective. Also, in difficult landscape geological settings where prospecting was least effective, ways of transformation to staged technological prospecting were worked out. Nowadays the staging technology of investigations is being introduced widely. As the theory of prospecting systems reliability is used more widely in prospecting investigations, its principles have been adapted to geological mapping and to exploration for diamond deposits and other minerals.

TECHNIQUES OF GEOLOGICAL PROSPECTING WORKS

Continuous study of the Yakutian diamondiferous province implies several stages, each of them is aimed to solve the geological searching problems of different scale. They are as follows: regional geological investigations, geological mapping, and search for kimberlite occurrences.

Regional OF geological investigations of 1 : 1 000 000 to 1 : 500 000 scale include the deciphering of satellite images, deep seismic sounding (DSS) and deep magnetotelluric sounding along individual profiles supplemented by analysis of areal small-scale gravity, magnetic and geological prospecting has been carried out up to that time. These works provide information on the structure, depth of bedding, relief of earth crust and upper mantle, crystalline basement, and kimberlite-host Lower Paleozoic rocks. Finally, a conclusion either this territory is prospect for kimberlite magmatism, or not is made.

So called "covered" areas, within which diamond deposits are overlain by Upper Paleozoic - Mesozoic rocks, require the refinement of created before small-scale geological maps. This type of works, carried out in separate areas while regional investigating, is called "deep geological mapping". It is fulfilled in 1: 200 000 scale and includes remote investigations, analysis of gravimetry-magnetic maps of 1: 00,000 scale, field geology-geomorphological and geochemical works, profiles of searching drillholes at a 8 to 8 km up to 4 to 2 km grid, and drillholes for structural investigations (1 drillhole per 5000 km^2).

These works provide a creation of specialized paleogeological maps and, finally, a review diamond forecasting map in which the areas promising for kimberlite occurrences are shown.

Geological mapping of 1 : 50 000 scale for general search predictions is aimed to compile a common geological map, to study the structure of kimberlite-host Paleozoic basement, to study and map intermediate collectors of diamonds and indicator minerals, to map tectonic faults, folds, and magmatic rocks, and finally to indicate the areas promising in respect to kimberlite bodies and their associations (clusters).

Geological mapping process applies a number of geology-geophysical methods (deciphering of satellite images and aeropictures, airborne magnetics of 1:25 000 scale – at the preliminary stage), and furthermore, geology-geomorphlogical and search routes for sampling of collectors on indicator minerals and geochemical sampling. Field works are aimed to outline, analyze and re-check geophysical, geochemical and geological anomalies.

Within "covered" areas the geological mapping using natural outcrops and open-pit mines is added with deep geological mapping plus, if necessary, 1: 50 000 gravimetry mapping and special electrical investigations (along lines or areal) that are principally carried out to solve structural mapping problems.

To discover exposed kimberlite bodies it is enough to perform heavy mineral sampling and small-volume sampling of alluvium. Discovery of buried kimberlite bodies requires the study of ancient diamond collectors with the help of mining (running

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of prospecting pits and explorating trenches) and drilling. Traditionally, at general geological mapping, initially one hole per 10-20 km^2 is drilled. Furthermore, at individual promising areas the grid of search drilling is determined by a specific geological environment (lithology-facial features of the basal horizon of collectors, features of ancient relief, and so on). The areas promising for discovery of buried kimberlites are used to be drilled at a 4 to 2, 2 to 2, and 2 to 1 grid. The lines of pits and trenches are put around the contour of exposure of productive collector horizons in order to evaluate their diamond content.

In each case mine-drill works are accompanied by detailed study and sampling of sections. Geological and geophysical data are processed and interpreted. Geological, geomorphological and mineral resources maps together with a set of special maps (paleogeographical, paleogeomorphological, paleotectonic, lithology-facial and geochemical maps) are eventually created to serve as a base for a forecast map. Forecast map must represent a prospect evaluation of the studied territory where plots for further searching must be outlined.

Searching process itself is conducted at prospect plots that were outlined during the previous works. The main purpose of searching is the discovery of diamond deposits.

Geological and mining conditions of searching in the territory of the Yakutian diamondiferous province are very complicated and diverse. This causes a wide differentiation in application of special search methods and techniques which are able to provide positive results in any definite search situation. Nevertheless, two main types of landscape-geological environments can be recognized conventionally: 1) "open" territories where kimberlites are exposed or overlain by a thin (up to 5 m) eluvial-deluvial layer, and 2) "covered" territories within which kimberlite bodies are overlain by younger, than host rocks, magmatic and sedimentary rock sequences of different thickness.

At the stage of searching not only the set of methods, but also the succession of carried out geology-geophysical investigations are of high importance.

For "open" areas the set includes airborne magnetic investigations of 1: 10 000 scale, geology-geomorphological field routes for sampling plus somewhere surface magnetic and electric prospecting of 1:5000 scale. These works are performed at the initial stage of searching. At the second (final) stage the revealed mineralogical, geophysical, and geochemical anomalies are attested by drills and pits, and the plots of buried and modern alluvial sediments and basal horizons, where high concentration of indicator minerals was established, are sampled on diamonds.

Traditionally, during the sampling is done by core-drilling of 112 mm to 90 mm diameter. Permafrost occurrence gives an opportunity to use a compressed air to cool a drill bit and remove slime. Search pits have a mean section of 1.25 m^2. While sampling alluvium with a help of special light manual unit equipped with grading sieves of 8 mm to 1 mm cell dimension, the samples of 1 m^3 to 3 m^3 volume are washed out. Standard sample that is washed out using a Siberian trough is of 20 liters volume.

At the early stages of exploitation of "covered" areas the drilling was accompanied by seismic investigations. Now, they try to make the search process as cheap as possible, therefore, seismics is used only to resolve structural questions at the stage of general searching.

Search drilling at the prospect plots of "covered" areas is preceded by preliminary laboratory studies that are aimed to reconstruct the tectonic environment existed in the territory during the epoch of kimberlite magmatism. Such investigations apply the results of general searching and geological mapping. Besides, the whole available additional information is analyzed to suppress the negative effect of overlapping assemblages on the search process.

Mineralogical sampling search method plays a major role while searching for kimberlites in almost all the environments. This method has been developed during the period of exploitation of the Yakutian diamondiferous province to provide the prediction and evaluation of kimberlite diamond content and the solution of paleogeological problems concerning the development of indicator mineral haloes.

GEOPHYSICAL SUPPLEMENT FOR DIAMOND EXPLORATION

Geophysical methods are applied at all the stages of diamond searching to solve two main problems:

– preparation of areas to carry out the detail geological-geophysical searching works;

– searching for kimberlites as local geophysical targets.

The first problem is aimed to distinguish most promising areas within vast territories. The investigations are carried out using a complex of geophysical methods with final compilation of 1: 100 000, 1: 500 000, and 1: 200 000 scale maps and schemes to conclude on the probability for occurrence of unknown kimberlite field within any part of the territory under study.

Geophysical methods at the stage of regional searching are as follows:

- deep seismic and magneto-telluric sounding;
- profile seismic investigations;
- airborne magnetic and ground gravimetric studies.

Deep seismic and magneto-telluric sounding studies the structural features of the earth's crust and upper mantle. Previous works revealed that the territories where kimberlitic magmatism is manifested are characterized by abnormal deep section parameters – sharp increase of seismic velocities along the Moho interface up to 8.6–8.9 km/sec, strong complexity of surface structure of the upper mantle and intracrustal boundaries, growth of electric resistance in individual Earth crust layers. These and some other parameters compose a base for the interpretation of regional geophysical data while outlining the areas where unknown kimberlite fields could be found.

Areal deep seismic and magneto-telluric sounding implies the 10×10 km mean distribution of observation points using digital registration apparatus. Seismic stations function autonomously, without personnel. To stimulate seismic waves the chemical explosive substances are employed.

Profile seismic investigation is a main method to study the structure and tectonics of the territory while marking the areas promising for kimberlite occurrences.

The method of reflected waves as common deep point which main procedures were taken from the oil-searching practice has gained widest acceptance.

Seismic Diffraction

Seismic section within the Siberian diamondiferous province incorporates the horizons with lithologic parameters that are stable along the strike on hundred and thousand kilometers. The horizons are separated by contrasting seismic boundaries where the reflection and refraction of elastic waves takes place. Recognition of such boundaries using seismic method allows to fulfill the very detailed study of the territory's structural outline.

Tectonic disjunctives represent the very important structural elements for they control the emplacement of kimberlite bodies. To date, a group of methods to reveal and trace the faults in wave fields that is based on the usage of dynamic and kinematic wave field parameters has been developed. To carry out seismic investigations the digital station with elastic waves stimulated by power-driven vibrational installation is employed. Moreover, such installation answers the ecological demands.

Primarily, the airborne magnetic and ground gravimetric methods provide the study of tectonics and structure of the territory to describe the families of faults that control the localization of the groups of kimberlite bodies.

As magnetic field elements, the faults are shown as extended linear anomalies which correspond to either basaltic dikes of different age intruding through tectonically weakened zones, or tectonic contacts that separate the metamorphic units of crystalline basement.

As gravitational elements, the faults relate to linear negative anomalies which correspond to the tectonic zones of leaky rocks.

The observation scales for the methods studying potential field are 1: 50 000 and 1: 25 000 when routes and profiles are laid across the strike of tectonic elements.

The second task of geophysical works is the search for kimberlite bodies as local geophysical targets. The complex of geophysical searching methods involves airborne and ground magnetic prospecting, electric prospecting using direct and alternating current, seismic prospecting and the method of interhole radiowave exposure.

To increase the searching reliability one or several methods are applied depending on the geological structure features of definite area.

Within the Siberian diamondiferous province there are two main types of geological structures on which the choice of applied geophysical methods depends.

The first type includes the areas where search targets are outcropped at the present surface level or buried beneath the thin alluvial sequences. In these conditions the search for kimberlite pipes is restricted by the application of airborne and ground magnetic prospecting of 1: 10 000 and 1: 5 000 scale and electric (direct current) prospecting of 1: 5 000 scale areal observations.

In magnetic field kimberlite bodies are seen as the isometric positive anomalies with the "off-contour" minimums typical of vertical heterogeneities. Magnetization of targets is of inductive type. Remnant magnetization of kimberlitic melt is commonly insignificant. Since kimberlites are hosted by carbonate rocks it is possible to reveal both high and weak magnetized targets by the usage of high-sensitive quantum and proton magneto-meters with 0.1 nT resolving ability.

Long-standing experience showed that some kimberlite bodies are not present as magnetic field anomalies due to epigenetic kimberlite alterations which disintegrated ore magnetic minerals. That is why the electric prospecting aimed to reveal local anomalies with increased conductivity has gained wide implementation. In these conditions the seismic and radiowave exposure methods are most informative.

wide implementation. In these conditions the seismic and radiowave exposure methods are most informative.

Seismic method implies the tracing of elastic waves reflected from not-deep seismic boundaries throughout the section of kimberlitic rocks. If seismic waves meet kimberlite body, the secondary waves will be generated at the boundaries of kimberlite pipe and inside it. As a result at the seismic section the local target is represented by wave diffraction. Despite high costs for areal seismic investigation the economical efficiency is achieved due to the less volumes of areal drilling.

Recently, the main technical problems of interhole radiowave exposure method have been solved and the method was introduced into everyday practice. The method is based on the mechanisms for the propagation of electromagnetic radio-frequency range waves in geological conditions. Aerial-feeder equipment emplaced into the boreholes is used as radiation and registration units.

MINERALOGICAL CRITERIA FOR KIMBERLITE DIAMONDGRAGE

The foundations of mineralogical criteria for kimberlite diamondiferousness were laid in the beginning of 70-ties in the work of N.V. Sobolev [1971] "On the mineralogical criteria for kimberlite diamondiferousness". He was the first to suggest that the minerals of mantle diamondiferous parageneses can be captured by kimberlite melts and transported to the earth's surface, and that the portion of these minerals in kimberlites must positively correlate with the portion of diamonds.

The detailed study of compositional features of crystal inclusions in diamonds, such as garnet, Cr-spinel, pyroxene, olivine, etc., allowed to recognize the types of upper mantle diamondiferous rocks and typomorphic compositional features of minerals associated with diamonds in nature.

The Siberian platform diamonds were shown to form in a rather wide compositional range of natural systems – from Cr-pyrope dunites extremely depleted in basaltic components to coesite-kyanite eclogites and grospydites essentially enriched in Si, Ca, and Al [Sobolev, 1974; Ponomarenko et al., 1976; 1977; Pokhilenko et al., 1977, 1980, 1982, 1993; Sobolev et al., 1984].

Among the various xenoliths of mantle diamondiferous rocks from the Yakutian diamondiferous province kimberlites there were found the exotic xenoliths of garnet pyroxenites [Ponomarenko et al., 1980], and ilmenite-pyrope lherzolites [Pokhilenko et al., 1976; Ponomarenko, 1977]. Mass-study of crystal inclusions (thousands inclusions) in diamonds from Yakutian kimberlites showed that over 95% of Yakutian diamonds relate to ultramafic assemblages, harzburgite-dunites paragenesis dominating (about 80%) [Sobolev, 1974; Efimova & Sobolev, 1977]. On the basis of available knowledge, while developing the mineralogical methods of the search for diamondiferous kimberlites, the main attention was paid to the study of specific compositional features of diamondiferous harzburgite-dunite minerals. It should be noted that for the search and forecast of diamondiferous kimberlites we use another compositional ranges for Cr-bearing subcalcium pyropes and Cr-spinels than South African geologists (Fig. 3.1).

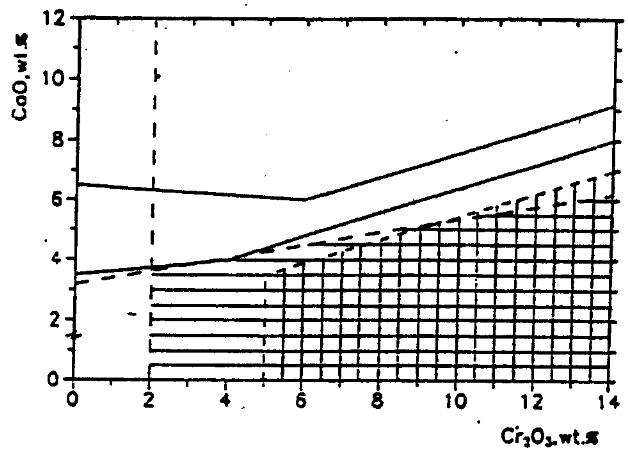

Fig.3.1. Estimation of a diamond content in kimberlites: western system – composition of garnets from G10 group (horyzontal shading); Russian system – composition of garnets from a diamond-bearing association (vertical shading)

According to our method the compositional field of subcalcium Cr-pyropes, that is used to determine the degree of potential kimberlite diamondiferousness, is restricted by $CaO = 1.6 + 0.38\ Cr_2O_3$ wt. %, $Cr_2O_3 = 5$ wt. %. The field of G_{10} garnets that is accepted by foreign geologists occupies quite larger area in the Cr_2O_3–CaO plot. Moreover, to increase the reliability of applied method we analyzed the compositional variations of pyropes from diamondiferous harzburgites (Ol-Ga-Opx-Chr-Diam) and xenoliths of graphite-bearing peridotites. Taking into consideration these results added with experimental data on the pyrope-knorringite immiscibility and reaction $Ol+Pyr \Leftrightarrow Opx + Chr$ in $SiO_2 - MgO - Al_2O_3 - Cr_2O_3$ system [Malinovsky & Doroshev, 1975; Kesson & Ringwood, 1989] we distinguished the narrow stripe in CaO– Cr_2O_3 coordinates which separates the field of Cr-pyropes from chromite-bearing harzburgites within the fields of graphite and diamond stability

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(Fig.3.2). All the points that occur to the right from this line belong to the diamond stability field. Varying portion of pyrope compositional points located to the left from this line relates to the graphite stability field – sometimes this portion can reach 100 %.

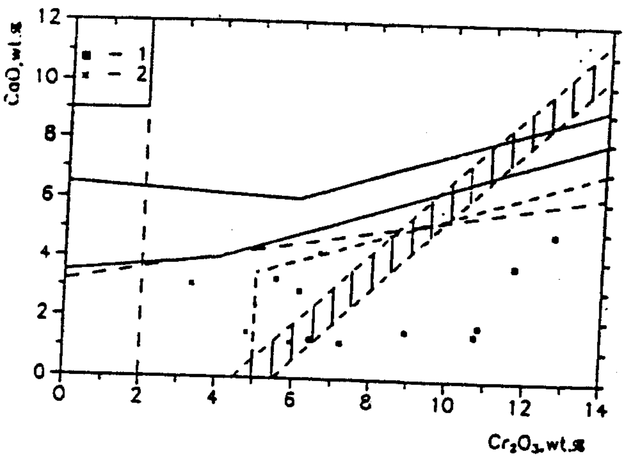

Fig.3.2. Composition of pyropes associating with chromite and enstatite in xenoliths of diamond- (black squares) and graphite-bearing (crosses) peridotites. Shaded stripe (14–17 mol. % of knorringite component) divides the fields of pyropes stability.

Thus, if the compositional points of Cr-bearing subcalcium pyropes fall to the right from the line, that separates the compositional fields for pyropes from Cr-graphite-bearing harzburgites and diamondiferous harzburgites according to the content of knorringite component, the pipe is uniquely diamondiferous.

If pyrope compositional points fall to the right from this line, the pipe seems to be diamond-free, since it can be related to the absence of mantle material that was captured at the levels where the pressure required for diamond stability can be reached.

The diamond-free kimberlite pipes with significant amount of such pyropes are available in both Yakutian and South African diamondiferous provinces.

The second mineral important for the evaluation of potential diamondiferousness of kimberlites is diamond associated chromite. Study of compositional features of chromite inclusions in diamonds and chromites from the xenoliths of diamondiferous harzburgite-dunites [Meyer & Boyd, 1972; Sobolev, 1974; Sobolev et al., 1975, 1984; Pokhilenko et al., 1993; Griffin et al., 1993] indicated that most of them contain over 62 wt.% Cr_2O_3 and less 0.7 wt.% TiO_2, and are characterized by quite low Fe^{3+}/Fe^{2+} ratio (Fig.3.3).

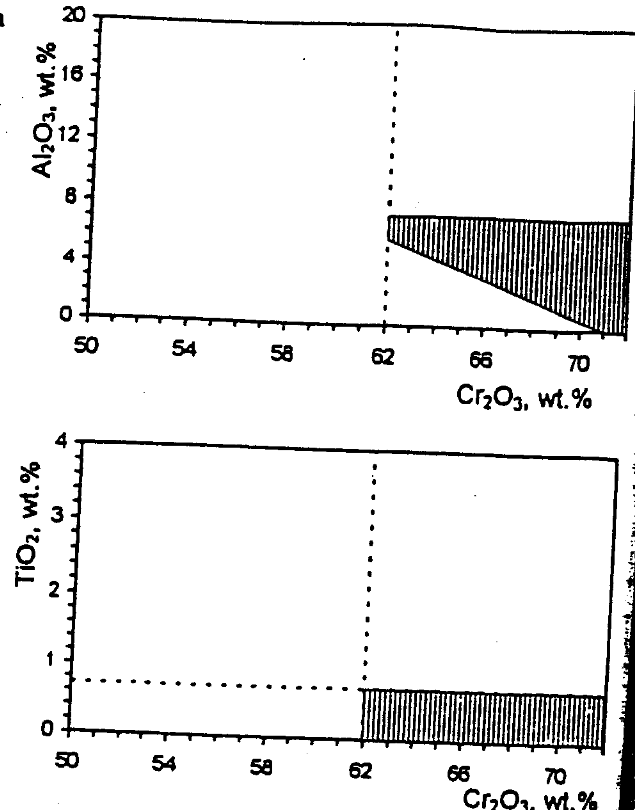

Fig. 3.3. Composition of chromites for estimation of a diamond-content.

Compositional field of chromites which we use in the forecast and search for potentially diamondiferous kimberlites is restricted by Cr_2O_3 wt. % = 71 – 1.637 Al_2O_3 wt. %, $Cr_2O_3 \geq 62$, $Al_2O_3 \leq 7.5$ wt. %, $TiO_2 \leq 0.7$ wt.%.

Aforesaid data show that our used compositional features of diamond-associated chromite are rather different from those used by South-African geologists [Gurney & Moore, 1994].

Also, we performed the analysis of the composition of diamond-associated olivines. Most olivines are high-magnesium varieties (Mg# = 91.5 – 94.5) with low CaO (< 0.06 wt.%). This indicates high pressures and rather low temperatures of their equilibrium. These olivines certainly contain Cr_2O_3 impurity (> 0.02 wt.%). A distinct positive correlation between relative olivine content and grade of kimberlite diamond content is recorded.

Significant portion of eclogite assemblage garnets that are associated with diamonds are characterized by 0.n wt. % Na_2O impurity [Sobolev

& Lavrentiev, 1971; Sobolev, 1974; McCandless & Gurney, 1986, 1989]. In search goals we use the following compositional ranges of eclogite garnets that are present only in diamondiferous pipes: $Na_2O > 0.1$ wt. %; $FeO > 15.0$ wt. % $Cr_2O_3 < 0.2$ wt.%.

Above characterized compositional features of minerals from diamond-bearing natural assemblages were established basing on several thousands of analyses of mineral inclusions in Yakutian diamonds on one hand, and over 50 thousands analyses of indicator minerals from over 120 kimberlite pipes of Yakutian diamondiferous province on the other hand.

PROSPECTING FOR DIAMOND DEPOSITS BY MINERALOGICAL METHODS

Mineralogical searching is a leading method for the discovery of diamond deposits and would remain so in the nearest future. The possibility of the search for kimberlites is secured by the occurrence of indicator minerals, that are stable enough to be preserved in exogenic environment, such as pyrope, picroilmenite, Cr-spinel, some times olivine and clinopyroxene, plus diamond itself. Due to their mechanical and physico-chemical stability these minerals can be transported at great distances and preserved for a long time in ancient deposits, even in corrosive environment. Just the mineral steadiness allows them to keep the "memory" about those historical events that are recorded in minerals as their morphological features, physical, chemical and other properties. By studying these properties it is possible to reconstruct the history of minerals and conditions under which they existed during the formation of mineral haloes. Without such information it is impossible to choose the necessary technique for searching and to evaluate the prospects.

Two main problems are to be solved during the process of mineralogical searching: 1 – identification of indicator mineral haloes; 2 – localization of kimberlite body.

Identification implies to clear up the question – due to what known or unknown primary source this halo has formed. If the studied halo or its fragment is identified to a known kimberlite body, the search task is thought to be fulfilled. If the occurrence of unknown kimberlite body (bodies) is presumed, the next stage of identification is the determination of its expected diamond content basing on mineralogical criteria for diamondiferousness. In general, the solution of identification tasks permits to gain more-or-less detailed "portrait" of the search target and to conclude whether the search for given kimberlite body is expedient. If the search is expedient, the locality of kimberlite body should be defined.

Both problems are solved using the same mineralogical material – the samples of indicator minerals selected from present and ancient productive deposits. However, the methods of investigation of this material are different. Besides, the mentioned search scheme is idealization. What actually happens is that the solution of each problems is unfailingly connected with big difficulties and uncertainties. Traditionally, identification is complicated by three main groups of factors:

1) physico-chemical and mechanical wearing of minerals during the formation of haloes that results in significant changes of mineral appearance and composition of mineral assemblages;

2) polygenetic character of haloes, i.e. in one halo the minerals from different primary sources can be mixed;

3) heterogeneous and heterochronous character of haloes, i.e. they can result from the re-deposition of indicator minerals from more ancient haloes of different litho-dynamic type and different age.

Moreover, the accumulation of indicator minerals and the size of haloes depend on the amplitude of erosion levels.

Primary morphology of indicator minerals

To estimate the degree and mode of alteration of minerals during the formation of haloes correctly, the knowledge of their initial "primary" state in a kimberlite body is necessary.

The term "primary" state of mineral implies morphology, first of all. Mineral morphology is more sensitive to the change of geological environment. Along with chemical composition it provides the main body of information for searching. Morphology of kimberlite minerals results from their long deep development, and magmatic and post-magmatic alterations. The major indicator minerals valuable for searching are pyrope, picroilmenite and Cr-spinel.

The morphogenesis of pyrope from kimberlite includes four stages: 1 – idiomorphic growth, 2 – resorption, 3 – keliphitization, 4 – post-magmatic alteration [Afanasiev et al., 1979].

The first stage is illustrated by faceted pyropes that were preserved as inclusions in xenoliths and thus prevented from later alterations. However, such findings are very rare, hence it is difficult to evaluate the scale of idiomorphic growth processes in deep conditions. The display of other processes is universal. The fractured oval pyrope grains coated by keliphitic rim are typical of kimberlites.

The fracturing of pyrope is a very important process related to post-magmatic processes. The cooling of pyropes suppresses the movement of dislocations inside crystal lattice, so that inner pyrope strains cannot be relaxed. Thus, under cooling and decompression the pyrope behavior resembles that of fragile objects. The action of thermal solutions with high surface energy reduces the surface energy of a mineral. As a result, inner strain can exceed the value of crucial strain, and fracturing takes place. The behavior of other mantle minerals is similar. Inner strains of diamonds are seen as abnormal two-refraction. Besides, the zones of elastic strains inside crystals are distributed unevenly, and their amount of accumulated energy is different. First, fractures appear within the highest-energy zones. Then, fracturing can be caused by the action of substances with high surface energy. In particular, the processes of corrosional fracturing of minerals continue in erosion environment, during the formation of weathering crusts.

The fracturing of pyrope in the post-magmatic stage is favourable to the penetration of thermal solutions and development of chlorite and corrosional relief on the walls of fractures. Hindered access of thermal solutions into developed fractures is responsible for dendritic, streamy, and cavernous relief of their walls, whereas over the oval grain surface the geometrically regular tilled relief is found. The walls of some fractures, that are later likely, are clean and smooth. Thus, a typical shape of pyrope, that is transported due to re-washing of kimberlite body, is an angular fragment with corrosional relief or initial oval surface, plus chlorite and keliphite rims or without them.

Our knowledge of the initial stages of picroilmenite morphogenesis is poor. Oval picroilmenite grains were found in ilmenite-clinopyroxene-garnet xenolith with graphic texture. Picroilmenite that resulted from the re-crystallization of lamellae, i.e. the coarsening of ilmenite grains through the amalgamation of lamellae, took place. So, we can not affirm that any picroilmenite crystals were idiomorphic like pyrope. Also, there is no evidence on the oval picroilmenite habite as a result of magmatic resorption. Nevertheless, oval shape is typical of picroilmenite from kimberlite.

Oval surface is covered by the relief of two types: rough and micro-pyramidal. The latter likely has late-magmatic or early post-magmatic origin and resulted from a more rapid dissolution of defected boundaries between the microblocks of picroilmenite surface.

There are three types of picroilmenite grains: 1 – single crystals, 2 – aggregates, 3 – combined modes. X-ray investigations showed that single crystals possess highly defective structure. Individual blocks from picroilmenite aggregates are of rather perfect structure. Combined picroilmenites are characterized by highly defective single crystal part and aggregate part with a high-quality individual blocks. Investigations indicated that aggregate grains form due to the recrystallization of single crystals. This process is a result of mineral tendency to relieve the excessive elastic energy that is typical of plastically deformed picroilmenite single crystals. Combined modes illustrate the uncompleted recrystallization.

Kimberlite bodies are quite differing in the ratio of the mentioned groups. In most pipes there are 20–30% of picroilmenite aggregates, whereas in some pipes, the Uralskaya pipe as example, almost all picroilmenite grains are presented as aggregates.

One more typical feature of picroilmenite inner structure is exsolution texture. It represents the lamellae that are oriented parallely to picroilmenite pinacoid and characterized by wide compositional range – from Cr-titanomagnetite to chromite (up to 61 wt.% of Cr_2O_3). The specific surface of lamellae in picroilmenite is very large and tends to be lowered by two ways: 1 – coalescence of fine lamellae into coarser ones, 2 – lamellae become isometric to form faceted grains. The display of both processes can be seen within a single crystal. In picroilmenite we observed the octahedral crystals of Cr-spinel that resulted from the transformation of exsolved texture. These Cr-spinel inclusions practically lose the features typical of exsolved grains.

Study of thermo-electric properties allows the suggestion that ultra-minor exsolved elements in picroilmenite are rather widely distributed. However, large enough exsolved grains visible under optic microscope are rare. Their occurrence causes the cleavage of picroilmenite grains which is exhibited as lighter splitting of a crystal parallely to lamellae orientation. There are three pipes in which all the picroilmenites are characterized by well-exhibited exsolved structures: Zimnyaya (Verkhne-Muna field), Grenada and Nadezhda (norther Yakutian province).

In post-magmatic conditions the alteration of picroilmenite proceeds in two principle ways: 1 – replacement by secondary minerals, 2 – corrosional fracturing. Replacement results in the formation of grey-brown rim around picroilmenite that is composed of weakly crystallized rutile or anatase. Corrosional fracturing is similar to that of pyrope.

Due to the whole set of morphogenesis processes, the kimberlite haloes are supplied by angular fragments of picroilmenite grains with/without the traces of initial bossy-oval surface. The described morphological and structural features are exhibited to a different extent.

According to the degree of isomorphism, Cr-spinel from kimberlite holds the second place after diamond. There are three groups of faceted crystals: 1 – sharp-edge octahedrons with smooth faces; 2 – octahedrons which edges and points are smoothed by vicinal faces, i.e irregular surfaces of octahedral anti-skeletal growth; 3 – crystals with only vicinal faces or the relics of octahedral faces. X-ray investigation indicates that octahedral crystals have rather perfect structure of crystalline lattice, octahedrons with vicinals have a blocky structure, and vicinal crystals are composed of numerous disoriented blocks. Crystal morphology does not relate to crystal chemistry. One xenolith can contain Cr-spinels of the same composition but differing in morphology.

Cr-spinel with polished intact faces are rare in kimberlites. Traditionally, crystals are subjected to magmatic corrosion to a variable degree. Two types of corrosion are distinguished: 1 – the corrosion that affects only vicinal surfaces, whereas octahedral faces remain untouched; 2 – corrosion that develops evenly over the whole crystal surface. The degree of corrosion varies from weak to strong one. The latter practically annihilates the primary morphology.

The main mode of post-magmatic processes is corrosional fracturing. In most cases the fracturing happens as crystal spalling. In some kimberlite bodies the other type of fracturing was reported – microfracturing of the outer rim of crystal. Such fracturing is typical of Australian lamproites. Microfracturing is responsible for the origination of vast surface along fracture walls. This activates diffusive processes and therefore induces the change of the composition of microfractured zone.

The behaviour of chemical elements is differing, although the increase of Ti-content is a common tendency. Our investigations confirmed that compositional zonation of Cr-spinels, including that of Australian lamproites, was formed during epigenetic processes, but not growth.

Thus, kimberlite haloes are supplied by Cr-spinel crystals of differing morphology, that have undergone magmatic corrosion and corrosional fracturing, sometimes with a microfractured outer rim.

Thus, the study of Cr-spinels showed that kimberlite bodies can be differentiated statistically according to their morphological features (habite, type and degree of magmatic corrosion, intactness).

Secondary alternation of indicator minerals

At day surface and in sedimentary sequences indicator mineral occur in unequilibrium conditions. This is responsible for exogenic alterations. The unequilibrium of minerals and their assemblages relate to two groups of factors: mechanical and physico-chemical.

Mechanical factors are induced by gravitational instability of a relief unit, within which a kimberlite body is outcropped. As a result, the body erodes and indicator minerals are transported towards most negative relief modes. As peneplanation proceeds, the processes of erosion and transport of minerals attenuate, whereas the processes of their fixation and sedimentation enhance. The mechanical factors of evolution are manifested as three forms: hydraulic grading, change of mineral concentration in haloes, and mechanical wearing.

In general, the distribution of transported minerals relative to the primary source is of exponential shape:

$$P(x) = P_o e^{-bx},$$

where P(x) is a mineral concentration at x distance from the primary source; Po, the initial concentration of minerals in the primary source; b, the coefficient of mineral inertness that is proportional to hydraulic size of the minerals [Afanasiev, Babenko, 1988]. More large and heavy minerals with increased b values drop behind small and light minerals during transportation. This leads to the gravitational and granulometric differentiation of transported assemblages. For kimberlite mineral haloes this process is exhibited in the concentration of heavier picroilmenite (compared to pyrope) and accumulation of coarse-grained minerals near the primary sources. A relative portion of pyrope increases and mean grain size decreases far from primary source. The b coefficient depends on the transporting power of water flows. The greater is this power, the better proceeds the differentiation. Thus, the minerals are drawn farther and the initial assemblage changes to a greater extent. As the peneplanation proceeds, the range of mineral scattering decreases and grading of their assemblages deteriorates. So, the deterioration of granulometry and density indicates the low hydrodynamic activity of the environment and, consequently, a small distance of transfer. Also, this formula shows that the concentration of indicator minerals, as they move away from kimberlite body, decreases exponentially. Therefore, although indicator minerals can be transported at a great distance, their majority is concentrated nearby the kimberlite body.

These tendencies take place only in continental environment. In marginal basins minerals fall into quite different hydraulic environment that is characterized by to-and-fro motions of clastic matter under the effect of waves. The distribution pattern of kimberlite minerals is not stream like on the continent, but band-like with across zonation. Minerals realize their hydraulic properties due to persistent stirring-up. Thus, size and density differentiation reach the highest degree there. Even monomineral separations of a narrow size range can accumulate.

Another type of alteration is mechanical attrition of minerals. The degree of wearing depends on the diameter of particles, their density, abrasive stability and the rate and distance of transportation. For the sake of simplicity, the degree of wearing is often considered as a distance function, only. We believe, that it is necessary to take into account the kinematic and dynamic factors of transportation. They, in general, characterize the lithodynamic environment of transportation and, eventually, the lithodynamic type of a collector of kimberlite minerals [Afanasiev, 1896]. There are three ways of transportation of clastic particles: as a suspension, saltation, and dragging. Mechanical attrition is obviously caused by another type of transportation. The latter is realized in a mass of moving clastic matter, when the wearing results from not only mineral-bottom double interaction, but at least triple interaction, like a ball-free mill. This mechanism does not play a significant role in the bed-river plain flows that possess a low hydraulic activity. Our observations at a standard object (Verkhne-Muna kimberlite field and the halo in the Muna River bed) showed that at a distance to 100 km only pyrope grains over 2 mm size have the traces of attrition. In beach environment, hydrodynamic regime is much more intense to result in the movement of a whole sequence of clastic matter. In these conditions the "mill" effect plays the leading role. Besides, the velocity of waves is higher than that of bed flows, and the total way passed by clastic particles during to-and-fro motions exceeds all possible distances of their transport on the continent. Granulometric grading of minerals promotes mechanical attrition in these conditions, since the particles of nearly equal size contact each other multiply, and their rotation due to the transportation results in their intense mutual friction. Thus, the degree of wearing depends on the environment of wearing, rather than the distance of transportation.

According to abrasive stability the major deep-seated kimberlite minerals form a following sequence (decrease): diamond – zircon – Cr-spinel – garnet – olivine – picroilmenite – Cr-diopside. It should be noted that the common opinion of low mechanical steadiness of olivine is wrong. Olivine strength is close to that of garnet. In present haloes they are transported together at tens kilometers. Olivine is preserved even in ancient sea-beach collectors not disturbed by crusting processes, e.g. in Jurassic conglomerates of the Lena River region. Quick "disappearance" of olivine from indicator mineral assemblages relate to its low content in most kimberlite bodies. Therefore, moving away from a primary source olivine soon stops to be detected by equal volumes of sampling. As olivine is low tolerant to erosion processes it is absent in ancient haloes.

Each kimberlite indicator mineral belongs to different paragenetic type, whose properties range widely. For example, due to increased fracturing, orange pyropes are less stable in abrasiveness, relative to most violet pyropes. Most "mature" i.e. strongly mechanically evolved sea-beach heavy mineral assemblages are represented by only monomineral garnet assemblages, or nearly so (e.g. the halo in Early Carboniferous gravellites of the Kyutyungdin graben). In these haloes diamond, that is similar in density and granulometry to garnet, can be accumulated to form rich diamondiferous placers. The absence of picroilmenite is explained by its almost complete annihilation due to attrition. According to our investigations picroilmenite abrasive stability is 9-10 time less than that of pyrope [Afanasiev et al., 1994].

Physico-chemical alteration of kimberlite minerals proceeds in a sedimentary sequence after the haloes are completely formed. There are four types of such changes known: weathering, diagenetic, metagenetic, under metasomatism.

The diagenesis processes effect rather weakly on kimberlite minerals found in a sediment. The main mode of alteration is corrosional fracturing.

Crust-formation processes are most powerful factors of epigenetic alteration of kimberlite minerals [Afanasiev et al., 1986]. The weathering of minerals is displayed as replacement, dissolution, and fracturing.

For garnet, two types of dissolution, were recognized: cuboid and dislocative.

Cuboid type is characteristic of garnets with a few of defects. Dissolution results in positive relief forms: drop-like, rugged, and eventually convex-face cuboid (Fig. 3.4). Dislocative type of dissolution is characteristic of the grains with a lot of defects (Fig.3.5). Corrosional fracturing and etching slits and channels develop by the dislocation and their accumulations (junctions).

Picroilmenite is either replaced by leucoxene (Fig.3.6), or dissolves to form a disordered cavernous relief (Fig. 3.7). The aggregate grains become loose.

Cr-spinel is rather stable during epigenetic alteration. The main form of weathering is corrosional fracturing that results in scattering and micro-fracturing (Fig. 3.8).

Weathering stability of kimberlite indicator minerals reduces from diamond to zircon, Cr-spinel, picroilmenite, pyrope, Cr-diopside and finally olivine. Haloes undergone weathering contain no olivine. Cr-diopside is preserved very rarely.

Fig. 3.4. Pyrope cuboid.

Fig.3.5. Pyrope with dislocation type of corrosion.

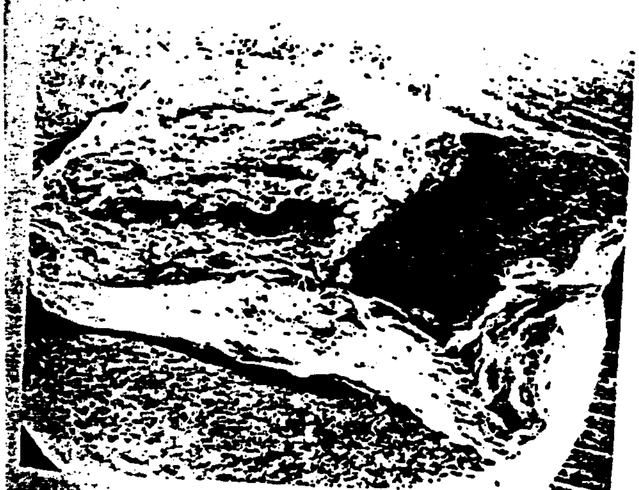

Fig. 3.6. Picroilmenite with leucoxene.

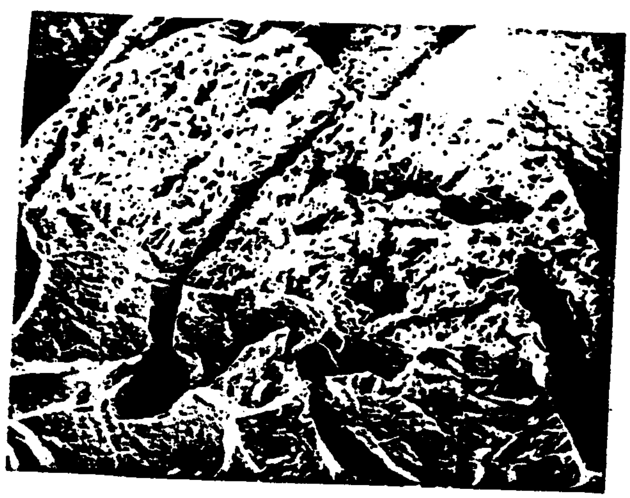

Fig. 3.7. Picroilmenite with dissolution relief.

The pyrope stability is sufficient for it to be kept in weathering crusts, however, pyrope is most sensitive indicator of the process of weathering. Picroilmenite and Cr-spinel can bear no signs of weathering, while they are available on the pyrope. No changes of diamond and zircon within the crust of weathering are established. There are also differences in stability of one-mineral varieties.

Stability of pyrope depends on Cr-content [Afanasiev et. al., 1984]. Therefore, weathered assemblages are rich in violet Cr-garnet from ultramafic assemblages, since Cr-poor orange garnets from mafic assemblages are predominantly destroyed. Thus, the same regularity is noted like for mechanical stability. There are several individual samples where mainly Cr-rich spinels are disrupted.

Fig. 3.8. Chromespinelide with microfissured rim.

The haloes of the Malo-Botuobiya region contain Mg- and Ti-poor picroilmenites that are ferromagnetic at room temperature. However, these picroilmenites are endemic for this region. As for paramagnetic picroilmenite, they show no distinct regularities in the change of assemblage composition.

As a whole, the processes of weathering cause a significant change in composition of heavy mineral assemblages and physiographic features of kimberlite minerals.

Metasomatic alteration of kimberlite minerals was established at the contact zones between the intrusions of differentiated traps and either kimberlite, or sedimentary rocks. The signs of metasomatism processes are found on the minerals from Upper Paleozoic sequences of the Malo-Botuobiya region and in the south-western Alakit field, where the Krasnopresnenskaya pipe is cut by differentiated trap intrusion. Under these conditions, garnet is replaced by chlorite to form pyramidal-tilled relief along the reactionary front [Afanasiev, 1985]. Picroilmenite dissolves to form crystal brushes of brown anatase. Cr-spinel is covered by tiny caverns and becomes loose due to corrosional fracturing. Diamond is unstable in metasomatic environment and therefore acquires the signs of catalytic oxidation. Relative stability of minerals during metasomatism is not estimated, yet. A stronger replacement of orange garnets by chlorite relative to Cr-rich violet garnets is noted. The intensity of alteration decreases far from the contact with intrusive body. In the near exocontact zone kimberlite minerals can completely disappear.

Metagenetic alteration of kimberlite minerals is established in folded zones, particularly, in Triassic sea-beach collectors of the Near-Upper Yana region [Afanasiev et. al., 1985], and in the Takatinskaya suite deposits of the Urals. The alteration is principally caused by the temperature and pressure growth. Pyrope alteration in these conditions is close to metasomatism: replacement by chlorite and creation of pyramidal-tiled relief take place. Orange Cr-poor garnets are replaced more intensively. As only sea-beach pyrope-bearing collectors were studied, the behavior of other minerals is unknown, yet.

A general trend of mechanical and physico-chemical alterations is responsible for the "maturation" of heavy mineral assemblages, i.e. elimination of non-stable individuals. Often the "maturation" is expressed as lowered dispersion of various properties of mineral assemblages, such as size, morphology and composition of mineral grains, etc. General course of evolution of mineral assemblages is exhibited on one hand in simplification of mineral composition due to the elimination of less-stable minerals. On the other hand, a partial erasure of "primary" signs, that characterize the mineral state in kimberlite, and their replacement by "secondary" signs, that reflect exogenic condition of mineral existence, take place. Exogenic alterations are specific for their character can provide our knowledge of the conditions under which they occurred. However, such phenomena as corrosional fracturing of minerals or creation of pyramidal-tiled relief can take place in different environment. Therefore, the type of geological setting should be taken into consideration.

The types of haloes of indicator minerals

The reconstruction of ancient halo formation conditions shows that haloes form in three lithodynamic environments, according to which the three types of haloes are recognized: 1 – alluvial, 2 – alluvial-beach, 3 – sea-beach.

Alluvial type of halo is formed in continental environment. There, indicator minerals from eroded kimberlite are transported by rivers, and together with other clasts migrate towards the sea. Typical features of these haloes are: 1 – by-stream distribution of indicator minerals, 2 – exponential decrease of mineral concentrations away from kimberlite bodies, 3 – low velocity of mineral grading, 4 – weak mineral wearing (minerals are found at a distance of tens kilometers).

Alluvial-beach haloes are formed within depressions with unstable hydraulic regime, periodical flooding by sea, irregular shore line and existence of ephemeral reservoirs. This environment is responsible for important specific features of haloes such as: 1 – filament-net areal distribution of indicator minerals, 2 – local display of high graded mineral assemblages, 3 – local display of increased concentration of indicator minerals, 4 – moderate wearing of minerals.

Sea-beach haloes are formed within a sea shore zone. There, for a long time the indicator minerals carried from continent are subjected to to-and-fro motions caused by the action of sea waves. As a results, in sea-beach setting the haloes with following typical features are formed: 1 – highest mineral wearing, 2 – formation of mainly pyrope-diamond assemblage due to the annihilation of less stable picroilmenite, 3 – highest grading of minerals, 4 – areal character of mineral distribution, 5 – unusually high mineral accumulations due to the additional mineral supply from the continent. The major and most reliable sign for the distinction of halo types is the degree of mineral mechanical wearing. We would like to note once again that the degree of mineral mechanical wearing depends not on the distance of mineral transportation, but the conditions of halo formation. If kimberlite body occurs not far from the sea shore line, the relative minerals would be strongly rounded just near to it. Nevertheless, our investigations of the present stream scattering in the Verkhne-Muna field showed that mineral transport by alluvial agents at distances over hundred kilometers causes only weak wearing evidences. In respect to searching studies each halo type possesses its own favourable features and restrictions. Alluvial type of haloes is most favourable to the search for primary sources. This results from the weak alteration of indicator minerals and their assemblages during the formation of haloes, and from the location of mineral concentration maximums near a kimberlite body. In these conditions diamond placers are formed at the cost of diamond-rich kimberlites and dispose near them. Sea-beach type of haloes is less favourable to the search for kimberlites. Mechanical alteration of minerals and the grading of mineral assemblages strongly distort the primary appearance of minerals. Besides, the minerals from different kimberlite bodies are mixed in these haloes. High concentrations of minerals are formed independently on their remoteness from primary source. Nevertheless, such environment is favourable to the accumulation of placers. As the coastal zone is supplied by diamonds from many kimberlite bodies, the diamond-rich placers can be formed from low-diamondiferous primary sources.

The areal character of the distribution of indicator minerals was mentioned to be an important feature of sea-beach type haloes. Actually, the ancient sea-beach haloes are of the same sort. They result from the transgressive movement of shore line towards the continent. Thus, the minerals that were re-sorted within a coastal zone appear at the bottom, away from the zone of wave action. Further, they are retained and buried by finer sediments. Being formed within a narrow belt of coastal zone the halo remains at the sea bottom, behind the moving shore line, and occupies a vast territory.

Heterogeneous and heterochronous character of the haloes of indicator minerals

Above there were described the "primary" types of haloes. The reason for their formation is that kimberlite bodies are a single deliverer of indicator minerals into haloes. This situation exists at the first stage of kimberlite re-washing. The formation of haloes stops when the cycle of sedimentation is finished, i.e. after the retain of minerals in a sediment and their burial by finer deposits. The same deposits cover kimberlites. In geological history, however, after the formation of kimberlite bodies, usually several cycles of sedimentation take place, during which the formed before deposits that contained indicator minerals can be partially or fully washed out. In this case indicator minerals travel from the ancient deposits to younger ones. Simultaneously, the buried kimberlite bodies are unsealed to deliver indicator minerals into the deposits under formation. Thus, in the following stage of sedimentation the haloes are supplied by minerals from two sources: 1 – ancient deposits, 2 – kimberlites. Therefore, in the forming halo the indicator minerals from the same kimberlite bodies, that were however washed out in several time stages, are mixed. Thus, indicator mineral assemblage acquires the heterochronous character.

Besides, the change of sedimentation regime can result in the mixing of the indicator minerals of different halo lithodynamic types, for example, sea-beach and continental.

Heterogeneous and heterochronous character of indicator mineral assemblages in alluvial and ancient deposits is typical of all the diamondiferous regions, in particular, the territory of Yakutian diamondiferous province. Only primary haloes related to the initial stage of kimberlite re-washing can be monogeneous and monochronous. The relics of these haloes can preserve fragmentally in a favourable structural-tectonic environment.

Re-deposition of minerals and heterogeneous-heterochronous character of halo assemblages cause big difficulties to the process of searching. Re-depositing breaks the direct link of indicator collector. In the Alakit field, the Upper Paleozoic deposits that cover kimberlites, contain also the minerals from Middle Paleozoic collector. However, the portion of minerals that were directly taken from kimberlites during Upper Paleozoic sedimentation is significantly higher.

Thus, the ancient haloes, like the present alluvial haloes of the II type of search setting, contain re-deposited, i.e. heterogeneous and heterochronous, material. Due to the multiple re-deposition in many haloes of the Malo-Botuobiya region, the minerals of all three lithodynamic halo types and altered in different degree can be found in a single sample. Taking into account the difficulties of sampling and the re-deposited character of most indicator minerals, the use of mineralogical method is insufficient to provide the discovery of kimberlite body. The facilities of this method are restricted by the recognition of somewhat certain area, within which the further searching should be carried out using either geophysical methods, or drilling on a dense grid. Like in the II type of search setting, the search results depend on the proportion of amplitudes of kimberlite erosion before and during the formation of the deposits that cover kimberlites.

In the Malo-Botuobiya region, where Upper Paleozoic collectors are widely distributed, the pre-Upper Paleozoic erosional level reaches 300 m, whereas the Upper Paleozoic erosional level is ten times lower. As a result, the bigger haloes overlap each other and contain chiefly re-deposited material. In these environment to separate the local prospect areas is very difficult.

In the Alakit field, the amplitudes of pre-Upper Paleozoic and Upper Paleozoic erosion are low and nearly equal. That is why rather small haloes occur close to primary source and contain both re-deposited material and the products of the Upper Paleozoic re-washing of kimberlites. Therefore, although both regions are situated in the same setting the results of their searching significantly differ: none kimberlite pipes were found beneath Upper Paleozoic deposits in the Malo-Botuobiya region, and tens buried pipes were discovered in the Alakit field.

Type IV. This setting is characterized by the wide distribution of ancient primary or re-deposited haloes of sea-beach lithodynamic type. In both, primary and re-deposited states these haloes were noted above to be unfavorable to the search for primary diamond deposits. Nevertheless, many diamond placers are connected with those haloes. Often, rich diamond placers are formed due to the re-deposition, since the streams accumulate in their beds the diamonds from the whole area which they drain.

Ancient sea-beach haloes are widespread in all the diamondiferous regions. We faced just these haloes in the first stage of searching. As the final aim is the discovery of primary diamond sources, the question arises is it possible to use these haloes for primary evaluation of diamond content. Special studies revealed that in the Yakutian province, at adjacent areas, the sea-beach parts of heterogeneous haloes are differing in the chemical features of pyrope and picroilmenite assemblages. This proves, that different segments of a single vast sea-beach collector were fed by different groups of kimberlite bodies, likely not very remote relatively each other. The character of the relief of the Siberian platform helps to understand this fact. The Siberian platform represented a peneplanated territory with low hydrodynamically active relief. Low hydrodynamic activity could not provide the transport of clastic material, including indicator minerals, at great distances. Fluctuation of the World Ocean level resulted in rapid transgressions and regressions of shallow-water seas, which in turn were responsible for the formation of sea-beach haloes. Thus, these haloes were supplied by not too remote kimberlite bodies. The transgression of basin could lead to the covering of kimberlites by sea-beach deposits. For example, we found rounded (up to balls) and corroded pyrope grains from sea-beach halo in the sample from eluvium of the Zarnitsa pipe, the Daldyn field. This proves that before the pipe was buried by sea-beach collector, after its washing out, the pyrope found themselves at the surface of pipe.

Thus, although it is impossible to search for kimberlite bodies after sea-beach haloes, the latter can be useful for small-scale forecast.

In conclusion, we can affirm that the various kinds of exogenic alteration of indicator minerals, differing lithodynamic environments for halo formation, differing geological structure and history of studied areas determine the different manner of searching – its facilities, restrictions, and results – in each definite situation. The available information promotes to choose the best fashion of searching process, or, if the prediction is unfavourable, to refuse from searching over that territory and in doing so avoid redundant time losses and save funds.

Identification and localization: implications for the prediction of diamond deposits

The discovery of diamond deposits by mineralogical methods requires solving two problems: 1) finding and identifying an indicator mineral halo; 2) localizing the primary source. Identification of haloes and localization of deposits are the components of prediction process being individual in each certain case. Nevertheless, there are some common rules that concern the procedure of identification and localization.

Identification regards those features of indicator minerals and their assemblages that do not strongly change during erosion, or when such changes can be taken into account. These features must illustrate the "portrait" of sought kimberlite body, i.e. they must keep the primary information about this body. In practice, two groups of features are used widely – physiographic and chemical features. Physiographic features include morphology, colour, fracturing, inclusions in transparent minerals, i.e. those signs that can be visually observed. One can always find those features according to which kimberlite bodies can be distinguished.

Most popular method for the determination of mineral chemical composition is X-ray microprobe analysis. The processing of microprobe results is aimed to solve two problems: 1) to evaluate the diamond content of primary source; 2) to compare samples in order to decide either they originate from a single source, or from different sources.

Theoretically, there is a lot of mineralogical features that can be used in identification goals. In practice, their number in limited by our research facilities, mostly: 1 – analytical database, 2 – possibility to interpret the obtained data in terms of identification. The latter situation is not trivial. If there are no reliable interpretation methods or they are poor, the intense mineralogical investigations (including those expensive) provide either poor search effect, or even false information.

Most identification features require the study of representative selection. Besides, it is difficult to identify the halo according to one-two features. Traditionally, the reliable solving of identification problems demands the use of several related features.

The signs of localization are those that strongly and regularly change away from a primary source. Firstly, these signs relate to the migration properties of minerals. The solving of localization problems is most topical for the third types of search setting, because in first and second types the migration of minerals is easily traced by the streams. When the searching is carried out accordin to the ancient haloes, the sampling is performed without the referencing to ancient streams, i. e. blindly. Therefore, the supposed whereabout of kimberlite body can be determined only by analyzing of the distribution of indicator mineral samples over the area, applying the signs of localization. We use the following set of major localization signs: 1 – concentration of minerals (exponentially decreases away from the source); 2 – granulometry – grain size (assemblage becomes poor in coarse grains away from the source); 3 – ratio of silicate to heavier ore minerals, firstly pyrope and picroilmenite (increases away from the source); 4 – degree of size grading (becomes higher away from the source); 5 – degree of wearing (becomes higher away from the source) [Afanasiev, 1989b]. In exotic cases, some more complex signs can be used.

Each sign is applied with account to its individual search value. The noted above signs are listed in the order of their value reduce.

We have worked out a special algorithm that allows the quantitative estimation of samples and recognition of local mineralogical anomalies related to kimberlite bodies.

Special method of mapping the haloes during exploration for buried diamond deposits has been developed and successfully tested in the Alakit field. There, this method permitted to find a large number of local mineralogical anomalies, some of them seemed to be related to the already known kimberlite bodies. For other anomalies the kimberlite occurrences are predicted. And some anomalies are referred to primary sources that were discovered within the recognized prospect areas using mainly geophysical methods.

Conclusion

Mineralogical methods of the searching for diamond deposits possess their own possibilities and restrictions. Their balance defines the effectiveness of these methods. In turn, on one hand, this balance depends on certain geological setting of search areas, geological history, lythodynamic types of haloes, and character and degree of exogenic alteration of indicator minerals. One the other hand, this balance depends on the mineralogy, size, age, erosion level, and other features of kimberlite bodies themselves. Therefore, there are no simple and universal rules to the search for diamond deposits. In each case, the search problem requires imaginative approach that should be based on extensive knowledge which some aspects were briefly characterized.

On the whole, the system of mineralogical search used in Russia has solved the problem of diamond exploration for different types of exploration condition, and permits one to evaluate possibilities and predict results. Due to the genetic approach to various aspects of the mineralogical search system, it could be adapted to most types of searching condition in different diamondiferous regions.

minerals and their primary source. According to the re-deposited minerals only local areas, where kimberlite bodies could occur, are possible to be predicted. Locality of forecasting depends on the type of re-deposited halo. Alluvial haloes are more favourable for searching.

To differentiate the re-deposited mineral is possible according to several signs, which most important are: 1 – a discrepancy between the wearing degree of minerals and formation conditions of their hosting deposits (for example, highly rounded pyropes of sea-beach halo type are found in present alluvial deposits in which they could not acquire such degree of rounding); 2 – recorded physico-chemical alteration of minerals that is incompatible with the conditions of formation and further existence of their host deposits (when present alluvial deposits contain the minerals with the signs of weathering). Therefore, a mineral keep the "memory" about the preceding events of its history. Sometimes, the signs of several sedimentation cycles, which traces are superimposed on previous ones, can be seen on the mineral. The knowledge of the regularity of indicator mineral behaviour in different exogenic environments allows the reconstruction of geological history during those periods which are impossible to describe (for example, if there are no geologically documented sedimentary sequences available).

During the re-depositing, indicator minerals displace relative to their previous location, i.e. haloes are dispersed (crawled away). However, often, newly formed continental deposits, being host for re-deposited minerals, are deluvial-proluvial or alluvial deposits of small rivers, i.e. formed in the setting of near transport of clastic matter. Thus, in most cases indicator minerals displace at small distances, and the newly formed halo, to a first approximation, inherits the location of preceding halo, or is displaced insignificantly. This is an important fact for it allows the usage of re-deposited minerals in forecasting goals.

Thus, the formation of indicator mineral haloes, according to which the search for diamond mineral deposits is carried out, is a complex multi-stage process. The general scheme of halo development is shown in Fig.3.9.

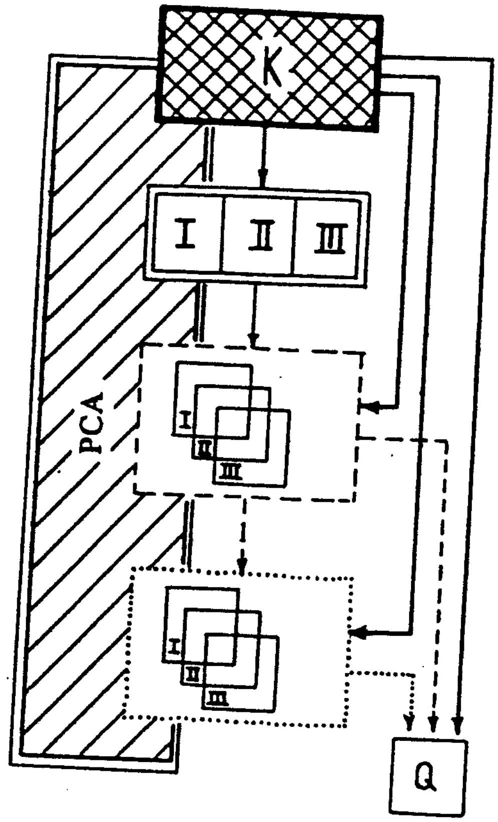

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Fig. 3.9. Evolution of haloes of indicator minerals. K– kimberlite body, I, II, III – lithodynamical halo types: I – alluvial, II – alluvial-beach, III – beach, PCA – physics-chemical alterations; Q – modern alluvium, → erosion of kimberlite body; ==> – redeposition of indicator minerals from ancient collectors.

Mineralogical types of search setting

Individual character of geological structure and geological history of each diamondiferous region, diversity of lithodynamic halo types, widespread processes of mineral re-deposition and their related heterogeneous and heterochronous character of mineral assemblages are responsible for the individual manner of searching that is required for each individual plot. In general, four search settings can be distinguished [Afanasiev et. al., 1981a].

Type I. Kimberlite bodies are exposed, ancient collectors of indicator minerals, and therefore re-deposited minerals are absent. Thus, alluvium is supplied by indicator minerals immediately from kimberlites by only those rivers that drain kimberlite bodies themselves. In this case the manner of searching is simple – by the "road" of indicator minerals, up stream of a river or brook, and along the slopes of valley, as far as the kimberlite body outcrops. However, one stream can be supplied by indicator minerals from several kimberlite bodies. Hence, it is necessary to sample not only river bed sediments, but all side tributaries and slopes in order to miss no one pipe. This type of search setting deals with only alluvial halo type which indicator minerals are weakly altered relative to those from a primary source.

Therefore in this situation, the detailed mineralogical investigations are not topical. They can be compensated by a dense grid of sampling of river-beds and slopes, that is sufficient to record all the targets. While using the mineralogical criteria only the evaluation of the diamond content of sought target is needed.

This type of search setting is not typical of the Yakutian diamondiferous province. It is available only in the Central-Aldan region, at the Khatystyr, Tobuk, and Chompolin clusters of pipes, the latter being not diamondiferous. The age of these pipes is post-Middle Jurassic, the younger deposits are unknown. The study of the structure and mineralogy of haloes confirmed the absence of re-deposited minerals there.

Type II. Kimberlite bodies are exposed; the existed ancient collectors were fully washed out. Therefore, there are two sources of indicator minerals – ancient collectors, from which the minerals are re-deposited into new deposits, and kimberlites. While being re-deposited, the minerals are spreading away and fall in all the streams within given area. The minerals from kimberlites fall only in those streams that drain kimberlite body. Thus, the streams washing kimberlites will carry both minerals from kimberlites and re-deposited minerals. The other streams will carry only the re-deposited material. In this setting the searching process must be based on the minerals from kimberlites. The re-deposited minerals are not suitable for searching. So, there appears the problem of reliable recognition of re-deposited minerals and minerals supplied instantly from kimberlites. The solution of this problem demands detailed mineralogical investigations that should be based on the knowledge of exogenic alteration features of indicator minerals. Along with, the mineralogical criteria for diamondiferousness are to be used, however, individually for each group.

This type of search setting is available at the vast territories of the northern Yakutian province. There, kimberlite-hosting Lower Paleozoic rocks outcrop. However, the results of mineralogical searching highly vary from one part of this territory to another.

In the Daldyn field, the results of searching are rather successful. Today, this field is thought to be a standard of search. In the Ebelyakh region (northern province), we failed to find kimberlites using mineralogical search methods in spite of a great amount of indicator minerals. This principally relates to the proportion of the amplitudes of ancient and present kimberlite erosion. In the Daldyn field, these amplitudes are comparable, therefore it is rather simple to observe the minerals taken from kimberlites among the re-deposited minerals. In the Ebelyakh region, the amplitude of ancient erosion is much higher, therefore, a great amount of indicator minerals was released. On the background of abundant indicator minerals, the products of coeval re-washing of kimberlites are very difficult to be recognized.

In the II type of search setting the mineralogical method is applicable if to success to distinguish the minerals arrived from kimberlites and re-deposited minerals. The search is held only by first group minerals. However, mineralogical methods are better to be added with geophysical methods, in particular, magnetic prospecting (airborne and ground magnetics).

This type of search setting if typical of not only the Yakutian diamondiferous province, but other world diamondiferous regions, where kimberlite bodies are exposed. If there is a lack of geological information about the existence of ancient collectors, it will be provided by the study of kimberlite indicator minerals in terms of the character and mode of exogenic alterations.

Type III. Kimberlite bodies are buried beneath the younger sediments that are the collectors of indicator minerals. This type of search setting is more complex due to the covering of both kimberlite bodies and indicator mineral haloes. Their sampling is performed either by mines and open pits, or drilling holes. In this case, we are not able to carry out "aimed" sampling, i.e. to select the most suitable places for sampling like on the opened areas. Besides, the volumes of sampling are small. Moreover, our investigations showed that the ancient haloes of Yakutian province also contain indicator minerals re-deposited from earlier collectors. So, Upper Paleozoic haloes of the Malo-Botuobiya region chiefly contain the minerals re-deposited from completely re-washed Middle Paleozoic (Upper Devonian ?) collector. Jurassic deposits from this region contain the minerals re-deposited from Upper Paleozoic collector, that in turn include the minerals from Middle Paleozoic collector. In the Alakit field, the Upper Paleozoic

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2

Target Data Services Canada Ltd.

Data Prepared For: **HAMLO INC** Attention: **RAYMOND HAIMILA**

Twp: 70,71 Rge: 22 West of: 4 Meridian

Project or Area Name: ____________________

QI DATA REPORT SHEET

Line #:	
Alt. Line #:	
Operator:	
First SP:	
Last SP:	
e Shot:	
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Group Interval:	
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Spread:	
Fold:	
Instruments:	
Geophones:	
Filter/Notch:	
Km:	
Cost per Km:	

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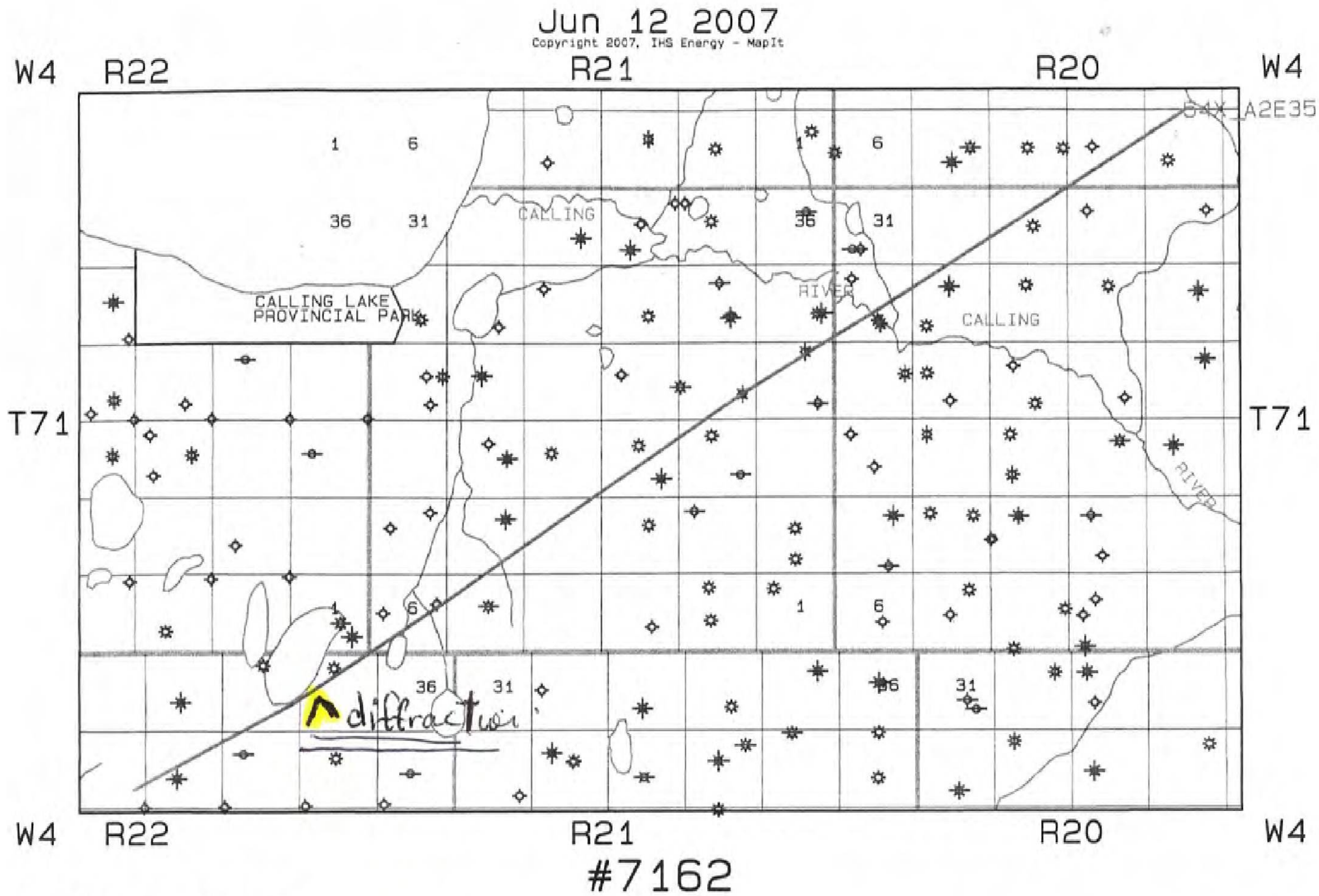

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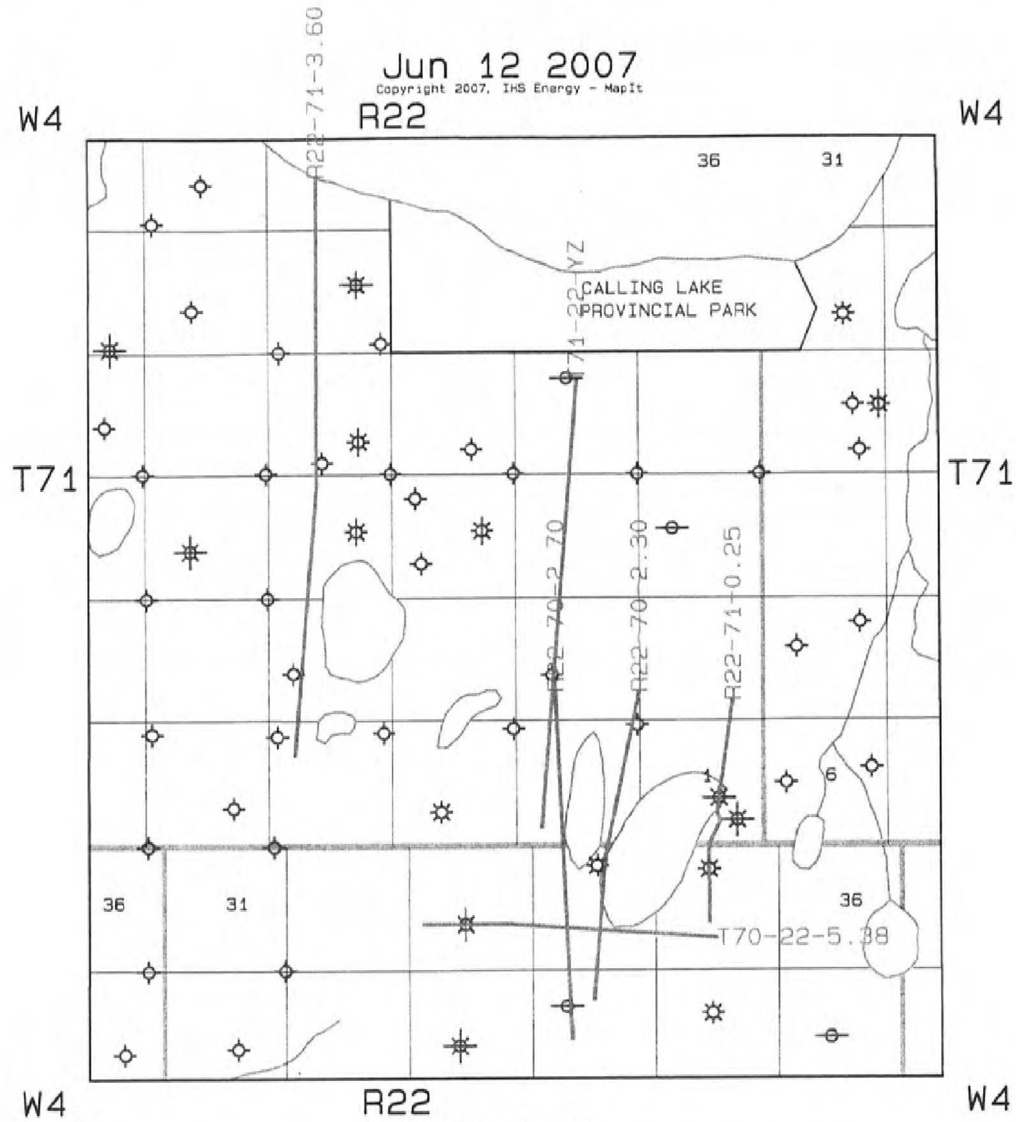

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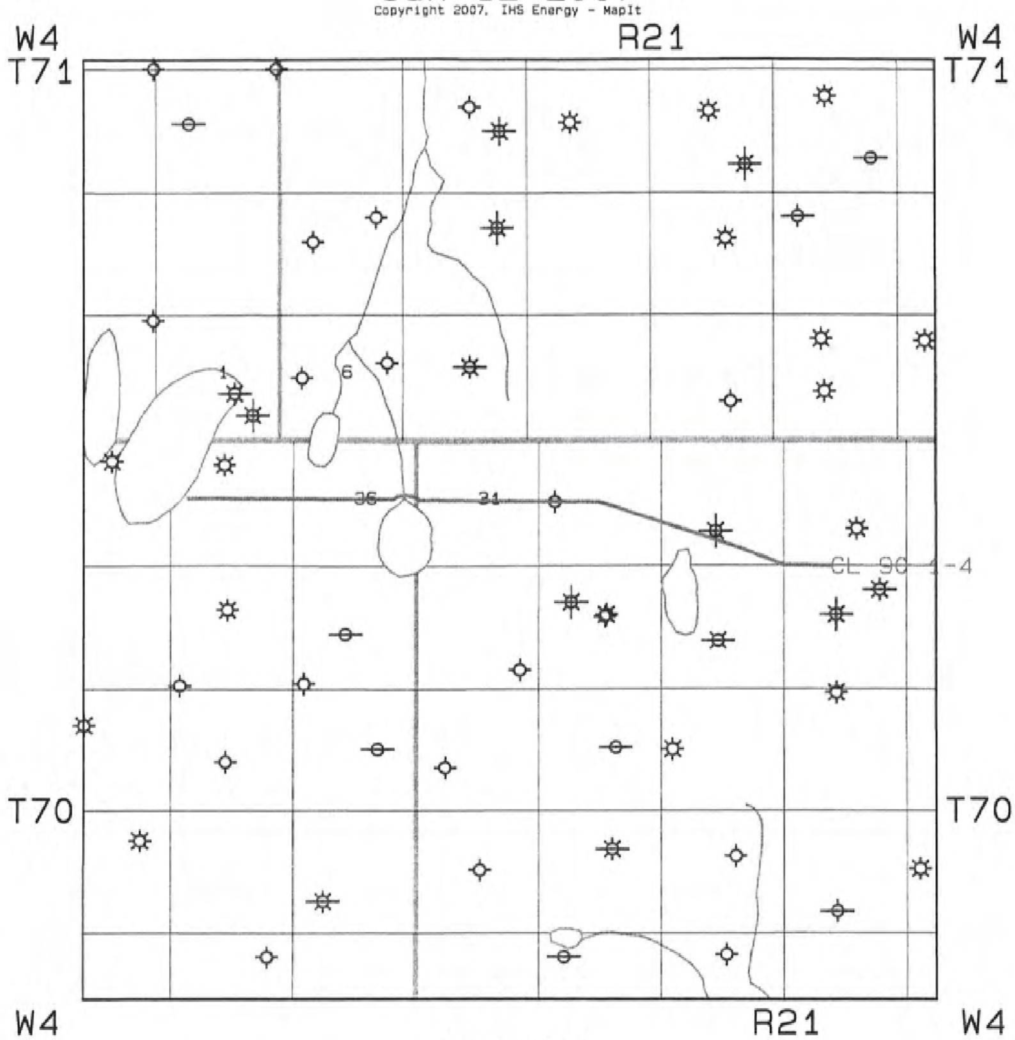
NOT AVAILABLE

Jun 12 2007



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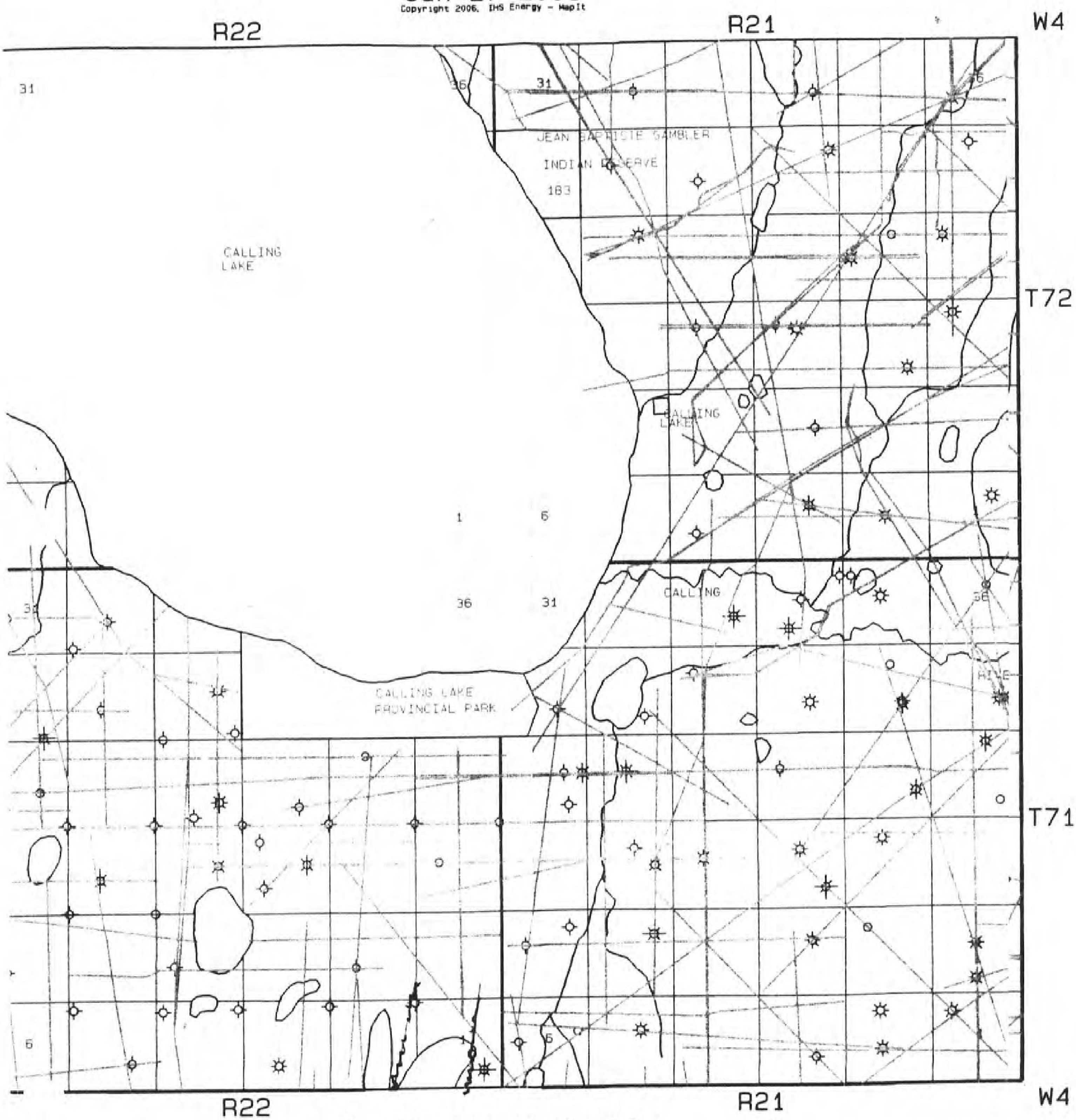

Raymond Haimila

Scale 1: 100000

KARY DATA

FAX (403) 781-6248

3

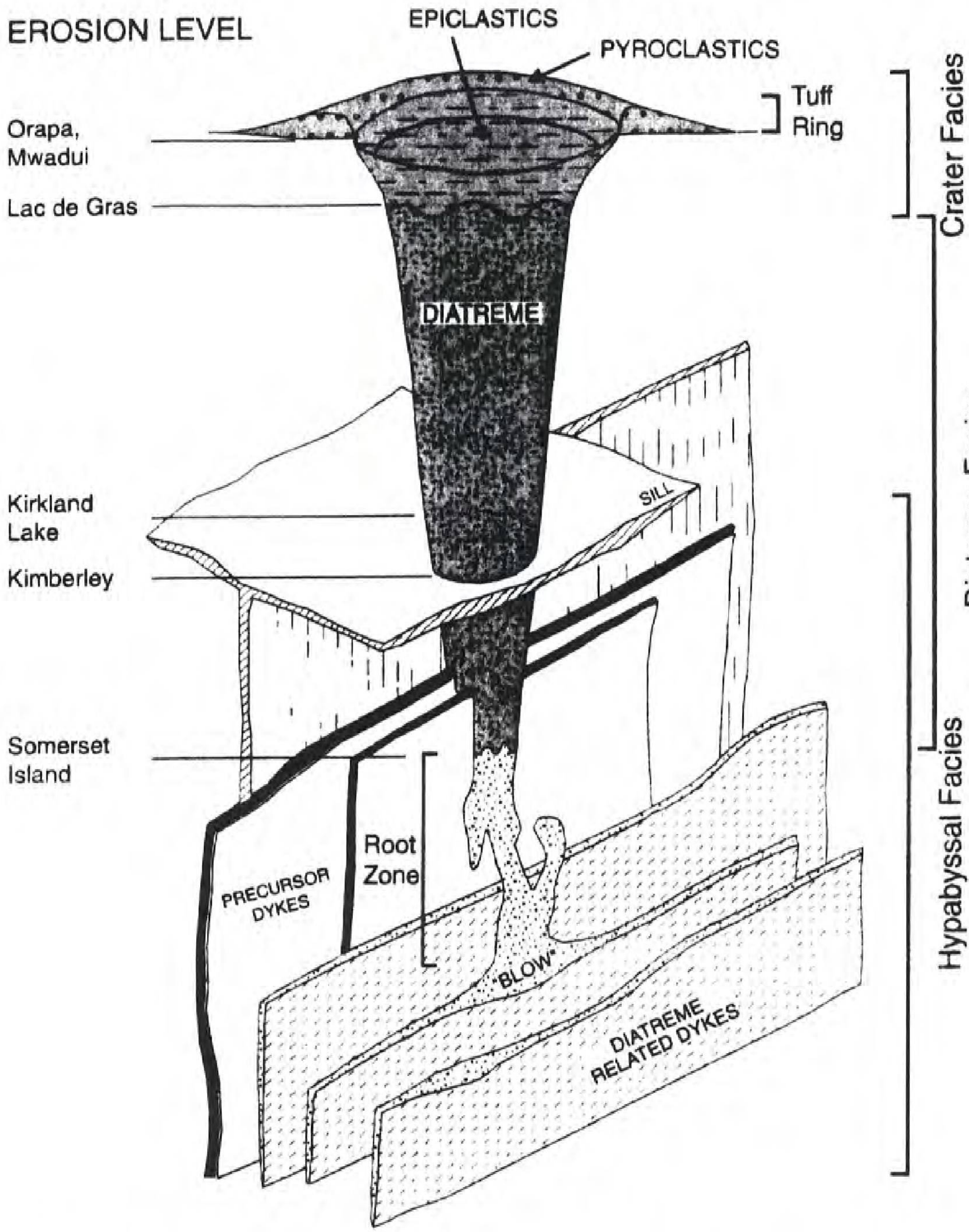

Figure 2. Generalized model of the classic South African type of kimberlite magmatic system, showing crater, diatreme, and hypabyssal facies rocks. Crater facies rocks consist of pyroclastic (tuff ring) and resedimented volcaniclastic rocks (crater infill); diatreme facies rocks consist mainly of tuffisitic kimberlite breccias; hypabyssal facies rocks are found in the root zone of the diatreme and consist of "blows" (enlarged dykes), dykes, and sills. Also shown are the present erosion levels of some representative economic and Canadian kimberlites. Modified from Mitchell (1986).

GEOLOGICAL SURVEY OF CANADA

OPEN FILE 3228

Edited by

A.N. LeCheminant, D.G. Richardson, R.N.W. DiLabio and K.A. Richardson

1996

modified from Kjarsgaard 1996 by R Haimila 2007

Kimberlites

B.A. Kjarsgaard

Kjarsgaard, B.A., 1996: Kimberlites; in Searching for Diamonds in Canada, A.N. LeCheminant, D.G. Richardson, R.N.W. DiLabio, and K.A. Richardson (ed.); Geological Survey of Canada, Open File 3228, p. 29-37.

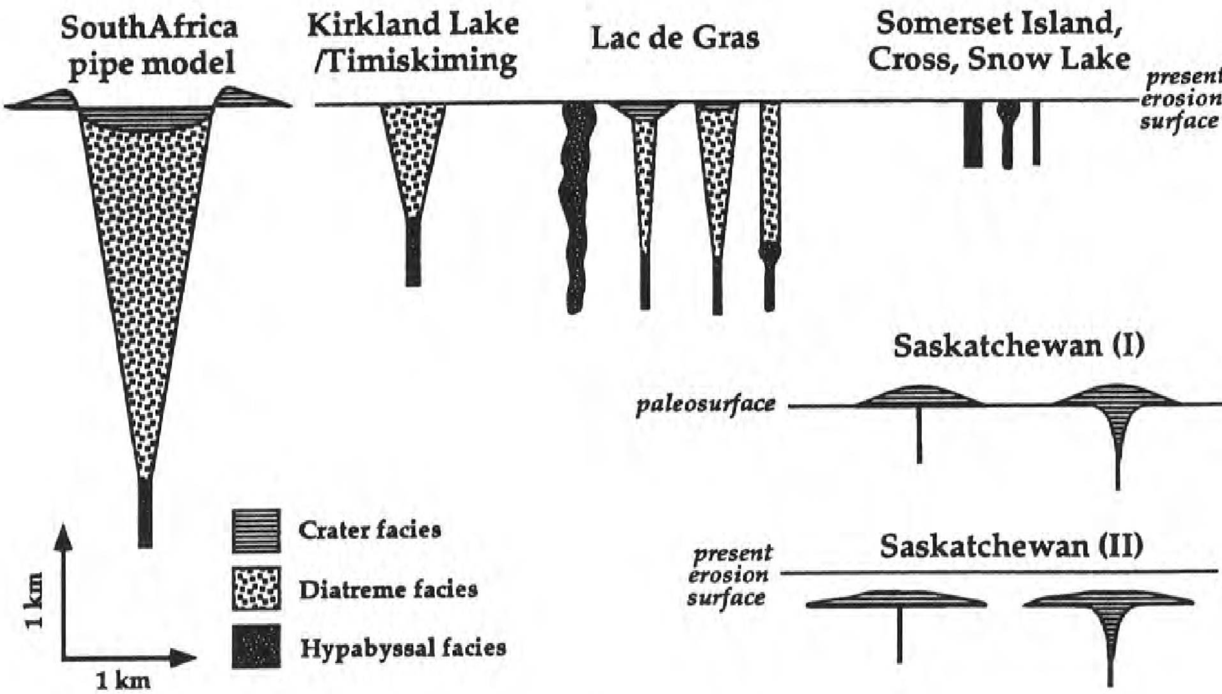

***Figure 3.** Variation in morphology of kimberlite pipes in Canada, as compared to the classic South African type pipe. Note that kimberlite pipes in Kirkland Lake/Timiskiming (diatreme facies) and Somerset Island/Cross/Snow Lake (hypabyssal facies) are interpreted as South African type pipe which have been variably eroded. In contrast, many of the Lac de Gras area pipes are 'miniature' versions of the classic South African type pipe, a morphology which is also observed in Yakutia. The central Saskatchewan kimberlites form tephra cones, with or without associated underlying vents (Saskatchewan I). Subsequent marine transgression, reworking and burial produces the present day 'pancake' or sheet-like morphology (Saskatchewan II).*

modified R. Haimila 2007

Physical Characteristics of Canadian Kimberlites

T.J. Katsube and B.A. Kjarsgaard

Katsube, T.J. and Kjarsgaard, B.A., 1996: Physical Characteristics of Canadian Kimberlites; in Searching for Diamonds in Canada, A.N. LeCheminant, D.G. Richardson, R.N.W. DiLabio, and K.A. Richardson (ed.): Geological Survey of Canada, Open File 3228, p. 241-242.

INTRODUCTION

Physical properties (e.g., density, porosity, resistivity, magnetic susceptibility) of 41 kimberlite samples from the Northwest Territories, Saskatchewan (Fort à la Corne and Sturgeon Lake), and Ontario have been measured (Katsube et al., 1992; Katsube and Scromeda, 1994; Scromeda et al., 1994) to obtain information on physical processes involved in an intruding kimberlite. This information is necessary to understand geophysical signatures to be expected from kimberlite pipes, and for development of geophysical methods with improved detecting capabilities below overburden, a requirement for geophysical exploration of kimberlite-hosted diamond pipes in central and northern Canada. While some kimberlite physical property data exist (e.g., da Costa, 1989), they are insufficient. This study includes, probably for the first time, physical properties related to the kimberlite facies: hypabyssal (HB), diatreme (DT), and crater (CR) facies kimberlites. This paper discusses the topics and progress being made in the GSC kimberlite physical property studies.

RESULTS

The results indicate that the physical properties are closely related to the kimberlite facies classification: hypabyssal (HB) and crater (CR) facies. They show that some kimberlites have electrical resistivity (ρ_r) values of 1000 to 60000 Ωm, indicating probably for the first time, that there are kimberlites with ρ_r above 500 Ωm. The pore structure differences result in the two groups of kimberlites (HB and CR) showing distinctly different physical properties. HB-kimberlites are characterized by high bulk density (δ), electrical resistivity (ρ_r), and formation factor (F) values, and low effective porosity (ϕ_E) values, resulting from poor pore inter-connectivity. CR-kimberlites are characterized by low δ, ρ_r and F values and high ϕ_E values, resulting from good pore inter-connectivity. Examples of these differences for δ and ρ_r are displayed in figures 1 and 2. Magnetic susceptibility (MS) is unrelated to pore structure, and thus shows no relation to the kimberlite facies. However, within each of the HB and CR kimberlite facies the relatively good relationship that exists between ρ_r and MS varies with the kimberlite facies, as shown in figure 2.

These studies may provide some guidance to geophysical signatures of importance for kimberlite identification and economic significance. Although, kimberlites display both high and low ρ_r and MS (Fig. 2), there may be cases where high ρ_r and MS are less likely to be related to diamonds.

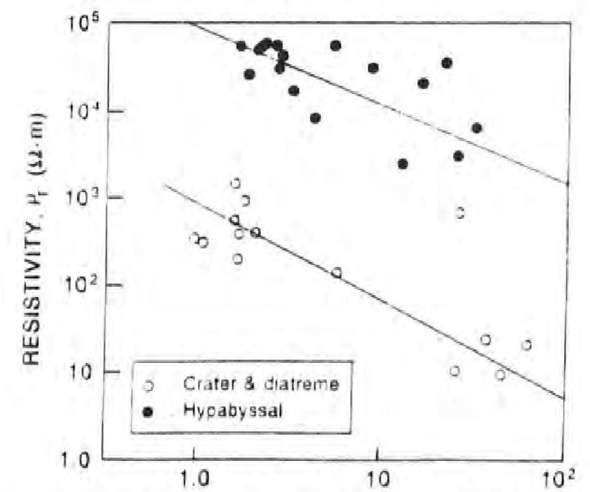

Figure 2: Bulk electrical resistivity (ρ_r) as a function of magnetic susceptibility (MS), showing two distinct groups: one for the hypabyssal (HB) kimberlites and the other for the diatreme/crater (DT/CR) kimberlites.

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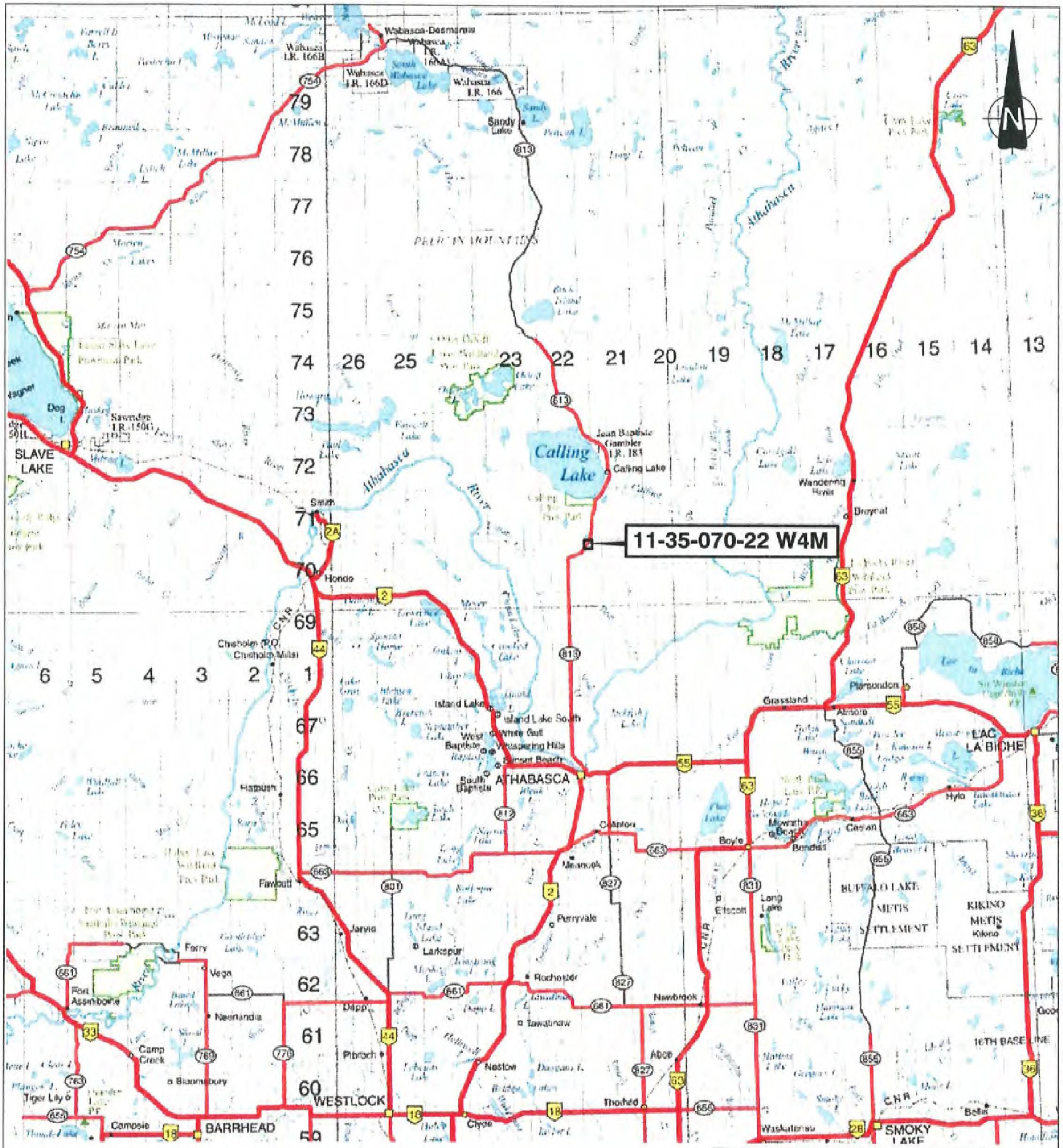
4



SOURCE: ALBERTA PROVINCIAL BASE MAP, ORIGINAL SCALE 1:1,000,000

0 10 20 30 40 50 km

SCALE 1 : 1,000,000

Environment & Water Resources

HALMCO INC.

ERT SURVEYS FOR KIMBERLITE EXPLORATION

CALLING LAKE, ALBERTA 11-35-070-22 W4M

SITE LOCATION

WorleyParsons Komex

resources & energy

June 26-29 date 2007	edited by	MJC/OTHERS drawn by	app by	PROJECT NUMBER: C66630000	FIGURE: 1

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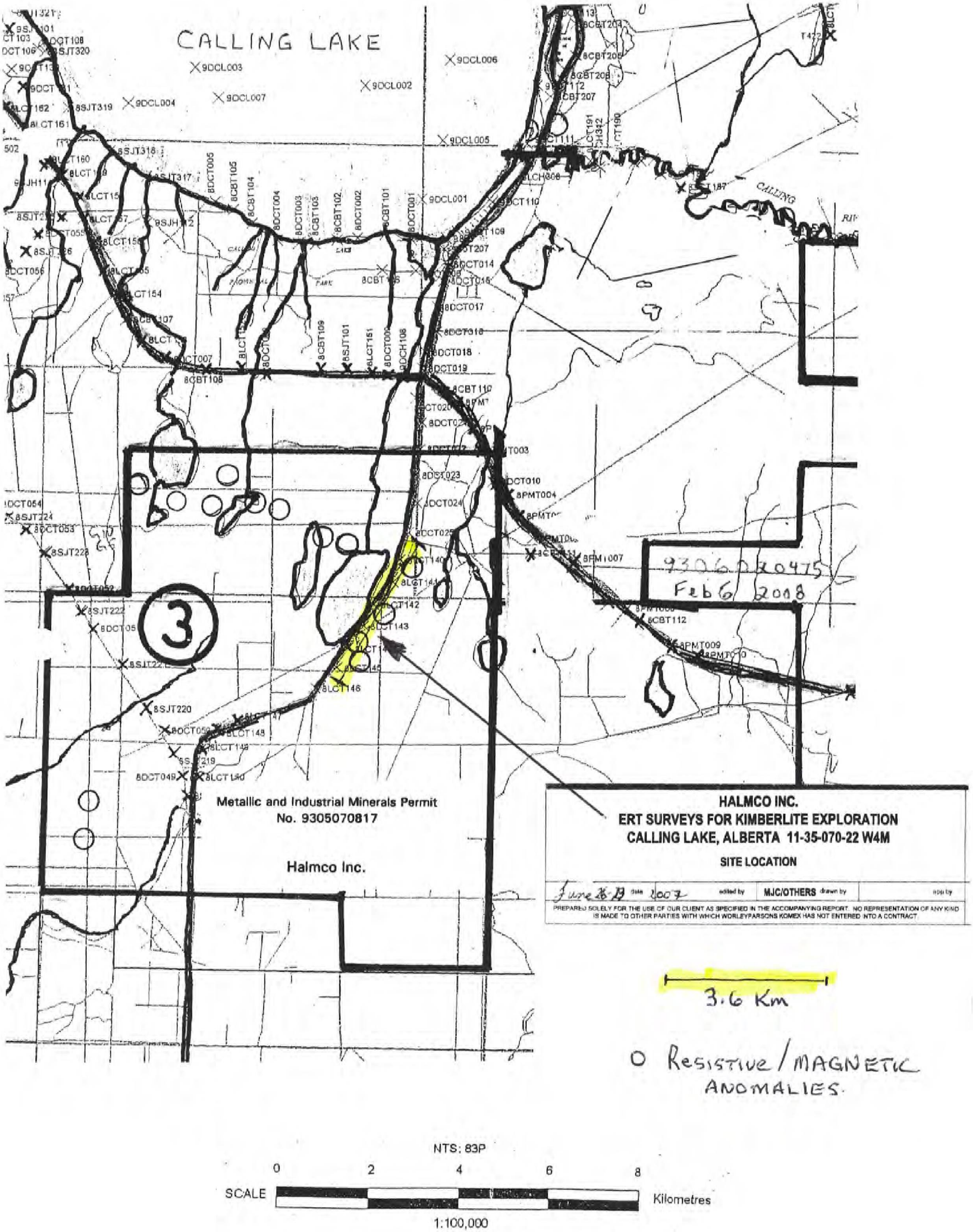

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Feb 6 2008
Metallic and Industrial Minerals Permit
No. 9305070817
Halmco Inc.
HALMCO INC.
ERT SURVEYS FOR KIMBERLITE EXPLORATION
CALLING LAKE, ALBERTA 11-35-070-22 W4M
SITE LOCATION
June 26-29 date 2007 edited by MJC/OTHERS drawn by app by
PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH WORLEYPARSONS KOMEX HAS NOT ENTERED INTO A CONTRACT.
3.6 Km
O Resistive / MAGNETIC ANOMALIES.
NTS: 83P
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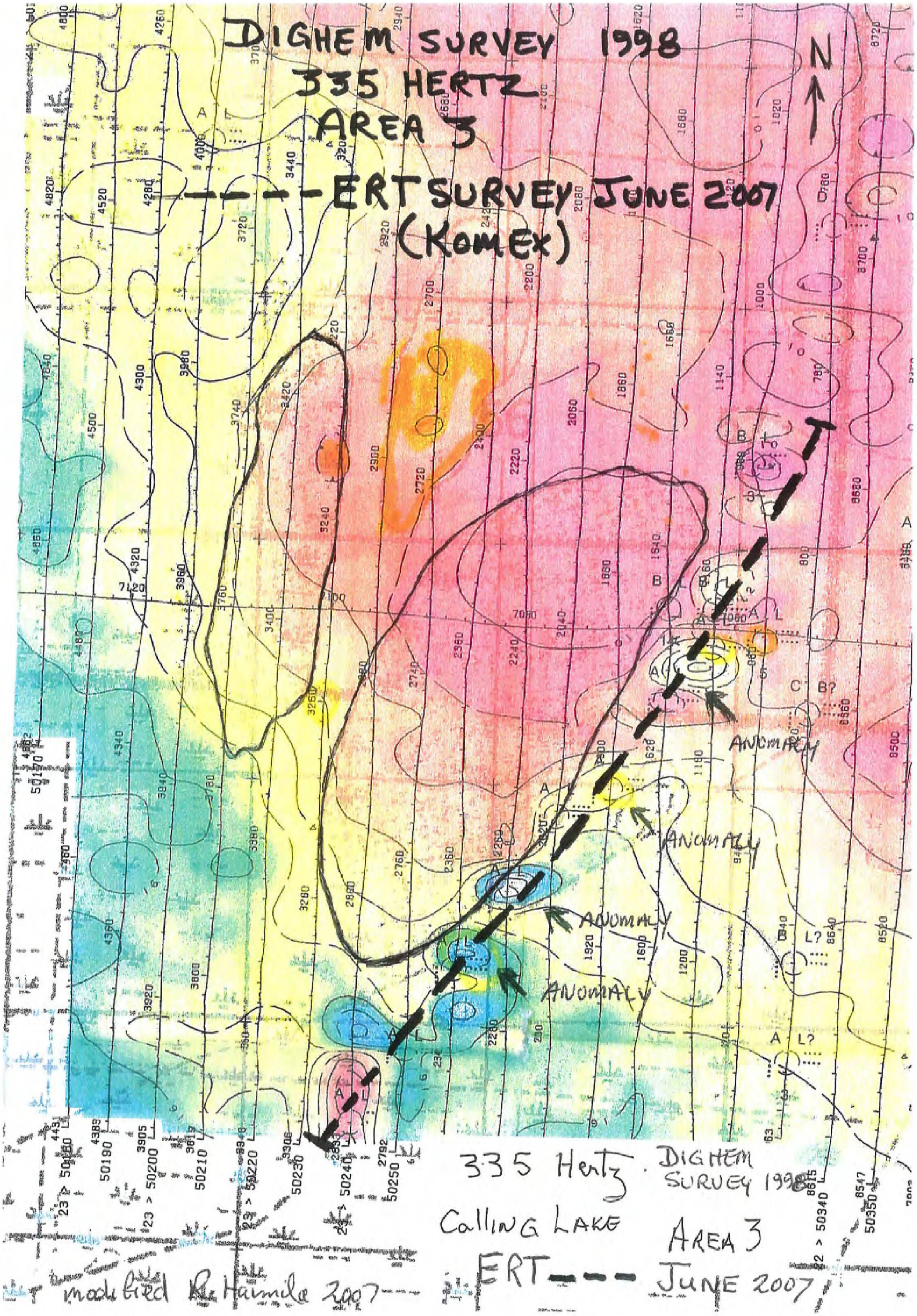

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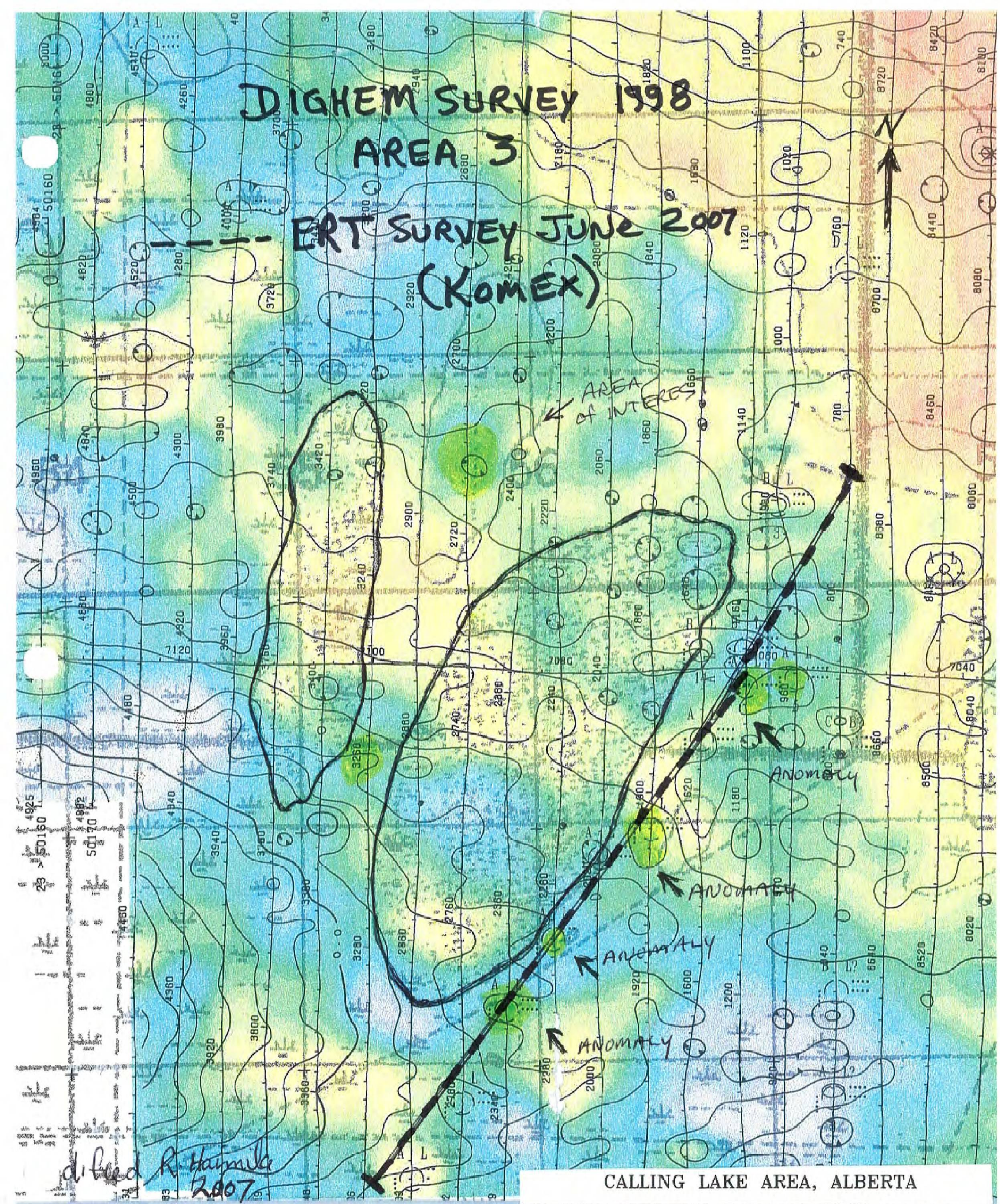
Calling LAKE
AREA 3
ERT JUNE 2007
modified R. Haimila 2007



CALLING LAKE AREA, ALBERTA

COLOURED 7200 Hz DIFFERENTIAL RESISTIVITY with CALCULATED VERTICAL GRADIENT MAGNETIC CONTOURS

ERT---(AREA 3) JUNE 2007
DIGHEM SURVEY 1998

PRIORITY AREA 3
AIR PHOTO SURVEY JUNE 2007

West

South

LOCATION of MAGNETIC LOW ANOMALY --
LOOKING for ACCESS for ERT SURVEY for
FALL of 2007

5

ACTUAL EXPENDITURE STATEMENT OF WORK BREAKDOWN

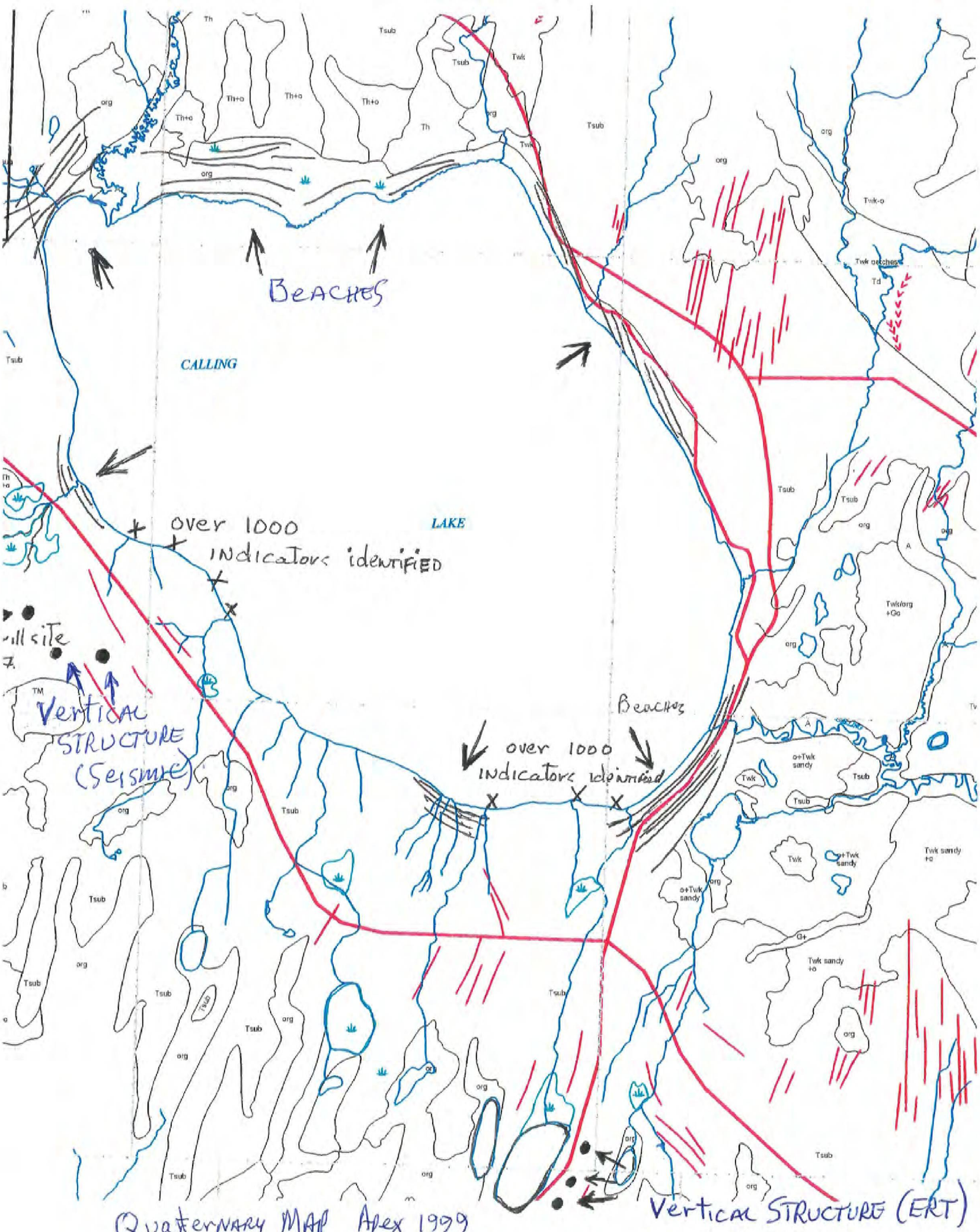
	AMOUNT SPENT
1. Prospecting	$
2. Geological mapping & petrography	$ 3,200.00
3. Geophysical Surveys	
a. Airborne	$
b. Ground	$ 33,550.00
4. Geochemical Surveys	$
5. Trenching and Stripping	$
6. Drilling	$
7. Assaying & whole rock analysis	$
8. Other Work Report Costs for Mineral Permit 9305070817	$ 1,400.00
SUBTOTAL	$ 38,150.00
9. Administration (10% of subtotal)	$ 3,815.00
TOTAL	$ 41,965.00

[redacted]
SIGNATURE

August 6 2007
DATE

Raymond Haimila
PRINT NAME

6



Quaternary Map Apex 1999
modified R. Haimila 2007.

MAP A for HALMCO INC.
Legend
The MAJOR TREND >3 SITES
SAMPLE WITH MULTIPLE DIAMOND INDICATOR MINERALS OF EXCELLENT QUALITY
Northern cut-off to the highly anomalous DIAMOND INDICATOR SITES located along the south shore of Calling Lake and the sites (diamond discovery) on the Calling River East.
The potential to discover a diamondiferous intrusive in the east Calling River and Calling Lake area of Alberta is significantly high.
Previous exploration of these areas (up-ice drilling and sampling) appears to provide a Northern cut-off to the highly anomalous DIAMOND INDICATOR SITES located along the south shore of Calling Lake and the sites (diamond discovery) on the Calling River East.
These anomalous diamond indicator sites are.significant in that they include diamond inclusion quality chrome diopsides, diamond inclusion eclogitic garnets, high magnesium picroilmenites, diamond inclusion olivines, a complete suite of pyrope garnets (GI to G12) including 65 Gurney G10 garnets, and a gem quality macro diamond—as well as significant diamond inclusion chromites.
Drainage and culture
river, stream, creek
major river
lake, pond
road, cutline
pipeline
major road
Sample locations
8SJH100 sample location with identifier
year collected
collectors initials
sample type
sample type: T = glacial till or beach sand
H = stream heavy mineral concentrate
L = lake bottom sediment
Map information - Tectonic Domains-Alberta
This map was produced using digital Alberta resource access maps (NTS 83P). Map projection is Universal Transverse Mercator, datum is NAD 27, zone 12. Map grid is township and range, west of the 4th meridian.
Location of Mineral Permits
GSL
STZ
1992 Central Transect
1994 Peace River Arch survey
1994 Petrel Forestry Trunk Road survey
1995 SALT program
Reprinted from Lithoprobe #47 (1995)
C = Chinchaga
T = Thorsby
Supracrustal ?
L = Locombe
STZ = Snowbird Tectonic Zone (Transcontinental Archean Shear Zone)
GSL = Great Slave Lake shear zone
Geologic boundaries
Cardium oilfields
Fig. 1. Tectonic domains of the Alberta basin (after Ross et al., 1989 GSC Open File rep. 2103) with LITHOPROBE transect lines and Cardium oilfields superimposed
Location map for Calling Lake Property
35 Km East-West Trend of Diamond Indicators
Undefined Zone
Claim Area
Buffalo Head Terrane
Talston Arc
STZ
Rimbey Arc
Wabamum Terrane
Thorsby Low
Reprinted from Geological Survey of Canada Bulletin 447 (1993)
Alberta Aeromagnetic Anomaly Map
Revised 2005-Haimila
Calling Lake
SAMPLE LOCATIONS
NTS: 83P
SCALE 0 2 4 6 8 Kilometres
1:100,000
APEX Geoscience Ltd.
Edmonton, Alberta, Canada
December, 1999
356 000 mE
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RANGE 24
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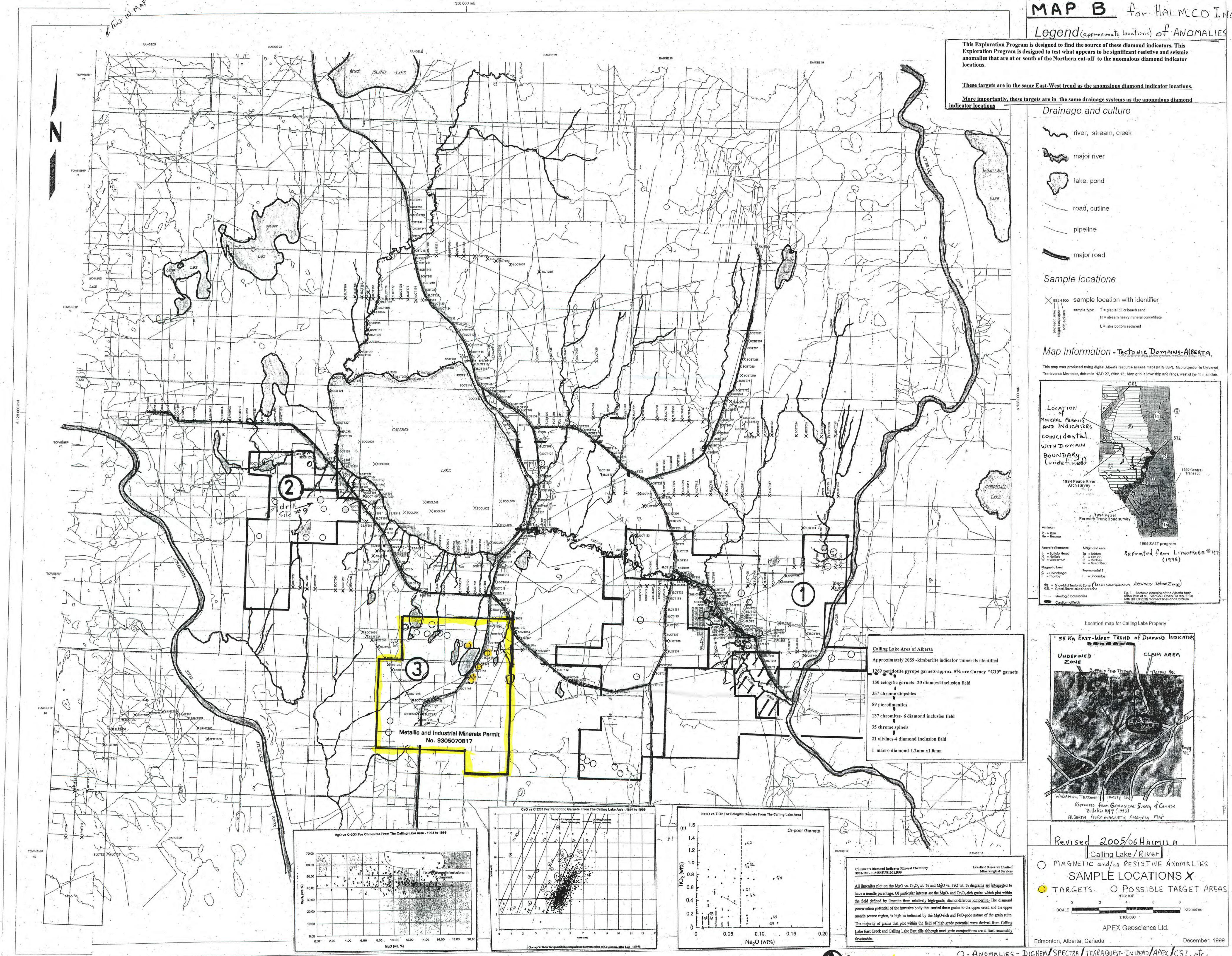
RANGE 20
RANGE 19
RANGE 18
TOWNSHIP 75
TOWNSHIP 74
TOWNSHIP 73
TOWNSHIP 72
TOWNSHIP 71
TOWNSHIP 70
N
FOLD IN MAP
ROCK ISLAND LAKE
ORLOFF LAKE
CALLING LAKE
MCMILLAN LAKE
CORRIGALL LAKE
ATHABASCA RIVER
Calling Lake Area of Alberta
Approximately 2059 -kimberlite indicator minerals identified
1269 peridotite pyrope garnets-approx. 5% are Gurney "G10" garnets
150 eclogitic garnets- 20 diamond inclusion field
357 chrome diopsides
89 picroilmenites
137 chromites- 6 diamond inclusion field
35 chrome spinels
21 olivines-4 diamond inclusion field
1 macro diamond-1.2mm x1.0mm
MgO vs Cr2O3 For Chromites From The Calling Lake Area - 1994 to 1999
Field of chromite inclusions in diamond
CaO vs Cr2O3 For Peridotitic Garnets From The Calling Lake Area - 1994 to 1998
Na2O vs TiO2 For Eclogitic Garnets From The Calling Lake Area
Cr-poor Garnets
Comments Diamond Indicator Mineral Chemistry
8901-180 - LIMS#JUN1001.R99
Lakefield Research Limited
Mineralogical Services
All ilmenites plot on the MgO vs. Cr2O3 wt. % and MgO vs. FeO wt. % diagrams are interpreted to have a mantle parentage. Of particular interest are the MgO- and Cr2O3-rich grains which plot within the field defined by ilmenite from relatively high-grade, diamondiferous kimberlite. The diamond preservation potential of the intrusive body that carried these grains to the upper crust, and the upper mantle source region, is high as indicated by the MgO-rich and FeO-poor nature of the grain suite. The majority of grains that plot within the field of high-grade potential were derived from Calling Lake East Creek and Calling Lake East tills although most grain compositions are at least reasonably favourable.



HALMCO'S MINERAL PERMIT 3 PRIORITY AREA O- ANOMALIES - DIGHEM/SPECTRA/TERRAQUEST-INTREPID/APEX/CSI, etc.

WorleyParsons Komex

resources & energy

AUG 0 9 2007

20070022

PART C

OF HALMCO INC'S ASSESSMENT REPORT

MINERAL PERMIT 9305070817

SUBMITTED AUGUST 8, 2007

ERT Survey for Kimberlite Exploration

Calling Lake, Alberta

C66630000

7 July 2007

Environment & Water Resources

Suite 100, 4500 – 16 Avenue NW
Calgary, AB T3B 0M6 Canada
Telephone: +1 403 247 0200
Toll-Free: 1 800 668 6772
Facsimile: +1 403 247 4811
worleyparsons.com

WorleyParsons Komex

resources & energy

HALMCO INC.

ERT SURVEY FOR KIMBERLITE EXPLORATION

CALLING LAKE, ALBERTA

PROJECT C66630000 - ERT SURVEY FOR KIMBERLITE EXPLORATION

FILE LOC.: CALGARY

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
Draft	Issued for review	C. Pooley	P. Bauman	P. Bauman	03-Jul-2007		
Final	Issued for review	C. Pooley	P. Bauman	P. Bauman	05-Jul-2007		

Disclaimer

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Any questions concerning the information or its interpretation should be directed to Paul Bauman or Chris Pooley at 403-247-0200.

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Figures

Appendices

1. INTRODUCTION

Halmco Incorporated (Halmco) retained WorleyParsons Komex to conduct a geophysical survey in the Calling Lake area to attempt to map vertical structures in the subsurface. A number of magnetic anomalies were previously identified in this area and were subsequently selected by Halmco as potential targets to be further characterized by electrical resistivity tomography (ERT). This report outlines the ERT survey completed, and reports on the results of the survey.

2. SURVEY CONTROL

Geophysical survey control was established using a Trimble GeoXT handheld Global Positioning System (GPS) unit. This unit has sub-meter positional accuracy. The positions of the ERT profiles and the boreholes were gathered with this unit. All positions are presented in Universal Transverse Mercator (UTM) coordinates, referenced to North American Datum 1927 (NAD27), Zone 12, North. All elevations are presented in meters above the ellipsoid.

3. GEOPHYSICAL FIELD SURVEY

3.1 Electrical Resistivity Tomography (ERT)

One ERT line was surveyed in this program. A Wenner array with a minimum electrode separation of 22.5 m was utilised for this survey, providing a maximum depth of imaging of approximately 300 meters below ground surface (mbgs).

ERT data are presented as a colour shaded cross-section, extending from the ground surface at a maximum depth of 300 mbgs, as noted above. Resistivity values are presented using the units of ohm-meters (ohm-m). Warm colours (pinks and reds) represent higher resistivity values, and cool colours (greens and blues) represent lower resistivity values. Topography has been included in the profile, and all processing has included correction factors to take into account geometric effects caused by the elevation differences along the section.

4. GEOPHYSICAL RESULTS

4.1 ERT Line 1

ERT Line 1 was acquired parallel to Highway 813, near Calling Lake, Alberta (Figure 1). The ERT line was positioned so as to pass over a number of anomalies that were identified by Halmco Inc. The approximate locations of the anomalies are marked on the ERT section (Figure 2). The upper 100 meters of the section is composed of relatively resistive material. A strong horizontal resistivity contrast has been marked on the section, and this is interpreted to be the top of bedrock. There are a number of locations where some vertical structures can be noted, mainly between line positions 750 m and 1750 m, between line positions 1950 m and 2250 m and between line positions 2700 m and 2850 m.

Between line positions 1775 m and 1875 m, a discrete lower resistivity anomaly was imaged. There was a water-filled borrow pit located adjacent to the ERT line, which may have had an affect on the data. The distance from the borrow pit was small as compared to the electrode spacing, so off-line effects may cause an anomaly to appear in the data. It is also possible that due to the location of this anomaly, the top being at 50 mbgs, this could in fact be a real feature. Intrusive investigations in the form of drilling would be recommended to more fully characterize this anomaly.

5. CLOSURE

We trust that this report satisfies your current requirements and provides suitable documentation for your records. If you have any questions or require further details, please contact the undersigned at any time.

Report Prepared by
WorleyParsons Komex

[redacted]

Chris Pooley, B.Sc., Geoph.I.T.

Junior Geophysicist

Senior Review by

PROFESSIONAL ENGINEER
PAUL D. BAUMAN
ALBERTA

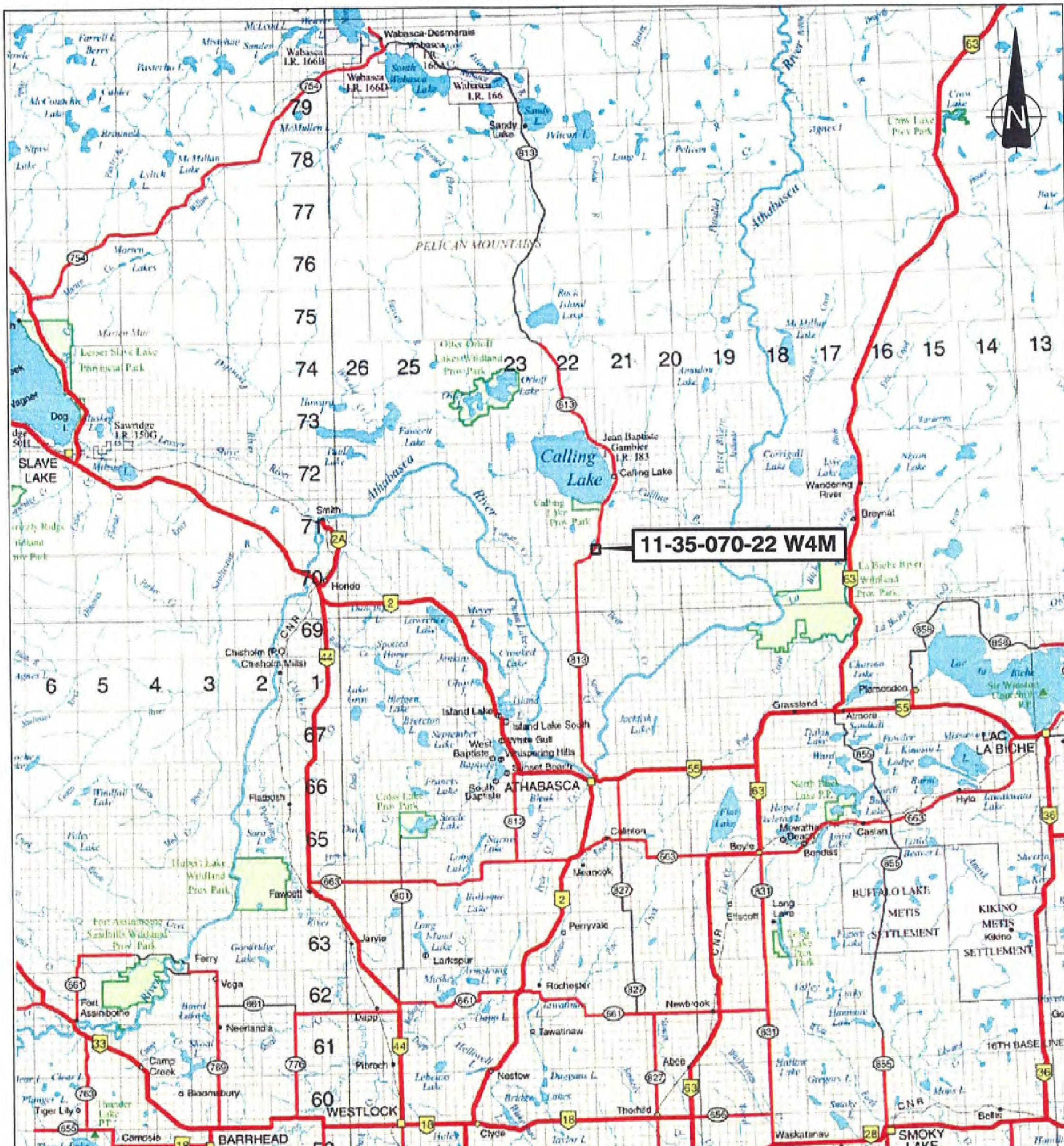
Paul Bauman, B.Sc., P.Eng., P.Geoph.

Principal Geophysicist

PERMIT TO PRACTICE
WORLEYPARSONS CANADA LTD.
Signature
Date July 7, 2007
PERMIT NUMBER: P[illegible]
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

FIGURES

Figures



SOURCE: ALBERTA PROVINCIAL BASE MAP, ORIGINAL SCALE 1:1,000,000

Environment & Water Resources

HALMCO INC. ERT SURVEYS FOR KIMBERLITE EXPLORATION CALLING LAKE, ALBERTA 11-35-070-22 W4M SITE LOCATION	WorleyParsons Komex resources & energy
July 7, 2007 date · - · edited by · MJC/OTHERS drawn by · CY · app by	PROJECT NUMBER: C66630000 · FIGURE: 1

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FILE: J:\66630000\SiteLoc.dwg Issued By: Calgary CAD

This is a PDF 8x11

FIELD PARAMETERS:
Data Collected: June 2007
Electrode Configuration : Wenner Array
Electrode Spacing: 22.5 m

Scale 1:2500

50 0 50 100 150
(meters)

Environment & Water Resources

HALMCO INC.
ERT SURVEYS FOR KIMBERLITE EXPLORATION
CALLING LAKE, ALBERTA
ELECTRICAL RESISTIVITY TOMOGRAPHY
RESISTIVITY CROSS-SECTION

WorleyParsons Komex
resources & energy

03-07-07 date	C.J.P. edited by	C.J.P. drawn by	Approved	PROJECT NUMBER: C66630000	FIGURE: 2

PREPARED SOLEY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH WORLEYPARSONS KOMEX HAS NOT ENTERED INTO CONTRACT.
FILE: J: C66630000 Geophysics ERT ERTLine#.map

APPENDIX 1

Appendix I Geophysical Methodology

ELECTRICAL RESISTIVITY TOMOGRAPHY

ERT is a technique for mapping the distribution of subsurface electrical resistivity (or its inverse, conductivity) in a cross-sectional format. Resistivity data are collected through a linear array of 61 electrodes coupled to a DC resistivity transmitter and receiver, and an electronic switching box. Data collection is carried out in a sequential and automated fashion that takes advantage of all possible combinations of current and measure electrodes. The data are downloaded to a computer for processing and analysis. The data are inverted using a 2-D finite difference or finite element inversion routine. The final product is a two-dimensional cross-section plotting resistivity (in ohm-m) versus depth.