083623

GEOCHEMICAL ASSESSMENT REPORT

on the

EL CLAIM GROUP

of

BENACHEE RESOURCES INC.
and
SNOWPIPE RESOURCES LTD.

November 17, 1993- November 16, 1995

MARA RIVER AREA,
NTS 76K/1, 2, 7, 8
66° 21' N, 108° 31' W
DISTRICT OF MACKENZIE,
NORTHWEST TERRITORIES

by

Rodney W. Arnold, P. Geo.

CANAMERA GEOLOGICAL LTD.
540 - 220 Cambie Street
Vancouver, B.C.

February 15, 1996

Volume 1 of 2

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SUMMARY

The property has undergone at least two major episodes of glaciation that scoured the terrain and deposited a layer of till. Exploration for kimberlite pipes has consisted primarily of glacial till sampling in search of a specific assemblage of minerals associated with kimberlites. These samples are processed and examined for traces of these minerals whose chemical composition distinguishes them as unique to an upper mantle origin. The geographical positions of these indicator minerals in the glacial dispersion train are noted and followed "up-ice" to the kimberlite source. Airborne magnetics and EM surveys are also used in conjunction with sampling to pinpoint various geophysical responses associated with weathered pipe structures.

Exploration of the property consisted of the collection of 281 till taken at varying densities along sample lines that traverse the property at roughly a SW-NE orientation. The initial work provided some encouragement so additional sampling was carried out in specific areas throughout the property as well as 3088.7 line kilometers of airborne geophysics to partially meet assessment requirements and to assist in evaluation of the property.

The report is composed of two volume; Volume 1 details the geochemical work including maps, figures and results; and Volume 2 contains the geophysical report and maps for thework done on the property during this time period.

INTRODUCTION

The Slave Structural Province of the Northwest Territories is an Archean segment of the North American Craton. It is underlain by metasedimentary and metavolcanic rocks of the Yellowknife Supergroup and by Archean granites and gneisses. The discovery of diamonds in the Lac de Gras region through the geochemical tracking of kimberlitic indicator minerals provided the impetus for a rush of exploration activity. Many junior companies staked out large land positions and carried out detailed geochemical exploration programs. Benachee Resources Inc. and Snowpipe Resources Ltd. were among the early participants in this activity through the staking of several properties including the EL property.

Location and Access

The EL claims are located in the Mackenzie District of the Northwest Territories (Figure 1). The center of the EL claims is located at 66° 21' N; 108° 31' W., about 130 kilometers east-northeast of the north end of Contwoyto Lake and 45 kilometers southwest of Bathurst Inlet. The junction of the Hackett and Mara rivers is located near the southern boundary of the claims; through the central and northern parts, the Mara River roughly bisects the property. The center of the property lies 225 kilometers north-northeast of Lac de Gras, and 517 kilometers N34°E of Yellowknife.

During the winter the area is accessible by ski-equipped aircraft, while in the summer, lakes suitable for float-equipped aircraft may be used for transportation of men and supplies. Larger aircraft can land on the 6000 foot gravel runway at the Lupin mine site, approximately 140 kilometers S61°W of the claim block center.

The Echo Bay Mines' winter road, which links Yellowknife to the Lupin mine site along Contwoyto Lake, runs approximately 135 kilometers bearing N61°E from the center of the EL property.

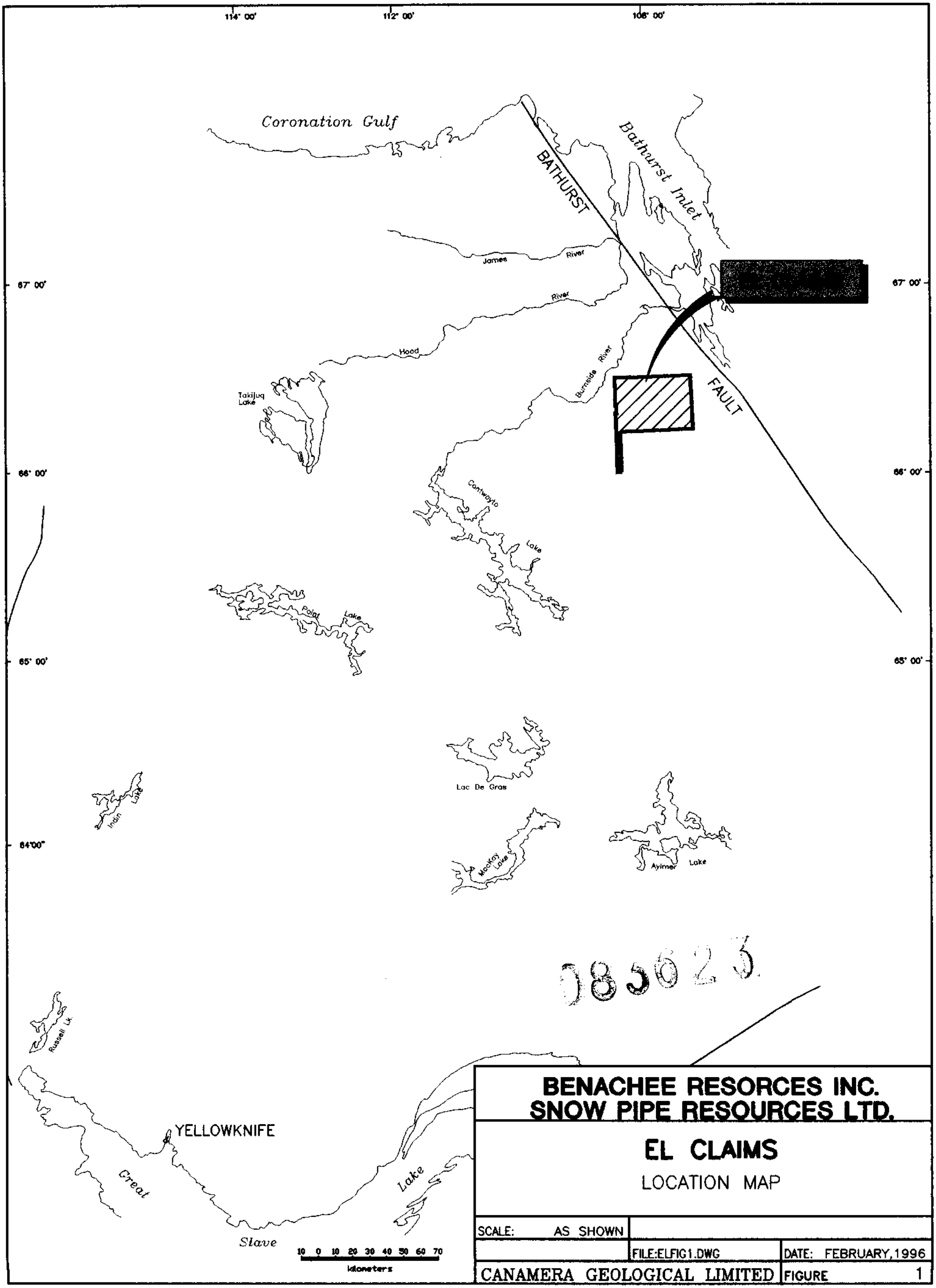
Topography And Climate

The EL property is located on the treeless tundra of the barren grounds, immediately south of the Arctic Circle with the claim center lying 16 kilometers south. Rolling rocky hills and ridges with numerous small lakes and low lying swampy muskeg dominate much of the property, especially in the south. The northern part of the claim block is marked by moderately steep to steep slopes (100 plus meters elevation changes) extending from gently rolling hills down to the Mara River. Local relief varies from 315 meters in the south to 594 meters above sea level near the northern claim boundary.

Climatic conditions on the barren grounds are extreme. Winter temperatures reach -45 degrees Celsius occasionally accompanied by high winds creating extreme wind chill conditions and extensive drifting snow; summer temperatures can reach the high 20's Celsius. However, the weather is highly variable and storms can occur at any time of the year. Average annual snowfall rarely exceeds 1 meter, most of which falls during autumn and spring storms.

During September and June, freeze-up and break-up restrict access to the property to helicopter only.

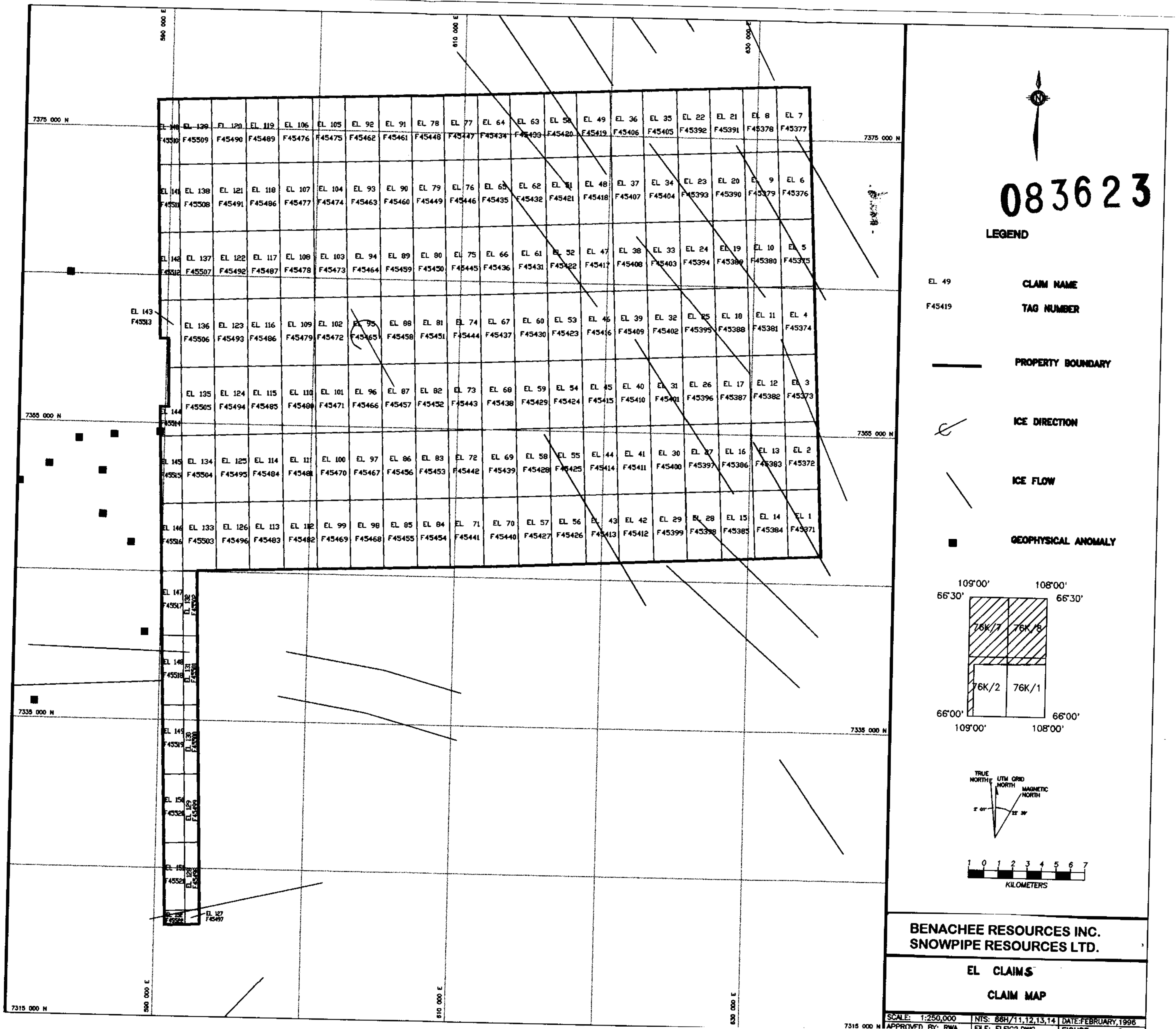
With the onset of summer, black flies and mosquitoes infest all areas of the barren grounds. Other local wildlife includes caribou, musk oxen, Arctic wolves, Arctic foxes, barren ground grizzlies, wolverines, Arctic hares and ptarmigan. Lake trout and Arctic char abound in the local lakes and rivers.


114° 00'
112° 00'
108° 00'
67° 00'
66° 00'
65° 00'
64°00"
Coronation Gulf
Bathurst Inlet
BATHURST
FAULT
James River
Hood River
Burnside River
Takijuq Lake
Contwoyto Lake
Point Lake
Lac De Gras
Indin Lake
MacKay Lake
Aylmer Lake
Russell Lk
YELLOWKNIFE
Great Slave Lake
10 0 10 20 30 40 50 60 70
kilometers
083623
BENACHEE RESOURCES INC.
SNOW PIPE RESOURCES LTD.
EL CLAIMS
LOCATION MAP
SCALE: AS SHOWN
FILE:ELFIG1.DWG
DATE: FEBRUARY,1996
CANAMERA GEOLOGICAL LIMITED
FIGURE 1

Claim Status

The EL property comprises 152 claims totaling 368,511.08 acres (Figure 2, Drawing 1). The EL block is a rectangular shaped block 32 kilometers north by 45 kilometers east.

The statement of exploration expenditures is listed in Appendix 1. A complete list of claim information is attached in Appendix 3.


083623
LEGEND
EL 49 CLAIM NAME
F45419 TAG NUMBER
PROPERTY BOUNDARY
ICE DIRECTION
ICE FLOW
GEOPHYSICAL ANOMALY
109°00' 108°00'
66°30' 66°30'
76K/7 76K/8
76K/2 76K/1
66°00' 66°00'
109°00' 108°00'
TRUE NORTH
UTM GRID NORTH
MAGNETIC NORTH
KILOMETERS
7375 000 N
7355 000 N
7335 000 N
7315 000 N
590 000 E
610 000 E
630 000 E
BENACHEE RESOURCES INC.
SNOWPIPE RESOURCES LTD.
EL CLAIMS
CLAIM MAP
SCALE: 1:250,000
NTS: 86H/11,12,13,14
DATE:FEBRUARY,1996

GEOLOGY

Introduction

The EL property straddles the southwestern edge of the Proterozoic (Aphebian) Kilihigok Basin and the Slave Structural Province near Bathurst Inlet. The Slave Structural Province (Figure 3) is an Archean granite-greenstone terrain containing belts of 2.70 to 2.67 Ga metasedimentary and metavolcanic rocks that were intruded extensively by syn- to post-volcanic granitic plutons between ca. 2.70 and 2.58 Ga (Relf, 1992). Proterozoic rocks underlie approximately 65% of the property.

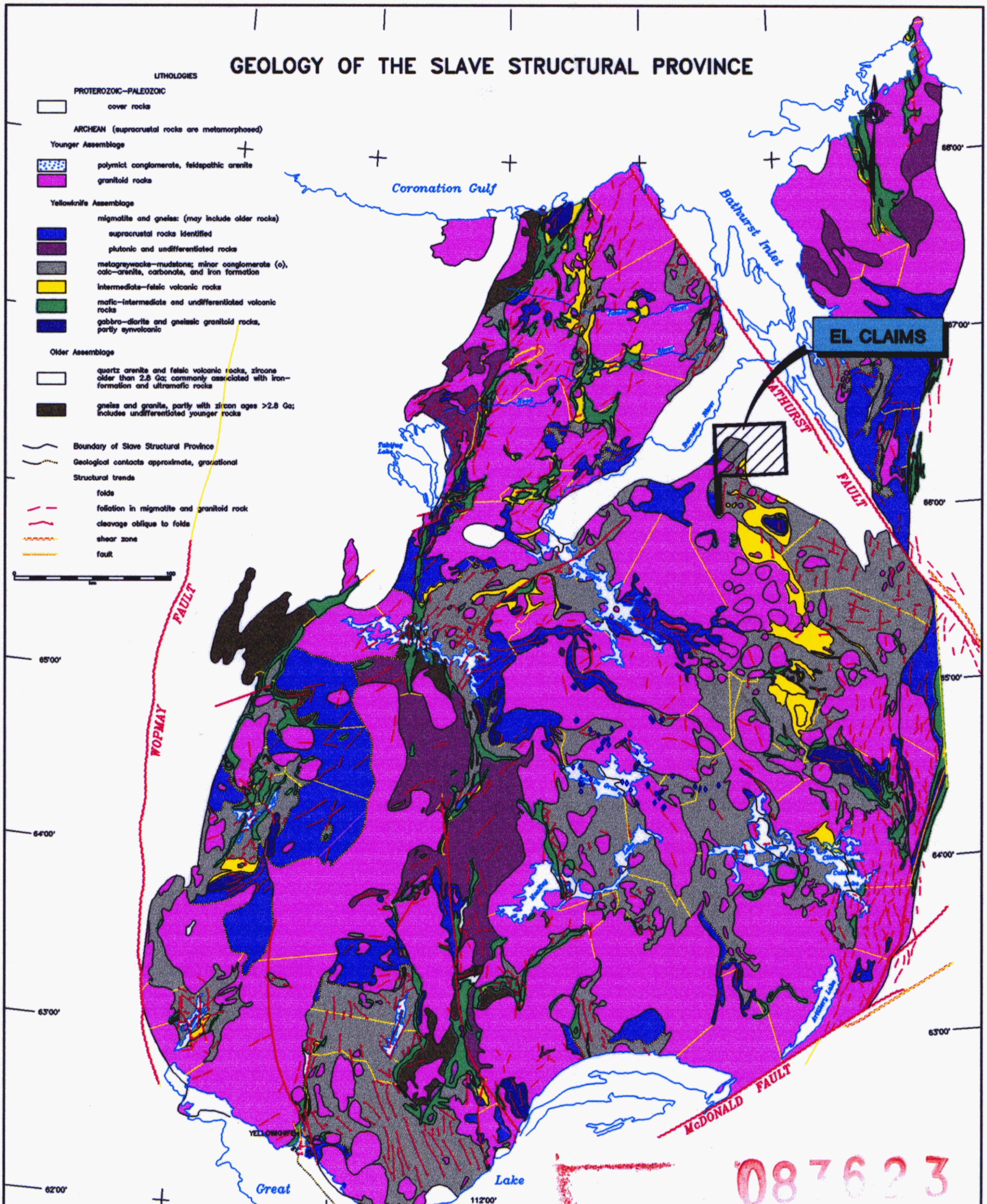
Archean Geology

Archean rocks within the Slave Structural Province are located between Great Slave Lake to the south and Coronation Gulf to the north. The Archean rocks are overlain by Proterozoic strata of the Wopmay Oregon on the west. Along the eastern edge, the province is roughly delineated by: the early Proterozoic Thelon deformation and metamorphic zone, the western edge of the Proterozoic deformation between the Bathurst and McDonald faults and the eastern limit of Archean migmatites (Fyson and Padgham, 1993).

Rocks within the Slave Structural Province are assigned to three lithotectonic assemblages identified as: an early assemblage of gneisses, granitic rocks and quartz arenites; Yellowknife Supergroup greywackes, mudstones, volcanic rocks and synvolcanic intrusions; and a younger sedimentary-plutonic assemblage of clastic sediments and granitic rocks. Approximately two-thirds of the province is underlain by post-Yellowknife Supergroup granitic rocks. Deformation and greenschist to amphibolite facies metamorphism affect all volcanic and sedimentary rocks (Fyson and Padgham, 1993).

Early Pre-Yellowknife Supergroup Assemblage

The early assemblage of pre-Yellowknife Supergroup rocks generally occurs west of 112° west, along the western edge of the Yellowknife supracrustal domain and between Point Lake and Coronation Gulf. It contains two groups: granites and gneisses of variable composition (tonalitic gneiss to potash granite), and a quartz arenite-felsic volcanic group. The quartz arenite-felsic volcanic association also includes distinctive magnetite iron formations and ultramafics and appear to be intimately tied to granitic basement rocks (Fyson and Padgham, 1993).



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BENACHEE RESOURCES INC.
SNOWPIPE RESOURCES LTD.

EL CLAIMS
REGIONAL GEOLOGY

Modified from Fyson & Padgham 1993–8

SCALE: AS SHOWN		DATE: FEBRUARY, 1996
APPROVED BY: RWA	FILE: ELFIG3.DWG	FIGURE NO. 3

Yellowknife Supergroup

The Yellowknife supracrustal-plutonic assemblage consists of three distinct assemblages: granitie and gneisses; volcanic and metasediments; and interbedded turbidites. In the Point Lake - Contwoyto Lake area, the Yellowknife Supergroup is comprised of five formations: two distinct belts of metavolcanic rocks known as the Point Lake Formation and the Central Volcanic Belt; metaturbidites of the Contwoyto and Itchen formations; and conglomerates and related clastic sedimentary rocks of the Keskarrah Formation.

Subvolcanic Rocks

This subdivision consists of foliated gabbroic, granitic and gneissic rocks and have a field relationship which infers that older rocks may be included within this group. There are however, radiogenic ages (2.7 - 2.65 Ga) suggesting that part of the group is synvolcanic with supracrustal rocks included with the Yellowknife Supergroup (Fyson and Padgham, 1993).

Metavolcanic Rocks

Volcanic belts within the Yellowknife Supergroup display a wide variation in composition - basaltic to rhyolitic, and appear in most volcanic belts within the assemblage. Dikes, sills and larger bodies (gabbroic and felsic) have intruded the volcanics. Volcanogenic sandstones, conglomerates, and iron formations occur as thin sedimentary units within the volcanics (Fyson and Padgham, 1993).

In the Point Lake - Contwoyto Lake region, a dominantly mafic metavolcanic and related intrusion referred to as the Point Lake Formation have mid-ocean-ridge basaltic affinities. Intermediate volcaniclastic rocks similar to those found in modern island arc settings are assigned to the Central Volcanic Belt In the Contwoyto Lake - Point Lake area plutonic rocks, of which the Wishbone monzogranite is the largest body, intruded between 2,667 and 2,650 million years ago. This intrusive, outcropping approximately 20 kilometers southwest of the Lupin mine, has been interpreted as a synvolcanic intrusion related to the Central Volcanic Belt (Relf, 1992).

Metasedimentary Rocks

Interbedded greywackes, siltstones and mudstones, which have been interpreted as turbidites, make up the largest areal extent of supracrustal rocks in the province. Included within this group of turbidites are two formations located between Contwoyto Lake and Point Lake which are distinguished by the presence of interbedded iron formation (Contwoyto Formation) and the absence of iron formation (Itchen Formation) (Bostock, 1980).

Other sedimentary rocks within this sequence include locally prominent conglomerates which have been derived from nearby volcanic rocks or from older granitic rocks (Point Lake area). A synvolcanic association is inferred in areas where greywackes and mudstones are interlayered with thin felsic and mafic volcanics. This assemblage also includes auriferous iron formations interbedded with fine grained siltstones and mudstones. Thinly bedded carbonates are associated with felsic volcanics in the Back River area (Fyson and Padgham, 1993).

Post-Yellowknife Supergroup Assemblage

Post-Yellowknife Supergroup granitic rocks of varying composition (diorite, tonalite, granodiorite, K-rich granite) underlie a large part of the province. Conglomerates and feldspathic sandstones within or adjacent to volcanic belts also contain clasts of post-volcanic granites (Fyson and Padgham, 1993).

In the Point Lake area, polymictic conglomerates and other clastic sedimentary rocks of the Keskarrah Formation represent the youngest Archean rocks. These rocks outcrop at Keskarrah Bay, on Point Lake, and uncomformably overlie both the Point Lake Formation and the pre-Yellowknife assemblage. Between 2,608 and 2,585 Ga, calc-alkaline rocks of diorite to granodiorite composition and peraluminous granites were emplaced (Relf, 1992). Rocks of this suite underlie approximately half of the Point Lake - Contwoyto Lake region.

Proterozoic Geology

Proterozoic metasedimentary cover rocks, having limited areal extent in the Slave Structural Province, are located near Rockinghorse Lake and northeast of Contwoyto Lake, straddling the Burnside River, and extending to Bathurst Inlet. These rocks comprise the Goulburn and Epworth groups and represent cratonic and marginal geosynclinal environments and lie unconformably on Archean basement (Bostock, 1980).

Regionally, four swarms of Proterozoic diabase dikes are recognized; two belts of diabase dikes belonging to the Mackenzie dike swarm occur in the Point Lake - Contwoyto Lake region. One belt occurs north of Contwoyto Lake; the second belt is located 60 kilometers to the west between Point Lake and Itchen Lake. The dikes are up to 150 meters thick, generally steeply dipping and strike north-northwesterly. The rocks are coarse grained, dark grey to green in color (Bostock, 1980) and form areas of local positive relief where they intrude easily eroded lithologies such as the metaturbidites and negative relief in areas where they are juxtaposed with granites and gneisses.

Structural Geology

Several structural elements are noted in the Slave Structural Province. Folding is most evident in sedimentary sequence, while narrow volcanic belts along the margins of these sedimentary domains appear as steep homoclines dipping towards the sediments. In the southern part of the map area where the volcanics are marginal to or located within wider sedimentary domains. Felsic centers (Back River area) are relatively broad and tend to have shallower dips. Folds tend to be steeply inclined and align parallel to contacts with volcanic and granitic rocks. They are truncated and deformed by younger intrusions indicating a syndeformational association. The last generation of large scale folds trend northward (Fyson and Padgham, 1993).

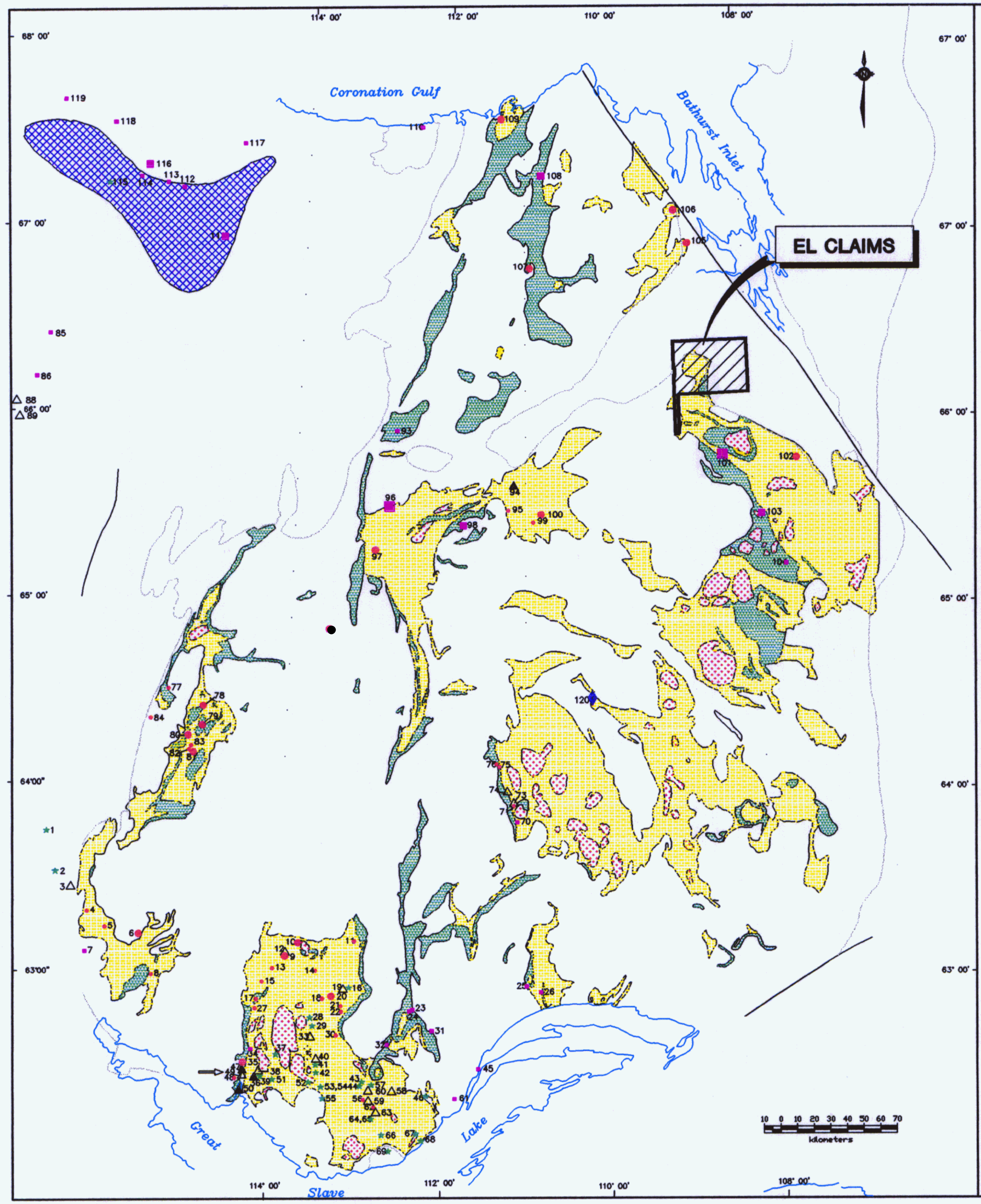
The alignment of volcanic belts or belt segments illustrate the structural trends. Lineaments formed by the volcanic belts and at the granite margins change from northwestward in the eastern part of the province to north-northwest and northeast in the area north of 66^0 N. Sharp contrasts in the structural trend occurs in the southwestern part of the province where volcanic belts and intrusion margins which trend northwest, northeast, and north are juxtaposed and develop an angular pattern. This angular orientation of volcanic belts suggests control of volcanism and structure by an underlying system of crustal-scale fractures (Padgham and Fyson, 1992).

Foliation in migmatitic metasediments tend to parallel bedding and along tight fold lines in weakly metamorphosed rocks. Foliation in granites is variable. Cleavage/schistosity is steeply inclined and generally oblique to the axial traces of large scale earlier folds. South of 66° N, cleavage is usually oriented north to northeast postdating cleavage that strike northwest. This suggests a reorientation of regional stresses.

Major shear zones are recognized as zones of high strain ductile deformation restricted to rock boundaries of contrasting competency. Movement along the McDonald and Bathurst faults occurred mainly during the Proterozoic. Most faults within the province are Proterozoic brittle fracture zones, some of which produce prominent topographic lineaments.

Economic Geology

The Lupin mine, operated by Echo Bay Mines Ltd. and located on Contwoyto Lake, is the only producing mine in the area. The ore body at Lupin consists of tightly folded, gold bearing pyrrhotite-hornblende iron formation within the metaturbidites of the Contwoyto Formation (Yellowknife Supergroup). These iron formations have been the subject of numerous exploration programs, however, the Lupin operation is the only economically viable deposit discovered to date. Major mineral occurrences are shown in Figure 4. The EL claim group is located at the north end of the Back River greenstone belt.



DEPOSITS

1. Sue–Diane Deposit
2. Cab Deposit
3. Rayrock Mine
4. Camp Lake Deposits
5. Slemon Deposit
6. Russel Lake Deposits
7. Sun Deposit
8. Mosher Lake Deposit
9. Bruce – Avis (Winter Lake) Deposits
10. Nicholas Lake Deposit
11. Syn and Ven Deposits
12. Discovery Mine
13. BBB and Ola Deposits
14. Gab Deposit
15. J. E. S. Johnson Lake Deposits
16. W–Storm Deposits
17. Clan Lake Deposits
18. Mitchell Lake Deposits
19. Camlaren Mine
20. Mahe Deposits
21. MQ (Daf) Deposits
22. WT (Myrt) Deposits
23. Sunrise Lake Deposit
24. Bear Deposit
25. Kennedy Lake Deposits 'BB Zone'
26. Susu Lake Deposit
27. Mon Deposit
28. Vo (Cata) Deposits
29. Blaisdell Lake (Bill) Deposits
30. Dome Lake (TT) Deposits
31. Lark Deposits
32. Turnback Lake Deposits
33. Old Parr Mine
34. Homer Deposits
35. Crestaurum Deposit
36. Ptarmigan Mine
37. Prelude Lake Deposits
38. (Star, Prosperous Lake) Deposits
39. Nite Deposits
40. Thompson – Lundmark Mine
41. Hidden Lake Deposits
42. Shorty 1 Deposits
43. Storm (Bea and Apr) Deposits
44. Dick Deposits
45. BBX Deposits
46. Thor (Echo) Deposits
47. Giant Mine
48. Rod Deposits
49. Supercrest (Akaitcho) Mine
50. Con Mine
51. Murphy (BB Zone, Bighill Lake) Deposits
52. Pancho Deposits
53. Ann Deposit (Reid Lake)
54. Jake Deposit
55. Paint (Harding Lake) Deposits
56. Norma (Beaulieu) Deposits
57. Gilmour Lake Deposits
58. Ruth Deposits
59. Beaulieu Yellowknife Mine
60. June Deposits
61. Sachowia Lake (Gogo) Deposit
62. Al Group Deposits
63. Bull Moose Lake Deposits
64. Hid Deposits
65. McDonald Dyke Deposit
66. Buckham Lake Deposits
67. Best Bet (Drever Lake) Deposit
68. Moose No. 2 Dyke Deposits
69. Thor Deposits
70. Deb Deposits
71. Saucer Lake Deposits
72. Tundra (Fat) Deposits
73. Tundra Gold Mine
74. Salmita Mine
75. Sour Lake Deposit
76. Jax Lake Deposits
77. Jingo (Dingo) Deposits
78. Spider Lake Deposits
79. Colomac Mine
80. Kim Deposits
81. Arseno (Indigo) Deposits
82. North Inca Deposits
83. Lexin Din (Leta Zone 1) Deposits
84. Norris Lake (kt) Deposit
85. GW Group Deposits
86. Mariner Deposit
87. Uranium Group Deposits
88. El–Bonanza Deposit (Echo Bay Mines)
89. Contact Lake Deposits
90. Terra Mine
91. Silver Bay Deposits
92. Norex Mine
93. Takijuk Lake (Hood River) Deposits
94. Lupin Mine
95. Pan (Barb) Deposit
96. Izok Lake Deposit
97. Ren Deposit
98. Gondor Deposit
99. Jon Deposit
100. Butterfly Lake (Au 23,24) Deposit
101. Hackett River Deposit
102. George Lake Deposits
103. Yava Deposit
104. Musk Group Deposit
105. Pistol Lake Deposit
106. Turner Lake Deposit
107. Ulu / Crown Deposits
108. High Lake Deposits
109. Coronation Gulf Deposits
110. Nerak Deposit
111. Muskox Deposit
112. South Burnt Creek Deposit
113. Dick Vein Deposit
114. Coronation (MGB) Deposits
115. Mountain Lake Deposits
116. Dot No. 47 (Wreck Lake) Deposit
117. June Deposit
118. Copper Lamb Deposit
119. Carl 7 Deposit
120. Point Lake (DiaMet) Kimberlite

083623

LEGEND

BASE METALS (Cu,Pb,Zn)
- > 10 MT
- 4 MT – 10 MT
- < 4 MT

PRECIOUS METALS (Au,Ag,Pt)
- > 2,000,000 oz.
- 200,000 –2,000,000 oz.
- < 200,000 oz.
- RARE EARTH DEPOSITS (U,Be,Li,etc.)
- DIAMONDS

- ARCHEAN VOLCANICS
- ARCHEAN SEDIMENTS
- HIGH URANIUM POTENTIAL
- INTRUSIVE ROCKS
- PRODUCING MINES
- EX–PRODUCING MINES

NEW INDIGO RESOURCES IN

MINERAL OCCURENCES
IN THE
SLAVE PROVINCE

SCALE: AS SHOWN		DATE: FEBRUARY 1996
APPROVED BY: RWA	FILE: FIG4.DWG	FIGURE 4

Many diamond exploration programs are currently in progress within the Slave Province; a region which only recently has been recognized as an environment favorable for the emplacement of kimberlite pipes. One such project is the BHP-Dia Met joint venture in the Lac de Gras-Exeter Lake area. BHP, the project operator, produced a 1,193 dry metric tonne bulk sample from the Koala pipe which returned 893 carats at an averaged value of US $82/tonne (GCNL No. 132, July 12, 1994).

Underground sampling at the Panda pipe, located 1.2 kilometers from Koala, returned 2557 carats from a 2835 tonnes sample for an average grade of 0.90 cts/dmt (as of December 12, 1994). At the Fox pipe, the underground bulk sampling program has been completed. A total sample of 6915 tonnes of kimberlite produced 11,960 diamonds weighing 166 carats for an overall grade of 0.26 cts/dmt. The average value per carat for this sample is about US $120. The proposed BHP/Dia Met development plan, based upon the on-going bulk sampling program, has expanded to include the: Panda, Misery, Koala, Fox and Leslie diamondiferous pipes.

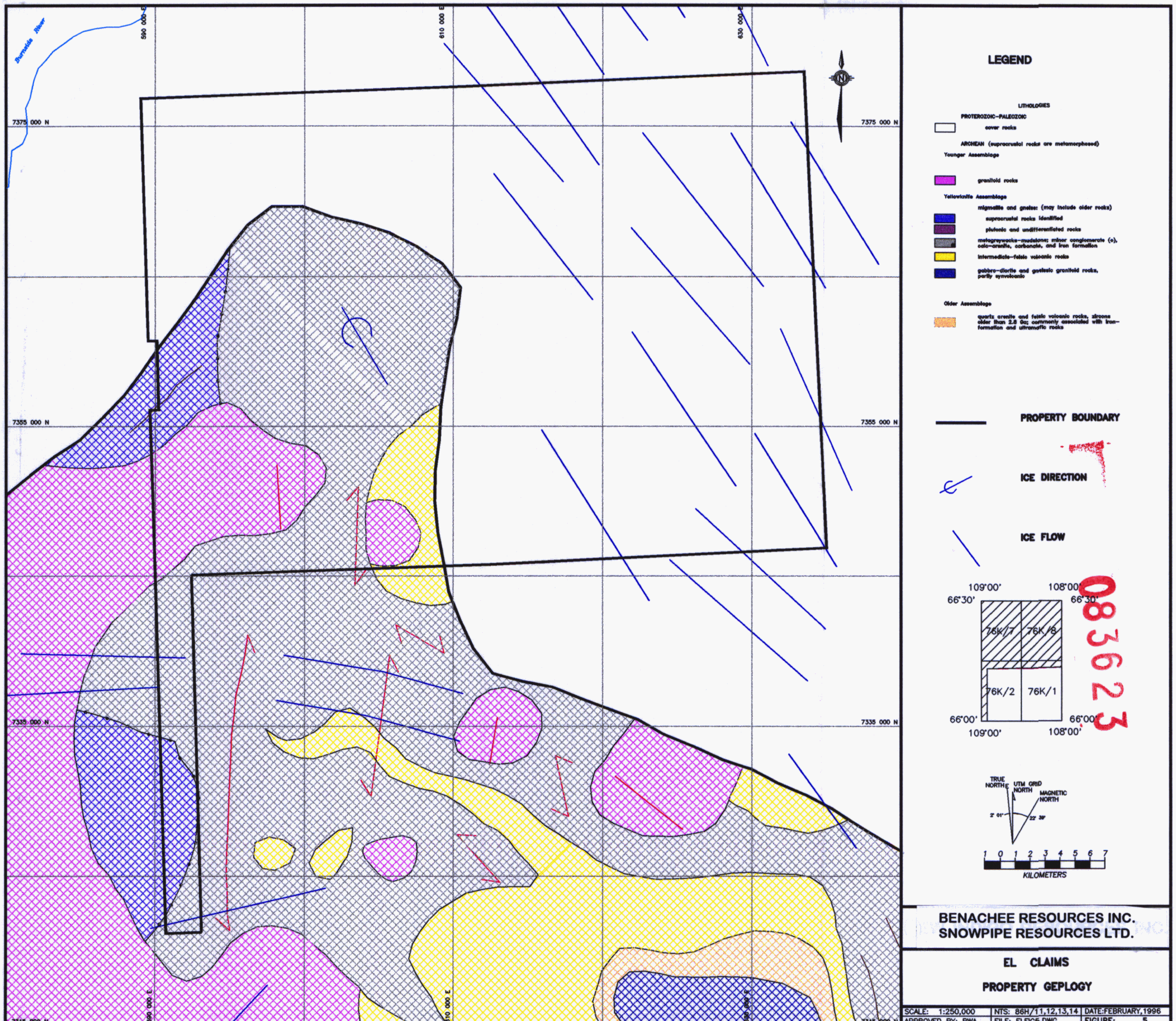
Project construction is slated to begin in 1996 with commercial production anticipated by the third quarter of 1997 (Dia Met Minerals Ltd. Company News Release, December 12, 1994).

Property Geology

The southwestern corner of the claim group is underlain by structurally complex Archean supracrustal rocks of the Yellowknife Supergroup which are intruded by granitic rocks. The supracrustal sequence consists mainly of greywackes and minor intermediate to felsic volcanic rocks. Aphebian metasediments of the Kilihigok Basin, which occur along the north and east margins of the claim group, unconformably overlie the Archean sequence. The Goulburn Group, which defines the Kilihigok Basin, consists mainly of terrigenous clastic rocks (Figure 5, Drawing 2).

Pleistocene Geology

Reconnaissance mapping of surficial deposits and ice direction indicators has been carried out over the property. M.J. Millard of Saskatchewan Research Council was commissioned to provide reconnaissance airphoto interpretation and field investigation of surficial geology over the BK project.



Burnside River
590 000 E
610 000 E
630 000 E
7375 000 N
7355 000 N
7335 000 N
7315 000 N
N
LEGEND
LITHOLOGIES
PROTEROZOIC-PALEOZOIC
cover rocks
ARCHEAN (supracrustal rocks are metamorphosed)
Younger Assemblage
granitoid rocks
Yellowknife Assemblage
migmatite and gneiss: (may include older rocks)
supracrustal rocks identified
plutonic and undifferentiated rocks
metagreywacke-mudstone; minor conglomerate (c), calc-arenite, carbonate, and iron formation
intermediate-felsic volcanic rocks
gabbro-diorite and gneissic granitoid rocks, partly synvolcanic
Older Assemblage
quartz arenite and felsic volcanic rocks, zircons older than 2.8 Ga; commonly associated with iron-formation and ultramafic rocks
PROPERTY BOUNDARY
ICE DIRECTION
ICE FLOW
109°00'
108°00'
66°30'
76K/7
76K/8
76K/2
76K/1
66°00'
TRUE NORTH
UTM GRID NORTH
MAGNETIC NORTH
KILOMETERS
BENACHEE RESOURCES INC.
SNOWPIPE RESOURCES LTD.
EL CLAIMS
PROPERTY GEPLOGY
SCALE: 1:250,000
NTS: 86H/11,12,13,14
DATE:FEBRUARY,1996
APPROVED BY: RWA
FILE: ELFIG5.DWG
FIGURE: 5

083623

Till is the most extensive surficial sediment. Two genetically different types of till deposits have been recognized: basal (subglacial) till and ablation (englacial) till. Subglacial till is deposited primarily from active ice and generally contains more local material than does englacial till. Thus, it is regarded as the best sample medium when conducting drift prospecting programs. Englacial till, deposited during ablation processes by stagnant ice, is often associated with other ice disintegration features such as esker systems.

Previous Exploration

No previous diamond exploratiuon has been done on the calim group. Since 1993 geochemical till sampling for heavy mineral indicators and a 250 meter spaced airborne magnetic and VLF-EM survey totaling 3088.7 kilometers was flown by Geoterrex in 1994 have been completed on the EL property.

CURRENT EXPLORATION (1993-1995)

Overview

The main focus of ground exploration on the EL property has been till sampling intended to quickly discover widespread, glacially transported, indicator mineral trains derived from kimberlitic pipes. This work has led to the discovery of indicator minerals in a number of samples and provided some impetus for additional till sampling. A total of 281 samples were collected and processed between November 17, 1993 and November 16, 1995. During this time period, 3088.7 line-kilometers of airborne magnetics and VLF-EM were flown by Geoterrex Limited.

GEOCHEMISTRY

Introduction

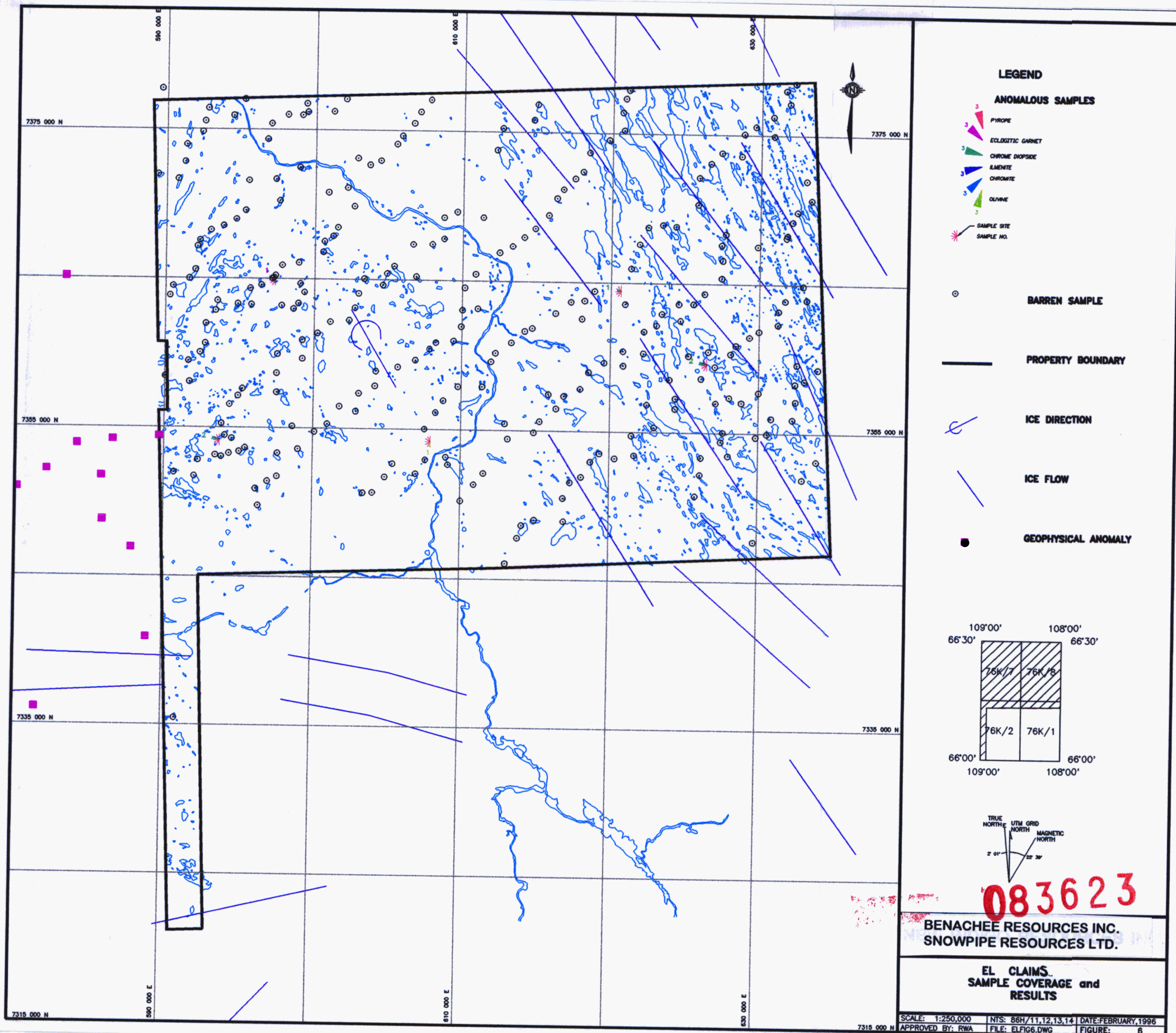
During previous exploration programs on the EL property, 281 till samples were collected by Canamera Geological Ltd. for Benachee Resources Inc. and Snowpipe Resources Ltd. These programs included initial and some follow-up sampling in areas of anomalous geochemical anomalies. Sample density for these additional surveys is, therefore, variable. Samples were processed for kimberlitic indicator minerals, pyrope and eclogitic garnet, chrome diopside, picro-ilmenite, chromite, and olivine, in the North Vancouver laboratory of Canamera Geological Ltd. The results derived from these samples form the body of this report (Figure 6, Drawing 3).

The sampling crew is a 13 man crew consisting of eight samplers, camp manager, assistant manager, camp maintenance man and helicopter support crew.

The camp was mobilized from Yellowknife via fixed wing Twin Otter aircraft. Helicopter support was Bell Jet Ranger 206 B and A-Star. Fuel and supplies were transported periodically from Yellowknife and samples back-hauled.

Field Collection

Frost-boils are the ideal sampling material. Frost-boils are quite numerous and easy to locate and represent underlying till material that has been reworked by fluid movement to produce a higher concentrations of sand-sized particles. The next best sample medium is glacial till. The till layer varies from a veneer of less than 2 meters thick to a thin blanket (2 to 10 meters thick) over most of the claim area (Aylsworth et al, 1988).


590 000 E
610 000 E
630 000 E
7375 000 N
7355 000 N
7335 000 N
7315 000 N
N
LEGEND
ANOMALOUS SAMPLES
PYROPE
ECLOGITIC GARNET
CHROME DIOPSIDE
ILMENITE
CHROMITE
OLIVINE
SAMPLE SITE
SAMPLE NO.
BARREN SAMPLE
PROPERTY BOUNDARY
ICE DIRECTION
ICE FLOW
GEOPHYSICAL ANOMALY
109°00'
108°00'
66°30'
76K/7
76K/8
76K/2
76K/1
66°00'
TRUE NORTH
UTM GRID NORTH
MAGNETIC NORTH
2° 01'
22° 30'
083623
BENACHEE RESOURCES INC.
SNOWPIPE RESOURCES LTD.
EL CLAIMS
SAMPLE COVERAGE and RESULTS
SCALE: 1:250,000
APPROVED BY: RWA
NTS: 86H/11,12,13,14
FILE: ELFIG6.DWG
DATE:FEBRUARY,1996
FIGURE: 6

Once a site has been located and the sample collected, sample material is passed through a 6 or 10 mesh wire screen (3.36 to 1.70 mm) into a collection basin. This screening process is carried out with the aid of water. The oversize is examined for kimberlite fragments and discarded if none are found. The material collected in the basin is submerged in water and agitated to liberate the majority of the fine clay and silt particles. The water, with the suspended particles, is then poured off leaving behind only the granular material. This screening and washing process is continued until approximately 15 kilograms of screened and washed material remains. The residual material is transferred to a 15 litre plastic bucket with sealable lids for transport.

For detailed follow-up, sample lines are selected to provide fill-in information where needed. These samples are usually taken dry, then washed and screened at a water source prior to shipment to the lab for processing. The sample density in an area is somewhat dependent on surficial features, i.e. rock outcrops, boulder fields, bogs, eskers, etc., and material availability

Sample Processing

Till samples, collected from the EL property, were processed in the Canamera's lab facilities located in North Vancouver. Gravity concentration methods and procedures were used in handling initial stages of mineral processing.

Producing a heavy mineral concentrate

Stage 1: Screening of sample material into 4 size fractions using a vibratory Sweco unit. Size categories are: 10 mesh (1.7 mm), 20 mesh (0.85 mm), 40 mesh (0.425 mm), and 60 mesh (0.250 mm)

Stage 2: Simple gravity separation of the -20 to +40 fraction using Wilfley tables to produce two products: low density material and high density material. Only the high density product is processed further

Stage 3: Heavy density product is magnetically separated at two settings to produce three distinct products; an ilmenite rich magnetic concentrate and a garnet-chrome diopside rich concentrate. The remaining material is the non-magnetic fraction.

Stage 4: Both the ilmenite and garnet-chrome diopside concentrates are further refined using a Magstream dense magnetic media separation.

Stage 5: Trained mineral sorters examine each final concentrate for kimberlitic pyrope garnet, chrome diopside, eclogitic garnet, ilmenite, chromite and olivine grains using binocular microscopes. Questionable grains are examined by the senior mineralogist and / or sent out for microprobe analysis.

At each stage of screening, separation, and concentration, a record of weights is maintained for all fractions. All sample splits are repackaged separately and kept in archives.

Additional analyses were conducted on 18 samples from the EL claims. These analyses involved the examination of fines to locate indicator minerals and further assist in property evaluation. Results of this work are recorded in Appendix 7.

Results and Interpretation

Reconnaissance sampling completed in 1993 and the subsequent surveys provided several potential areas for follow-up on the EL property. However, the EL claims have few indicator minerals and no real dispersion trails (Figure 6, Drawing 3). Five anomalous areas, with one anomalous sample in each area, have been identified. The two anomalous sample locations in 76K/8 appear to be part of a possible up-ice? heavy mineral indicator train traceable from the claim group to the north of the EL property (see Appendix 9 - List of Assessment Reports). The three other anomalous sample locations (in 76K/7) appear to be isolated samples unrelated to any mineral dispersion train.

These EL sampling results can be interpreted in a number of ways. One interpretation would suggest that some kimberlite pipes does not contain abundant quantities of indicator minerals. There are documented cases of such pipes in the Lac de Gras area. Another interpretation could involve the masking of the indicator mineral horizon with a cover of glacial drift immediately down-ice from a geophysical anomaly, thereby not producing a geochemical expression in-situ. Additional sampling further down-ice would discover the mineral dispersion trail but likely diluted by passing through a larger quantity of till.

However, insufficient sampling has been done to adequately define any mineral trains. The up-ice direction from these locations must be sampled to determine a definite termination point. In addition, a detailed airborne or ground geophysical survey in the immediate and up-ice direction may point to the indicator mineral source and must be completed before a kimberlite target suitable for drill testing can be determined.

GEOPHYSICS

Introduction

Geoterrex Limited, of Ottawa, Ontario was contracted by Canamera Geological Limited to carry out a detailed airborne geophysical survey and report on the EL property as part of a large airborne survey area (Appendix 8). The flying took place between June 13th, 1993 through August 28th, 1994. A total of 3088.7 line-km were completed in this portion of the survey. Till sample follow-up has not been carried out on any of the geophysical anomalies to date.

Results and Discussion

No kimberlitic geophysical anomalies were derived from the property scale Geoterrex survey therefore, correlation between anomalous sample sites and questionable geophysical anomalies can not be make. Also, any geophysical targets located have not been tied to geochemical anomalies because the geophysics was completed prior to sampling, therefore correlation was not attempted. However, some possible? base metal geophysical targets may be located within the underlying Archean volcanic/sedimentary rock units. These have not been adequately investigated but should be the focus of a future exploration program.

CONCLUSIONS AND RECOMMENDATIONS

The general concept of detailed till sampling together with airborne magnetics and ground geophysical surveys has proven an effective method for targeting potential kimberlite pipes. This multi-disciplined approach to exploration has discovered numerous pipes in the Lac de Gras area. Since each kimberlite can have a unique geophysical and geochemical signature, the continued focus of the current and future exploration programs must be on detailed geochemical and geophysical follow-up of anomalies to target specific areas. Additional detailed sampling is required in the areas with kimberlitic indicator minerals to adequately test and terminate possible dispersion trains. Sample material should be described in detail and glacial direction indicators should be collected in the vicinity of sample sites whenever possible.

Report by:

Rodney W. Arnold, P. Geo.

APPENDIX 1

STATEMENT OF COSTS

EL PROPERTY
1993-1995 ASSESSMENT COST BREAKDOWN for period 11/17/1993 through 11/16/1995

I. ACREAGE:		*# claims*	*acres*
Total acreage of EL property: All EL claims (EL 1-3; 12-17; 26-28; 66-68; 73-82; 87-90; 92-96; 102-107; 119)		40	103,300.0
Net EL acreage for 1995 assessment period			**103,300.0**

II. SAMPLING:

		# SAMPLES	*VALUE*
Total samples taken 1993 - 1995		281	$309,100
Samples collected and processed (11/17/93 - 11/16/95)		**281**	$309,100
Less samples lost in field	0	281	$309,100
Net sampling expenditures for 1995 assessment period		281	$309,100

III. Geophysics:
** All survey costs include personnel, transport, and support*

Geoterrex airborne magnetics and VLF-EM
** Applicable property wide*

	Line km	***Survey cost***
	3088.7	$101,927
		$101,927

IV. Special lab work

Special lab work completed:	***# samples***	***cost / sample***	
Coarse Grain	0	$200	$0
Excess -20+40	0	$200	$0
Fine Grain -40 / +50	18	$200	$3,600
Fine Grain -50 / +60	0	$200	$0
Half Sort Raised to Full	0	$200	$0
Quality Resort	0	$200	$0
Resort	0	$200	$0
O/B -20 / +40	0	$300	$0
	18		**$3,600**

Net special laboratory expenditures for 1995 assessment period	**$3,600**

VI. Other property expenditures

Surficial geology mapping *None completed*	$0
Aerial photo flying *None completed*	$0
Professional and technical services *Canamera Vancouver 11/17/93 - 11/16/95 - applicable property wide*	$2,500

Net assorted property expenditures for 1995 assessment period $2,500

TOTAL EL PROPERTY EXPENDITURES $417,127

Assessed at ***$4.00*** *per acre for all claims* $413,200

ASSESSMENT DURATION

All EL claims (EL 1-3; 12-17; 26-28; 66-68; 73-82; 87-90; 92-96; 102-107; 119)
renewed for additional 1 years (@ $2 / acre / year)

TOTAL EXCESS EXPENDITURES FOR EL PROPERTY $3,927
applied to EL 119

FILING FEE @ $0.10 / ACRE / YR $10,330.00

EL PROPERTY

EXPLORATION EXPENDITURES

FOR PERIOD: NOVEMBER 17, 1993 - NOVEMBER 16, 1995

		TOTAL $
SAMPLE COLLECTION		
PROJECT PREPARATION		$5,084
PERSONNEL		
	Camp Geologist, Assistant, Cook and 8 samplers (11 man camps) approximately 80 man-days in total	$24,092
CAMP BUILDING AND MOBILIZATION		$11,009
DEMOBILIZATION AND CLEANUP		$3,087
FIELD SUPPLIES		$2,964
PERSONNEL BOARD		$4,698
PERSONNEL ROOM		$8,808
COMMUNICATIONS		$964
SAMPLING EQUIP RENTAL		$4,698
SAMPLING SUPPLIES		$1,258
	Fuel Caching	$2,415
	Twin Otter	$36,231
	Helicopter (DRY)	$85,680
FUEL CONSUMPTION		
	HELICOPTER Fuel	
	Jet B	$14,115
	CAMP Fuel	
	p-50 stove	$2,402
	p-40 diesel	$458
	CAMP Fuel	
	Propane	$1,061
SAFETY EQUIPMENT		$1,677
SAMPLE SHIPPING		$14,095
TOTAL FIELD COLLECTION EXPENDITURES		**$224,800**

SAMPLE PROCESSING EXPENDITURES

**cost of probe work and abrasion summary included **		
281 samples @ $300/sample (including screening, tabling, magnetic separation, magstream, and mineral sorting)		**$84,300**

TOTAL SAMPLE EXPLORATION COSTS

samples collected	281		
average cost per sample	$1,100	(average winter and summer)	**$309,100**

SPECIAL LABORATORY SAMPLE COSTS

Special lab work - 18 samples @ $200/sample				$3,600
Coarse Grain	0	$200		
Excess -20+40	0	$200		
Fine Grain -40 / +50	18	$200	$3,600	
Fine Grain -50 / +60	0	$200		
Half Sort Raised to Full	0	$200		
Quality Resort	0	$200		
Resort	0	$200		
O/B -20 / +40	0	$300		
	18		$3,600	

TOTAL GEOCHEMICAL ANALYSES EXPENDITURES	**$312,700**

TOTAL GEOPHYSICAL EXPLORATION EXPENDITURES

AIRBORNE GEOPHYSICAL EXPENDITURES

Survey 1 - Geoterrex Magnetics and EM		
Line-kilometres flown	3088.7	
Charge per line-km - all inclusive	$33	
Total Costs		**$101,927**

REPORT WRITING	**$2,500**
TOTAL EXPLORATION EXPEDITURES	**$417,127**

APPENDIX 2

BREAKDOWN OF EXPENDITURES

BREAKDOWN OF EXPENDITURES

EXPENDITURES

Total Exploration Expenditures for EL PROPERTY = $417,127
(Appendix 1)
Consisting of property wide till sampling and processing
and airborne geophysics

ACREAGE

Total applied EL PROPERTY acreage = 103,300 (Appendix 3)

REQUIRED WORK

Required value of work =$2/acre/year
Value per year = $206,600.00

APPLIED YEARS OF WORK CREDIT

Application of two years (2) credit on:
EL 1-3; 12-17; 26-28; 73-82; 87-90; 92-96; 102-107; and 119
= $413,200.00
Exploration expenditures = $417,127

EXCESS CREDIT

Appliy Excess Credit of
$3927.00 to EL 119.

APPENDIX 3

CLAIM DATA

EL PROPERTY - FORM 9 ATTACHMENT

14-Feb-96

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45371	EL 1	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-01 / 076-K-08 / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45372	EL 2	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45373	EL 3	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45374	EL 4	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45375	EL 5	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45376	EL 6	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45377	EL 7	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45378	EL 8	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45379	EL 9	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45380	EL 10	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45381	EL 11	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45382	EL 12	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45383	EL 13	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45384	EL 14	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / 076-K-01 / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45385	EL 15	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-01 / 076-K-08 / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45386	EL 16	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45387	EL 17	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45388	EL 18	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45389	EL 19	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45390	EL 20	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45391	EL 21	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45392	EL 22	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45393	EL 23	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45394	EL 24	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45395	EL 25	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45396	EL 26	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45397	EL 27	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45398	EL 28	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / 076-K-01 / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45399	EL 29	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-01 / 076-K-08 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45400	EL 30	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45401	EL 31	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45402	EL 32	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45403	EL 33	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45404	EL 34	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45405	EL 35	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45406	EL 36	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45407	EL 37	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45408	EL 38	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45409	EL 39	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45410	EL 40	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45411	EL 41	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45412	EL 42	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / 076-K-01 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45413	EL 43	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-01 / 076-K-08 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45414	EL 44	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45415	EL 45	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45416	EL 46	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45417	EL 47	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45418	EL 48	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45419	EL 49	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45420	EL 50	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45421	EL 51	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45422	EL 52	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45423	EL 53	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45424	EL 54	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45425	EL 55	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45426	EL 56	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / 076-K-01 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45427	EL 57	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-01 / 076-K-08 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45428	EL 58	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45429	EL 59	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45430	EL 60	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45431	EL 61	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45432	EL 62	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45433	EL 63	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45434	EL 64	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / 076-K-07 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45435	EL 65	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-08 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45436	EL 66	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / 076-K-07 / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45437	EL 67	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-08 / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45438	EL 68	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-08 / 076-K-07 / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45439	EL 69	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-08 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45440	EL 70	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-01 / 076-K-02 / 076-K-07 /	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45441	EL 71	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / 076-K-07 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45442	EL 72	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45443	EL 73	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45444	EL 74	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45445	EL 75	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45446	EL 76	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45447	EL 77	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45448	EL 78	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45449	EL 79	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45450	EL 80	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45451	EL 81	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45452	EL 82	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45453	EL 83	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45454	EL 84	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-02 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45455	EL 85	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / 076-K-07 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45456	EL 86	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45457	EL 87	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45458	EL 88	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45459	EL 89	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45460	EL 90	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45461	EL 91	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45462	EL 92	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45463	EL 93	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45464	EL 94	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45465	EL 95	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45466	EL 96	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45467	EL 97	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45468	EL 98	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-02 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45469	EL 99	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / 076-K-07 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45470	EL 100	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45471	EL 101	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45472	EL 102	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45473	EL 103	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45474	EL 104	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45475	EL 105	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45476	EL 106	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45477	EL 107	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	0.00	0	0	2	11/17/1993	11/17/1996
F45478	EL 108	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45479	EL 109	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45480	EL 110	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45481	EL 111	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45482	EL 112	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-02 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45483	EL 113	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / 076-K-07 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45484	EL 114	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45485	EL 115	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45486	EL 116	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45487	EL 117	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45488	EL 118	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45489	EL 119	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	10330	3,927.10	0	0	2	11/17/1993	11/17/1996
F45490	EL 120	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45491	EL 121	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45492	EL 122	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45493	EL 123	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45494	EL 124	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45495	EL 125	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45496	EL 126	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-02 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45497	EL 127	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	230.62	0	0.00	0	0	0	11/17/1993	11/17/1995
F45498	EL 128	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1100.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45499	EL 129	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1100.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45500	EL 130	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1100.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45501	EL 131	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1100.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45502	EL 132	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1100.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45503	EL 133	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / 076-K-07 / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45504	EL 134	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45505	EL 135	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45506	EL 136	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45507	EL 137	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45508	EL 138	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995

CLAIM NUMBER	CLAIM NAME	OWNER(S)	NTS SHEET(S)	AREA (ACRES)	NEW WORK	EXCESS:	CASH	SURPLUS	YEARS APPLIED	RECORDED	NEW ANNIVERSARY
F45509	EL 139	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	2582.5	0	0.00	0	0	0	11/17/1993	11/17/1995
F45510	EL 140	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45511	EL 141	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45512	EL 142	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45513	EL 143	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	1645.7	0	0.00	0	0	0	11/17/1993	11/17/1995
F45514	EL 144	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	1250.7	0	0.00	0	0	0	11/17/1993	11/17/1995
F45515	EL 145	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45516	EL 146	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-07 / 076-K-02 / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45517	EL 147	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45518	EL 148	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45519	EL 149	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45520	EL 150	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45521	EL 151	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	1607.3	0	0.00	0	0	0	11/17/1993	11/17/1995
F45522	EL 152	BENACHEE RESOURCES INC. / SNOWPIPE RESOURCES LTD.	076-K-02 / - / - / -	337.06	0	0.00	0	0	0	11/17/1993	11/17/1995

total # of acres = **368,511.08**

total amount of new work = **$413,200.00**

total amount of excess = **$3,927.10**

total # of claims **152**

total amount of cash = **$0.00**

total amount of surplus = **$0.00**

APPENDIX 4

STATEMENT OF QUALIFICATIONS

STATEMENT OF QUALIFICATIONS

I, Rodney W. Arnold, resident at 41751 Yarrow Central Road, Chilliwack, British Columbia, V2R 5G3, hereby certify that:

I am a consulting geologist and have worked in the mineral exploration and mining industry since 1979.

I received a Bachelor of Science degree in Geology from the University of Calgary in 1974.

I am a registered member of the Association of Professional Engineers and Geoscientists of British Columbia (1993).

I have been involved with staking and exploration on the EL property since 1995 and am familiar with the current state of exploration.

I have no direct or indirect interest in the EL property or in the shares of Benachee Resources Inc. and Snowpipe Resources Ltd. nor do I expect any.

Permission is hereby granted for the use of this report, or excerpts thereof, for any legal purposes normal to the business of Benachee Resources Inc. and Snowpipe Resources Ltd. The author reserves the right to approve any summaries or alterations.

Dated at Vancouver, British Columbia, this 14h day of February, 1996

Rodney W. Arnold, P. Geo.

PROFESSIONAL
PROVINCE OF
R.W. ARNOLD
BRITISH COLUMBIA
GEOSCIENTIST

APPENDIX 5

REFERENCES AND BIBLIOGRAPHY

REFERENCES AND BIBLIOGRAPHY

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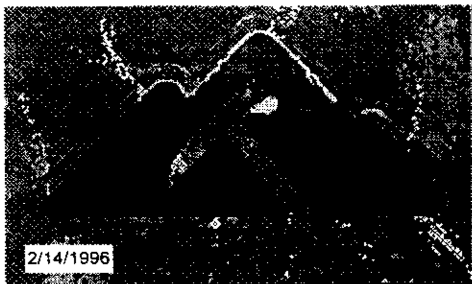
APPENDIX 6

GEOCHEMICAL DATA



2/14/1996

CANAMERA GEOLOGICAL LTD.

Sample Processing Summary For EL Claim to 11/17/95

COLLECTION			CONCENTRATION		SORTING			Indicator Recovery Totals:					
Sample #:	NTS:	Claim:	Tabling Wt/gm:	Conc. Wt/gm:	Sort Wt/gm	Result Class:	Status:	PY	EG	CD	ILM	CR	OL
019992	76K7	EL 117	4600	400	36	ANOMALOUS	C	0	1	0	0	0	0
038329	76K7	EL 125	3500	428	103	ANOMALOUS	C	0	0	2	0	0	0
039818	76K8	EL 38	4300	266	58	ANOMALOUS	C	0	0	1	0	0	0
039928	76K7	EL 83	3900	282	82	ANOMALOUS	C	0	0	0	0	0	1
041558	76K8	EL 26	3500	130	34	ANOMALOUS	C	0	0	2	0	0	0
5 ANOMALOUS Samples													
015549	76K8	EL 63	2000	120	11	BARREN	I	0	0	0	0	0	0
015550	76K8	EL 63	2400	230	7	BARREN	I	0	0	0	0	0	0
015551	76K8	EL 64	2800	254	9	BARREN	I	0	0	0	0	0	0
015552	76K8	EL 64	2500	122	9	BARREN	I	0	0	0	0	0	0
015861	76K8	EL 47	4100	228	38	BARREN	I	0	0	0	0	0	0
015862	76K8	EL 48	3400	294	47	BARREN	I	0	0	0	0	0	0
015863	76K8	EL 51	3100	294	29	BARREN	I	0	0	0	0	0	0
015864	76K8	EL 51	3100	162	16	BARREN	I	0	0	0	0	0	0
015865	76K8	EL 61	3100	374	16	BARREN	I	0	0	0	0	0	0
016265	76K8	EL 23	4400	406	37	BARREN	I	0	0	0	0	0	0
016266	76K8	EL 33	4000	264	28	BARREN	I	0	0	0	0	0	0
016267	76K8	EL 33	3800	128	17	BARREN	I	0	0	0	0	0	0
016268	76K8	EL 38	3200	330	27	BARREN	I	0	0	0	0	0	0
016269	76K8	EL 38	4400	168	42	BARREN	I	0	0	0	0	0	0
016270	76K8	EL 38	3100	606	20	BARREN	C	0	0	0	0	0	0
016271	76K8	EL 39		86	24	BARREN	C	0	0	0	0	0	0
016272	76K7	EL 74	8700	4200	15	BARREN	C	0	0	0	0	0	0
016273	76K7	EL 74	5300	338	35	BARREN	C	0	0	0	0	0	0
016274	76K7	EL 74	2400	296	32	BARREN	C	0	0	0	0	0	0
016275	76K7	EL 74	3200	366	11	BARREN	I	0	0	0	0	0	0
016505	76K8	EL 36	3600	320	35	BARREN	I	0	0	0	0	0	0
016506	76K8	EL 36	4300	260	14	BARREN	I	0	0	0	0	0	0
016507	76K8	EL 49	4300	436	11	BARREN	I	0	0	0	0	0	0
016557	76K7	EL 107	6900	432	37	BARREN	I	0	0	0	0	0	0
016558	76K7	EL 118	5100	446	39	BARREN	I	0	0	0	0	0	0
016559	76K7	EL 107	5600	670	72	BARREN	H	0	0	0	0	0	0
016560	76K7	EL 118	6500	348	56	BARREN	I	0	0	0	0	0	0
016561	76K7	EL 121	5700	394	7	BARREN	I	0	0	0	0	0	0
016562	76K7	EL 121	6300	464	27	BARREN	I	0	0	0	0	0	0

Status Legend: I=intial sort , H=half sort , Q=quarter sort , F=final result, C=complete

COLLECTION			CONCENTRATION		SORTING			Indicator Recovery Totals:					
Sample #:	NTS:	Claim:	Tabling W/gm:	Conc. W/gm:	Sort W/gm	Result Class:	Status:	PY	EG	CD	ILM	CR	OL
016606	76K7	EL 78	2110	72	4	BARREN	I	0	0	0	0	0	0
016607	76K7	EL 91	1900	252	12	BARREN	I	0	0	0	0	0	0
016613	76K7	EL 89	3500	192	24	BARREN	C	0	0	0	0	0	0
016614	76K7	EL 94	3000	258	35	BARREN	C	0	0	0	0	0	0
016615	76K7	EL 94	3300	240	15	BARREN	C	0	0	0	0	0	0
016616	76K7	EL 95	4500	416	34	BARREN	I	0	0	0	0	0	0
016617	76K7	EL 95	4600	360	33	BARREN	I	0	0	0	0	0	0
016618	76K7	EL 102	3100	292	37	BARREN	C	0	0	0	0	0	0
016619	76K7	EL 109	3600	324	42	BARREN	C	0	0	0	0	0	0
017034	76K7	EL 93	4500	286	49	BARREN	H	0	0	0	0	0	0
017035	76K7	EL 104	5200	362	35	BARREN	I	0	0	0	0	0	0
017036	76K7	EL 103	4900	386	57	BARREN	I	0	0	0	0	0	0
017037	76K7	EL 103	4200	596	44	BARREN	I	0	0	0	0	0	0
017038	76K7	EL 103	4500	824	60	BARREN	C	0	0	0	0	0	0
017078	76K7	EL 119	1900	58	8	BARREN	C	0	0	0	0	0	0
017079	76K7	EL 106	4100	218	35	BARREN	I	0	0	0	0	0	0
017080	76K7	EL 106	4500	370	49	BARREN	C	0	0	0	0	0	0
017090	76K8	EL 7	3500	446	25	BARREN	I	0	0	0	0	0	0
017091	76K8	EL 7	4000	418	47	BARREN	I	0	0	0	0	0	0
017092	76K8	EL 7	900	158	34	BARREN	I	0	0	0	0	0	0
017093	76K8	EL 8	4100	712	112	BARREN	I	0	0	0	0	0	0
017094	76K8	EL 8	2900	264	11	BARREN	I	0	0	0	0	0	0
017095	76K8	EL 8	4600	492	64	BARREN	I	0	0	0	0	0	0
019687	76K7	EL 80	2650	296	46	BARREN	I	0	0	0	0	0	0
019688	76K7	EL 80	4200	270	37	BARREN	I	0	0	0	0	0	0
019689	76K7	EL 89	4600	196	25	BARREN	C	0	0	0	0	0	0
019690	76K7	EL 80	3500	530	26	BARREN	C	0	0	0	0	0	0
019691	76K7	EL 89	3800	396	54	BARREN	I	0	0	0	0	0	0
019692	76K7	EL 89	3400	370	24	BARREN	C	0	0	0	0	0	0
019693	76K7	EL 120	4000	436	71	BARREN	I	0	0	0	0	0	0
019694	76K7	EL 138	3400	172	32	BARREN	C	0	0	0	0	0	0
019695	76K7	EL 137	3700	204	27	BARREN	C	0	0	0	0	0	0
019696	76K7	EL 137	4200	428	25	BARREN	H	0	0	0	0	0	0
019697	76K7	EL 137	3900	314	36	BARREN	C	0	0	0	0	0	0
019698	76K7	EL 142	5200	442	43	BARREN	I	0	0	0	0	0	0
019884	76K7	EL 106	3100	232	15	BARREN	C	0	0	0	0	0	0
019985	76K8	EL 6	3100	306	6	BARREN	I	0	0	0	0	0	0
019986	76K8	EL 5	3500	494	33	BARREN	H	0	0	0	0	0	0
019987	76K8	EL 5	3400	148	47	BARREN	I	0	0	0	0	0	0
019988	76K8	EL 5	5600	366	14	BARREN	I	0	0	0	0	0	0
019989	76K8	EL 10		192	94	BARREN	H	0	0	0	0	0	0
019990	76K7	EL 108	1160	246	43	BARREN	H	0	0	0	0	0	0
019991	76K7	EL 108	3200	194	33	BARREN	I	0	0	0	0	0	0
019993	76K7	EL 117	3800	426	33	BARREN	I	0	0	0	0	0	0
019994	76K7	EL 117	3000	252	29	BARREN	H	0	0	0	0	0	0
019995	76K7	EL 116	998	268	36	BARREN	H	0	0	0	0	0	0
019996	76K7	EL 123	4100	478	41	BARREN	H	0	0	0	0	0	0

Status Legend: I=intial sort , H=half sort , Q=quarter sort , F=final result, C=complete

COLLECTION			CONCENTRATION		SORTING			Indicator Recovery Totals:					
Sample #:	NTS:	Claim:	Tabling W/gm:	Conc. W/gm:	Sort W/gm	Result Class:	Status:	PY	EG	CD	ILM	CR	OL
038325	76K7	EL 145	5000	760	70	BARREN	H	0	0	0	0	0	0
038326	76K7	EL 134	5000	422	85	BARREN	I	0	0	0	0	0	0
038327	76K7	EL 134	5500	632	72	BARREN	H	0	0	0	0	0	0
038328	76K7	EL 125	3600	302	61	BARREN	C	0	0	0	0	0	0
038330	76K7	EL 124	5000	528	129	BARREN	C	0	0	0	0	0	0
039613	76K8	EL 27	5300	466	65	BARREN	H	0	0	0	0	0	0
039649	76K7	EL 117	5000	292	64	BARREN	C	0	0	0	0	0	0
039650	76K7	EL 117	4800	280	24	BARREN	C	0	0	0	0	0	0
039651	76K7	EL 117	6800	468	21	BARREN	C	0	0	0	0	0	0
039652	76K7	EL 102	4400	512	81	BARREN	C	0	0	0	0	0	0
039653	76K7	EL 109	5400	532	113	BARREN	C	0	0	0	0	0	0
039654	76K7	EL 116	4700	550	54	BARREN	H	0	0	0	0	0	0
039655	76K7	EL 115	5000	316	69	BARREN	I	0	0	0	0	0	0
039656	76K7	EL 115	4100	522	51	BARREN	H	0	0	0	0	0	0
039657	76K7	EL 124	4800	384	63	BARREN	H	0	0	0	0	0	0
039658	76K7	EL 142	4000	182	39	BARREN	C	0	0	0	0	0	0
039659	76K7	EL 137	5500	604	71	BARREN	H	0	0	0	0	0	0
039660	76K7	EL 120	3900	426	94	BARREN	C	0	0	0	0	0	0
039661	76K7	EL 119	5500	604	78	BARREN	H	0	0	0	0	0	0
039662	76K7	EL 118	4800	236	53	BARREN	C	0	0	0	0	0	0
039663	76K7	EL 105	4900	866	157	BARREN	C	0	0	0	0	0	0
039664	76K7	EL 104	3600	214	34	BARREN	C	0	0	0	0	0	0
039665	76K7	EL 78	4300	102	39	BARREN	C	0	0	0	0	0	0
039666	76K7	EL 78	2800	302	34	BARREN	C	0	0	0	0	0	0
039667	76K7	EL 91	4600	268	93	BARREN	C	0	0	0	0	0	0
039668	76K7	EL 91	4200	522	77	BARREN	H	0	0	0	0	0	0
039669	76K7	EL 90	5400	474	75	BARREN	C	0	0	0	0	0	0
039670	76K7	EL 93	5400	616	56	BARREN	Q	0	0	0	0	0	0
039763	76K7	EL 140	4600	466	61	BARREN	H	0	0	0	0	0	0
039764	76K7	EL 141	5000	570	78	BARREN	H	0	0	0	0	0	0
039765	76K7	EL 138	5000	626	51	BARREN	H	0	0	0	0	0	0
039766	76K7	EL 139	5000	676	91	BARREN	H	0	0	0	0	0	0
039767	76K7	EL 139	5000	886	63	BARREN	Q	0	0	0	0	0	0
039768	76K7	EL 139	5000	1014	51	BARREN	Q	0	0	0	0	0	0
039769	76K7	EL 139	4400	278	62	BARREN	H	0	0	0	0	0	0
039770	76K8	EL 32	5000		63	BARREN	H	0	0	0	0	0	0
039771	76K8	EL 32	5000	344	95	BARREN	I	0	0	0	0	0	0
039772	76K8	EL 39	5500	490	68	BARREN	C	0	0	0	0	0	0
039773	76K8	EL 39	5500	330	64	BARREN	C	0	0	0	0	0	0
039774	76K8	EL 40	5000	354	55	BARREN	I	0	0	0	0	0	0
039775	76K8	EL 39	5000	334	73	BARREN	I	0	0	0	0	0	0
039800	76K8	EL 4	5000	336	64	BARREN	H	0	0	0	0	0	0
039806	76K7	EL 97	5200	440	97	BARREN	C	0	0	0	0	0	0
039807	76K7	EL 97	1300	130	23	BARREN	C	0	0	0	0	0	0
039808	76K7	EL 97	4100	270	51	BARREN	C	0	0	0	0	0	0
039809	76K7	EL 97	5000	326	70	BARREN	I	0	0	0	0	0	0
039810	76K7	EL 86	4300	540	51	BARREN	H	0	0	0	0	0	0

Status Legend: I=intial sort , H=half sort , Q=quarter sort , F=final result, C=complete

COLLECTION			CONCENTRATION		SORTING			Indicator Recovery Totals:					
Sample #:	NTS:	Claim:	Tabling Wt/gm:	Conc. Wt/gm:	Sort Wt/gm	Result Class:	Status:	PY	EG	CD	ILM	CR	OL
039811	76K7	EL 93	4900	368	73	BARREN	H	0	0	0	0	0	0
039812	76K7	EL 104	5300	606	60	BARREN	Q	0	0	0	0	0	0
039813	76K7	EL 75	5000	482	63	BARREN	H	0	0	0	0	0	0
039814	76K7	EL 75	4500	420	78	BARREN	C	0	0	0	0	0	0
039815	76K7	EL 65	4700	414	69	BARREN	C	0	0	0	0	0	0
039816	76K7	EL 76	4900	594	58	BARREN	C	0	0	0	0	0	0
039817	76K7	EL 79	4000	406	64	BARREN	C	0	0	0	0	0	0
039819	76K8	EL 47	3800	318	51	BARREN	C	0	0	0	0	0	0
039820	76K7	EL 46	5400	362	41	BARREN	C	0	0	0	0	0	0
039865	76K7	EL 113	5600	528	61	BARREN	H	0	0	0	0	0	0
039866	76K7	EL 114	5100	542	104	BARREN	C	0	0	0	0	0	0
039867	76K7	EL 114	5300	566	125	BARREN	C	0	0	0	0	0	0
039868	76K7	EL 114	2400	302	76	BARREN	C	0	0	0	0	0	0
039869	76K7	EL 114	4000	408	95	BARREN	C	0	0	0	0	0	0
039870	76K7	EL 111	5000	526	63	BARREN	H	0	0	0	0	0	0
039878	76K7	EL 81	5500	910	58	BARREN	Q	0	0	0	0	0	0
039879	76K7	EL 81	5100	614	52	BARREN	H	0	0	0	0	0	0
039880	76K7	EL 88	5100	460	56	BARREN	H	0	0	0	0	0	0
039881	76K7	EL 87	3800	340	56	BARREN	C	0	0	0	0	0	0
039882	76K7	EL 96	5000	416	120	BARREN	C	0	0	0	0	0	0
039883	76K7	EL 96	5500	256	60	BARREN	C	0	0	0	0	0	0
039884	76K7	EL 96	4000	302	79	BARREN	C	0	0	0	0	0	0
039885	76K7	EL 96	5200	234	54	BARREN	I	0	0	0	0	0	0
039886	76K8	EL 3	5400	810	62	BARREN	H	0	0	0	0	0	0
039887	76K8	EL 3	5000		26	BARREN	I	0	0	0	0	0	0
039888	76K8	EL 3	4900	348	46	BARREN	C	0	0	0	0	0	0
039889	76K8	EL 3	5000	170	38	BARREN	I	0	0	0	0	0	0
039890	76K8	EL 3	5600	310	72	BARREN	C	0	0	0	0	0	0
039891	76K8	EL 12	5100	268	39	BARREN	C	0	0	0	0	0	0
039892	76K8	EL 12	5200	204	82	BARREN	C	0	0	0	0	0	0
039893	76K8	EL 13	5500	382	85	BARREN	C	0	0	0	0	0	0
039894	76K8	EL 28	5500	330	79	BARREN	C	0	0	0	0	0	0
039895	76K8	EL 27	5200	418	87	BARREN	C	0	0	0	0	0	0
039896	76K8	EL 27	5000	374	84	BARREN	I	0	0	0	0	0	0
039897	76K8	EL 16	5000	474	83	BARREN	I	0	0	0	0	0	0
039898	76K8	EL 27	5000	310	63	BARREN	I	0	0	0	0	0	0
039927	76K7	EL 83	5500	700	151	BARREN	C	0	0	0	0	0	0
039929	76K7	EL 82	4500	414	87	BARREN	C	0	0	0	0	0	0
039930	76K7	EL 82	5000	648	95	BARREN	H	0	0	0	0	0	0
039931	76K7	EL 82	4000	332	56	BARREN	C	0	0	0	0	0	0
039932	76K8	EL 68	4100	498	58	BARREN	C	0	0	0	0	0	0
039933	76K8	EL 58	4700	698	75	BARREN	C	0	0	0	0	0	0
039934	76K8	EL 59	4500	316	42	BARREN	C	0	0	0	0	0	0
039935	76K8	EL 54	5400	316	56	BARREN	C	0	0	0	0	0	0
039937	76K8	EL 2	3900	400	54	BARREN	C	0	0	0	0	0	0
039938	76K8	EL 2	3100	158	36	BARREN	C	0	0	0	0	0	0
039939	76K8	EL 16	3800	284	57	BARREN	C	0	0	0	0	0	0

Status Legend: I=intial sort , H=half sort , Q=quarter sort , F=final result, C=complete

COLLECTION			CONCENTRATION		SORTING			Indicator Recovery Totals:					
Sample #:	NTS:	Claim:	Tabling Wt/gm:	Conc. Wt/gm:	Sort Wt/gm	Result Class:	Status:	PY	EG	CD	ILM	CR	OL
039940	76K8	EL 11	5000	448	73	BARREN	I	0	0	0	0	0	0
039941	76K8	EL 18	3000	88	35	BARREN	C	0	0	0	0	0	0
039942	76K8	EL 25	3100	174	65	BARREN	C	0	0	0	0	0	0
039943	76K8	EL 69	5200	348	44	BARREN	C	0	0	0	0	0	0
039944	76K8	EL 59	4100	370	33	BARREN	C	0	0	0	0	0	0
039945	76K8	EL 59	4800	940	51	BARREN	H	0	0	0	0	0	0
039946	76K8	EL 10	5300	846	65	BARREN	C	0	0	0	0	0	0
039947	76K7	EL 124	4300	378	50	BARREN	H	0	0	0	0	0	0
039948	76K7	EL 101	4700	706	93	BARREN	H	0	0	0	0	0	0
039949	76K8	EL 73	3500	476	72	BARREN	C	0	0	0	0	0	0
039950	76K7	EL 73	4500	632	56	BARREN	H	0	0	0	0	0	0
039951	76K8	EL 4	3400	558	87	BARREN	C	0	0	0	0	0	0
039952	76K8	EL 11	4400	382	65	BARREN	H	0	0	0	0	0	0
039953	76K8	EL 11	4800	182	38	BARREN	C	0	0	0	0	0	0
039954	76K8	EL 11	4100	144	29	BARREN	C	0	0	0	0	0	0
039955	76K8	EL 18	3800	200	32	BARREN	C	0	0	0	0	0	0
039956	76K8	EL 17	4300	280	50	BARREN	H	0	0	0	0	0	0
039957	76K8	EL 21	5500	620	72	BARREN	C	0	0	0	0	0	0
039958	76K8	EL 20	4400	772	70	BARREN	C	0	0	0	0	0	0
039959	76K8	EL 20	5100	532	88	BARREN	C	0	0	0	0	0	0
039960	76K8	EL 23	5200	626	75	BARREN	C	0	0	0	0	0	0
039961	76K8	EL 23	4600	382	41	BARREN	C	0	0	0	0	0	0
041501	76K7	EL 144	4000	222	67	BARREN	C	0	0	0	0	0	0
041502	76K7	EL 135	3500		74	BARREN	C	0	0	0	0	0	0
041503	76K7	EL 136	3800	268	96	BARREN	C	0	0	0	0	0	0
041504	76K7	EL 136	3200	306	54	BARREN	H	0	0	0	0	0	0
041505	76K7	EL 136	4000	216	99	BARREN	C	0	0	0	0	0	0
041506	76K7	EL 136	3800	526	64	BARREN	H	0	0	0	0	0	0
041507	76K7	EL 122	3600	316	86	BARREN	C	0	0	0	0	0	0
041508	76K8	EL 19	4500	236	27	BARREN	C	0	0	0	0	0	0
041509	76K8	EL 19	3700	162	24	BARREN	C	0	0	0	0	0	0
041510	76K8	EL 19	4000	212	22	BARREN	C	0	0	0	0	0	0
041511	76K8	EL 19	3200	110	12	BARREN	C	0	0	0	0	0	0
041512	76K8	EL 25	3300	130	17	BARREN	C	0	0	0	0	0	0
041513	76K8	EL 25	3400	122	21	BARREN	C	0	0	0	0	0	0
041514	76K8	EL 32	3700	92	12	BARREN	C	0	0	0	0	0	0
041515	76K8	EL 32	3700	250	34	BARREN	C	0	0	0	0	0	0
041518	76K8	EL 41	3500	220	93	BARREN	C	0	0	0	0	0	0
041519	76K8	EL 41	2500	234	29	BARREN	C	0	0	0	0	0	0
041520	76K8	EL 44	3700	294	60	BARREN	H	0	0	0	0	0	0
041521	76K8	EL 44	3700	448	74	BARREN	C	0	0	0	0	0	0
041522	76K8	EL 55	4000	480	74	BARREN	C	0	0	0	0	0	0
041523	76K8	EL 55	4300	284	44	BARREN	C	0	0	0	0	0	0
041524	76K8	EL 55	3600	400	63	BARREN	H	0	0	0	0	0	0
041525	76K8	EL 55	2500	188	55	BARREN	C	0	0	0	0	0	0
041534	76K9	EL 41	4500	254	35	BARREN	C	0	0	0	0	0	0
041535	76K9	EL 51	3800	140	27	BARREN	C	0	0	0	0	0	0

Status Legend: I=intial sort , H=half sort , Q=quarter sort , F=final result, C=complete

COLLECTION			CONCENTRATION		SORTING			Indicator Recovery Totals:					
Sample #:	NTS:	Claim:	Tabling W/gm:	Conc. W/gm:	Sort W/gm	Result Class:	Status:	PY	EG	CD	ILM	CR	OL
041536	76K9	EL 61	3600	296	51	BARREN	C	0	0	0	0	0	0
041537	76K9	EL 66	3300	298	51	BARREN	C	0	0	0	0	0	0
041538	76K8	EL 66	4000	226	66	BARREN	C	0	0	0	0	0	0
041539	76K8	EL 36	4900	348	88	BARREN	C	0	0	0	0	0	0
041540	76K8	EL 36	3200	150	31	BARREN	C	0	0	0	0	0	0
041551	76K7	EL 124	3300	326	88	BARREN	C	0	0	0	0	0	0
041552	76K8	EL 41	6900	460	43	BARREN	C	0	0	0	0	0	0
041553	76K8	EL 40	3600	416	44	BARREN	C	0	0	0	0	0	0
041554	76K8	EL 31	2100	136	19	BARREN	C	0	0	0	0	0	0
041555	76K8	EL 31	4200	396	83	BARREN	C	0	0	0	0	0	0
041556	76K8	EL 31	3000	126	32	BARREN	C	0	0	0	0	0	0
041557	76K8	EL 26	3400	280	66	BARREN	C	0	0	0	0	0	0
041559	76K7	EL 72	4800	334	42	BARREN	C	0	0	0	0	0	0
041560	76K7	EL 72	4300	570	69	BARREN	C	0	0	0	0	0	0
041561	76K7	EL 72	4600	528	61	BARREN	C	0	0	0	0	0	0
041562	76K7	EL 110	3600	232	84	BARREN	C	0	0	0	0	0	0
041563	76K7	EL 110	2800	324	53	BARREN	H	0	0	0	0	0	0
041564	76K7	EL 101	4800	442	91	BARREN	C	0	0	0	0	0	0
041601	76K8	EL 45	5500	318	55	BARREN	I	0	0	0	0	0	0
041602	76K8	EL 45	5000	634	77	BARREN	I	0	0	0	0	0	0
041603	76K8	EL 54	5200	104	17	BARREN	C	0	0	0	0	0	0
041630	76K7	EL 123	5200	734	59	BARREN	H	0	0	0	0	0	0
041703	76K8	EL 6	2900	434	8	BARREN	C	0	0	0	0	0	0
041751	76K7	EL 53	4800	146	32	BARREN	C	0	0	0	0	0	0
041752	76K8	EL 53	4000	420	56	BARREN	H	0	0	0	0	0	0
041753	76K8	EL 60	3000	256	36	BARREN	C	0	0	0	0	0	0
041754	76K8	EL 60	5100	248	62	BARREN	C	0	0	0	0	0	0
041755	76K8	EL 60	3100	282	89	BARREN	C	0	0	0	0	0	0
041756	76K8	EL 67	3300	302	89	BARREN	C	0	0	0	0	0	0
041757	76K8	EL 67	4400	596	57	BARREN	H	0	0	0	0	0	0
041758	76K8	EL 67	4800	394	62	BARREN	C	0	0	0	0	0	0
051093	76K7	EL 124	4800	866	54	BARREN	C	0	0	0	0	0	0
051094	76K7	EL 124	3500	292	20	BARREN	C	0	0	0	0	0	0
051095	76K7	EL 125	4000	322	25	BARREN	C	0	0	0	0	0	0
051096	76K7	EL 125	4900	370	25	BARREN	C	0	0	0	0	0	0
051097	76K7	EL 125	4100	200	17	BARREN	C	0	0	0	0	0	0
051099	76K7	EL 125	2100	126	11	BARREN	C	0	0	0	0	0	0
051222	76K8	EL 26	3900	160	23	BARREN	C	0	0	0	0	0	0
051223	76K8	EL 12	2000	118	6	BARREN	C	0	0	0	0	0	0
051224	76K8	EL 15	4100	272	18	BARREN	C	0	0	0	0	0	0
051225	76K8	EL 17	4400	252	20	BARREN	C	0	0	0	0	0	0
051226	76K8	EL 17	4800	154	14	BARREN	C	0	0	0	0	0	0
051227	76K8	EL 26	3400	222	17	BARREN	C	0	0	0	0	0	0
051228	76K8	EL 26	4200	160	24	BARREN	C	0	0	0	0	0	0
051311	76K10	EL, 56	5000	634	28	BARREN	I	0	0	0	0	0	0
051312	76K10	EL 57	4900	540	40	BARREN	C	0	0	0	0	0	0
051313	76K10	EL 70	3300	212	16	BARREN	C	0	0	0	0	0	0

Status Legend: I=intial sort , H=half sort , Q=quarter sort , F=final result, C=complete

COLLECTION			CONCENTRATION		SORTING			Indicator Recovery Totals:					
Sample #:	NTS:	Claim:	Tabling Wt/gm:	Conc. Wt/gm:	Sort Wt/gm	Result Class:	Status:	PY	EG	CD	ILM	CR	OL
051314	76K10	EL 70	4700	228	20	**BARREN**	**C**	0	0	0	0	0	0
051315	76K10	EL 70	5000	784	50	**BARREN**	**I**	0	0	0	0	0	0
051316	76K10	EL 83	4600	682	32	**BARREN**	**C**	0	0	0	0	0	0
051317	76K7	EL 83	5500	600	86	**BARREN**	**C**	0	0	0	0	0	0
051520	76K3	EL 129	3800	278	20	**BARREN**	**C**	0	0	0	0	0	0
051556	76K7	EL 18	4700	704	31	**BARREN**	**C**	0	0	0	0	0	0
051557	76K7	EL 18	5100	424	28	**BARREN**	**C**	0	0	0	0	0	0
051558	76K7	EL 109	4800	742	38	**BARREN**	**C**	0	0	0	0	0	0
051559	76K7	EL 109	3100	262	24	**BARREN**	**C**	0	0	0	0	0	0
051560	76K7	EL 109	4900	400	35	**BARREN**	**C**	0	0	0	0	0	0
051562	76K7	EL 106	3500	714	65	**BARREN**	**C**	0	0	0	0	0	0
051563	76K7	EL 106	3300	274	31	**BARREN**	**C**	0	0	0	0	0	0

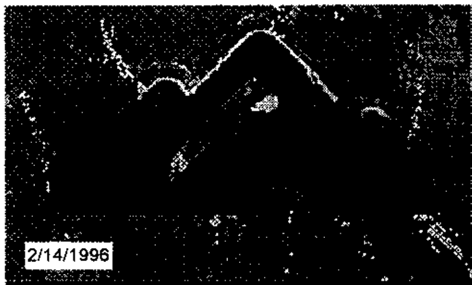
276 BARREN Samples

281

Status Legend: I=intial sort , H=half sort , Q=quarter sort , F=final result, C=complete

APPENDIX 7

SPECIAL LABORATORY ANALYSES RESULTS



2/14/1996

CANAMERA GEOLOGICAL LTD.

Special Lab Request and Resort Sample Summary for The EL Claim Group to 11/17/95

COLLECTION				CONCENTRATION		SORTING		Indicator Recovery Totals:					
Sample #:	Status/Request:	NTS:	Claim:	Tabling Wt/gm:	Conc. Wt/gm:	Sort Wt/gm	Result Class:	PY	EG	CD	ILM	CR	OL
016270	Raise to 'C' Status	76K8	EL 38	3100	606	20	BARREN	0	0	0	0	0	0
016618	Raise to 'C' Status	76K7	EL 102	3100	292	12	BARREN	0	0	0	0	0	0
017080	Raise to 'C' Status	76K7	EL 106	4500	370	25	BARREN	0	0	0	0	0	0
019884	Raise to 'C' Status	76K7	EL 106	3100	232	15	BARREN	0	0	0	0	0	0
019992	Raise to 'C' Status	76K7	EL 117	4600	400	36	BARREN	0	0	0	0	0	0
038329	Fine Grain	76K7	EL 125	3500	428	14	BARREN	0	0	0	0	0	0
038330	Excess -20+40	76K7	EL 124	5000	528	6	BARREN	0	0	0	0	0	0
038330	Raise to 'C' Status	76K7	EL 124	5000	528	62	BARREN	0	0	0	0	0	0
039653	Raise to 'C' Status	76K7	EL 109	5400	532	56	BARREN	0	0	0	0	0	0
039663	Raise to 'C' Status	76K7	EL 105	4900	866	79	BARREN	0	0	0	0	0	0
039818	Fine Grain	76K8	EL 38	4300	266	20	BARREN	0	0	0	0	0	0
039866	Raise to 'C' Status	76K7	EL 114	5100	542	52	BARREN	0	0	0	0	0	0
039867	Raise to 'C' Status	76K7	EL 114	5300	566	62	BARREN	0	0	0	0	0	0
039882	Excess -20+40	76K7	EL 96	5000	416	5	BARREN	0	0	0	0	0	0
039882	Raise to 'C' Status	76K7	EL 96	5000	416	57	BARREN	0	0	0	0	0	0
039927	Raise to 'C' Status	76K7	EL 83	5500	700	75	BARREN	0	0	0	0	0	0
039928	Fine Grain	76K7	EL 83	3900	282	10	BARREN	0	0	0	0	0	0
041558	Fine Grain	76K8	EL 26	3500	130	5	BARREN	0	0	0	0	0	0

18 BARREN Samples

APPENDIX 9

LIST OF ASSESSMENT REPORTS

List of Assessment Reports

Geochemical And Geophysical Assessment Report on the Benachee Resources Inc/ Snowpipe Resources Ltd PSHC Property; March , 1993 - March , 1995; 10 volumes; Ken Hicks; June 20, 1995; NTS 76K, 76M, 76N, 86P; DIAND #083499

Geochemical And Geophysical Assessment Report on the Benachee Resources Inc/ Snowpipe Resources Ltd. RBYM Property; March 18, 1993 - March 17, 1995; 12 volumes; Ken Hicks; June 12, 1995; NTS 76L, 76K, 86I; DIAND #083492

GEOCHEMICAL AND GEOPHYSICAL ASSESSMENT REPORT

on the

EL CLAIM GROUP

of 083623

BENACHEE RESOURCES INC.
and
SNOWPIPE RESOURCES LTD.

November 17, 1993- November 16, 1995

MARA RIVER AREA,
NTS 76K/1, 2, 7, 8
66° 21' N, 108° 31' W
DISTRICT OF MACKENZIE,
NORTHWEST TERRITORIES

by

Rodney W. Arnold, P. Geo.

CANAMERA GEOLOGICAL LTD.
540 - 220 Cambie Street
Vancouver, B.C.

February 15, 1996

Volume 2 of 2

APPENDIX 8

GEOPHYSICAL REPORT AND FIGURES

VOLUME 2 OF 2

12M, 116P, 96R

LOGISTICS, PROCESSING and INTERPRETATION REPORT

of the
AIRBORNE GEOTEM® ELECTROMAGNETIC
& MAGNETIC SURVEY

over the
NORTHWEST TERRITORIES

AREA 6

for
LYTTON MINERALS LTD.

January 1995
Project N° 815

geoterrex

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2.3 System parameters 1
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B	GEOTEM® System
C	GEOTEM® Interpretation Notes
D	Exploration for Kimberlites
E	Airborne induced polarization is here!

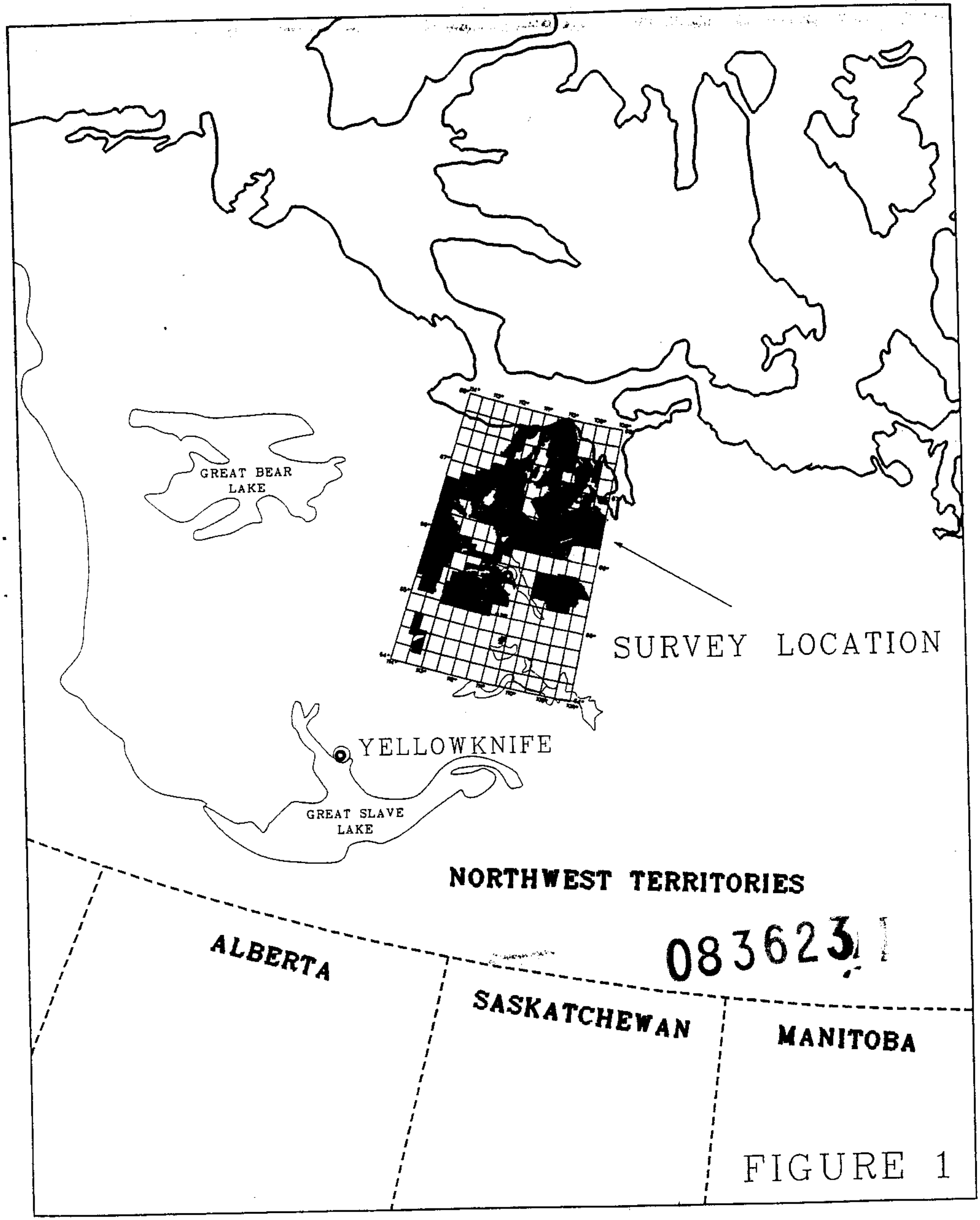
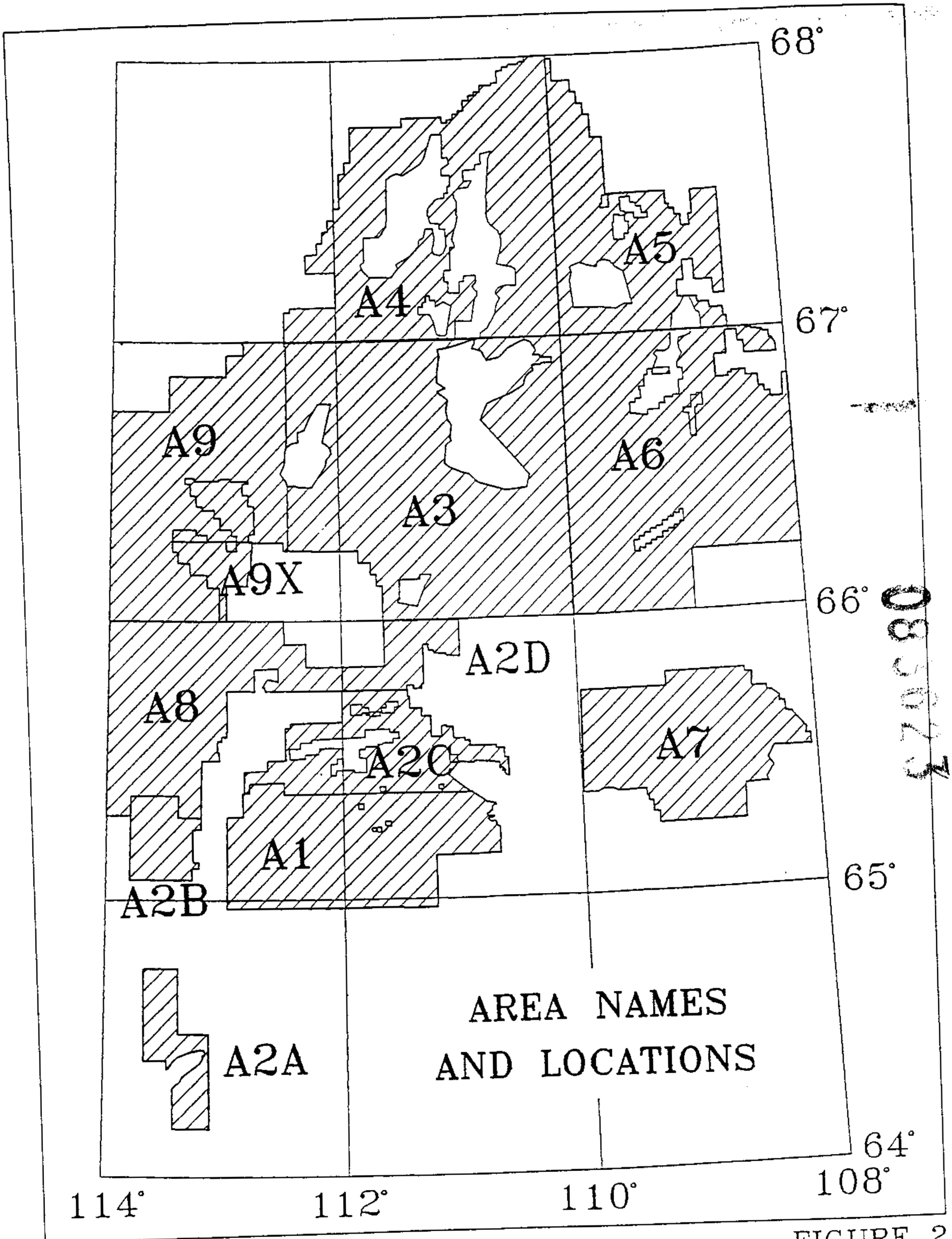

GREAT BEAR
LAKE
SURVEY LOCATION
YELLOWKNIFE
GREAT SLAVE
LAKE
NORTHWEST TERRITORIES
ALBERTA
SASKATCHEWAN
MANITOBA
083623

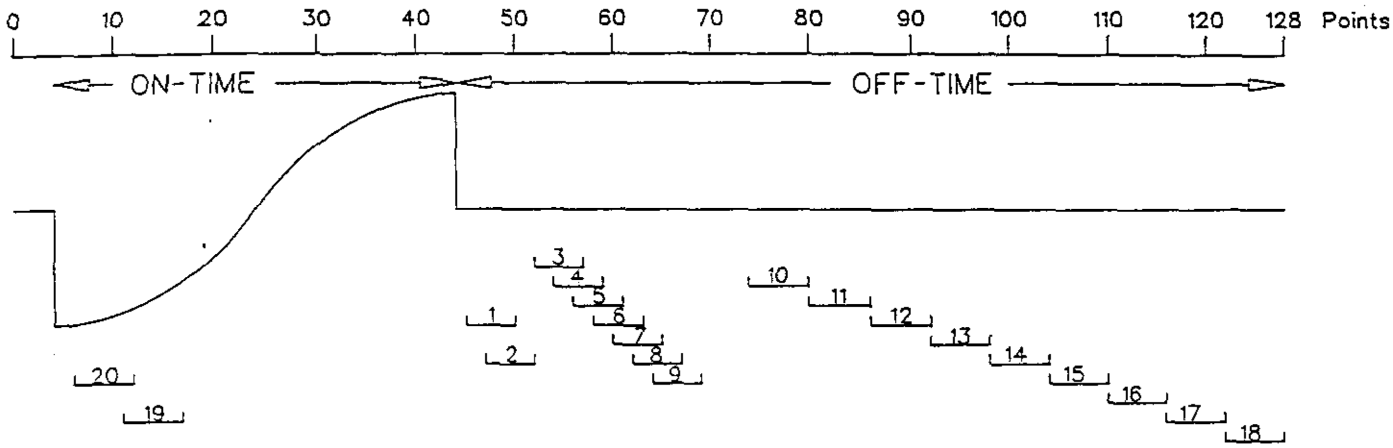
FIGURE 1



68°
67°
66°
65°
64°
114°
112°
110°
108°
A4
A5
A9
A3
A6
A9X
A2D
A8
A2C
A7
A1
A2B
A2A
AREA NAMES
AND LOCATIONS

FIGURE 2

GEOTEM Waveform & Sampling Gates   Frequency 150Hz



CHANNEL	START POINT	END POINT	START TIME	END TIME	WIDTH
1	45	50	27	157	130
2	47	52	79	209	130
3	52	57	209	339	130
4	54	59	261	391	130
5	56	61	313	443	130
6	58	63	365	495	130
7	60	65	417	547	130
8	62	67	469	599	130
9	64	69	521	651	130
10	74	80	782	938	156
11	80	86	938	1094	156
12	86	92	1094	1250	156
13	92	98	1250	1406	156
14	98	104	1406	1563	156
15	104	110	1563	1719	156
16	110	116	1719	1875	156
17	116	122	1875	2031	156
18	122	128	2031	2187	156
19	11	17	−858	−702	156
20	6	12	−988	−832	156

All times are given in micro seconds from the end of the pulse

FIGURE 3

PROJECT REPORT

1 GENERAL

Flown for: LYTTON MINERALS Limited

Flown by: GEOTERREX, Ottawa

Area: Northwest Territories, Areas 1, 2A, 2B, 2C, 2D, 3, 4, 5, 6, 7, 8 and 9. This report covers area 6, sheets 76K/6 to 76K/16. Sheets 76K/3 and 76K/4 are covered in the Area 6 (interim) report.

System: Airborne Magnetic and Electromagnetic (GEOTEM®) survey

Date: June 13th to October 2nd, 1993 and June 21st to August 30th, 1994.

Survey objectives: magnetic/electromagnetic signature associated with kimberlite pipes and massive sulphide mineralization

2 SURVEY OPERATIONS

2.1 Location of survey

Between latitudes 66° and 67°N and longitudes 108° to 110°W, centred approximately 350 km NE of Yellowknife.

2.2 Flight grid

Area: Block 6

Nominal terrain clearance: 110 m

Line orientation of E-W at a spacing of 250 m.

Control line orientation of N-S at a spacing of 5 km.

Total line kilometres of: 29,344 total kilometres

2.3 System parameters

a) platform: *Aircraft:* CASA C-212 STOL twin-engine turbo prop

Survey speed: 120 knots (approximately 62 m/sec)

Flying height: nominal terrain clearance of 110 m

b) GEOTEM® system

Base frequency: 150 Hz

Pulse width: 1042 μs

Pulse delay: 104 μs

Off-time: 2151 μs

Transmitter: vertical axis loop of 232 m^2,
number of turns: 3,
current of 665 amperes,
dipole moment of 4.6 x $10^5 Am^2$,
nominal height above ground of 110 metres.

Receiver: horizontal axis coil,
raw sample rate of 128 points per complete cycle (26.04 microseconds per point), equal to 38400 samples/sec,
final recording rate of 6 samples/sec,
height above ground of 54 metres,
gate centres in the off-time (in microseconds from the end of the pulse):

channel 1: 92	channel 11: 1016
channel 2: 144	channel 12: 1172
channel 3: 274	channel 13: 1328
channel 4: 326	channel 14: 1484
channel 5: 378	channel 15: 1641
channel 6: 430	channel 16: 1797
channel 7: 482	channel 17: 1953
channel 8: 534	channel 18: 2109
channel 9: 586	channel 19: -780
channel 10: 860	channel 20: -910

c) ***Magnetometer***

Type: Cesium vapour, towed bird installation

Sensitivity: 0.01 nT

Sample rate: 10 samples/sec

Height above ground: 63 metres

d) ***Navigation equipment***

GPS receiver: Sercel NR103, 10 channel receiver

Video camera: Panasonic VHS

e) ***Acquisition system***

GEODAS system developed by Geoterrex, DOS 486 based, recording to disk and transferred to floptical disk.

Real-time analogue display of multichannel data (software selectable) on a RMS-GR33a-1 heat-sensitive graphic recorder.

f) ***Base station equipment***

Magnetometer: Cesium vapour, sampling at 1 sec and 0.01 nT sensitivity

GPS receiver: Sercel NR103 10 channel receiver

Digital acquisition: DOS 386 laptop

Analogue display: Ink jet printer

2.4 Survey specifications

Data was reflown when any of the following conditions were not met:

Altitude variation: not to exceed a terrain clearance of 135 m over a distance greater than 1.5 km

EM noise level: not to exceed ± 20 ppm over a distance greater than 3 km, as displayed on the late-time filtered analogue channels

Magnetic noise level: not to exceed ± 0.5 nT over distance greater than 3 km

Magnetic diurnal conditions: deviations not to exceed 15 nT over a chord of 1 minute in length

Line spacing: not to exceed the specified line spacing by more than 50% over a distance greater than 3 km

2.5 Pre-survey tests and calibrations

Verification of system lags

Magnetometer: 3.2 seconds

GEOTEM®: 2.5 seconds

GPS receiver: 0.6 seconds

2.6 Field operations

Survey base: flying operations based out of the Echo Bay Mine camp at Lupin and field processing done in Yellowknife

Survey dates: June 13th to October 2, 1993 and June 21st to August 28th, 1994

Field personnel:

Pilots: S.Hay, H. Girouard, A. Capyk, G. Stonehouse, A. Ozkin, R. McDorman, T. McGuire, L. Lacroix, S. Malle

Electronic technicians: T. Jempson, A. Proulx, M. Clarke, F. Corriveau, K. Lamirande

Engineers: C. Ivimey, J. Trepanier, R. Hattle

Data processor: D. Pagotto

Geophysicists: S. Clarke, J. Thurston, R. Williams, D. Beattie

Survey statistics:

Total production: (all areas flown) 150,001 km

Number of flights: 309

Hours of flying: 1164

Average production per flight: 485 km

Average production per hour of flying: 129 km

Daily production average: 834 km

Summary of Programme

Area	Size (km)	1993/94 Coverage (flown)	To be flown
1	18219	completed, 14 NTS sheets	none
2A	3932	completed, 5 NTS sheets	none
2B	3348	completed, 4 NTS sheets	none
2C	9498	completed, 9 NTS sheets	none
2D	3086	completed, 2 NTS sheets	none
3	39974	partial, 15 of 19 sheets (35050 km)	4715 km
4, 5	41935	partial, 9629 km	32737 km
6	36038	8 full, 6 partial of 16 sheets (29,344 km)	6694 km
7	16326	none	16326 km
8	17281	partial, 6 of 8 sheets (14,048 km)	3233 km
9 + ext.	26018	partial, 14 of 15 sheets (23,848 km)	2170 km
Tests	398	completed	none

3 DATA PROCESSING

3.1 Flight path recovery

Data used: GPS latitude and longitude with post-flight differential corrections applied, converted to UTM metres.

Final UTM positions:

Projection: Clarke 1866 spheroid

Central meridian: 111° west

False Easting: 500,000

False Northing: 0

Scale factor: 0.9996

3.2 Diurnal magnetics

Noise editing: 4th difference editing set for spikes of greater than 0.5 nT

Culture editing: events removed by polynomial interpolation via a graphic screen editor

Noise filtering: triangular filter set to remove wavelengths of 5 seconds or less

Extraction of long wavelength component: filter set to retain only wavelengths of greater than 25 seconds

3.3 Magnetics

Lag correction: 3.2 seconds

Noise editing: 4th difference routine set to remove spikes of greater than 0.5 nT

Noise filtering: triangular filter set to remove wavelengths of less than 0.6 second

Diurnal subtraction: long wavelength component of diurnal removed

(wavelenghts greater than 25 seonds)

Levelling: The first stage of levelling of the magnetic data (correcting for residual diurnal effects, altitude differences and positioning errors) was done on the line data by automatically comparing the values of the total field at the intersection of each line and control line. The differences were analyzed and a compensation was calculated at each intersection in order to provide a pattern of smoothly varying adjustments along each line and control line. Erratic differences, implying an error in the intersection location, were carefully checked and corrected.

The second stage of levelling consisted of applying a micro-levelling routine to the gridded data to remove small residual errors that are not properly removed by conventional levelling of the line data. The difference in the gridded data sets before and after the application of the micro-levelling routine were computed and extracted along the original survey lines to be stored in the final line data set as the secondary magnetic compensation values.

Gridding: 100 m interval

I.G.R.F.: calculated for the period 1994.5 at an elevation of 450 m above sea level

3.4 Electromagnetics

Lag correction: 2.5 seconds

Data correction: The data was inspected for the presence of EM spherics (electrical discharges in the atmosphere). In a routine involving up to four separate passes, spherics are located on the basis of anomaly width, decay rate and reversal. Any data corrupted by spherics was replaced by interpolated values.

The frequency distribution and noise amplitudes of the data was then studied by examining selected lines using a graphical screen editor.

The derived information was used to design filters which separate the high frequency instrumental noise from the true signal.

GEOTEM® data is subjected to minimal base level drift and is automatically normalized to ppm. The very slight drift that does occur, most often restricted to the earlier channels, was easily identified and corrected by reviewing the channel base levels on a graphic screen editor.

Decay constant calculation: channels 4 to 9 fitted to a single exponential function to generate the "early" decay constant and channels 10 to 18 fitted to generate the "late" time constant

Apparent conductivity calculation: on-time apparent conductivity calculated from the amplitude response of channel 20, based on the homogeneous half-space model. The "early" off-time apparent conductivity and "late" off-time apparent conductivity were also generated from the "early" and "late" decay constant values respectively, also based on the response from a homogeneous half-space.

Anomaly selection: focusing on the better bedrock related conductors, the peak selection was done using channel 10, fitting channels 5 to 18 to the vertical plate model to generate the conductivity-thickness product (CTP) and the depth to the top of the source.

Gridding: 100 m interval

3.5 Final products

3.5.1 Maps:

a) *Parameter:* **total field magnetics**

Scale: 1:50,000

Number of sheets: 16 sheets, following the NTS designation

Flight path: no

Contour interval: 10 nT

Copies/media: 3 colour prints; 1 blackline mylar

Base: UTM grid

b) *Parameter:* **basemap**

Scale: 1:50,000

Number of sheets: 16 sheets, following the NTS designation

Flight path: yes

Contour interval: n/a

Copies/media: 1 mylar

Base: scanned topographic

c) *Parameter:* **calculated vertical gradient of magnetics**

Scale: 1:50,000

Number of sheets: 16 sheets, following the NTS designation

Flight path: no

Contour interval: 50 nT/km

Copies/media: 3 colour prints

Base: UTM grid

d) *Parameter:* **on-time apparent conductivity**

Scale: 1:50,000

Number of sheets: 16 sheets, following the NTS designation

Flight path: no

Contour interval: 0.25 mS/m

Copies/media: 3 colour prints; 1 blackline mylar

Base: UTM grid

e) *Parameter:* **channel 4 amplitude**

Scale: 1:50,000

Number of sheets: 16 sheets, following the NTS designation

Flight path: no

Contour interval: 10 ppm interval

Copies/media: 3 colour prints

Base: UTM grid

f) *Parameter:* **multiparameter classification map**, displaying the following information:

- contours of the total field magnetics
- EM anomaly selection from the "late" off-time
- *on-time apparent conductivity above background*
- channel 4 response above background

Scale: 1:50,000

Number of sheets: 16 sheets, following the NTS designation

Flight path: no

Contour interval: 10 nT (magnetics)

Copies/media: 3 colour prints

Base: UTM grid

g) **Interpretation overlay** at 1:50,000 delivered on mylar and produced only for the NTS sheets where primary targets have been identified for ground follow-up. The following information is presented:

- zones of interest which include: structural features derived from the magnetics; EM bedrock conductor axes and conductive zones; primary selected targets (for either kimberlites or base metals) with their categories.

- secondary targets, outside or inside zones of immediate interest
- scanned topography

3.5.2 Digital Archives

Digital archvies are provided for profile, line and gridded data on CD-ROM media as outlined below.

a) *Profile data:*

Geoterrex data base file with DOS compatible viewing software provided for line profile data.

b) *Line data:*

GEOSOFT ASCII format of all final processed data fields. See Appendix A for format desciption and list of parameters.

c) *Grid data:*

GEOSOFT grid files of the following final contour maps:

(i) channel 20 conductivity, (ii) channel 4 amplitude, (iii) total field magnetic, and (iv) C.V.G. magnetic.

4 INTERPRETATION OF THE GEOTEM® AND MAGNETIC SIGNATURE

4.1 Geophysics for kimberlites

Throughout the world, geophysical techniques are commonly used in the search for kimberlite, a known source of diamonds. In order to be detected, the physical properties of the kimberlite must be significantly different from those of the surrounding rock. It is possible to detect contrasts in conductivity and magnetic susceptibility from the air using electromagnetic and magnetic techniques. The electromagnetic response is due to a conductive surface layer, attributed to weathering alteration and the magnetic response is attributed to magnetite and ilmenite within the kimberlite. The pipe-like shape of kimberlite diatremes results in an anomaly pattern which is easy to identify.

Diamondiferous kimberlites have been found in the Northwest Territories of Canada, an area glaciated in the Pleistocene and therefore devoid of a significant weathered zone. By configuring the GEOTEM® airborne electromagnetic system to maximize the sampling information obtained during the off-time, focusing on the early, high-frequency data and taking measurements while the transmitter is on, it is possible to detect weakly conductive kimberlites because there is a sufficient contrast with the highly resistive country rock. The magnetic field is sampled 10 times per second in a sensor 63 m above the ground, allowing very high definition of weak, short wavelength anomalies.

In applying geophysics, namely magnetics and electromagnetics, to the search for kimberlites, the following criteria are usually followed:

- Kimberlite pipes normally have a distinctive magnetic signature due to the presence of magnetite in the unweathered portion of the pipe. However, depending on the degree and depth of weathering and on the initial concentration of magnetite, this signature may vary from strongly defined to only very weakly defined and may in certain cases be completely absent.

- The top weathered clay layer of a kimberlite (known as the yellow ground) is usually marked by a localized conductive response. Again, the strength of this response will depend on the amount and properties of the yellow ground. If the yellow ground has either been removed through erosion or has been deeply buried from glaciation, then the electromagnetic response will be missing.

- The occurence of pipes, often in clusters, may reflect pre-existing structural controls, such as intersections of faults and dykes.

- The pipes are generally circular to sub-circular in outline, having diameters of 100 to 1500 m. These features often have surface expressions visible on air photos or topographic maps. In glaciated terrains, the weathering of the pipes often result in small surface depressions creating small sub-circular lakes. Note the important correlation here, between the occurence of lakes and the channel 20 data. A small sub-circular lake (diameter of 1 km or less) having a high channel 20 response may indicate the presence of an underlying kimberlite.

4.2 Presentation of the Interpretation

The geophysical response over kimberlitic pipes can vary greatly depending on the depth of intrusion, degree of weathering and erosion, compositional variations, etc. However, in all cases, the response reflects a localized source of limited dimensions which may be completely isolated or part of a cluster. For this reason, the focus of the interpretation is an attempt to classify the variety of signatures, both magnetic and electromagnetic in terms of their possible source, from what appear to be localized features of limited dimensions. To facilitate this task, a colour coded multiparameter map was created to allow visual correlation of the magnetic and electromagnetic (both from on-time and off-time) signature on the same map. Table 1 describes the information presented on the multiparameter map.

As shown in table 1, the information presented on the multiparameter map allow the user to quickly focus on isolated responses and identify key characteristics which will lead to the classification of the source. However, the definition of any indivisudal target on this map is quite diffuse and therefore the following data maps and products must be used to properly evaluate and define the targets:

- Colour map of the total intensity magnetics
- Colour map of the magnetic vertical gradient
- Colour map of the on-time apparent conductivity
- Colour map of the off-time channel 4 amplitude
- Topographic map
- All data channels in profile form.

Although the main objective of the survey is the search for kimberlite pipes, given the vast area of terrain covered over this seciton of the Canadian Shield, there exists a strong possibility of also flying over base metal targets. This aspect of the survey was not overlooked and is therefore included in the source location and classification.

The following criteria were used in the definition of the targets outlined on the interpretation overlay.

For kimberlite targets:

- They should be isolated features, reflecting a pipe-like response, affecting no more than 3 or 4 consecutive lines.
- They should have an on-time apparent conductivity response normally above 5 mS/m. If a selection based on the on-time apparent conductivity (with or without a matching response in the off-time), is part of a longer trend along a lake, it must be substantially above the general lake bottom conductivity to suggest a separate source. Faulting across a lake will often locally increase the conductive response, but generally not enough to suggest a separate conductive source.
- Does the EM selection correlate with an isolated magnetic response?
- Is there any structural support from the magnetics? (i.e. faulting, dyke intersection, contact zone, etc.)
- Does the topographic map indicate any localized, sub-circular feature, such as a small lake or depression?

For base metal targets:

- The conductive zone should have a short strike length, usually under 1.5 km.
- The conductor may be isolated or part of a more extensive formational group.
- The conductor may correlate directly with a magnetic feature of similar dimensions.
- The EM response should have a low to moderate amplitude with a slow, steady decay into late-times instead of the high amplitude, rapid decay signature associated with a kimberlite response (see figure 1).
- The EM selection should display structural support from the magnetics.

An interpretation overlay is provided which identifies the possible kimberlite and base metal targets. Table 2 presents the interpretation legend as it appears on the overlay. Although the multiparameter map has been created for all of the survey sheets at 1:50,000, the interpretation overlays only exist for those sheets were possible targets have been identified. The information presented on the interpretation overlay was obtained by proceeding through the following steps:

- The bedrock conductor axes were delineated from the EM anomaly peak locations (mid to late off-time response) as represented by the standard circle notation. All natural breaks and offsets were respected to properly reflect local faulting and discontinuities.

- The electromagnetic information was then examined for isloated, localized sources, above background conductivities. Any areas of interest based on the criteria mentioned earlier were then classified and labelled accordingly.

- The magnetic signature was then examined to locate obvious isolated dipole-type responses, either positive or negative. Any potential source identified at this step must truly reflect the response from an isolated pipe-like body and must not be an ambiguous magnetic response associated with a nearby dyke or other intrusive body. An additional symbol is added to the selection on the overlay to indicate where an isolated magnetic feature also correlates with an EM selection, giving it an improved rating.

- The EM selections derived from the multiparameter map were then examined in profile form and those that matched the optimum shape expected over a kimberlite pipe (see figure 1) were further identified on the interpretation overlay by adding the appropriate symbol. These selections receive the highest rating.

- Boxes were then drawn around the areas of EM seletions and within these boxes, all major structural features (such as dykes, faults, lithological boundaries and intrusive bodies) were outlined from the magnetic signature. These boxes are zones of interest which are meant to draw attention to sub-areas within the survey map sheet where ground follow-up should be considered. Potential targets have been categorized and labelled and maximum geological/structural information is provided as outlined from the magnetics. Other secondary possible targets may be identified on the overlay, outside the zones of interest. Their follow-up should be envisaged pending other available information and encouraging results derived from the neighbouring zones of interest.

- Finally, these primary selections were labelled and listed on a primary target selection table (see table 3, next section) along with their respective categories. Given the wide range of geophysical signature expected over the targets (particularly with the kimberlite pipes), it is difficult to provide a definite priority classification to the selections. However, with caution, the order of the categories as shown in the summary sheet (1 to 14 for kimberlites and 1 to 4 for base metals) reflects the likeliest potential based on the magnetic and electromagnetic signature alone. Other available information such as geochemistry and ground survey data, may alter the order given to the various categories.

- Table 4 lists secondary target selections. These selections fall below the level of geophysical significance set for Table 3, but could be of interest when viewed in light of other information (geochemical, geological, etc.). Secondary selections are included on primary interpretation overlays but overlays are not created for sheets which resulted in only secondary selections. It is usually not appropriate to categorize the secondary target selections as tightly as is done for the primary selections. Accordingly table 4 uses a reduced range of the primary symbols to indicate the type of target.

- In addition to any specific remarks made in tables 3 and 4, further comments on the interpretation are included in section 5 prior to these tables when appropriate.

4.3 *Primary selection categories*

Possible Kimberlite Selections

Symbol	Category	Explanation
	1	Correlation of on-time apparent conductivity and off-time channel 4 responses with coincident magnetic signature and displaying good anomaly characteristics in profile form. Reflects an isolated conductive source of surface with some depth extent and magnetic expression.
	2	Correlation of on-time apparent conductivity and off-time channel 4 responses displaying good anomaly characteristics in profile form. Reflects an isolated conductive source at surface with some depth extent.
	3	On-time apparent conductivity anomaly with no off-time response, with coincident magnetic signature and displaying good anomaly characteristics in profile form. Reflects a weak, isolated conductive source at surface only with magnetic expression.
	4	Correlation of off-time apparent conductivity and off-time channel 4 responses with coincident magnetic signature. Reflects an isolated conductive source at surface with some depth extent and magnetic expression, but lacking good anomaly characteristics in profile form.
	5	On-time apparent conductivity anomaly with no off-time response, but displaying good anomaly characteristics in profile form. Reflects a weak, isolated conductive source at surface only with no magnetic expression.
	6	Off-time channel 4 response only with no on-time signature but with a coincident magnetic response and displaying good anomaly characteristics in profile form. Reflects a buried, isolated conductive source with no surface expression but with magnetic signature.
	7	Correlation of on-time apparent conductivity and off-time channel 4 responses. Reflects an isolated conductive source

at surface with some depth extent, but lacking good anomaly characteristics in profile form and magnetic signature.

8  On-time apparent conductivity anomaly with no off-time response but with coincident magnetic signature. Reflects a weak, isolated conductive source at surface with magnetic signature, but lacking good anomaly characteristics in profile form.

9  Off-time channel 4 response only with no on-time signature but displaying good anomaly characteristics in profile form. Reflects a buried, isolated conductive source with no surface expression and lacking magnetic signature.

10  On-time apparent conductivity anomaly with no off-time response and lacking magnetic signature or good anomaly characteristics in profile form. Reflects a weak, isolated conductive source at surface only.

11  Off-time channel 4 response only with no on-time signature but with coincident magnetic expression. Reflects a buried, isolated conductive source with magnetic signature, but lacking surface expression and good anomaly characteristics in profile form.

12  Off-time channel 4 response only with no on-time signature and lacking good anomaly characteristics in profile form and magnetic signature. Reflects a buried, isolated conductive source with no surface expression.

13  Possible magnetic dipole reponse of reversed remnant magnetization. Reflects an isolated, circular magnetic source at or near surface.

14  Possible dipole response of normal remnant magnetization. Reflects an isolated, circular magnetic source at or near surface.

Possible Base Metal Selections

Symbol	Category	Explanation
	1bm	Late off-time response with coincident magnetic signature and displaying good anomaly shape in profile form. Reflects a bedrock source of limited strike length displaying magnetic signature and enhanced conductance.
	2bm	Late off-time conductive response displaying good anomaly shape in profile form. Reflects a bedrock source of limited strike length, displaying enhanced conductance but lacking magnetic expression.
	3bm	Late off-time conductive response with coincident magnetic expression but lacking good anomaly characteristics in profile form. Reflects a bedrock source of limited strike length with magnetic signature.
	4bm	Late off-time conductive response, lacking magnetic signature and good anomaly characteristics in profile form. Reflects a bedrock source of limited strike length.

Notes

- Based on the electromagnetic and magnetic information alone, the categories given are listed in order of priorities in terms of their potential as possible kimberlite or base metal targets. Other information available, such as geochemistry and other ground data, may alter the order given to the various categories.

- An asterix (*) beside any one of the selections indicates that the topographic detail supports the presence of an isolated pipe-like body (Lake, local depression).

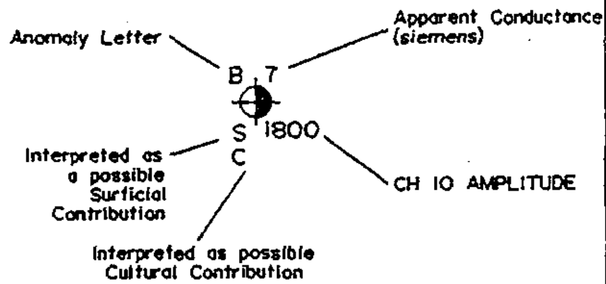
- All kimberlite categories, except perhaps 3, 5, 8 and 10, can also be applied to potential base metal targets, but would be given lower priority than the categories directly assigned to base metal selections.

LEGEND TEXT FOR THE MAG/EM MULTIPARAMETER MAP

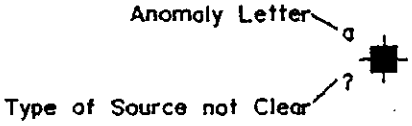
COLOUR	SIGNIFICANCE
LIGHT BLUE	Apparent conductivity (from on-time channel 20) ranging from 1.25 to 5 mS/m, corresponds to weak surficial conductivity with no depth extent. Reflects mainly lake bottom conductivity.
MAGENTA	Apparent conductivity (from on-time channel 20) above 5 mS/m, reflecting stronger surface conductivity with little depth extent.
LIGHT YELLOW	Off-time channel 4 response, generally less than 500 ppm, reflecting a weak, buried conductive source with no surface expression.
YELLOW	Off-time channel 4 response, above 500 ppm, reflecting a stronger, buried conductive source with no surface expression.
ORANGE	Areas where the on-time apparent conductivity above 5 mS/m and the off-time channel 4 responses coincide indicating a conductive source at surface with some depth extent.
GREEN	Areas where the on-time apparent conductivity of less than 5 mS/m and the off-time channel 4 responses coincide, indicating a conductive source with some depth extent but with only a weak surface expression.
WHITE	Resistive background (conductivity less than 1.25 mS/m)
BLACK	EM anomaly peak locations selected from the late portion of the off-time signal, reflecting conductive axes within the bedrock.

GEOTEM® Peak Response Symbols

ANOMALY	CLASSIFICATION OF OFF-TIME RESPONSE FROM TURN-OFF TO
	Channels 5-7 and/or Surficial
	Channels 9-10
	Channels 11-12
	Channels 13-14
	Channels 15-16
	Channels 17-18



Culture Response



GREY	Isogam contour lines of the total magnetic field with a 10 nT interval.

TABLE 1(a)

GENERAL CLASSIFICATION OF EM RESPONSES (from on-time apparent conductivity, channel 4 amplitude and late time anomaly peaks) BASED ON THE COLOUR PATTERNS ON THE MULTIPARAMETER MAP

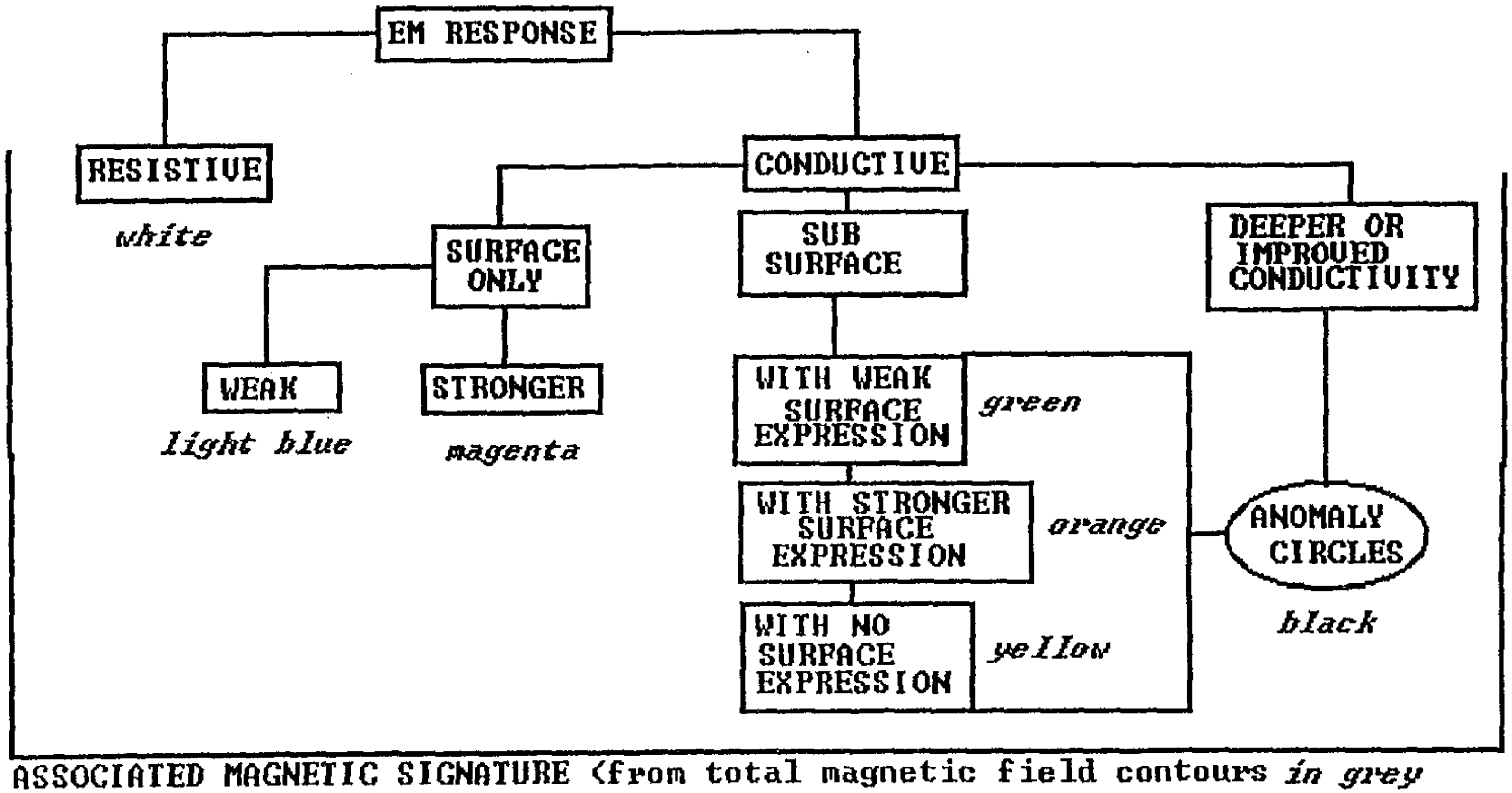


TABLE 1(b)

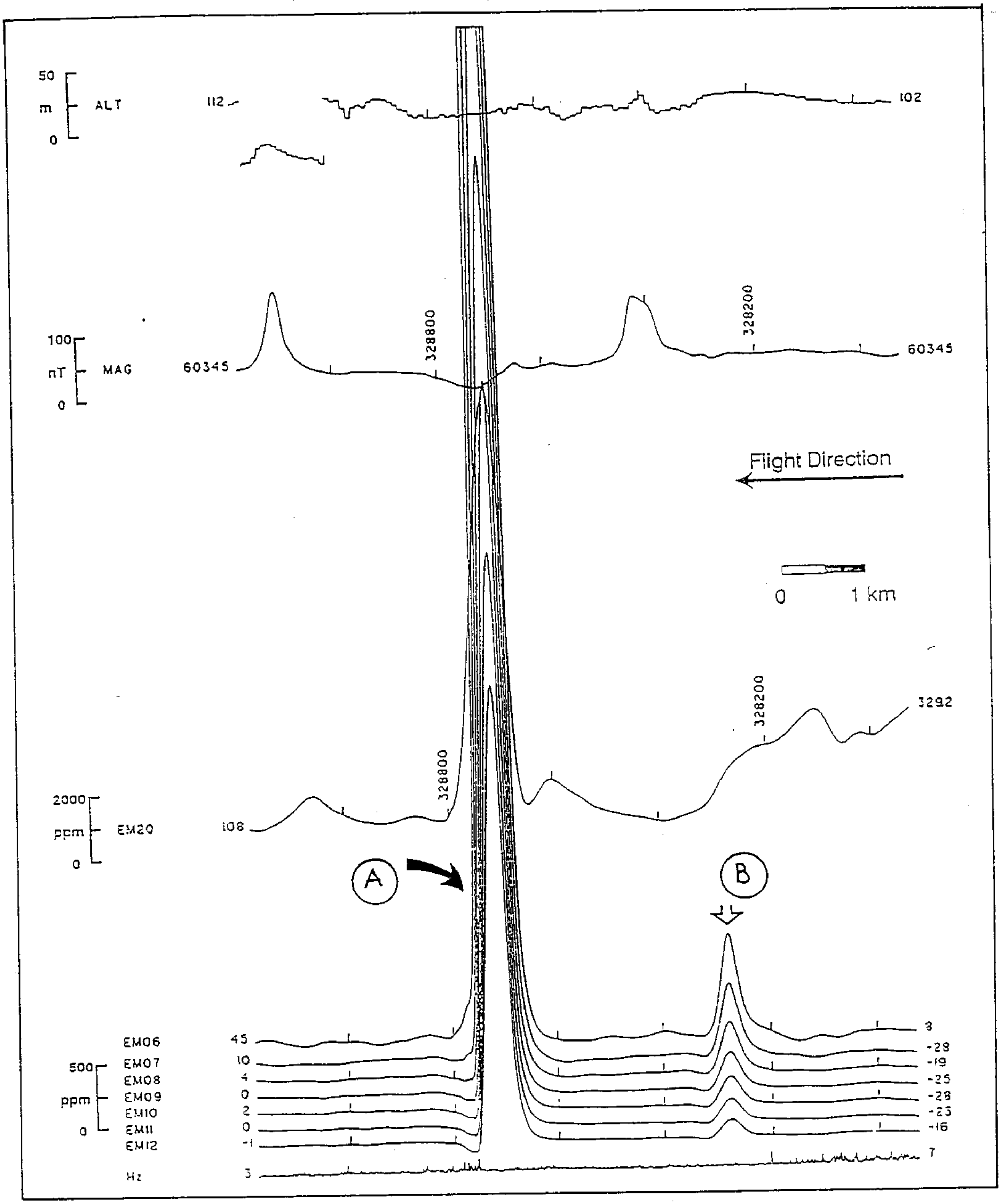
INTERPRETATION LEGEND

SYMBOL	PARAMETER	SIGNIFICANCE
●	Correlation of on-time apparent conductivity and off-time channel 4 responses.	Isolated conductive source with surface expression and some depth extent.
◑	Off-time channel 4 response only, with no on-time signature.	Buried, isolated conductive source with no surface expression.
○	On-time apparent conductivity anomaly with no off-time response.	Weak, isolated conductive source with surface expression only.
⊞ ⊟	Magnetic dipole response, positive or negative magnetization.	Isolated circular magnetic body at or near surface.
△	Late off-time conductive response.	Bedrock source, having a limited strike length and displaying enhanced conductance.
□	Applied to any of the above categories displaying a coincident magnetic signature.	
◯	Applied to any of the above categories displaying optimum shape in profile form.	
✳	Applied to any of the above categories displaying a coincident topographic feature.	
- - - - - - - - - - -	Off-time conductor axis.	Formational conductor, such as schist, graphite, clay.
————————	Linear magnetic body.	Dyke at or near surface.
⊔⊔⊔⊔⊔⊔⊔⊔⊔⊔	Magnetic boundary.	Lithological contact. Ticks point towards the side of higher susceptibility.
∧∧∧∧∧	Discontinuity in the magnetic signature.	Possible fault.
1	Feature listed in the report.	
	Conductive Zone	Formational conductor or zone of surficial alteration.

NOTE: Magnetic features are only interpreted inside the boxed areas, to highlight the magnetic/structural information associated with the EM selections.

TABLE 2

GEOTEM PROFILE RESPONSE



(A) Typical GEOTEM response over a kimberlite pipe

(B) Typical GEOTEM response over a bedrock (base metal sulphides) source

FIGURE 4

5 INTERPRETATION RESULTS FOR AREA 6

Nine primary targets were selected on the 12 NTS map sheets covered in this report. Secondary target selections are listed and categorized in table 4. Categories and symbols are described in the previous section of this report. A location is provided for each target by: a) flight line number plus anomaly label or fiducial number, and b) UTM coordinates. In cases where the target includes several electromagnetic anomalies the location of just one central or major anomaly is provided. This may not coincide exactly with the target symbol position on the interpretation overlay as this symbol may be placed between 2 or more anomalies.

Remarks are included for individual selections when appropriate.

Interpretation Comments

As is common in other areas of this survey, the sediments on the bottoms of lakes are often conductive. In the resistive Arctic environment of the Northwest Territories the apparent conductivity (A.C.) map created from the channel 20 on-time data effectively delineates most lake and the variations in conductivity within larger (greater than about 1 km) lakes.

A polarizability effect which occurs in the Arctic permafrost often results in early off-time (channel 4) negatives (see "Airborne induced polarization is here!", Appendix E of this report). These negatives occur most frequently over lakes—particularly more conductive lakes. The electromagnetic response of known kimberlites in the Northwest Territories cover a wide range, but generally, lack of a significant early off-time (channel 4) response decreases the significance of an A.C. anomaly. For larger lakes, with a broad A.C. anomaly a negative channel 4 response has been interpreted here as non-prospective. However, small conductive lakes (approximately 1 km or less) will often produce a well shaped A.C. peak, coincident with a negative channel 4 which is probably due to a conductive lake bottom and a polarizability effect. Such lakes were generally not selected as targets unless the lake is of a roundish shape, in which case were then listed as a secondary target. If the A.C. in such lakes is significantly higher than other lakes on that sheet, it might be upgraded to a primary selection.

Sometimes in the Arctic environment, positive channel 4 values occur adjacent to the negative channel 4 areas over lakes and wet lands. These "local transitional positives" usually occur in association with lakes exhibiting a higher A.C. but may occur with values under 5 mS/m. The channel 4 positives are usually 300 ppm or less and often have negative trailing/leading edges. They decay quite quickly and channel 6 shows little if any deflection. When this phenomenon occurs on adjacent flight lines it usually displays directional sensitivity resulting in a "herringbone" effect. The cause of these local transitional positives is not well understood.

The geophysical data from area 6 does not indicate the presence of any anomalies showing the typical NWT kimberlite response. However there are a number of anomalies that are attractive massive sulfide targets.

Some of these targets are areas of enhanced conductivity identified within a large sub-oval band of conductive material.

This conductive band closely follows the boundary between the Bear Creek Group (P12) and the Peacock Hills and Kuuvik formations (P13) indicated by Bowie[1]. There is a strong possibility that the mapped conductivity, and the selected anomalies are due to argillaceous material.

[1] Bowie,C.
Cartographic overlay of Geology, Slave craton and environs (OF 2559) on shaded total field magnetic data, District of Mackenzie, Northwest Territories.
Geological Survey of Canada, Open file 2964, scale 1:1,000,000

TABLE 3
PRIMARY TARGET SELECTIONS
AREA 6

MAP SHEET NO.	SELECTION		LOCATION				REMARKS
	NO.	CATE-GORY	LINE NO.	FIDUCIAL OR ANOMALY	UTM		
					NORTHING	EASTING	
76 K/5	1	1 bm	6141	72551	7355290	565100	- locally enchanced late decay constant; strong current migration
	2	1 bm	6147	77535	7356760	565540	- localy enhanced late decay constant; strong current migration
76 K/6	1	2 bm	6136	L	7353920	584081	
76 K/12	1	1 bm	6300	A	7395070	562050	- local enhancement of conductive trend
	2	1 bm	6307	B	7396860	563340	- local enhancement of conductive trend
76 K/13	1	2 bm	6387	E	7416860	555150	- part of late time conductive trend across 6 lines
76 K/14	1	1 bm	6378	B	7414440	582360	- local enhancement of conductive trend
	2	1 bm	6379	O	7414700	584860	- local enhancement of conductive trend
	3	1 bm	6383	A	7416240	583510	

Note: A.C. = apparent conductivity measured from on-time response

TABLE 4
SECONDARY TARGET SELECTIONS
AREA 6

MAP SHEET NO.	SELECTION CATEGORY	LOCATION				REMARKS
		LINE NO.	FIDUCIAL OR ANOMALY	UTM		
				NORTHING	EASTING	
76 K/6	2 bm	6124	F	7350980	580445	
	2 bm	6131	B	7352695	588900	
	2 bm	6132	L	7352960	582110	
	2 bm	6159	C	7359755	574940	- local enhancement of conductive trend
	2 bm	6167	A	7361750	578620	- local enhancement of conductive trend
	2 bm	6199	B	7369690	587677	- local enhancement of conductive trend
76 K/7	14	6176/2	67174	7363870	597640	
	4 bm	6179/2	56485	7364650	595020	
	2 bm	6206/3	G	7371440	589215	- Local enhancement of conductive trend
	2 bm	6218	D	7374390	590700	
76 K/10	10*	6265	69310	7386070	596820	
	8*	6306	71778	7396460	600410	
76 K/11	4 bm	6317	A	7399290	570790	

TABLE 4
SECONDARY TARGET SELECTIONS
AREA 6

MAP SHEET NO.	SELECTION CATEGORY	LOCATION				REMARKS
		LINE NO.	FIDUCIAL OR ANOMALY	UTM		
				NORTHING	EASTING	
	2 bm	6331	A	7402810	566570	- good conductor within weak conductive trend
76 K/12	10*	6264	70328	7386300	545210	
	14	6267	67040	7386840	546160	
	10*	6288	51921	739210	547520	
	14	6297	69785	7394460	548560	
	10*	6308	74407	7397180	545000	- round lake, negative channel 4, lake bottom responses?
	14	6310	76744	7397710	545260	
	10*	6312	79818	7398200	548250	- round lake, negative channel 4, lake bottom response?
	10*	6285	56518	7391350	553800	- round lake, negative channel 4, lake bottom response?
76 K/13	2 bm	6391	H	7417860	554200	
	10*	6368	66609	7413870	544860	- round lake, negative channel 4, lake bottom response?
	10*	6375	45762	7412210	548520	- round lake, negative channel 4, lake bottom response?

TABLE 4
SECONDARY TARGET SELECTIONS
AREA 6

MAP SHEET NO.	SELECTION CATEGORY	LOCATION				REMARKS
		LINE NO.	FIDUCIAL OR ANOMALY	UTM		
				NORTHING	EASTING	
76 K/14	3 bm	6355	D	7408760	577820	
	3 bm	6364	D	7410990	581940	
	2 bm	6395	C	7418720	584640	

Note: A.C. = apparent conductivity measured from on-time response

Appendix A
Archive Format Description

LINE ARCHIVE FORMAT DESCRIPTION

CLIENT: ....*Lytton Minerals Limited*

DATA: ....*Airborne Magnetic and GEOTEM Electromagnetic data*

FORMAT: ....*ASCII, coded 40 I 10*

HEADER RECORD: ....*Single line ID (example) line 210*
ID = line X 100 + part #

LOGICAL RECORD: ....*400 byte record + CR & LF = 402*

DATA RECORD CONTENT

PARAMETER	*CHARACTERS*	*CONTENTS*
1	1-10	X (UTM metres)
2	11-20	Y (UTM metres)
3	21-30	Fiducial (seconds after midnight)
4	31-40	EM channel 1, processed (ppm)
5	41-50	EM channel 2, processed (ppm)
6	51-60	EM channel 3, processed (ppm)
7	61-70	EM channel 4, processed (ppm)
8	71-80	EM channel 5, processed (ppm)
9	81-90	EM channel 6, processed (ppm)
10	91-100	EM channel 7, processed (ppm)
11	101-110	EM channel 8, processed (ppm)
12	111-120	EM channel 9, processed (ppm)
13	121-130	EM channel 10, processed (ppm)
14	131-140	EM channel 11, processed (ppm)
15	141-150	EM channel 12, processed (ppm)
16	151-160	EM channel 13, processed (ppm)
17	161-170	EM channel 14, processed (ppm)
18	171-180	EM channel 15, processed (ppm)
19	181-190	EM channel 16, processed (ppm)
20	191-200	EM channel 17, processed (ppm)
21	201-210	EM channel 18, processed (ppm)
22	211-220	EM channel 19, processed (ppm)

23	*221-230*	*EM channel 20, processed (ppm)*
24	*231-240*	*EM primary field (microvolts)*
25	*241-250*	*Powerline noise monitor (microvolts)*
26	*251-260*	*Early decay constant (microseconds)*
27	*261-270*	*Late decay constant (microseconds)*
28	*271-280*	*Apparent conductivity from the early off-time channels (mS/m x 1000)*
29	*281-290*	*Apparent conductivity from the late off-time channels (mS/m x 1000)*
30	*291-300*	*Apparent conductivity from the on-time channel 20 (mS/m x 1000)*
31	*301-310*	*Radar altimeter (feet)*
32	*311-320*	*Diurnal magnetics, edited (nT x 100)*
33	*321-330*	*Total field magnetics, edited (nT x 100)*
34	*331-340*	*Compensation field 1 (nT x 100)*
35	*341-350*	*Total field magnetics, levelled and IGRF subtracted (nT x 100)*
36	*351-360*	*IGRF values (nT x 100)*
37	*361-370*	*Latitude (degrees x 1000000)*
38	*371-380*	*Longitude (degrees x 1000000)*
39	*381-390*	*Compensation field 2 (nT x 100)*
40	*391-400*	*Vertical gradient of magnetics (nT/km x 100)*
	401-401	*CR*
	402-402	*LF*

NOTES

1. Coordinates are in UTM metres,based on the Clarke 1866 Spheroid projection using a central meridian of 111 degrees West,a false northing of 0, a false easting of 500000 and a scale factor of 0.9996.

2. The fiducial value is the time in seconds past midnight. Each second of data is archived as 6 consecutive data samples with each of the samples for the one second having the same fiducial number.

3. The apparent conductivity values stored as parameter 30 were computed from the amplitude data of the on-time channel 20 based on the homogeneous half-space model.The apparent conductivity derived from the early and late off-time data (parameters 28 &29) were converted from the corresponding decay constant values, based also on the homogeneous half-space model.

4. Parameter 34, identified as compensation 1, represents the magnetic levelling adjustments made using the regular line-tieline intersection information in line form.Parameter 39,identified as compensation 2, represents the final levelling

Appendix B
GEOTEM® System

GEOTEM[1] ELECTROMAGNETIC SYSTEM

General

The operation of a towed-bird time-domain electromagnetic (EM) system involves the measurement of decaying secondary electromagnetic fields induced in the ground by a series of short current pulses generated from an aircraft-mounted transmitter. Variations in the decay characteristics of the secondary field (sampled and displayed as channels) are analyzed and interpreted to provide information about the subsurface geology. The response of such a system utilizing a vertical-axis transmitter dipole and a horizontal-axis receiver coil has been documented by various authors including Palacky and West (1973, Geophysics, v. 38, p. 1145-1158).

The principle of sampling the induced secondary field in the absence of the primary field (during the "off time") gives rise to an excellent signal-to-noise ratio and an increased depth of penetration compared to conventional continuous wave (frequency domain) electromagnetic systems. Such a system is also relatively free of noise due to air turbulence.

Through free-air model studies using the University of Toronto's Plate and Layered Earth programs it may be shown that the "depth of investigation" depends upon the geometry of the target. Typical depth limits would be 250 m below surface for a homogeneous half-space, 350 m for an inductively thin sheet or 200 m for a large vertical plate conductor. These depth estimates are based on the assumptions that a significant response is recorded 1.4 ms after the primary field is turned off and that the overlying or surrounding material is resistive. If a pre-selected range of channels is deemed adequate to detect or resolve a given target, then the depth of investigation increases significantly.

In addition to substantial penetration, time-domain systems respond to a wide range of conductors. With measurements taken during the off time, significant effects are seen for conductors with conductance of 0.8 S or greater, thus responding to the majority of geological feautures deemed relevant in most exploration projects.

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[1] GEOTEM®: Registered Trade Mark of Geoterrex Limited.

The method also offers very good discrimination of conductor geometry. The ability to distinguish between flat-lying and vertical conductors combined with excellent depth penetration results in good differentiation of bedrock conductors from surficial conductors.

Most of the preceding discussion concerns theoretical responses for all time-domain installations of similar geometry. The factor which distinguishes the various systems is their ability to faithfully and completely represent the secondary field response.

Equipment and Procedure

GEOTEM (GEOterrex Transient ElectroMagnetic system) is a time-domain towed-bird electromagnetic system incorporating a high-speed digital EM receiver. The primary electromagnetic pulses are created by a series of discontinuous sinusoidal current pulses fed into a three-turn shielded transmitting loop surrounding the aircraft and fixed to the nose, tail and wing tips. The pulse repetition rate is typically 150 Hz (300 bipolar pulses per second), 125 Hz, 90 Hz or 75 Hz. At 150 Hz, as used in this survey, each current pulse can last 1030 µs followed by 2303 µs off-time. Present peak current through the loop is 600 A resulting in a primary magnetic dipole moment of $4.5 \times 10^5 A.m^2$.

The receiver is a wire coil with a ferrite core. It is mounted horizontally in a bird which is towed by the aircraft on a 135-metre cable. The cable is demagnetized to reduce noise levels. Mean terrain clearance for the aircraft is 120 m with the bird situated 56 m below, and 123 m behind, the aircraft. The geometry of the system is displayed in Figure 1.

For each primary pulse a secondary magnetic field is produced by decaying eddy currents in the ground. These in turn induce a voltage in the receiver coil which is a measure of the electromagnetic field. Figure 2 gives a graphical display of the GEOTEM signal.

The measured signals pass through anti-aliasing filters and are then digitized with an A/D converter at sampling rates of up to 40 kHz. The digital data flows from the A/D converter into an array processor where all the numerically intensive processing tasks, such as Fourier analysis, are carried out. The array processor is under the control of a multi-tasking minicomputer which provides all of the software management.

GEOTEM® SYSTEM

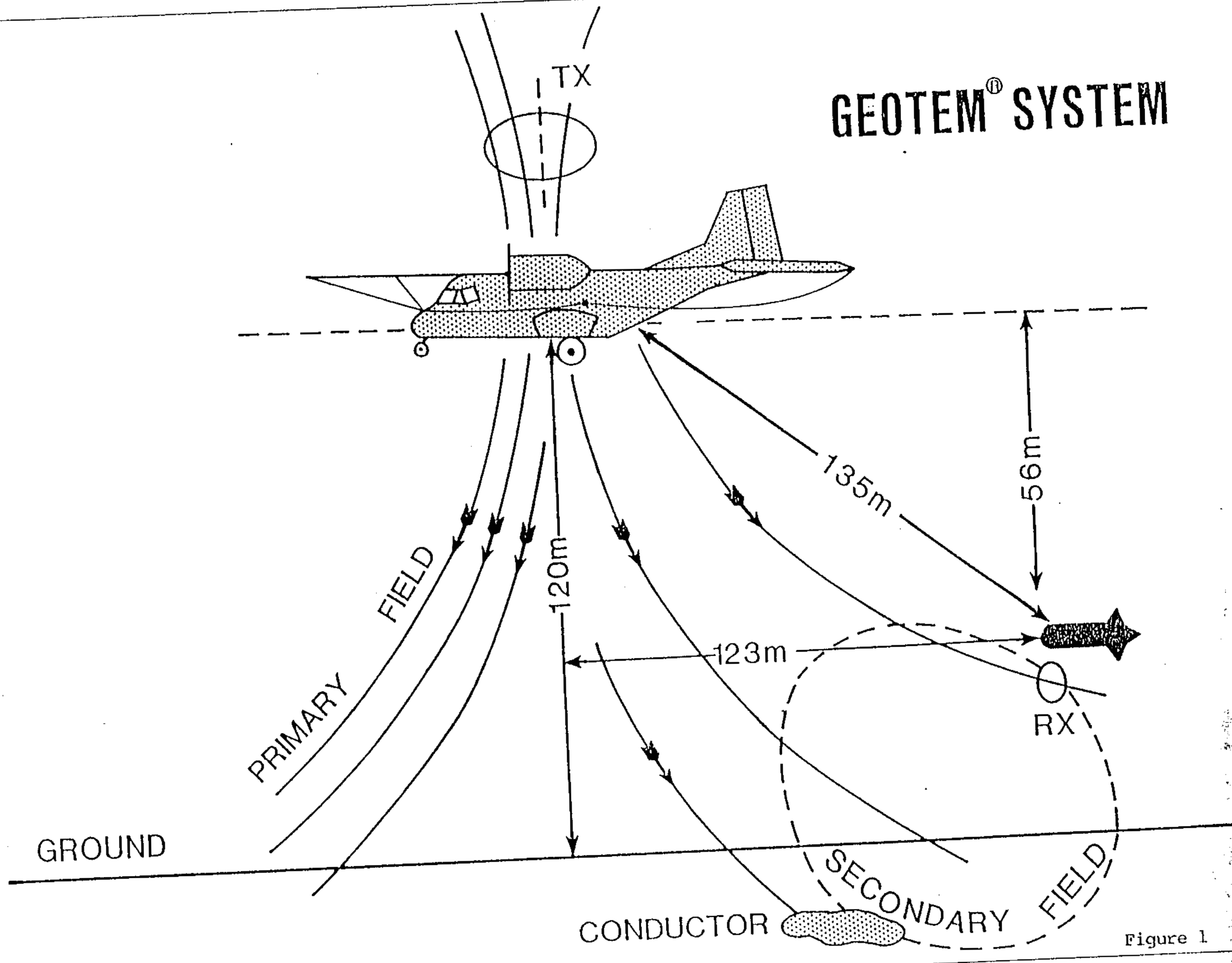

Figure 1

GEOTEM® SIGNAL

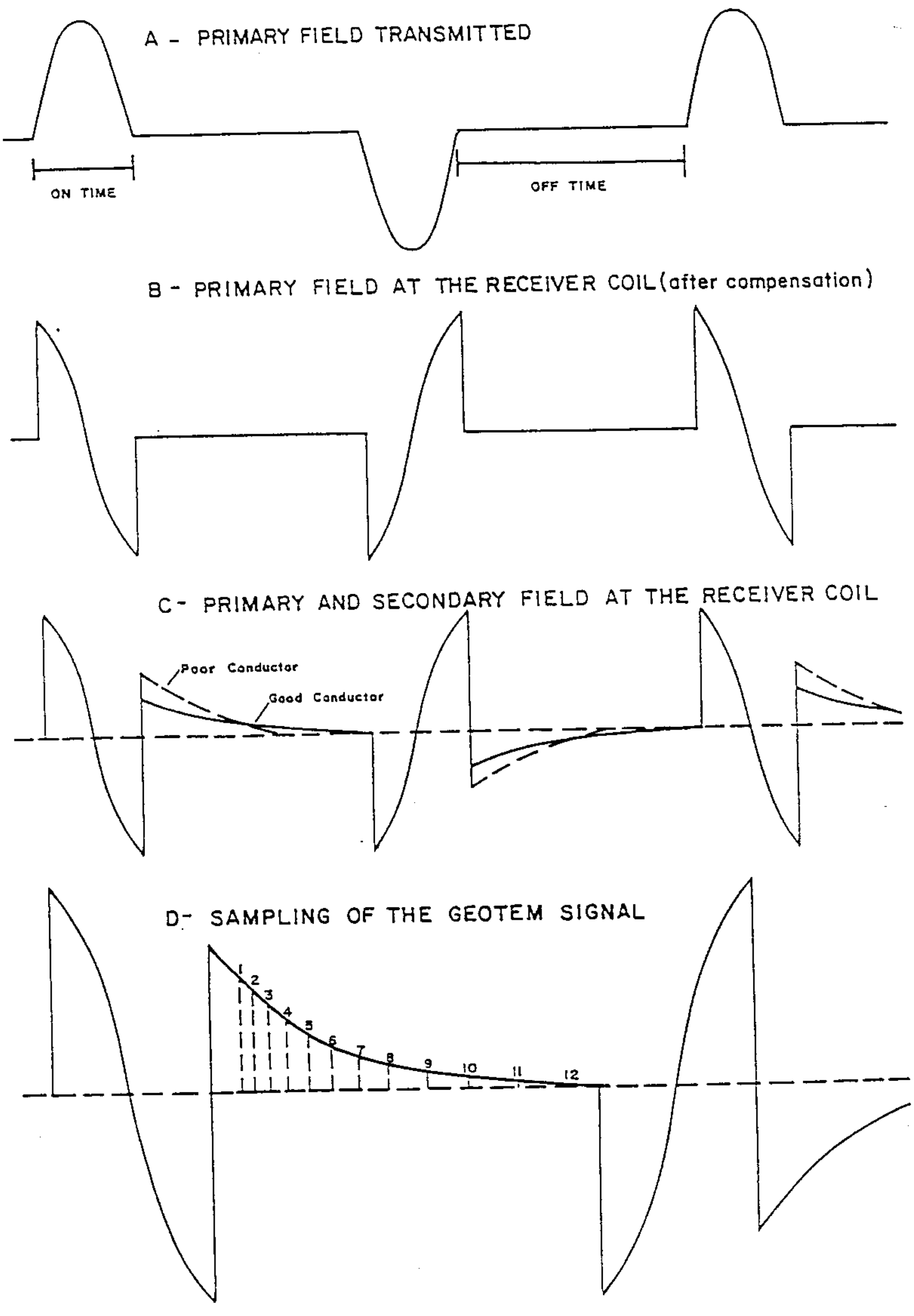

Figure 2

Operations which are carried out in the receiver are:

1. Compensation. During flight the transmitter creates eddy currents within the structure of the aircraft and these have a measurable effect at the bird. Compensation for this signal is effected numerically within the receiver by a statistical analysis of the signal detected at the bird in the absence of ground response. This is achieved by flying at an altitude such that no ground response is measurable (usually in excess of 600 m above ground level). The observed signal is used to define a compensation signal which is subtracted from the observed to produce a null and thus effectively buck out any response due to the aircraft.

2. Normalization. All EM response channels are automatically calibrated and reduced to parts per million (ppm) of the primary field in the receiver. This is achieved by dividing the measured voltage by the voltage induced by the primary field at the bird.

3. Transient Analysis. Harmonic analysis permits the separation of specific types of noise from the signal in real time.

4. Digital Stacking. Stacking is carried out to reduce the effect of broadband noise on the data.

5. Windowing of Transient Data. The GEOTEM digital receiver samples the secondary and primary electromagnetic field and stores the signal in up to 20 time gates whose centres and widths are software selectable and which may be placed anywhere within or outside the transmitter pulse. This flexibility offers the advantage of arranging the gates to suit the goals of a particular survey, ensuring that the signal is appropriately sampled through its entire dynamic range.

One of the major roles of the GEOTEM digital EM receiver is to provide diagnostic information on system functions and to allow for identification of noise events, such as spherics, which may be selectively removed from the EM signal.

The receiver automatically calibrates its received signal with reference to the primary field in ppm and hence compensates for the transmitter drift. Due to the fact that the receiver is digital, the receiver drift is minimal. These factors result in more reliable resistivity mapping where base level shifts can dramatically affect results.

GEOTEM's high digital sampling rate yields maximum resolution of the secondary field. The absence of an analog system time-constant filter results in minimal signal distortion and, therefore, superior representation of the anomaly amplitudes and shapes.

Appendix C
GEOTEM® Interpretation Notes

GEOTEM[R1] INTERPRETATION

I. INTRODUCTION

The basis of the transient electromagnetic (EM) geophysical surveying technique relies on the premise that changes in the primary EM field produced in the transmitting loop will result in eddy currents being generated in any conductors in the ground. The eddy currents then decay to produce a secondary EM field which may be sensed as a voltage in the receiver coil.

GEOTEM (**GEO**terrex **T**ransient **E**lectro**M**agnetic system) is an airborne transient (or time-domain) towed-bird EM system incorporating a high-speed digital receiver which records the secondary field response with a high degree of accuracy. Most often the total magnetic field is recorded concurrently.

Although the approach to GEOTEM interpretation varies from one survey to another depending on the type of data presentation, objectives and local conditions, the following generalizations may provide the reader with some helpful background information.

The main purpose of the interpretation is to determine the probable origin of the conductors detected during the survey and to suggest recommendations for further exploration. This is possible through an objective analysis of all characteristics of the different types of conductors and associated magnetic anomalies, if any. If possible the airborne results are compared to other available data. A certitude is seldom reached, but a high probability is achieved in identifying the conductive causes in most cases. One of the most difficult problems is usually the differentiation between surface conductors and bedrock conductors.

II. TYPES OF CONDUCTORS

A. Bedrock Conductors

The different types of bedrock conductors normally encountered are the following:

1. Graphites. Graphitic horizons (including a large variety of carbonaceous rocks) occur in sedimentary formations of the Precambrian as well as in volcanic tuffs, often concentrated in shear zones. They correspond generally to long, multiple conductors lying in parallel bands. They have no magnetic expression unless associated with pyrrhotite or magnetite. Their conductivity is variable but generally high.

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[1] GEOTEM[R]: Registered Trade Mark of Geoterrex Limited.

2. Massive sulphides. Massive sulphide deposits usually manifest themselves as short conductors of high conductivity, often with a coincident magnetic anomaly. Some massive sulphides, however, are not magnetic, others are not very conductive (discontinuous mineralization), and some may be located among formational conductors so that one must not be too rigid in applying the selection criteria.

   In addition, there are syngenetic sulphides whose conductive pattern may be similar to that of graphitic horizons but these are generally not as prevalent as graphites.

3. Magnetite and some serpentinized ultrabasics. These rocks are conductive and very magnetic.

4. Manganese oxides. This mineralization may give rise to a weak EM response.

B. Surficial Conductors

1. Beds of clay and alluvium, some swamps, and brackish ground water are usually poorly conductive to moderately conductive.

2. Lateritic formations, residual soils and the weathered layer of the bedrock may cause surface anomalous zones, the conductivity of which is generally low to medium but can occasionally be high. Their presence is often related to the underlying bedrock.

C. Cultural Conductors (Man-Made)

1. Power lines. These frequently, but not always, produce a conductive type of response on the GEOTEM record. In the case of direct radiation of its field, a power line is easily recognized by a GEOTEM anomaly which exhibits phase changes between different channels. In the case of a grounded wire, or steel pylon, the anomaly may look very much like a bedrock conductor.

2. Grounded fences or pipelines. These will invariably produce responses much like a bedrock conductor. Whenever they cannot be identified positively, a ground check is recommended.

3. General culture. Other localized sources such as certain buildings, bridges, irrigation systems, tailings ponds etc., may produce GEOTEM anomalies. Their instances, however, are rare and often they can be identified on the visual path recovery system.

III. ANALYSIS OF THE CONDUCTORS

The apparent conductivity alone is not generally a decisive criterion in the analysis of a conductor. In particular, one should note:

- its shape and size,
- all local variations of characteristics within a conductive zone,
- any associated geophysical parameter (e.g. magnetics),
- the geological environment,
- the structural context, and
- the pattern of surrounding conductors.

The first objective of the interpretation is to classify each conductive zone according to one of the three categories which best defines its probable origin. The categories are cultural, surficial and bedrock. A second objective is to assign to each zone a priority rating as to its potential as an economic prospect.

A. Cultural Conductors

The majority of cultural anomalies occur along roads and are accompanied by a response on the power line monitor. (This monitor is set to 50 or 60 Hz, depending on the local power grid.) Power lines are the most common source of the anomalies and many are recognized immediately by virtue of phase reversals or an abnormal rate of decay. A certain number yield normal GEOTEM anomalies which could be mistaken for bedrock responses. There are also some power lines which have no GEOTEM response whatsoever.

The power line monitor, of course, is of great assistance in identifying cultural anomalies of this type. It is important to note, however, that geological conductors in the vicinity of power lines may exhibit a weak response on the monitor because of current induction via the earth.

Fences, pipelines, communication lines, railways and other man-made conductors can give rise to GEOTEM responses, the strength of which will depend on the grounding of these objects.

Another facet of this analysis is the line-to-line comparison of anomaly character along suspected man-made conductors. In general, the amplitude, the rate of decay, and the anomaly width should not vary a great deal along any one conductor, except for the change in amplitude related to terrain clearance variation. A marked departure from the average response character along any given feature gives rise to the possibility of a second conductor.

In most cases a visual examination of the site will suffice to verify the presence of a man-made conductor. If a second conductor is suspected the ground check is more difficult to accomplish. The object would be to determine if there is (i) a change in the man-made construction, (ii) a difference in the grounding conditions, (iii) a second cultural source, or (iv) if there is, indeed, a geological conductor in addition to the known man-made source.

B. Surficial Conductors

This term is used for geological conductors in the overburden, either glacial or residual in origin, and in the weathered layer of the bedrock. Most surficial conductors are probably caused by clay minerals. In some environments the presence of salts will contribute to the conductivity. Other possible electrolytic conductors are residual soils, swamps, brackish ground water and alluvium such as lake or river-bottom deposits, flood plains and estuaries.

Normally, most surficial materials have low to intermediate conductivity so they are not easily mistaken for highly conductive bedrock features. Also, many of them are wide and their anomaly shapes are typical of broad horizontal sheets.

When surficial conductivity is high it is usually still possible to distinguish between a horizontal plate (more likely to be surficial material) and a vertical body (more likely to be a bedrock source) thanks to the asymmetry of the GEOTEM responses observed at the edges of a broad conductor when flying adjacent lines in opposite directions. The configuration of the system is such that the response recorded at the leading edge is more pronounced than that registered at the trailing edge. Figure 1 illustrates the "edge effect" and the resulting conductive pattern in plan view. In practice there are many variations on this very diagnostic phenomenon.

One of the more ambiguous situations as to the true source of the response is when surface conductivity is related to bedrock lithology as for example, surface alteration of an underlying bedrock unit. At times, it is also difficult to distinguish between a weak conductor within the bedrock (e.g. near-massive sulphides) and a surficial source.

In the search for massive sulphides or other bedrock targets, surficial conductivity is generally considered as interference but there are situations where the interpretation of surficial-type conductors is the primary goal. When soils, weathered or altered products are conductive, and in-situ, the GEOTEM responses are a very useful aid to geologic mapping. Shears and faults are often identified by weak, usually narrow, anomalies.

Analysis of surficial conductivity can be used in the exploration for such features as lignite deposits, kimberlites, paleochannels and ground water. In coastal or arid areas, surficial responses may serve to define the limits of fresh, brackish and salty water.

EDGE EFFECT

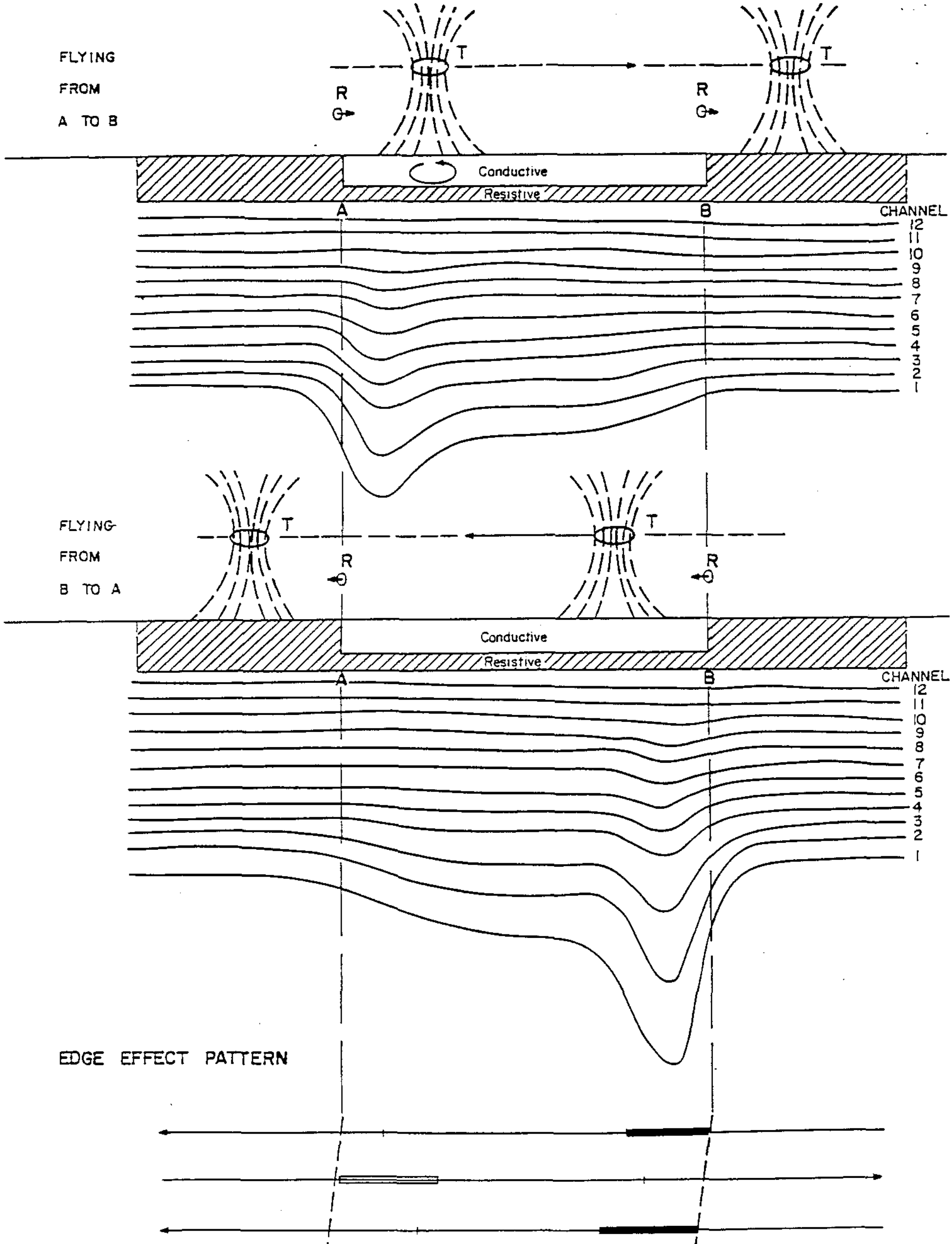


FIGURE 1

C. Bedrock Conductors

This category comprises those anomalies which cannot be classified according to the criteria established for cultural and surficial responses. It is difficult to assign a universal set of values which typify bedrock conductivity because any individual zone or anomaly might exhibit some, but not all, of these values and still be a bedrock conductor. The following criteria are considered indicative of a bedrock conductor:

1. An intermediate to high conductivity identified by a response with slow decay, with deflections most often present in the later channels.

2. The anomaly should be narrow, relatively symmetrical, with a well-defined peak.

3. There should be no serious displacement of anomaly position or change in anomaly shape (other than mirror image) with respect to flight direction, except in the case of non-vertical dipping bodies. The alternating character of the response as a result of line direction can be diagnostic of conductor geometry. Figures 2 to 6 illustrate anomalies associated with different target models.

4. A small to intermediate amplitude. Large amplitudes are normally associated with surficial conductors. The amplitude varies according to the depth of the source.

5. A degree of continuity of the EM characteristics across several lines.

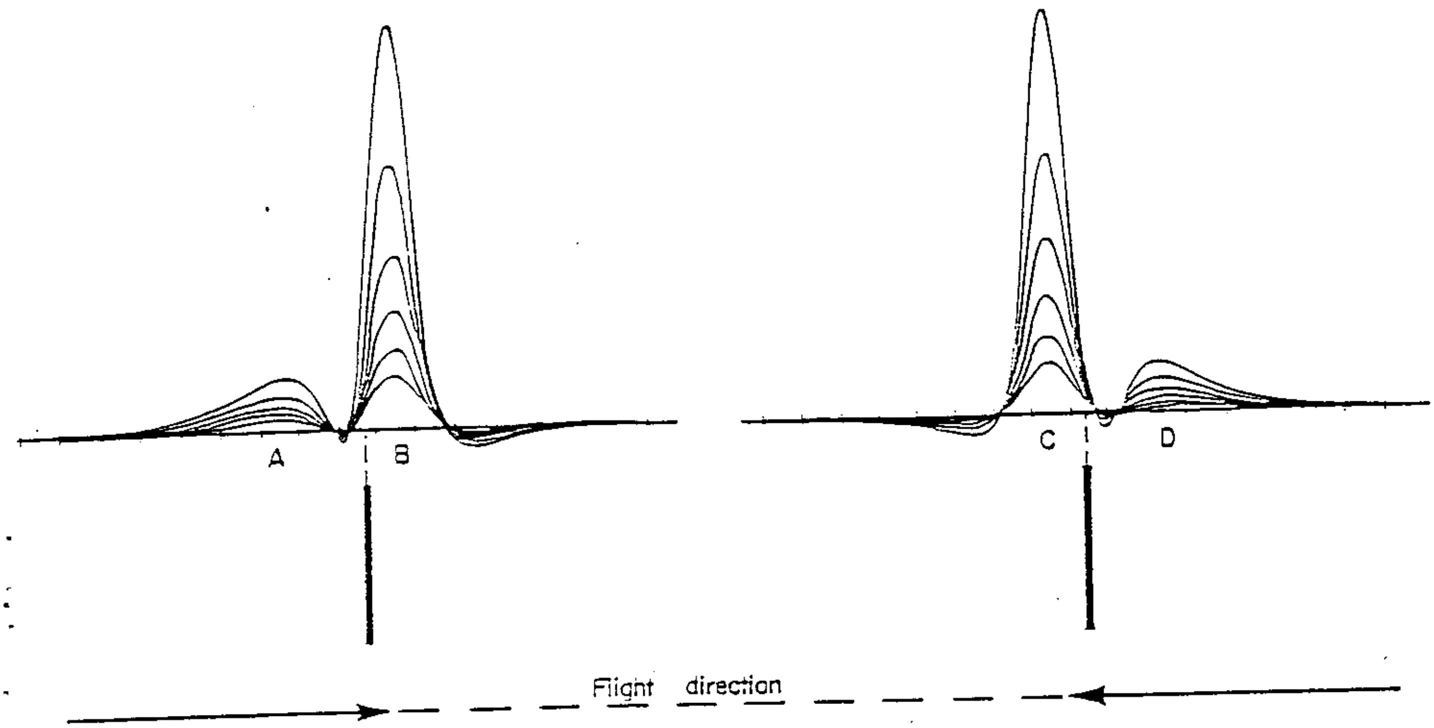
6. An associated magnetic response of similar dimensions. One should note, however, that those rocks which weather to produce a conductive upper layer will possess this magnetic association. In the absence of one or more of the characteristics defined in 1, 2, 3 and 4, the related magnetic response cannot be considered significant.

Most obvious bedrock conductors occur in long, relatively monotonous, sometimes multiple zones following formational strike. Graphitic material is usually the most probable source. Massive syngenetic sulphides extending for many kilometres are known in nature but, in general, they are not common. Long formational structures associated with a strong magnetic expression may be indicative of banded iron formations.

A bedrock conductor reflecting the presence of a massive sulphide would normally exhibit the following characteristics:

- a high conductivity,
- a good anomaly shape (narrow and well-defined peak),
- a small to intermediate amplitude,
- an isolated setting,

THE VERTICAL PLATE RESPONSE



ANOMALY MAP PRESENTATION (no lag applied)

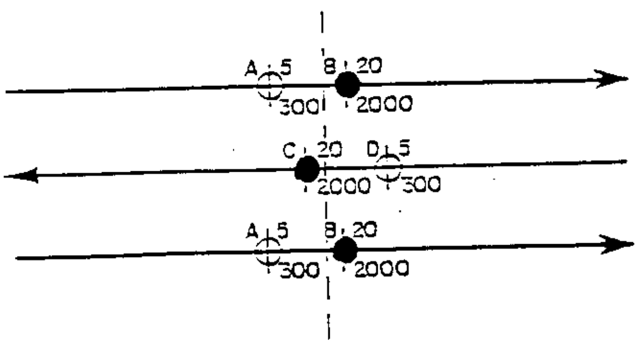


Figure 2

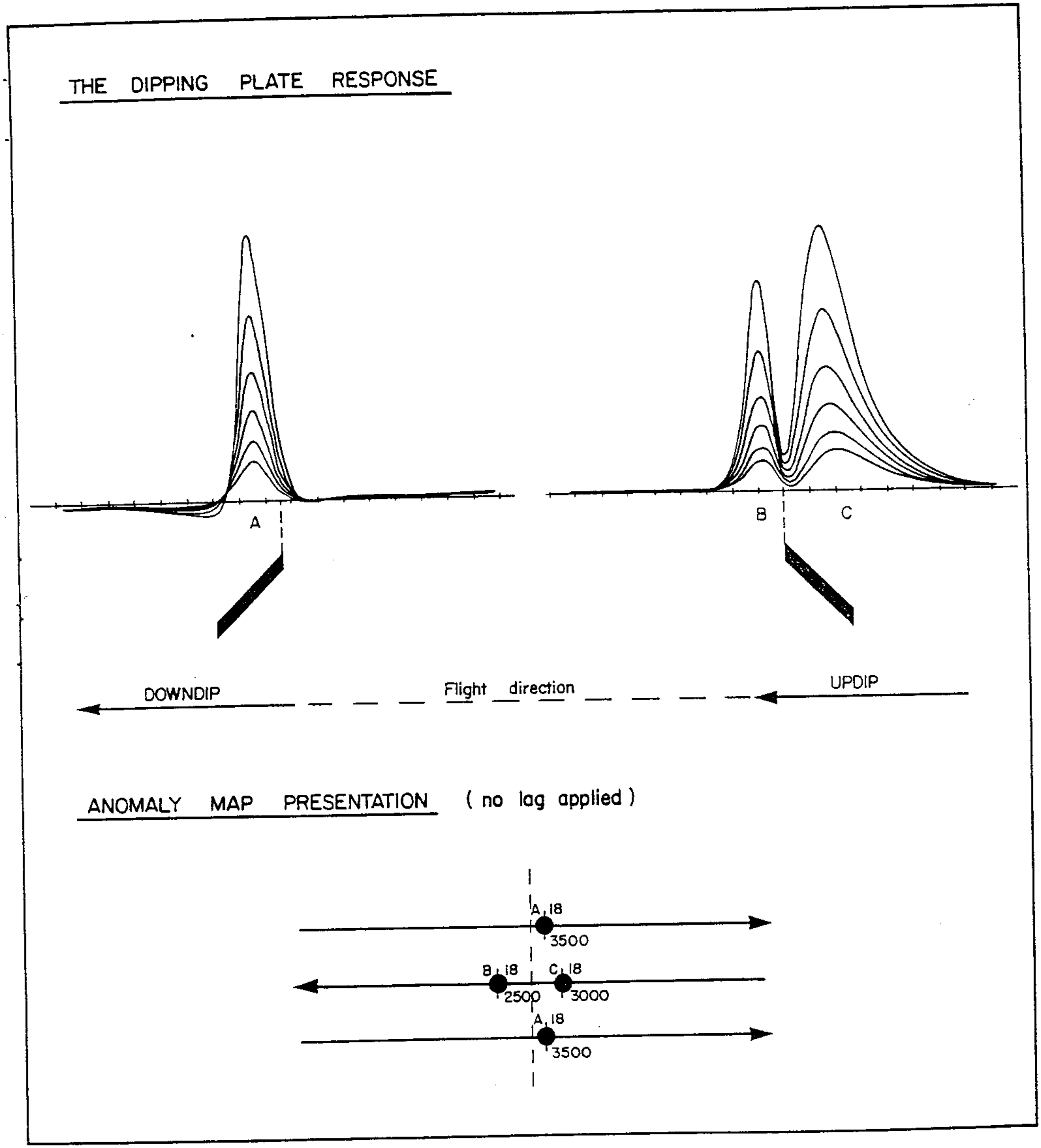
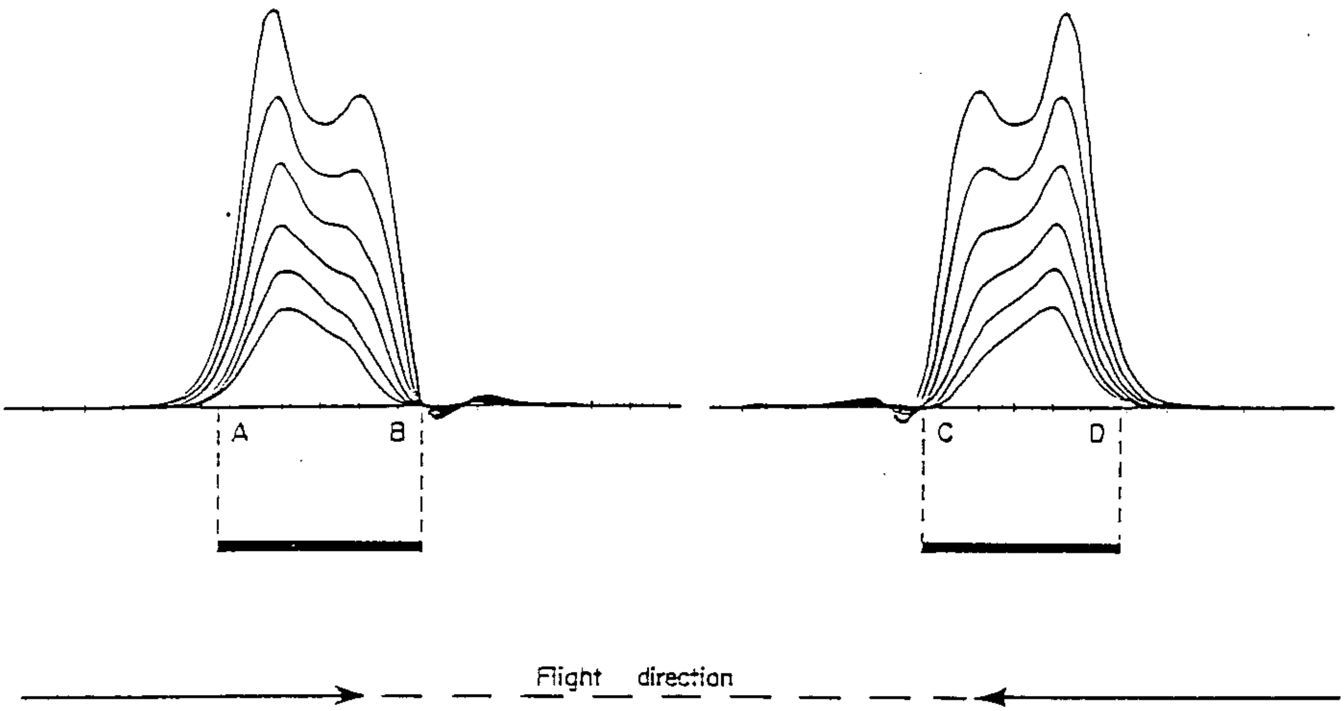

THE DIPPING PLATE RESPONSE
A
B
C
DOWNDIP
Flight direction
UPDIP
ANOMALY MAP PRESENTATION (no lag applied)
A 18
3500
B 18
2500
C 18
3000
A 18
3500

Figure 3

THE HORIZONTAL PLATE RESPONSE



ANOMALY MAP PRESENTATION (no lag applied)

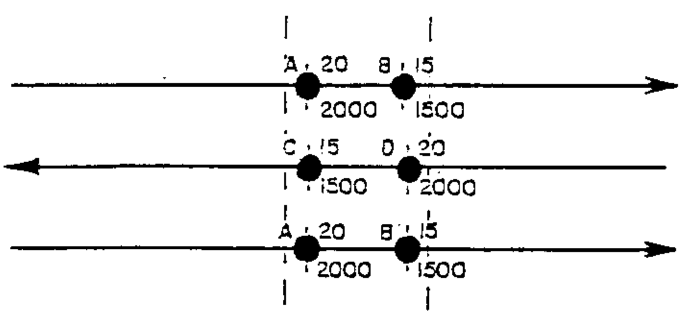
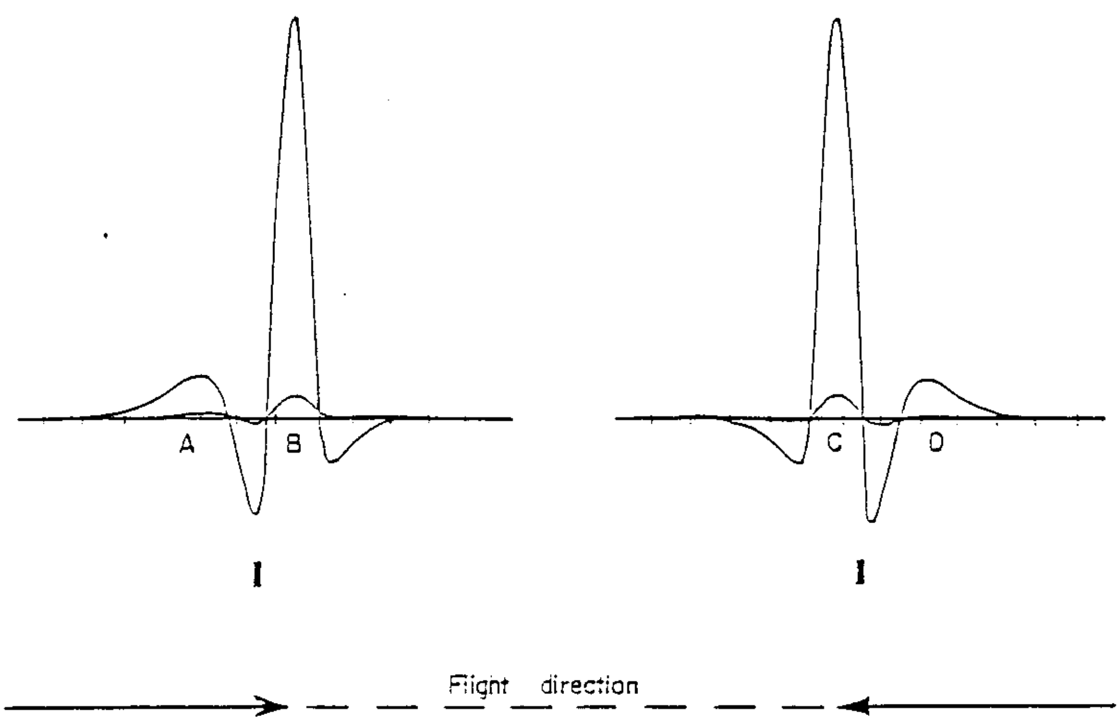


Figure 4

THE VERTICAL RIBBON RESPONSE



ANOMALY MAP PRESENTATION (no lag applied)

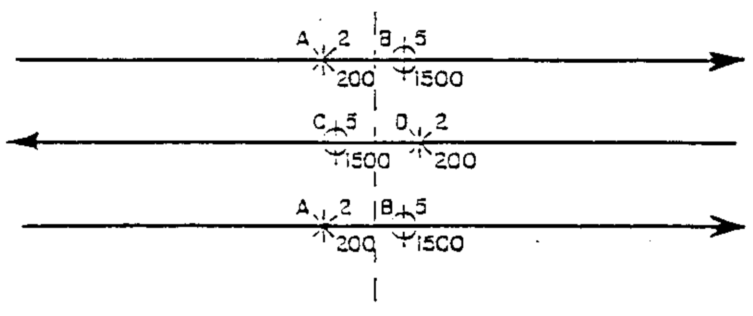
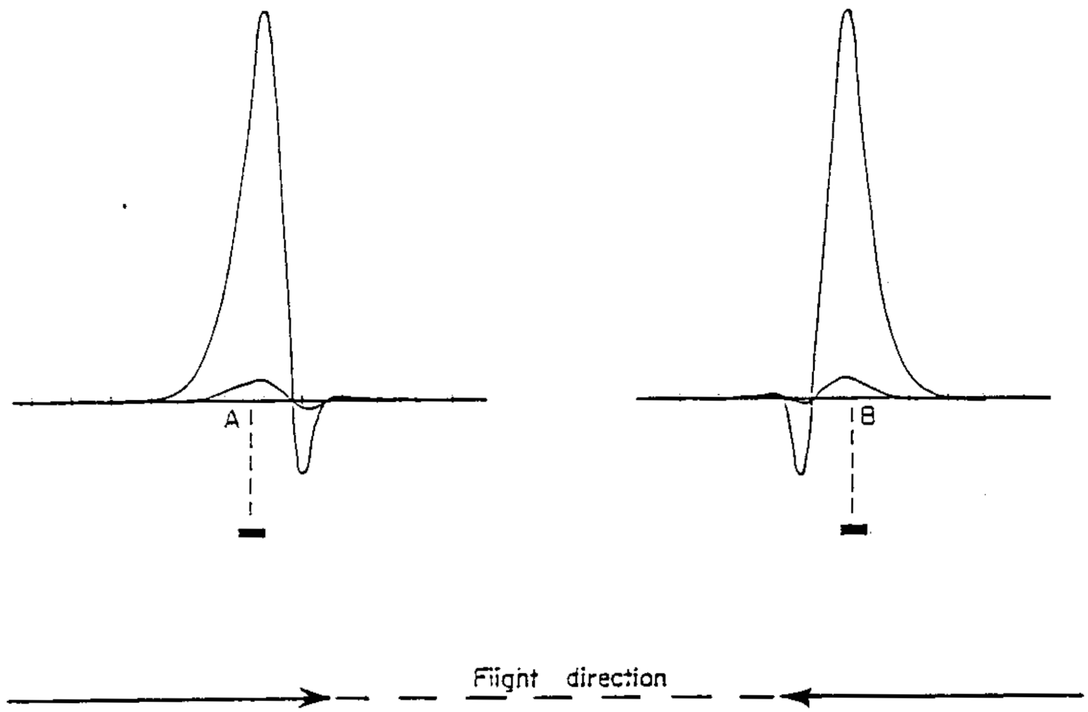


Figure 5

THE HORIZONTAL RIBBON RESPONSE



ANOMALY MAP PRESENTATION (no lag applied)

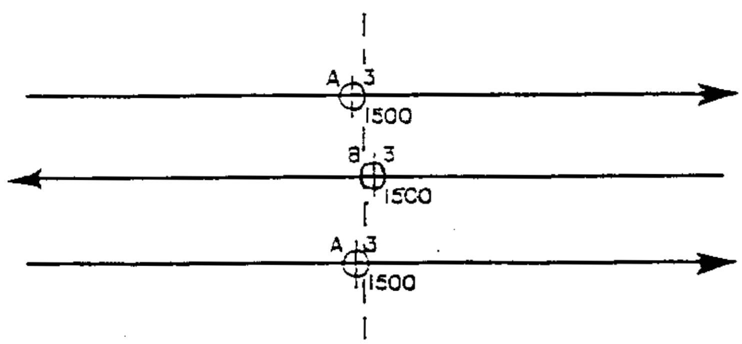


Figure 6

- a short strike length (in general, not exceeding one kilometre), and
- preferably, with a localized magnetic anomaly of matching dimensions.

The selection of targets from within extensive (formational) belts is much more difficult than in the case of isolated conductors. Local variations in the EM characteristics, such as in the amplitude, decay, shape etc., can be used as evidence for a relatively localized occurrence. Changes in the character of the EM responses, however, may be simply reflecting differences in the conductive formations themselves rather than indicating the presence of massive sulphides and, for this reason, the degree of confidence is reduced.

Another useful guide for identifying localized variations within formational conductors is to examine the magnetic data compiled as isomagnetic contours. Further study of the magnetic data can reveal the presence of faults, contacts and other features which, in turn, help define areas of potential economic interest.

Finally, once ground investigations begin, it must be remembered that the continual comparison of ground knowledge to the airborne information is an essential step in maximizing the usefulness of the GEOTEM data.

Appendix D
Exploration for kimberlites

EXPLORATION FOR KIMBERLITES:

A review of geophysical exploration methods with examples from Point Lake, NWT, using an optimized GEOTEM® system

GEOTERREX LTD.

OTTAWA, CANADA

1993

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ABSTRACT

Throughout the world, geophysical techniques are commonly used in the search for kimberlite, a known source of diamonds. In order to be detected, the physical properties of the kimberlite must be significantly different from those of the surrounding rock. It is possible to detect contrasts in conductivity and magnetic susceptibility from the air using electromagnetic and magnetic techniques. The electromagnetic response is due to a conductive surface layer, attributed to weathering alteration and the magnetic response is attributed to magnetite and ilmenite within the kimberlite. The pipe-like shape of kimberlite diatremes results in an anomaly pattern which is easy to identify.

Diamondiferous kimberlites have recently been found in the Northwest Territories of Canada, an area glaciated in the Pleistocene and therefore devoid of a significant weathered zone. By configuring the GEOTEM® airborne electromagnetic system to operate at high frequencies (270 Hz) and to take measurements while the transmitter is switched on, it is possible to detect weakly conductive kimberlites because there is a sufficient contrast with the highly resistive country rock. Recent system modifications also allow the magnetic field to be sampled 47 metres closer to the ground and ten times more frequently, allowing much better definition of weak, small anomalies. Example data collected from test flights over kimberlites near Lac de Gras, Northwest Territories, demonstrates the effectiveness of the optimized system for reconnaissance surveying.

INTRODUCTION

The value of diamonds is such that an economic deposit will contain significantly less than 1 part per million of diamonds (Hausel et al., 1979). The geophysical search for diamonds is therefore dependent on the successful detection of the host material, kimberlitic or lamproitic rock. This requires an understanding of the geology and physical properties of the host rock and how they contrast with the surrounding country rock.

This paper will briefly review the use of geophysical methods as applied to kimberlite exploration worldwide and in North America, and then discuss two examples from the Northwest Territories (NWT) of Canada, where airborne methods can be used to detect moderately conductive kimberlites with subtle magnetic anomalies.

Kimberlite Geology

Kimberlite is an ultrabasic igneous rock which can occur as sills, dikes or diatremes (pipes). The sills and dikes are only rarely mined (Gerryts, 1967), but about one in a hundred pipes contain an economic deposit of diamonds (Brummer, 1978; Kamara, 1981). The classic model of a pipe is generally conical in shape, comprising unweathered kimberlite at the base, through serpentenized blue ground, weathered yellow ground to ejecta at the surface (Wagner, 1971; da Costa, 1989). Figure 1 shows an idealized kimberlite pipe, but most examples have been buried, eroded or have undergone some combination of the two processes. The pipe, believed to be emplaced by an explosive eruption, is a mixture of agglomerate, tuff, inclusions and breccia (Hawthorne, 1975). Many phases of eruption have been identified in pipes, so the rock can be highly inhomogeneous.

Diamonds are believed to form at about 150 km depth below a craton with deep roots (Kirkley et al., 1991). The diamonds are then transported to the surface by an eruption, generally at the center of the craton and conjecturally near a major crustal structure (Dawson, 1971). Kimberlites normally occur in swarms and are spread apparently at randomly over a large area (Hausel et al., 1979).

In this paper, no distinction will be drawn between kimberlite and lamproite; mineralogically they are different, but both can be diamondiferous and each has a similar range of geophysical properties (Atkinson, 1986).

Geophysical methods and physical properties

The physical properties of kimberlites and the use of geophysical methods in exploration has been summarized by Gerryts (1967), Kamara (1981) and Atkinson (1986). The magnetic susceptibility of the kimberlites are high, up to $6x10^{-2}$ SI (Litinskii, 1963), a consequence of containing up to 8% primary magnetite and ilmenite in the fresh rock and having secondary magnetite in the serpentinized rock (Gerryts, 1967). Because of the high susceptibilities, magnetic methods have been used in Russia (Barygin, 1962), Africa (Macnae, 1979) India (Kamara, 1981) and Australia (Jenke, 1983). Macnae (1979) noted that the magnetic signature in African kimberlites was highly variable, a consequence of the different intrusive phases and the resultant variable mineralogy. Similar variability has been noted in Siberia (Barygin, 1962) and South Africa; however, in Tanzania kimberlites have been found to have a very small magnetic contrast with surrounding rocks (Gerryts, 1967). Reversed remnant magnetization has also been observed in the Western Australia pipes (Jenke, 1983).

In Tanzania and the Sierra Leone, the kimberlites appear more conductive than the surrounding granitic rock because the latter weathers to kaolinite, while the kimberlite weathers to montmorillonite and nontronite (Gerryts, 1967; Kamara, 1981). In circumstances when the surrounding rock has a highly conductive weathered layer, the pipe can be relatively resistive (Jenke, 1983). Resistivity surveys can be used to detect conductivity contrasts, except in areas such as the Sierra Leone, where the contact resistance can be high (Gerryts, 1967). Ground electromagnetic (EM) surveys overcome this difficulty and the data can be acquired more rapidly, so these techniques have been used in Australia (Jenke, 1983) and India (Verma, 1983).

Specific clay minerals in the weathered zone can be identified using airborne multispectral scanning techniques. Although the method has been used with some success in Western Australia (Atkinson, 1986), it does not appear to have widespread use.

Weathered alteration zones sometimes have a distinct radiometric signature. Even though radiometric data are often acquired with airborne magnetics data, there are few published examples of radiometrics being used for kimberlite exploration. Macnae (1979) reports that Paterson and MacFadyen found the ground radiometric signature of kimberlites was too small to be detected from the air, while Kamara (1981) concluded that the radiometric signature of kimberlite was such that they could not be distinguished from a sedimentary country rock. Even so, 6 out of 26 pipes in the Ellendale field of Western Australia have a distinct radiometric signature (Atkinson, 1986).

In South Africa, weathered kimberlite has a low density, which results in a negative anomaly on a gravity profile (da Costa, 1989). The anomaly magnitudes are generally about 1 mGal, but data can be difficult to interpret where the depth of overburden changes or where kimberlite occurs near the boundary of two rock types with differing densities (Gerryts, 1967). Because pipes sometimes occur near structural boundaries (eg. da Costa, 1989), lateral variations in the density of the surrounding material can be quite common.

Since the weathered zone has a lower acoustic impedance, seismic refraction techniques have been used in some studies (eg. Hausel et al., 1979; da Costa, 1989). The cost of seismic methods and gravity surveying is such that these techniques are unlikely to be used for exploration or for delineating the extent of known pipes.

The most commonly used geophysical tool for airborne reconnaissance appears to be magnetics. This is despite some beliefs that diamondiferous pipes are less likely to be magnetic (Atkinson, 1986). Macnae (1979) describes an exploration program using airborne EM and magnetics which discovered eight South African kimberlite pipes. He concluded that magnetics alone would only have detected 38% of the pipes detected by EM alone. On the other hand, in the western Australian environment where the overburden is extremely conductive EM only detected 60% of the anomalies detected by magnetics (Jenke, 1983/Atkinson, 1986). In spite of the evidence that magnetics may not always be successful, it is a common exploration tool in Australia (Sumpton and Arnott, 1985) and Canada (Reed and Sinclair, 1991). However, airborne EM methods used in conjunction with airborne magnetics will always identify more pipes than magnetics alone, provided the specifications for the magnetics surveys are similar. Indeed, a combination of EM and magnetics is recommended by da Costa (1989).

North American diamonds -- historical perspective

The only diamond deposit mined in North America was at Prairie Creek, Arkansas, where more than 2000 carats of diamonds were extracted prior to 1908 (Wagner, 1971). The magnetic response of the pipe was measured by Stearn (1932), who found a 2000 nT anomaly on the ground, but no response over adjacent kimberlitic rocks.

During the gold rush period of the nineteenth century alluvial diamonds were discovered in glacial drift located in states south of the Great Lakes and in the province of Ontario (Brummer, 1978). Other locations where diamonds have been found include northern California, Alaska and the Yukon (Gibbins and Atkinson, 1992). The source of the diamonds around the

Great Lakes was once believed to be pipes near James Bay (Brummer, 1978), but their location is now hypothesised to be along the St. Lawrence rift system and extending under the Great Lakes (Gibbins and Atkinson, 1992). There is a diamondiferous pipe on Ile Bizard, near Montreal (Brummer, 1978) and a barren pipe in Iron County Michigan (Cannon and Mudrey, 1981) which may be associated with this rift system.

Since 1960, more than 90 occurrences of kimberlite have been discovered near the Colorado/Wyoming state border of the USA (Hausel et al., 1979). Eleven of the pipes contain microdiamonds, with the largest stone being 0.059 carat; however, diamonds are not currently being mined from this area. McCallum et al. (1975) report that the yellow ground has a high conductivity (about 30 mS/m), but the magnetic susceptibility is such that magnetic surveys would be of "limited value".

Various kimberlite dikes have been documented in eastern Canada, eg at Kirkland Lake (Brummer, 1978), but none are diamondiferous. In the Canadian arctic, nineteen kimberlite pipes were discovered on Somerset Island during the early seventies; although they are diamondiferous the quantities of diamonds is not significant (Brummer, 1978). Diamondiferous kimberlites have recently been discovered in Saskatchewan, but no pipe yet appears to contain an economic deposit (Schiller, 1992).

DIAMOND EXPLORATION IN THE NORTHWEST TERRITORIES

The imagination of the exploration industry was captured on November 5, 1991, by the following press release:

> "The BHP-DiaMet diamond exploration joint-venture, in the Northwest Territories, announces that core hole PL 91-1 at Point Lake intersected kimberlite from 445 ft. to the end of the hole at 920 ft. A 59kg sample of the kimberlite yielded 81 small diamonds, all measuring less than 2 mm. in diameter. Some of the diamonds are gem quality.
>
> "These results, at this stage in the development of the property, are considered significant, although they do not demonstrate an economic deposit. The results are significantly encouraging that the operator BHP-Utah is planning to add to the

exploration program of this winter bulk sampling of 200 tons of the kimberlite..."

This announcement and subsequent results by BHP-DiaMet and other explorers in the area has sparked a diamond rush in the Canadian north.

Physical properties of Canadian kimberlites from Somerset Island (Northwest Territories) and Sturgeon Lake (Saskatchewan) have been measured by Katsube et al. (1992). The range of susceptibilities is $(0.8 - 36.0) \times 10^{-3}$ SI, the larger values being comparable to those for magnetic ultramafic intrusives. Conductivity measurements lie between 0.016 mS/m, at very low porosity, to 3 mS/m, at 18% porosity. This represents a range of values generally considered to be resistive. Kimberlite is generally porous, having effective porosities between 1.8 and 19.1%, which means it is more likely to be altered to clay minerals and carbonates (Katsube et al., 1992).

In the area around the BHP/DiaMet discovery, the Slave Province of the Canadian Shield, the magnetic signature is highly variable, making the identification of kimberlites difficult on the basis of magnetic data alone. This is particularly true if the kimberlite is normally polarized, but signatures can be easier to identify if the kimberlite is reversed polarized.

The use of electromagnetics is not straightforward either. Reed and Sinclair describe an exploration program which discovered a number of pipe-like tuffisitic breccias bodies in another part of the Canadian Shield near James Bay, Ontario. The bodies were discovered using magnetic surveying alone and the EM response was either weak, or could not be distinguished from the response of the surrounding glacial till. They attribute the lack of strongly conductive material to the removal of the conductive yellow ground by the Pleistocene glaciation (if the yellow ground existed in the first place). Reed and Sinclair believe that those kimberlites which do have a weak EM anomaly have a higher porosity or have been altered to conductive serpentine.

Early indications of results from the NWT are that kimberlites frequently occur beneath lakes, presumably because glacial action gouged out the kimberlite, which is softer than the surrounding country rock, leaving a depression which would later form a lake. Factors which could contribute to the material near the kimberlite pipe having a greater conductivity than the surrounding rock are the water in the lake, the lake bottom sediments, the waterlogged porous kimberlite and any weathering which could take place because of the greater porosity. To date, definitive reports as to which mechanism is most important have yet to be released.

The GEOTEM® airborne electromagnetic system

The standard GEOTEM® system, described in Annan and Lockwood (1991) and Pedersen and Thomson (1990), is comprised of an EM system and a magnetometer mounted on a CASA 212-200 turbo-prop STOL aircraft (Figure 2). The electromagnetic transmitter is a horizontal three-turn loop wound around the nose, tail and wing tips. A series of discontinuous half-sinusoidal current pulses are passed through the loop and the voltage response is measured in a horizontal induction coil flying in a bird towed 56 m below and 120 m behind the center of the aircraft.

The repetition rate of the current waveform is typically set to 75, 90, 125 or 150 Hz (resulting in 150, 180, 250 or 300 bipolar pulses per second). Figure 3 shows the transmitted and measured waveforms. The half-sinusoidal pulse is normally switched on for 1080 μs and the off-time will depend on the waveform repetition rate (e.g. 2253 μs for 150 Hz). Present peak current flowing in the transmitter loop is 650 A resulting in a primary dipole moment of 4.5×10^5 Am^2. Typically, time-domain EM systems measure the response in the off-time, when it is simpler to separate the voltage due to the current in the transmitter (zero) from the voltage due to the secondary current induced in the ground.

A magnetometer, mounted in a stinger at the rear of the aircraft, is subject to interference from the magnetic field of the transmitter, so it is necessary to turn off the transmitter once a second to take magnetic measurements.

Fixed-wing towed-bird EM systems such as GEOTEM® sample a greater volume of rock than rigid boom helicopter systems (Ward, 1967). Hence a broader line spacing can be used, making the systems ideal for covering large survey areas such as those required in reconnaissance exploration for kimberlites.

In the Northwest Territories, the GEOTEM® system can be adapted to facilitate the search for weakly magnetic, moderately conductive bodies of small spatial extent. To this end, the following changes were made:

1) The base frequency was increased to 270 Hz. This allows more samples to be stacked per reading and will result in better quality data. At 270 Hz the off-time is reduced to 750 μs, which is more than adequate in highly resistive terrains typical of the Canadian Shield.

2) Measurement windows were placed during the transmitter on-time. The samples taken immediately after the pulse is turned on contain information not available during the off-time, which can be used to map subtle changes in the apparent conductivity of the ground (Annan and Smith, 1993).

3) The magnetometer was placed in a bird flying 47 m below and 82 m behind the aircraft. Because the magnetometer is closer to the ground it is capable of detecting the response of weakly susceptible bodies.

4) The magnetometer data can now be acquired 10 times per second. This is possible because the magnetometer is further from aircraft and the interference from the transmitter is reduced. The increased sampling rate gives better spatial definition of small bodies with sharp magnetic responses, such as kimberlite pipes.

CASE HISTORY EXAMPLES

Data have been collected in two areas in the Northwest Territories: over the discovery kimberlite at Point Lake and over a nearby kimberlite, here named Willy Nilly.

Point Lake, Lac de Gras

The Point Lake test area and the location of the flight lines are shown on Figure 4. The discovery hole is listed as having co-ordinates at approximately 64°37'N, 110°10'W, and is reported to have intersected kimberlite below a small lake (Gibbons and Atkinson, 1992). A more accurate location of the Point Lake pipe is 64°35'11"N, 110°8'35"W, placing it below the lake marked with an arrow and traversed by lines 3703, 3704, and 3705. There is a small lake to the east of the pipe and the large body of water further to the east is Lac de Gras.

Data collected along profile line 3704, flown from east to west, has been plotted on Figure 5 with west on the left hand side. The 'Rad' trace is the altitude of the aircraft as measured by the radar altimeter and the trace labelled 'Mag' is the magnetic total field data. The EM data, shown at the bottom of the profile are the off-time channels EM6 to EM12 and EM20, the on-time channel from which the apparent conductivity is derived (assuming a half-space model). Each off-time channel represents the voltage response measured in windows at delay times after the transmitter has switched off. The center of each window is listed below.

Channel	EM6	400µs
	EM7	460µs
	EM8	520µs
	EM9	570µs
	EM10	635µs
	EM11	690µs
	EM12	750µs

The response in channels EM1 to EM5 are very similar to EM6 only larger and have not been plotted.

The magnetics data, showing a weak negative over the pipe and a strong positive 2 km to the east, could not be considered to give a definitive signature over the kimberlite. The negative implies the kimberlite pipe has a reversed polarized remnant magnetization which is slightly stronger than the induced magnetization. The magnetic latitude is 84°N, which is effectively at the pole, so symmetric anomalies can be expected.

The EM data, however, show a distinct response over the kimberlite. There is no off-time response over the small lake to the east or over Lac de Gras, so the Point Lake anomaly is unlikely to be caused by normal lake-bottom sediments. The on-time data (EM20), however, does show that the lake bottom sediments are weakly conductive.

Contour plots of the data reveal information about the lateral variations in the area. The magnetic contours (Figure 6) show a positive feature trending ENE, which appears as five isolated highs, likely an artifact of the coarse line spacing. There is a large low to the east and an isolated low over the kimberlite. The contour plot of the channel 7 amplitude (Figure 7) shows a clear anomaly over the kimberlite and another small conductor to the east (marked with large and small arrows respectively). Elsewhere, the response is zero, so little else can be concluded about the conductivity of the surrounding area from the off-time measurements. However, the on-time apparent conductivity plan (Figure 8) gives a better representation of the conductivity structure in the area, showing weakly conductive sediments (1 to 5 mS/m) below Lac de Gras and in the lake systems either side of Point Lake. On this map, the kimberlite is also a distinct feature, having a conductivity of 20 mS/m, a moderately large value. The conductive zones associated with the lakes cover an area which is larger than the area of the lakes themselves because the response falls off slowly at the edge of the lake and because the contouring algorithm has smeared the conductive zones slightly.

Willy Nilly

The flight path map of the Willy Nilly area is shown on Figure 9. The profile data for line 14, flown from north to south is shown on Figure 10 with south on the left hand side. There is a distinct negative anomaly on the magnetic data and on the EM data there is a strong positive (marked by an arrow) with a smaller negative on the southern flank. Flanking negatives, such as seen here, are a result of the coupling between a flat-lying conductor and the asymmetric airborne EM system. One kilometre to the north, there is a weak EM anomaly, evident only in the on-time data, presumably caused by the sediments under the northern part of the lake. Contour plots of the magnetics (Figure 11) and the channel 7 amplitude (Figure 12) show the diagnostic circular features associated with kimberlite pipes. Although, we have no ground-truth information, word of mouth reports on drilling results indicate the source is another kimberlite.

On Figure 12, the negative to the south of the positive, is consistent with that seen on the profiles; however, the negatives to the east and west are most likely contouring artifacts. Figure 13 is the apparent conductivity calculated from the on-time data. Again, weak conductivities (less than 10 mS/m) correspond with lake sediments and the swamp to the south. Note, however, that there are no negatives to the south, east or west of the circular anomaly. Compared with the off-time amplitude data, the on-time apparent conductivity data are less subject to the artifacts which can be ascribed to system asymmetry.

CONCLUSIONS

Geophysical methods can be used to explore successfully for kimberlite pipes. For reconnaissance exploration, the magnetic and electromagnetic methods are most suitable as the kimberlite response is anomalous and measurements can be acquired using an airborne platform. With a fixed wing system, such as GEOTEM®, the footprint is sufficiently large that the line spacing can safely be increased to 250 to 300 m without sacrificing the ability to detect targets away from the line.

Exploration for kimberlite pipes in the Northwest Territories, was facilitated by a number of alterations to the airborne system configuration. Because the environment is resistive, the waveform repetition rate was increased to 270 Hz, resulting in cleaner data. As well, on-time measurements allowed high-frequency information to be obtained and the apparent conductivities to be calculated down to 0.5 mS/m. As kimberlites can be magnetic, high quality magnetic data, was obtained by mounting the magnetometer in a towed bird and sampling the field 10 times per second or once every 6 metres.

The results obtained show magnetic anomalies over the kimberlites. The amplitudes of the anomalies varied, but both were negative, suggesting the bodies identified possess some remnant magnetization. Features associated with the lakes and swamps cannot be seen on the off-time EM data, but are evident as weakly conductive features (1 - 10 mS/m) in the on-time apparent conductivity data. The kimberlites are seen as distinct features on the off-time data and as moderately conductive features (10 -20 mS/m) on the apparent conductivity data. The enhanced conductivity of the kimberlite could be due to thicker lake sediments above the kimberlite, greater fluid content because of a higher porosity, or alteration (albeit weak) to serpentine, clay minerals or carbonates.

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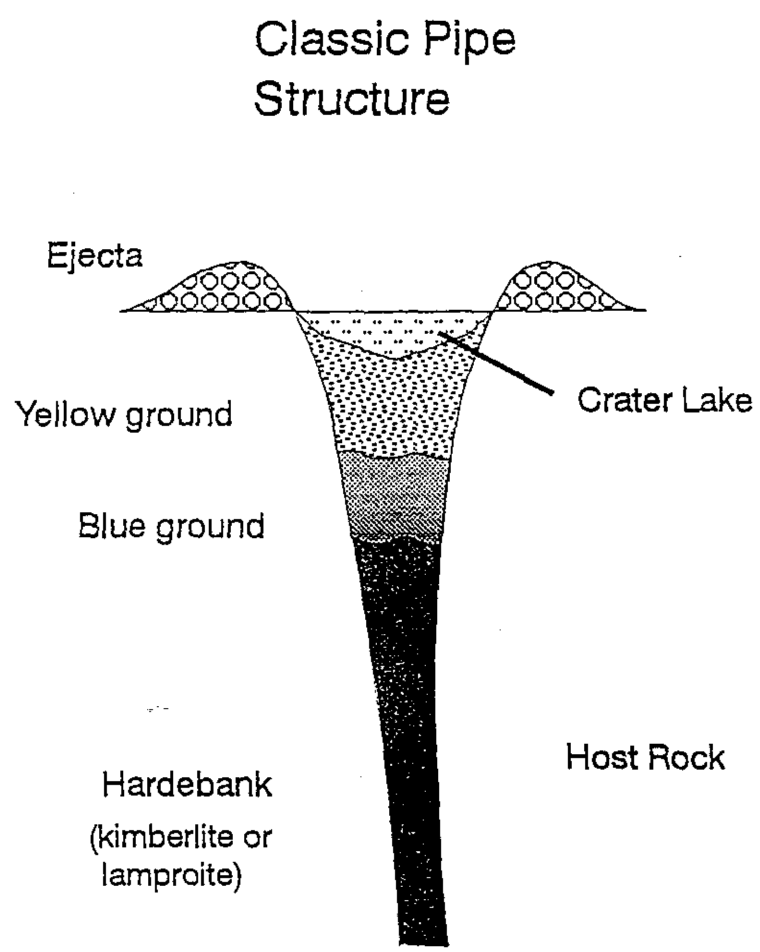

Fig. 1. A schematic diagram of a kimberlite pipe showing the unweathered hardebank at the base, the slightly weathered blue ground, and the weathered yellow ground. At the surface is a crater lake surrounded by material ejected from the pipe. Individual pipes will be eroded and/or buried by subsequent sedimentation.

Appendix E
Airborne induced polarization is here!

Airborne induced polarization is here!

(In special circumstances)

GEOTERREX

OTTAWA, CANADA

1994

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ABSTRACT

Airborne induced polarization (IP) measurements can be obtained, *but* only in the limited circumstances when the ground is sufficiently resistive that the normal electromagnetic (EM) response is small and when the polarizability of the ground is sufficiently large that the IP response can dominate the EM response. Further, the dispersion in conductivity must be within the bandwidth of the EM system. One example of a response type which can be explained by IP effects are the negative transients observed on a GEOTEM® survey in the high arctic of Canada. The dispersion in conductivity required to explain the data is very large, but is not inconsistent with some laboratory measurements. Whether the dispersion is due to an electrolytic or dielectric polarization is not clear from the limited ground follow-up; but, in either case, the polarization can be considered to be induced by eddy currents associated with the EM response of the ground. If IP effects cause the negative transients in the GEOTEM® data, then the data can be used to estimate the polarizabilities in the area.

INTRODUCTION

Whilst airborne GEOTEM (a trademark of Geoterrex) data were being acquired in the high arctic of northern Canada during the spring of 1991, an unusual response feature became evident: numerous coherent negative transients in the off-time windows. One plausible explanation of these negatives is that they are due to an induced polarization (IP) effect. Similar negative transients have been seen in ground electromagnetic (EM) data, principally when a coincident or in-loop EM system is being used (e.g., Spies, 1980). For ground EM systems, the negatives are surprisingly common and can be shown to occur when EM response is large at early times, decays rapidly to zero and the IP response is sufficiently large to dominate the small EM

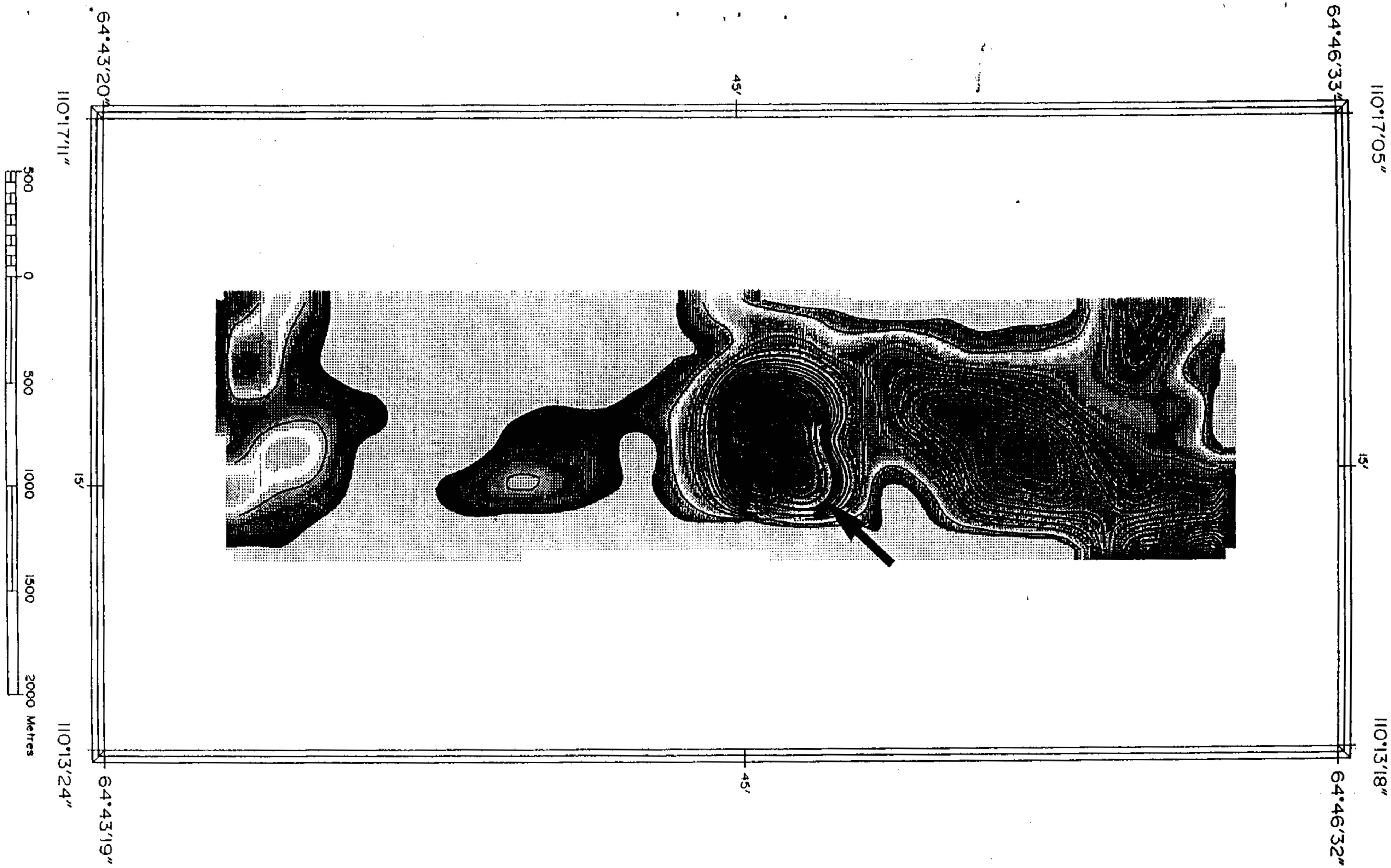

Fig. 13. Contours of the apparent conductivity calculated from the channel 20 on-time data assuming a half-space model. The area is as shown on Figure 9 and the contour interval is 1 mS/m.

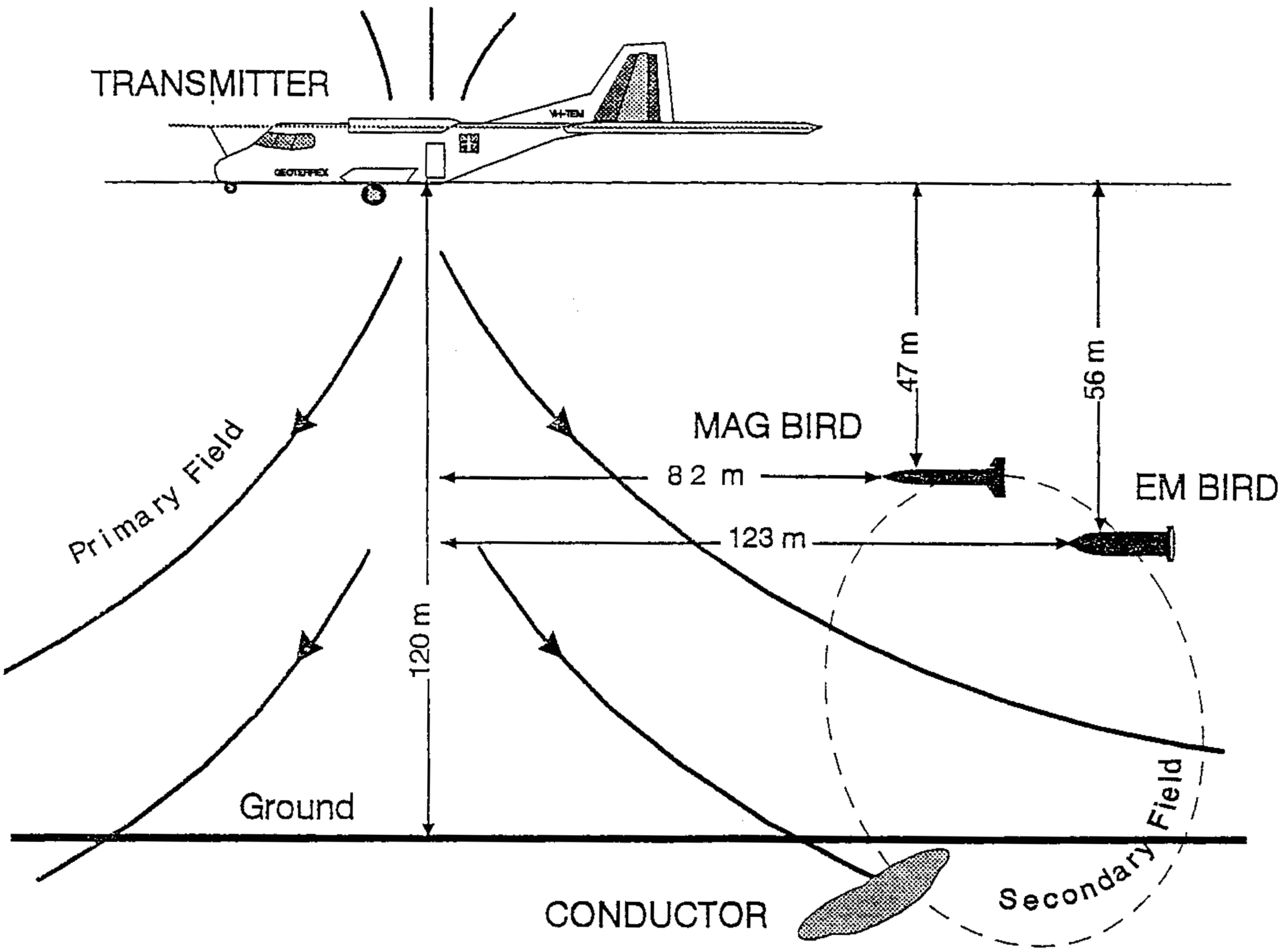

Fig. 2. The geometric configuration of the GEOTEM® airborne electromagnetic and magnetic system. The transmitter loop is wound horizontally around the aircraft giving a vertical dipole moment and the receiver coil is a horizontal dipole contained in the EM bird. A cesium vapour magnetometer is mounted in the mag. bird. The two birds are towed behind the aircraft on two separate cables.

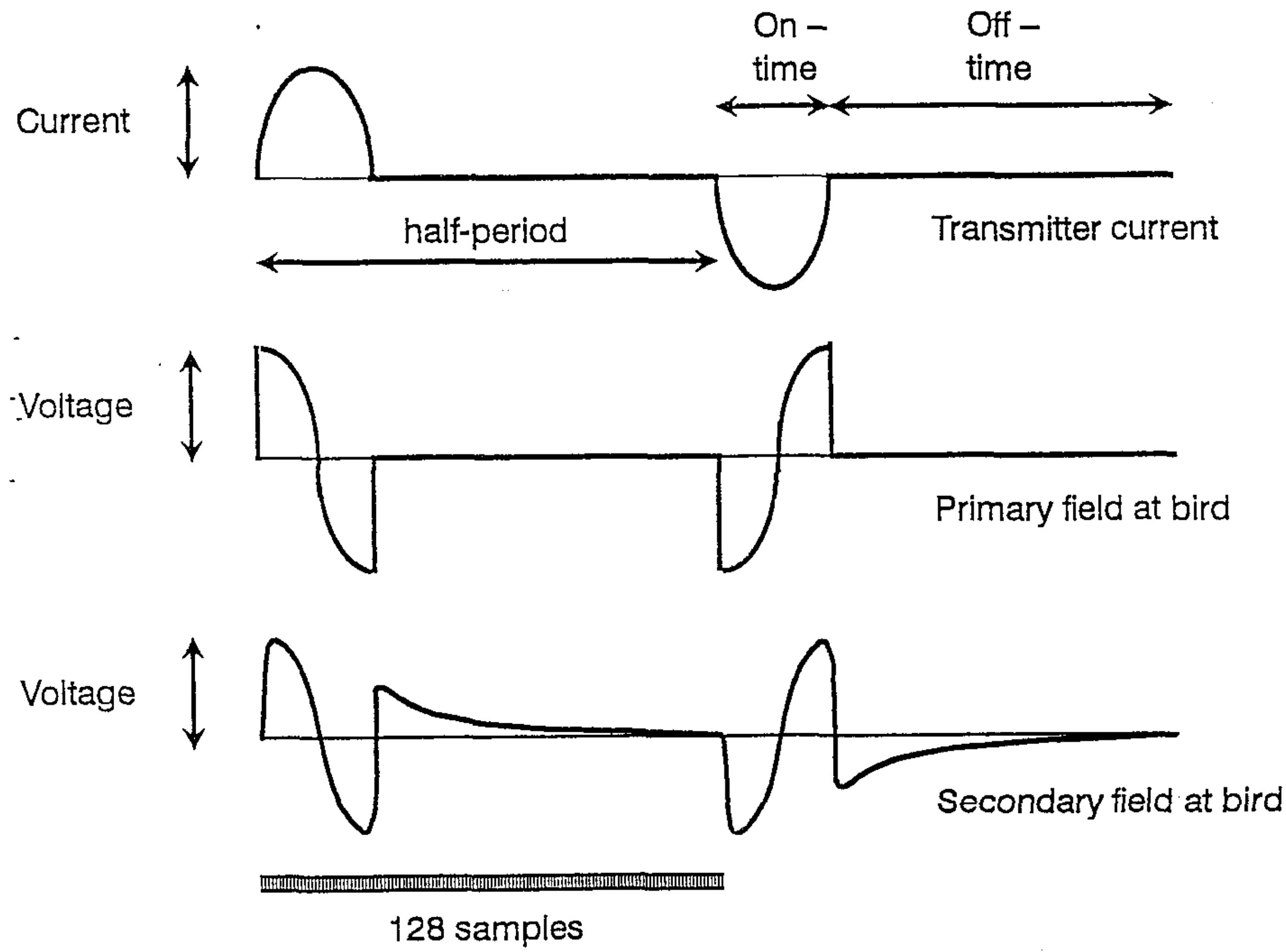

Fig. 3. The half-sinusoidal bipolar transmitter current waveform, showing the on-time and off-time. The primary field at the bird is proportional to the time derivative of the transmitter current and the form of the secondary field is as shown at the bottom. Typically measurements are made with 128 samples per half period, which are later binned into 20 windows.

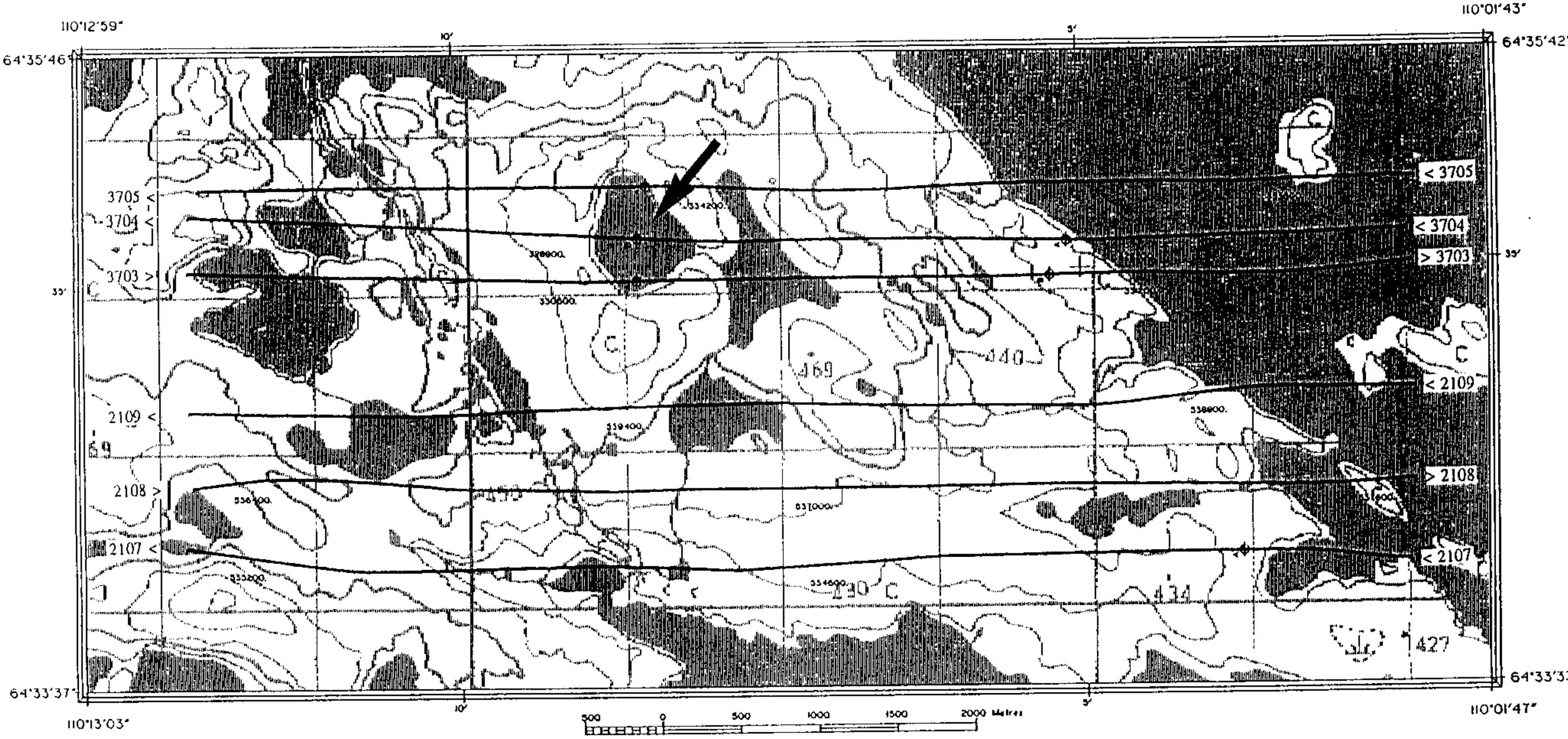

Fig. 4. The flight path and GEOTEM® anomaly plan for the Point Lake area. Lac de Gras is to the right and Point Lake, marked with three adjacent anomaly symbols, is slightly above and to the left of the center of the area. The flight line numbers are on either end of the flight lines and the directions are as shown with the arrows. The contour values give the elevation in metres.

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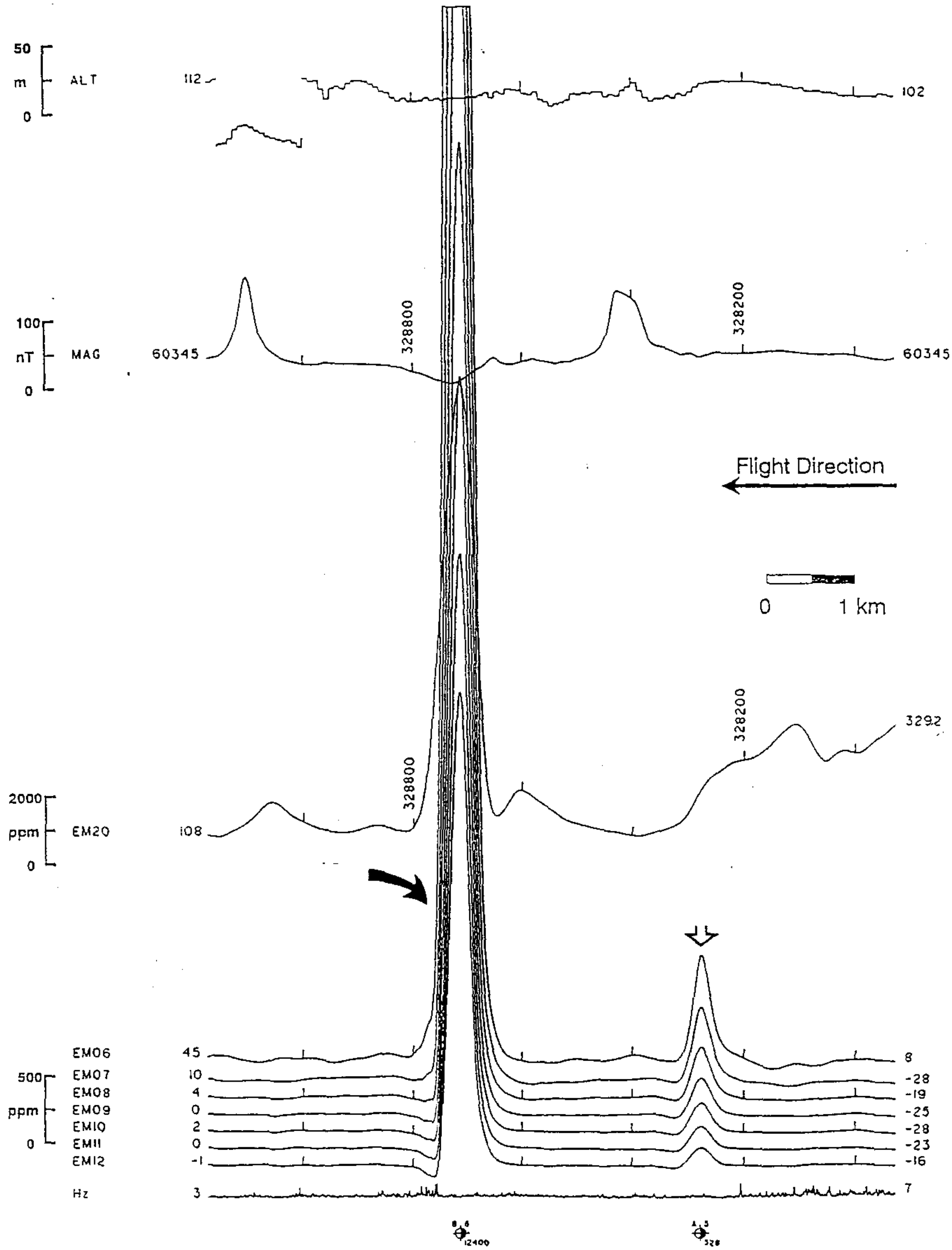

Fig. 5. The GEOTEM® response profile for line 3704. The anomaly symbols at the bottom are labelled with an alphabetic identifier, the apparent conductance (of a thin plate) and the channel 7 amplitude at the peak of the anomaly. Each profile has been annotated with the measured value at either end and the respective vertical scales are shown on the far left. The bottom trace, labelled Hz, gives an indication of powerline noise which is small throughout the survey area.

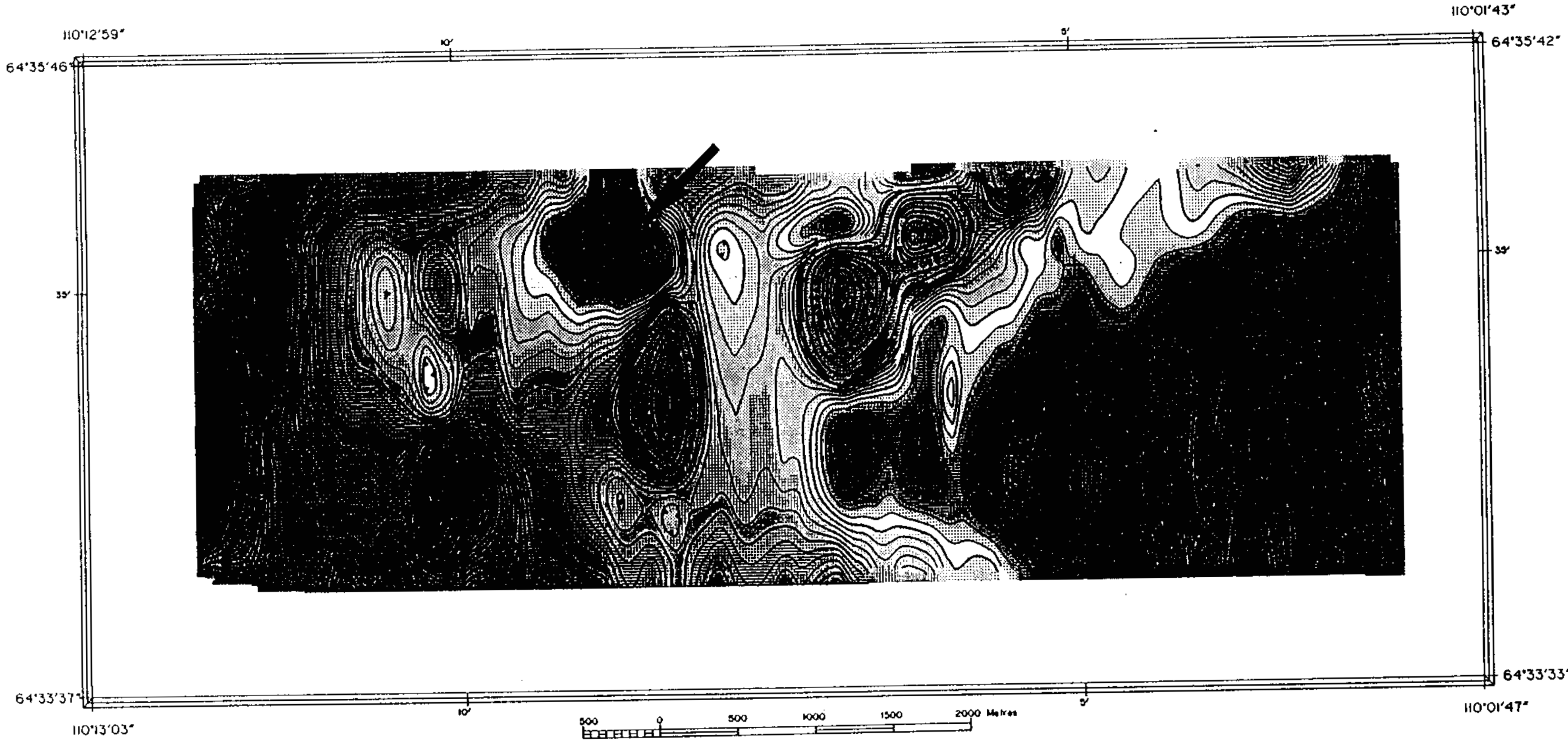

Fig. 6. Contours of the total magnetic field for the area shown in Figure 4. The contour interval is 2 nT.

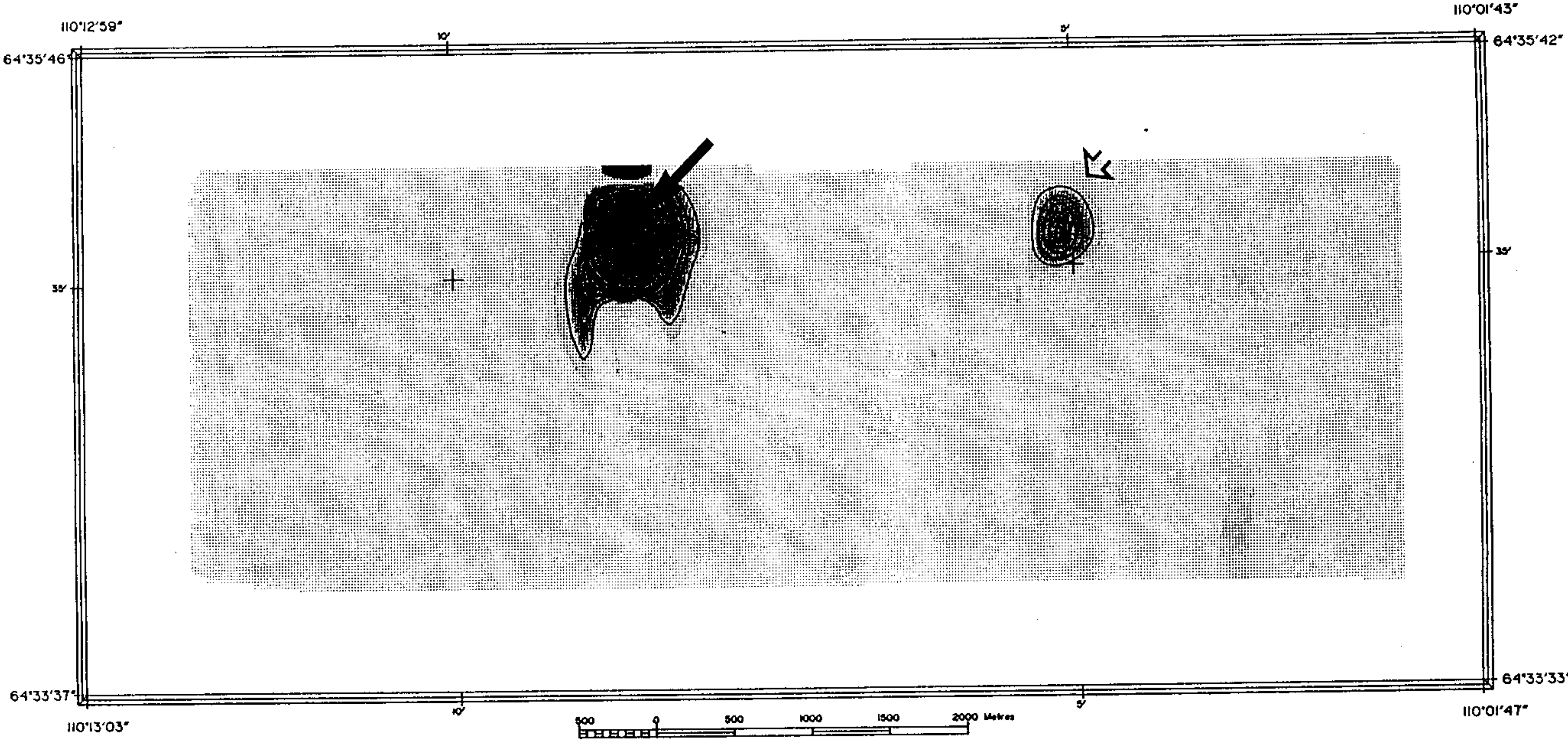

Fig. 7. Contours of the measured response in GEOTEM® channel 7 for the area shown in Figure 4. The contour interval is 100 ppm.

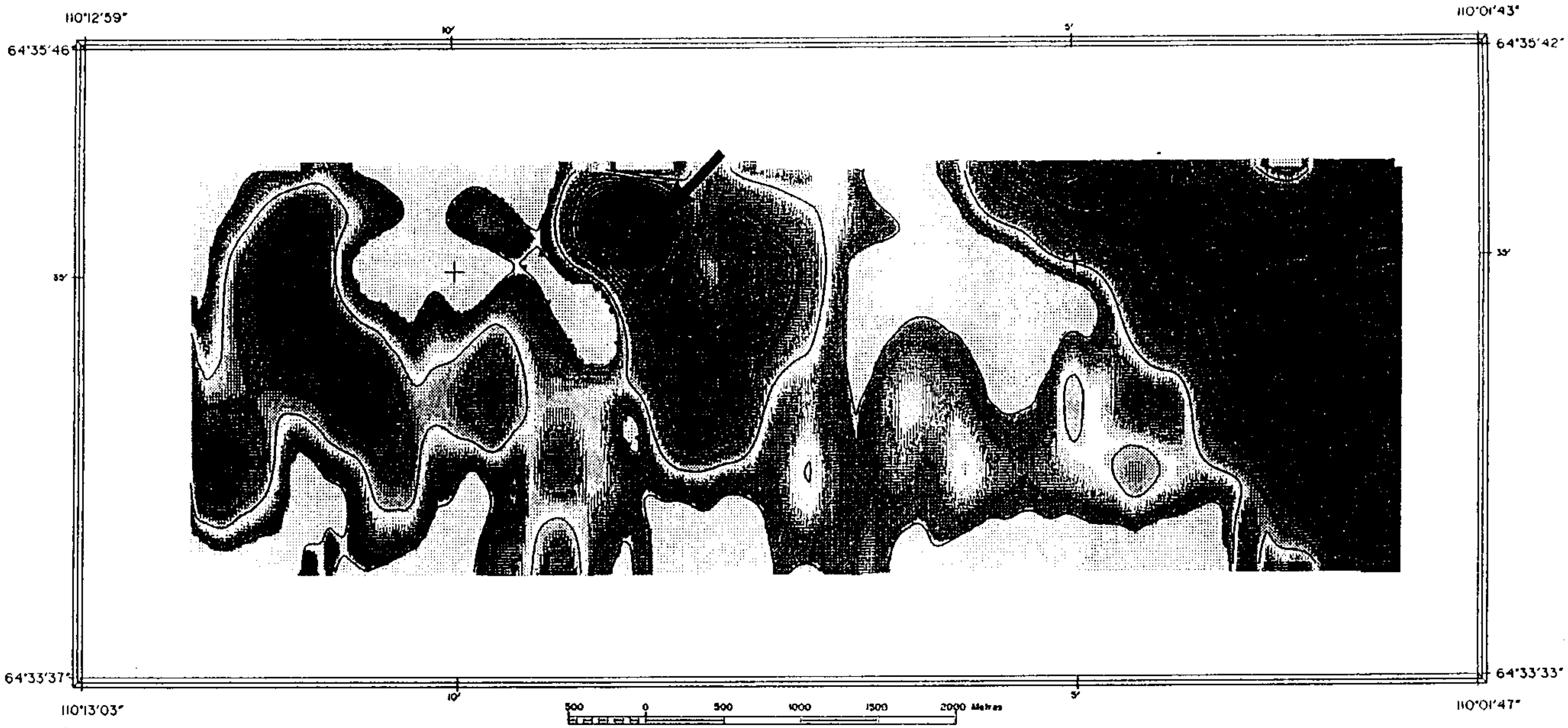

Fig. 8. Contours of the apparent conductivity calculated from the channel 20 on-time data assuming a half-space model. The area is as shown on Figure 4 and the contour interval is 1 mS/m.

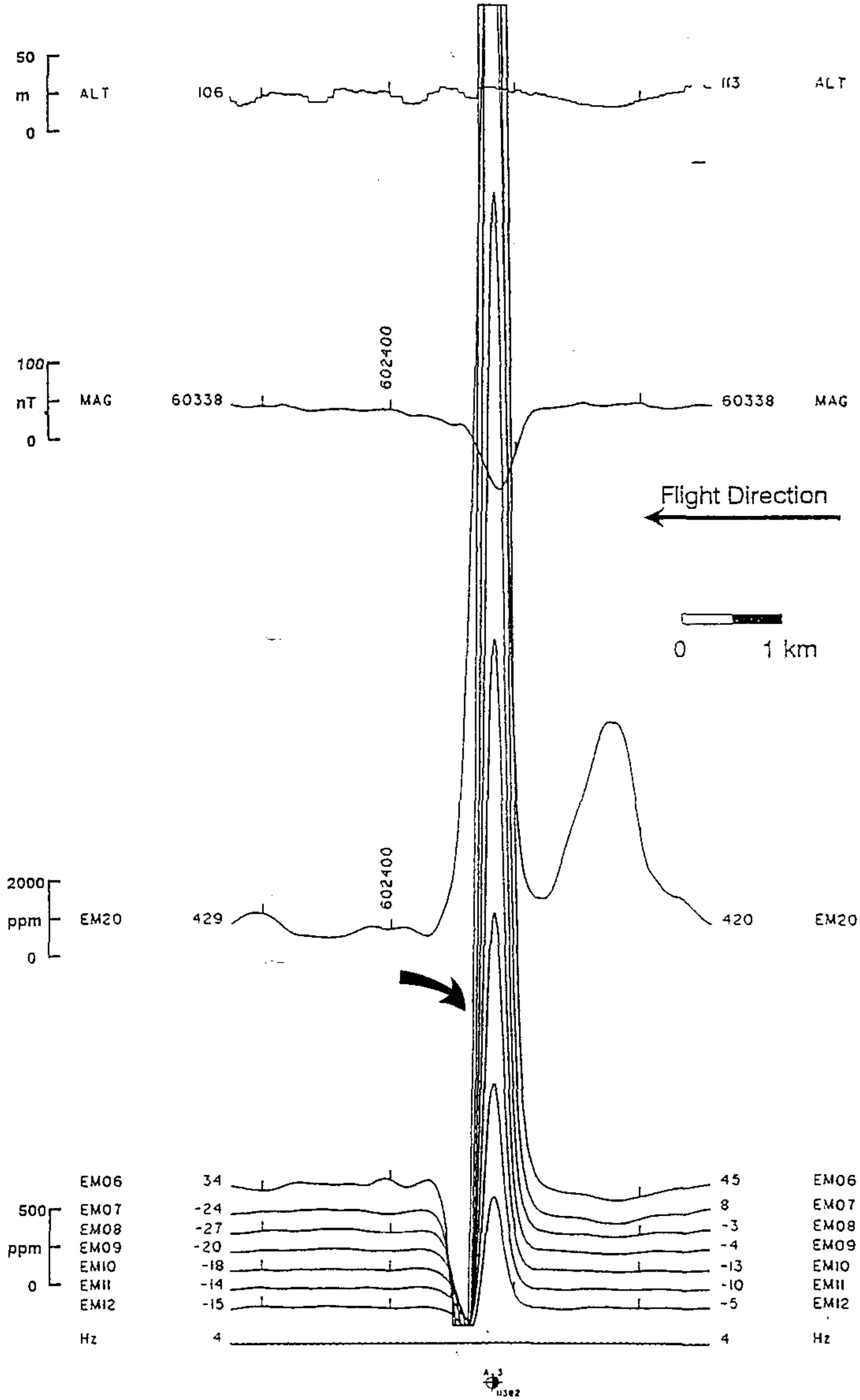

Fig. 10. The GEOTEM® response profile for line 14. The anomaly symbol at the bottom is labelled with an alphabetic identifier, the apparent conductance (assuming a thin plate model) and the channel 7 amplitude at the peak of the anomaly. Each profile has been annotated with the measured value at either end and the respective vertical scales are shown on the far left. The bottom trace, labelled Hz, gives an indication of powerline noise which is small throughout the survey area.

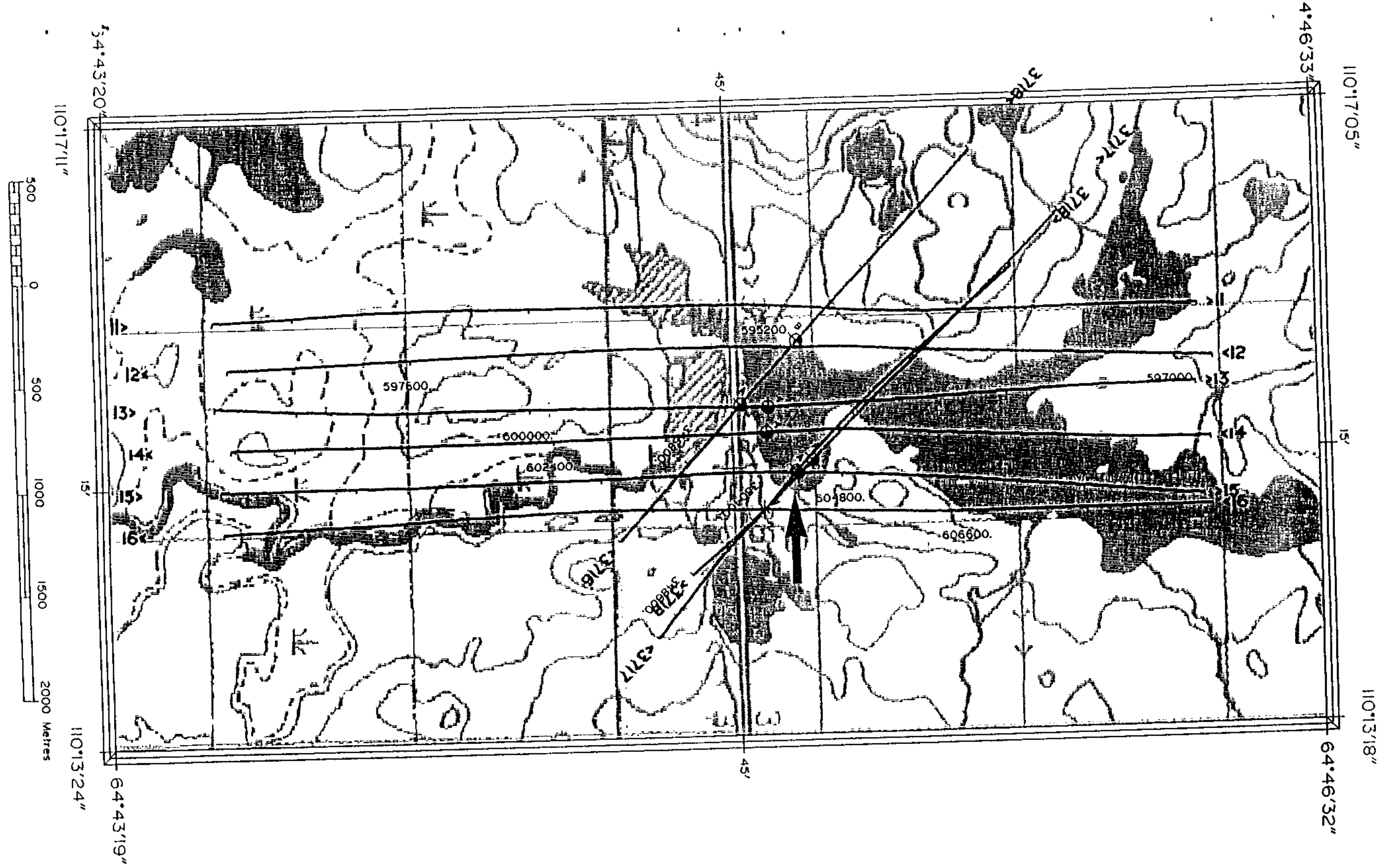

Fig. 9. The flight path and GEOTEM® anomaly plan for the Willy Nilly area. The kimberlite location is marked with anomaly symbols at the center of the area. The flight line numbers are on either end of the flight lines and the directions are as shown with the arrows. The contour values give the elevation in metres.

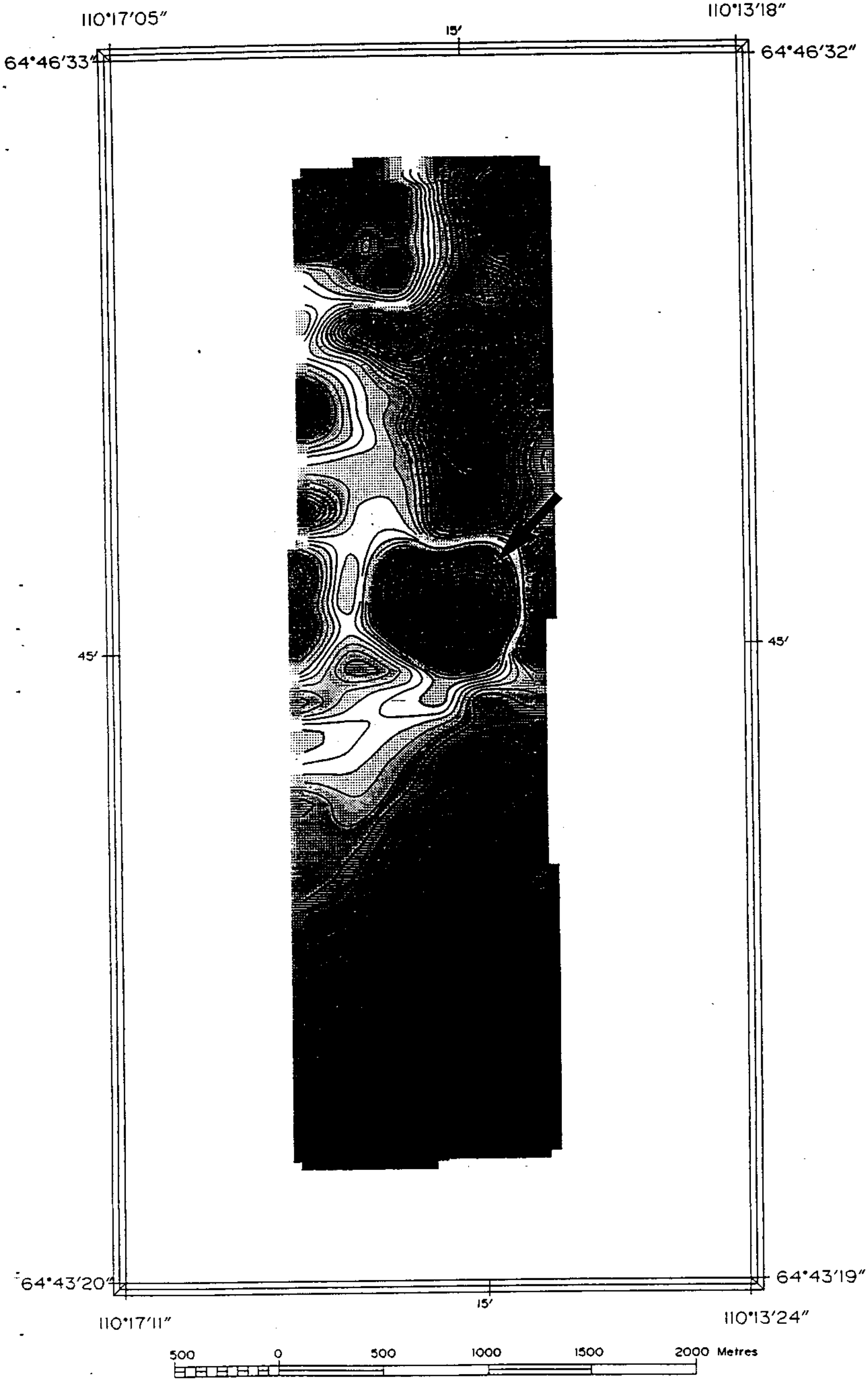

Fig. 11. Contours of the total magnetic field for the area shown in Figure 9. The contour interval is 2 nT.

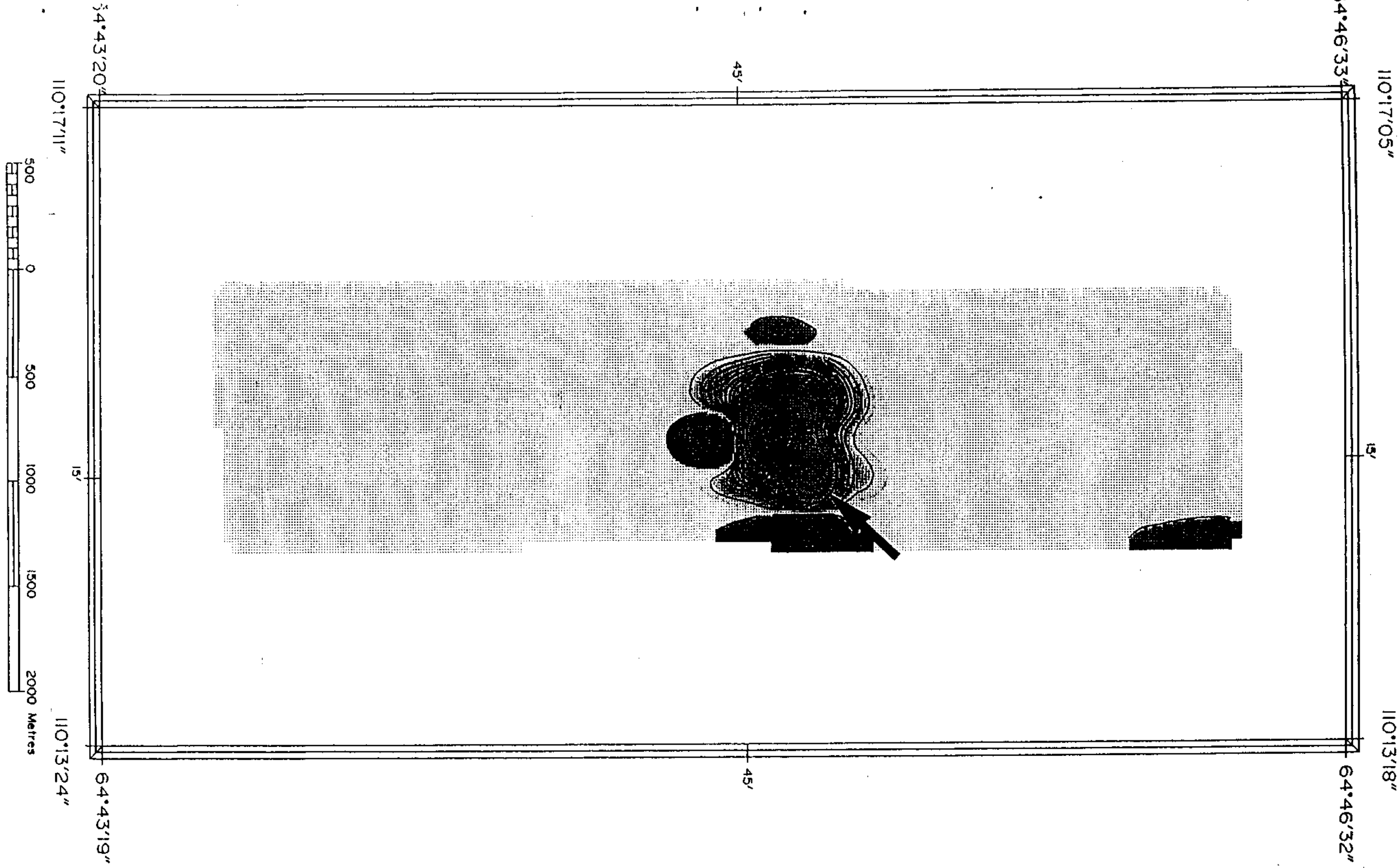

Fig. 12. Contours of the measured response in GEOTEM® channel 7 for the area shown in Figure 9. The contour interval is 100 ppm.

response at late delay times (Smith and West, 1989). Field and theoretical studies indicate that this most commonly occurs when surficial conductive ground is polarizable in the EM bandwidth (Smith and West, 1988a, 1989; Hohmann and Newman 1990). If IP effects are assumed to be the cause of the negative transients in the GEOTEM data, then the data can be used to give an estimate of the polarizabilities in the area.

SURVEY AREA

The area studied in this paper is shown on Figure 1. It comprises eleven flight lines, each of about 10 km length. This area is part of a much larger survey, but the smaller area discussed contains some good examples of the negatives and has some ground geophysics at a local test site. The airborne EM flight path map is overlaid on a geological map. The local geology consists of a sedimentary sequence comprising shales, carbonates and sandstones. The three lines of ground follow-up and the drill-hole marked on the map are close to the shale horizon which is an important marker unit above a horizon considered to be more prospective for mineral deposits. The circular anomaly symbols mark the positions where the airborne EM response indicates an anomalously large conductivity. In this case the anomalies are all associated with conductive sea water.

THE MEASURED DATA

Figure 2 shows the response profile for line 49. The line was flown from right to left, and the off-time EM responses at 0.40, 0.55, 0.71, 0.86, 1.02 and 1.17 ms are shown with solid lines. The thick grey line is the halfspace conductivity as derived from the on-time channel using the algorithm of Annan et al. (1994). The left axis labels pertain to the off-time data and the right axis labels to the conductivity. The large off-time responses (>10 000 ppm) are associated with the sea water. There is a negative response about 1.3 km from the right end of the profile, which is very small when compared with the sea water response. Away from the sea water, on line

46 (Figure 3) the negatives become the most dominant feature in the off-time response although their actual magnitude is similar to that seen on line 49 (note the change in vertical scales). The shape of the response curves at each delay time is difficult to ascertain, as the responses are close to zero and the curves plot on top of each other. Hence, the response has been plotted with the zero line for each curve offset by 400 ppm on Figure 4. On this plot, the negatives are seen as depressions on each curve. A further example is shown on Figure 5, which is the line flown over the ground geophysical test site. The magnitude of the negatives are well above the noise level, which in this survey is between 20 and 30 ppm. Note that in almost all cases the negatives occur where there is a positive peak in the on-time conductivity curve and the shape of the positive anomaly virtually mirrors that of the negative anomaly.

The spatial form of the geophysical response can be ascertained from images of the geophysical data. The magnetic data, collected as a matter of routine with the GEOTEM system, are shown on Figure 6. The variation from right to left is gradual, indicating that the sources of the magnetic anomalies are deep within the basement. The apparent conductivity, as defined from the on-time data, is displayed on Figure 7. The sea water is the most active part of the map and the ground would appear to be more conductive on the left half, perhaps due to the invasion of conductive sea water into the ground water. The area to the right is less coherent and does not appear to correlate well with the geology. The negative responses are shown as black zones on the 0.4 ms off-time data (Figure 8). Note that the grey scale has been stretched to enhance these negatives and other low amplitude features.

Possible causes for the negatives.

1) Negatives can sometimes occur near powerlines or some other form of cultural noise such as electric fences. There are no such cultural features of this type in the survey area proximal to the negatives, so this explanation can be ruled out.

2) A negative response is frequently seen associated with strong conductors. The coupling of the asymmetric airborne EM system to the conductor is such that the response will be negative after the transmitter and receiver have both passed over the conductor. These type of "trailing-edge" negatives are invariably seen adjacent to a strong positive response which occurs when the transmitter and receiver straddle the conductor. In this case there is no nearby positive response.

3) The negatives could be associated with a problem with the EM system or its calibration. However, when the negatives were first recognized, lines were reflown on different days with different calibrations and found to be repeatable. If there was a problem with the calibration, the negatives would occur throughout the survey area, and not at a particular location. Also, the spatial correlation of the negatives strongly imply that they are real and related to a variation in the physical properties of the earth. Furthermore, the polarity of the on-time response is normal as are the off-time responses in the areas of conductive sea water. This suggests there is no abnormality with the system at these delay times.

4) The negatives are a result of IP effects. When IP effects are observed in EM data a relatively large current is required to charge the ground. This current is known as the impressed current in IP and the fundamental inductive current in the "IP in EM" literature (e.g., Smith and West, 1988b). That this current is flowing in the ground is apparent from the enhanced on-time response. The IP effects then become evident at late delay times when the fundamental inductive response has decayed away and the effect of the smaller polarization current can be observed. The polarization current can be thought of as a negative image of the history of the fundamental inductive current (Smith et al., 1988), which explains why the negatives have the same

shape but the opposite sign as the on-time response. In fact, the only way the off-time data can mirror the on-time data is if the current has reversed direction and the most reasonable way that this can occur is if there is an induced polarization effect.

Data modelling.

The lateral extent of the negatives on Figure 5 is about 400 m, which is comparable with the volume of rock sampled by the GEOTEM system. Hence, in modelling the data, a model of infinite lateral extent such as a layered model should therefore be a good approximation. The anomalous response 1.6 km from the right of profile line 45 has been modelled, as it is associated with the ground geophysical test site and hence has some control information.

The negative decay is shown on Figure 9, with solid squares. At the earliest time after the current is switched off, the measured response is 1000 ppm. After a subsequent 200 ms the response has decayed to 1/e of this value, so the time constant of the decay is 200 ms, which is equivalent to a frequency of about 5000 Hz. The data have been modelled with a layered earth computer program which is conceptually similar to that of Morrison et al. (1969), but uses the electromagnetic formulation of Ward ànd Hohmann (1988), Chave's (1983) inverse Hankel transform routine and a fast Fourier transform. The conductivity σ of the layers can vary as a function of frequency, ω, in a manner described by a Cole-Cole dispersion model (Pelton et al., 1978), which uses a single characteristic time constant T. The Cole-Cole model for conductivity is defined as follows:

$$\sigma(\omega)=\sigma_{\infty}-\frac{\sigma_{\infty}m}{1+(1-m)(i\omega T)^{c}}$$

where σ_{∞} is the conductivity at high frequencies, m is the Cole-Cole chargeability, c is the exponential factor and $i = \sqrt{-1}$. A response very similar to the measured response can be obtained using two models:

a) a thin sheet of 0.13 S and a 35 percent dispersion of the conductivity in the GEOTEM off-time frequency range (500 - 2500 Hz), and

b) a half-space of 0.003 S/m and a 37 percent dispersion in the same frequency range.

The full parameters of the Cole-Cole inversion have not been given, as there are strong non-uniquenesses and the only well-resolved parameter is the difference in conductivity at the upper and lower extremes of the EM frequency band -- the quantity here termed the percent dispersion. The model data decay slightly too slowly at early decay times and too fast at later delay times and this misfit could likely be reduced by more careful selection of the Cole-Cole parameter c or the incorporation of multiple time constants into the Cole-Cole model.

In modelling the data it became apparent that the negative decay was largely independent of the conductivity structure, and strongly dependent on the polarization properties of the ground. The only EM data which appeared dependent on the conductivity model was the on-time data. However, for both the thin sheet and half-space models the on-time data agree with the measured data to within 0.5 percent. Hence, the conductivity structure has not been determined from the modelling; the thin sheet and half-space models merely represent two extremes in a spectrum of possible models that can be made to fit the data. The true conductivity model likely lies somewhere between the two extremes.

A dispersion in conductivity of 37 percent is considered to be outside the range of dispersions considered normal for the IP technique. However, larger dispersions are not uncommon in explaining the IP effects seen in ground EM data, particulary in permafrost terrain (Walker and Kawasaki, 1988). Also, the airborne EM off-time frequency band (500 - 2500 Hz) is considerably removed from the IP frequency range (0.1 to 10 Hz), so substantially different dispersions could be expected. Conductivity normally varies slowly with frequency, so if a material is strongly dispersive in one bandwidth, it is also likely to show a relatively strong dispersion in the other bandwidth.

An example of a material which shows a moderate dispersion in the IP frequency range and a strong dispersion in the GEOTEM bandwidth is a piece of frozen kaolinite -- sample API-K5 from Olhoeft (1975). The dispersion curve for this material is shown on Figure 10. This type of dispersion is consistent with the IP data collected on ground follow-up of the negative anomaly (Figure 11). The ground IP anomalies associated with the negative transients are only moderate (about 8 ms), but are more dispersive than elsewhere on the section. Note that the apparent resistivity is also anomalously low. Although other geophysical and geological data were collected, they were intended to find new ore deposits and have not helped to explain the source of the strongly polarizable material in the ground. For example, there were about 1 percent disseminated sulphides in the drill-hole marked with a cross on the map, but there is no indication of whether this could be the source of the polarization inthe EM frequency range. The dispersion mechanism is yet to be determined, but possible sources are:

1) a dielectric effect associated with permafrost,
2) a charge build up due to a difference in the electrical conductivity of frozen and unfrozen ground,
3) an electrochemical polarization in that small portion of water which remains unfrozen even in permafrosted terrain (Williams and Smith, 1989), or
4) due to dissolved ions in the thin active (thawed) layer at the surface of the earth, or
5) combinations of the above.

POLARIZABILITY MAPS FROM GEOTEM DATA

The polarizability (or chargeability) m can be estimated from the airborne EM data using Seigel's law (Seigel, 1959)

$$m = - V^{s} / V^{p},$$

where V^{s} is the sum of all the negative off-time channels and V^{p} is normal positive voltage measured while the transmitter is switched on (the primary voltage).

Confirmation that reasonable estimates of the polarizability can be obtained is demonstrated by calculating the response for a large number of different polarizable models and then using this calculated data to estimate the polarizability. Plotting the estimated polarizability as a function of the true polarizability in the bandwidth of the off-time data (Figure 12) shows that the estimated value can either be a good estimate or an underestimate, generally by a factor of about 2. Such an underestimate is not considered critical provided that the relativity of polarizabilites is maintained along a profile line. In grounded-source IP the apparent chargeability is generally an underestimate of the intrinsic chargeability. This is best illustrated in Hohmann (1990), where for three-dimensional models, the factor B_2 for converting intrinsic to apparent chargeabilities ranged in magnitude from 0.65 to zero -- representing an underestimate by a factor of about 2 or more.

The GEOTEM data collected in the test area have been converted to polarizability and imaged on Figure 13. The data show two highly polarizable zones; one coincides with the shale horizon and a second parallel zone for which there is no mapped geological feature. In neither case has the exact source of the negatives been ascertained from the ground follow-up.

CONCLUSIONS

In the high arctic of northern Canada, GEOTEM data have been collected which show a strong negative anomaly with no associated positive. The data can be explained by an IP effect which manifests itself as a strong dispersion in the GEOTEM frequency range. Such strong dispersions have been seen in laboratory measurements of frozen clays and could reasonably be expected in the soils and rocks of the high arctic during the spring time.

The data can be converted to a measure of the polarizability and hence the induced polarization properties of the ground can be mapped from the air. It should be emphasized that such IP effects can only be measured in very special circumstances, when the conductivity is less than 3 mS/m and when the dispersion in the off-time bandwidth is very strong. These criteria are satisfied surprisingly often in the Northwest Territories of Canada, principally over lakes. However, the vast majority of transient EM responses are due to the normal inductive EM currents, so the primary purpose of an airborne EM survey should be to map the conductivity. In the special circumstances when the polarizability of the ground can be measured, this should be considered additional bonus information.

The source of the polarization cannot be ascertained from the airborne data or from the very limited ground geophysical data collected for the purposes of massive sulphide exploration. Also, it has not been resolved whether the polarization is due to electrolytic or electrochemical polarization (the normal IP effect) or dielectric polarization (permittivity effects). This issue would best be answered with physical property measurements, with the samples having the same pressure, temperature and thermal history as at the time of the survey.

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Jan Klein wishes to thank Jovan Silic for computing the first synthetic models which showed the airborne EM negative transients could conceivably be a result of an induced polarization effect. Mike O'Connell and Ray Lockwood, both of Geoterrex, also performed model calculations which helped to understand the responses obtained.

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FIGURE CAPTIONS

Fig. 1. A plan view of the survey area showing the flight lines, the interpreted geology, a diamond drill-hole, marked with a +, and the three survey lines comprising the test site for ground geophysical follow-up work.

Fig. 2. The GEOTEM response profile on line 49, showing six off-time channels (thin dark lines with the scale on the left axis) and the apparent conductivity as derived from the on-time data (thick grey line and scale on the right axis). The large off-time response is over sea water. Note the small negative 1.3 km from the right of the profile. The delay time of each off-time channel is shown on the legend, with earlier delay times generally corresponding to larger amplitudes.

Fig. 3. A response profile away from sea water (line 46), where the negatives are now more apparent (although their magnitude is still as small as on Figure 2). The curves and labelling is as for Figure 2.

Fig. 4. The same as Figure 3, except the curves have been offset by incrementing the zero baseline of each curve by 400 ppm.

Fig. 5. GEOTEM response profile for line 45. The negative 1.6 km from the right of the profile coincides with the geophysical test site for ground follow-up.

Fig. 6. The magnetic field in the survey area shown as a greyscale image enhanced using histogram equalization (equal area presentation). Apart from a strong gradient, little else is evident in the image.

Fig. 7. The apparent conductivity of the area shown as a greyscale image enhanced using histogram equalization (equal area presentation). The top left of the area is active due to patches of conductive sea water and the left is generally more conductive than the right.

Fig. 8. The GEOTEM 0.4 ms off-time response in the survey area shown as a greyscale image enhanced using histogram equalization (equal area

presentation). The large responses (light shade) are associated with conductive sea water, while the black shades denote negative values. The histogram equalization has emphasized small values, both positive and negative.

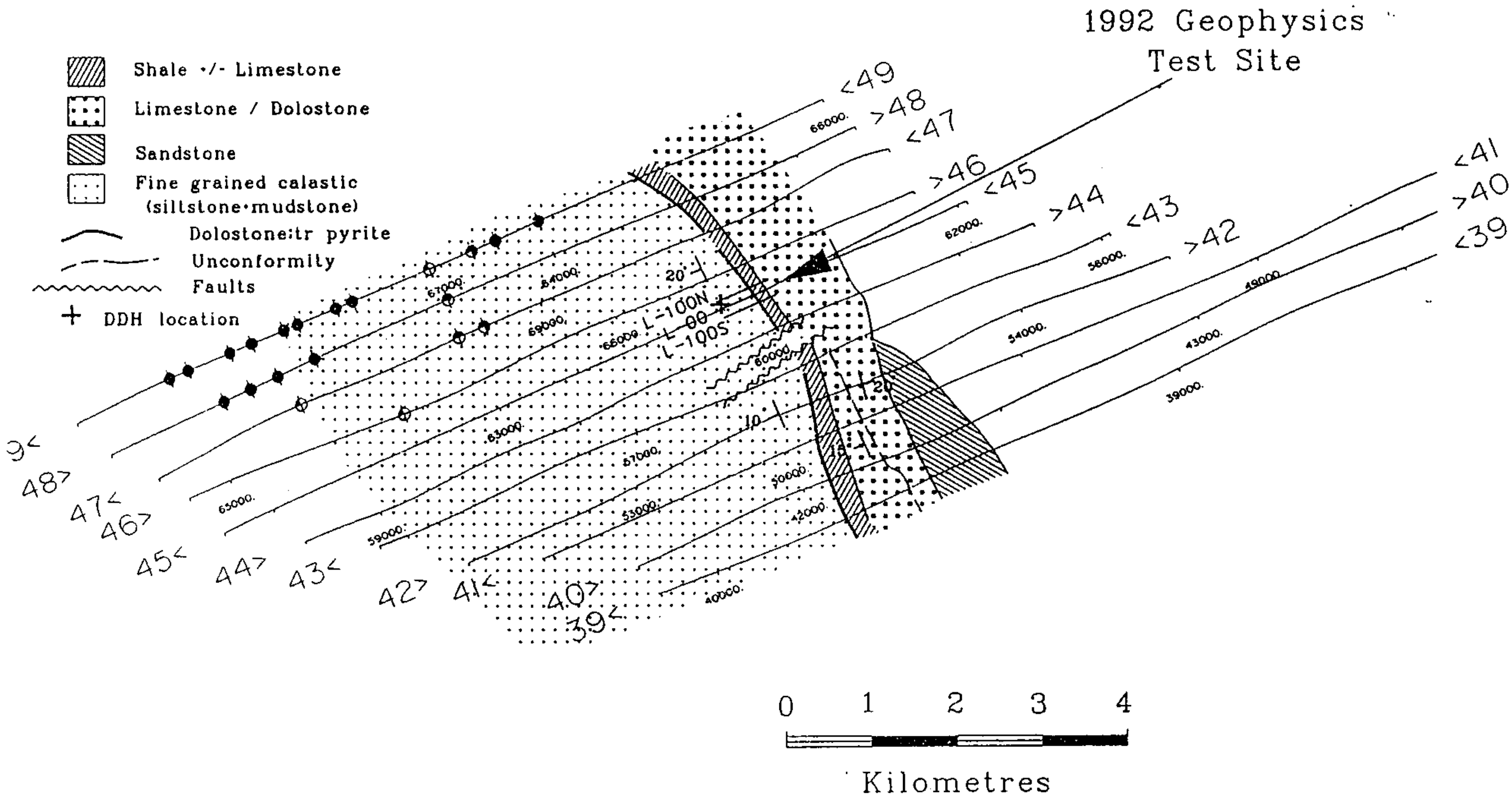
Fig. 9. The measured decay (square symbols) at the center of the negative anomaly 1.6 km from the right of line 45 (Figure 5). The time constant of the decay is 0.2 ms. The solid line shows the calculated response for a thin sheet of conductance 0.13 S and a dispersion in conductivity of 35 percent in the GEOTEM off-time bandwidth (500-2500 Hz); the dashed line is the calculated response of a half-space of conductivity 3 mS/m and a dispersion of 37 percent in the GEOTEM bandwidth.

Fig. 10. The conductivity dispersion curve of sample API-K5, a piece of frozen kaolinite (after Olhoeft, 1975). Between 500 and 2500 Hz the conductivity drops from 80 000 to 50 000 Ω•m, a dispersion of 40 percent.

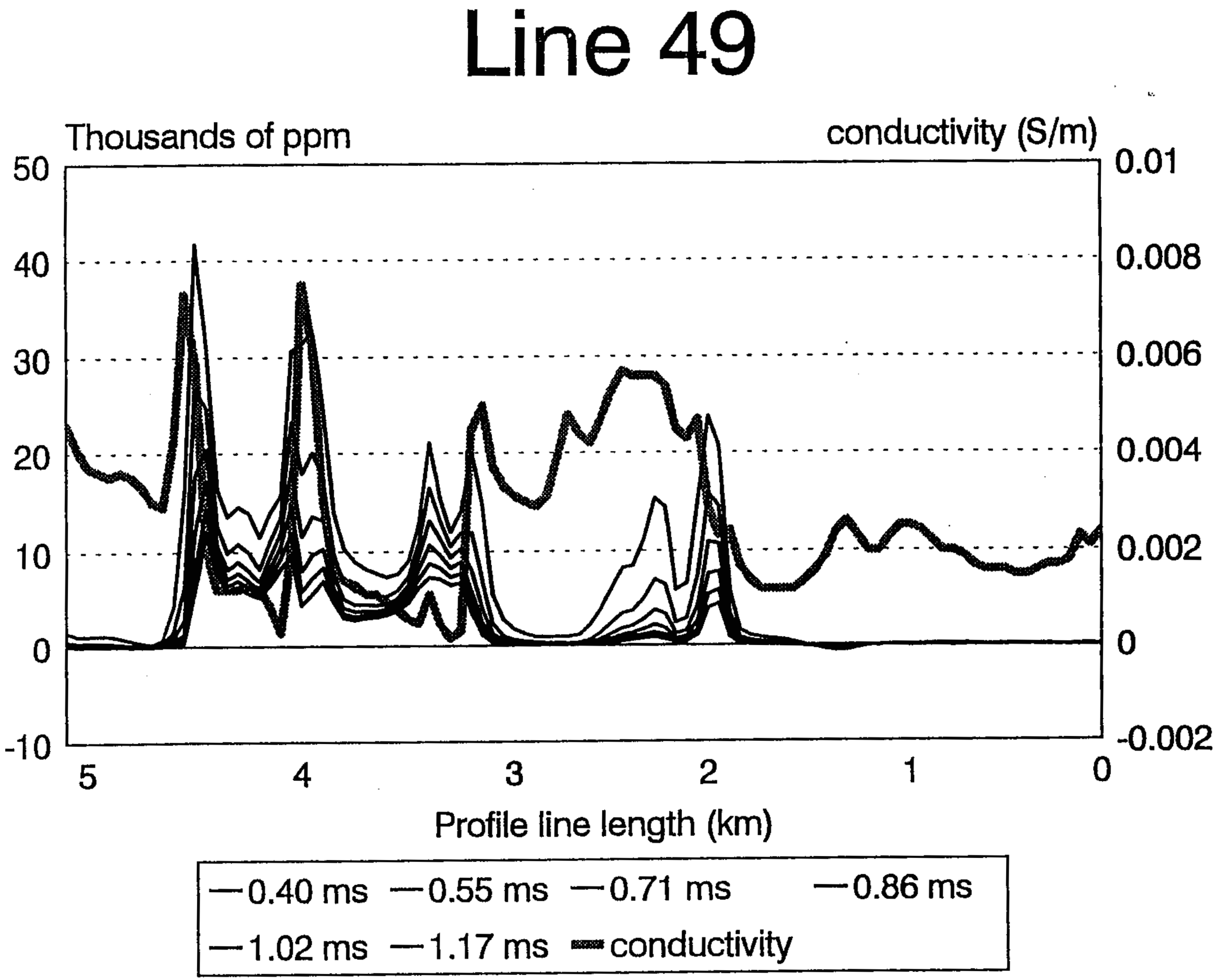
Fig. 11. IP data collected on the ground along line L-00 using a pole-dipole array with the pole to the right. The IP receiver is the Huntec Mark IV. The dipole spacing is 20 m. The chargeabilities are small, but greater over the shales than elsewhere on the section.

Fig. 12. The polarizability as estimated from the synthetic GEOTEM data calculated for a number of different models, plotted against the dispersion of those models in the off-time bandwidth (500-2500 Hz). The estimated polarizability is generally an underestimate of the true polarizability.

Fig. 13. An image of the polarizability (in percent) as calculated from the GEOTEM data. There are two strongly polarizable zones, the rightmost one coincides with the mapped shale horizon.

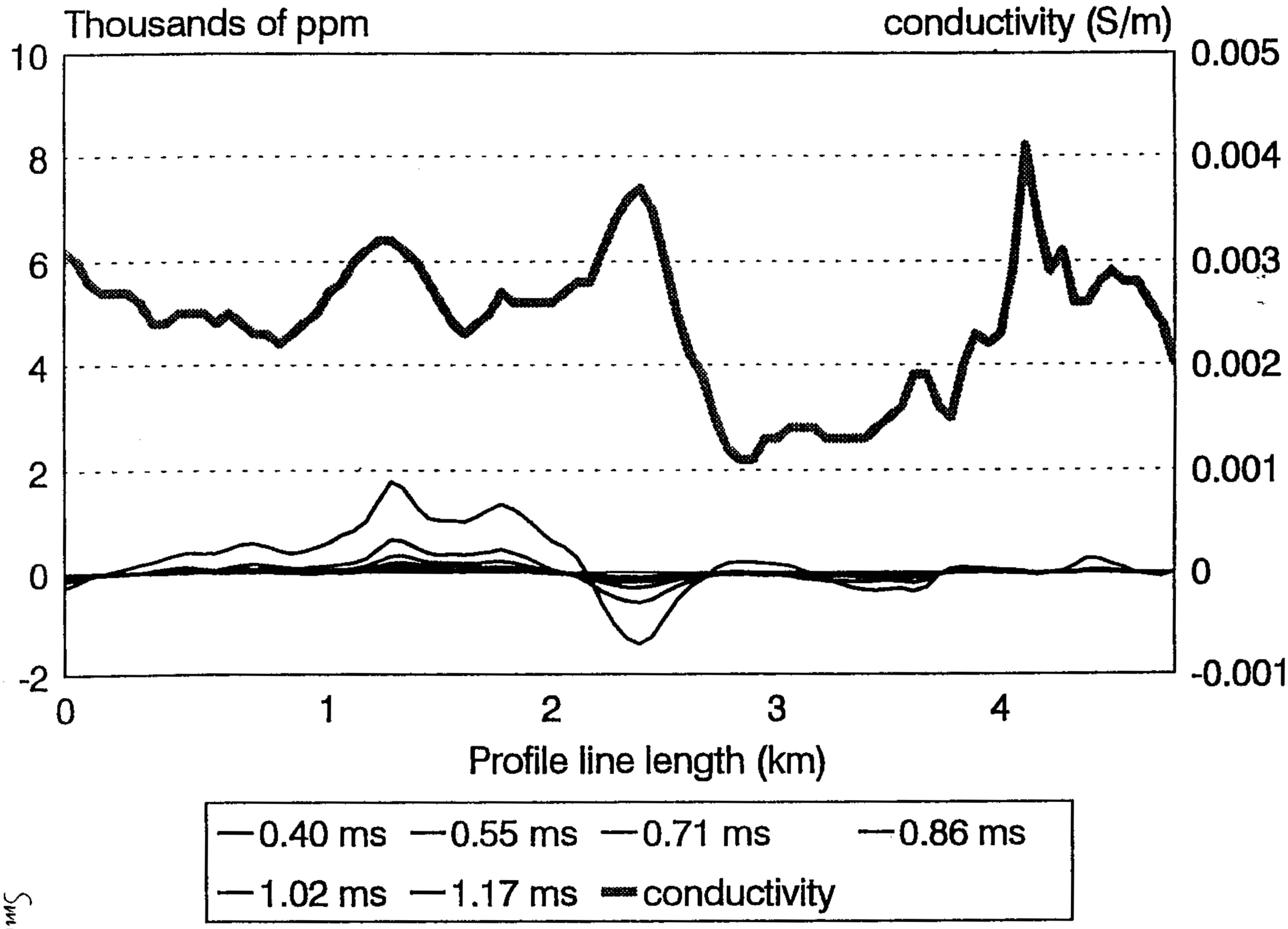


Smith &
Klein
Fig 1



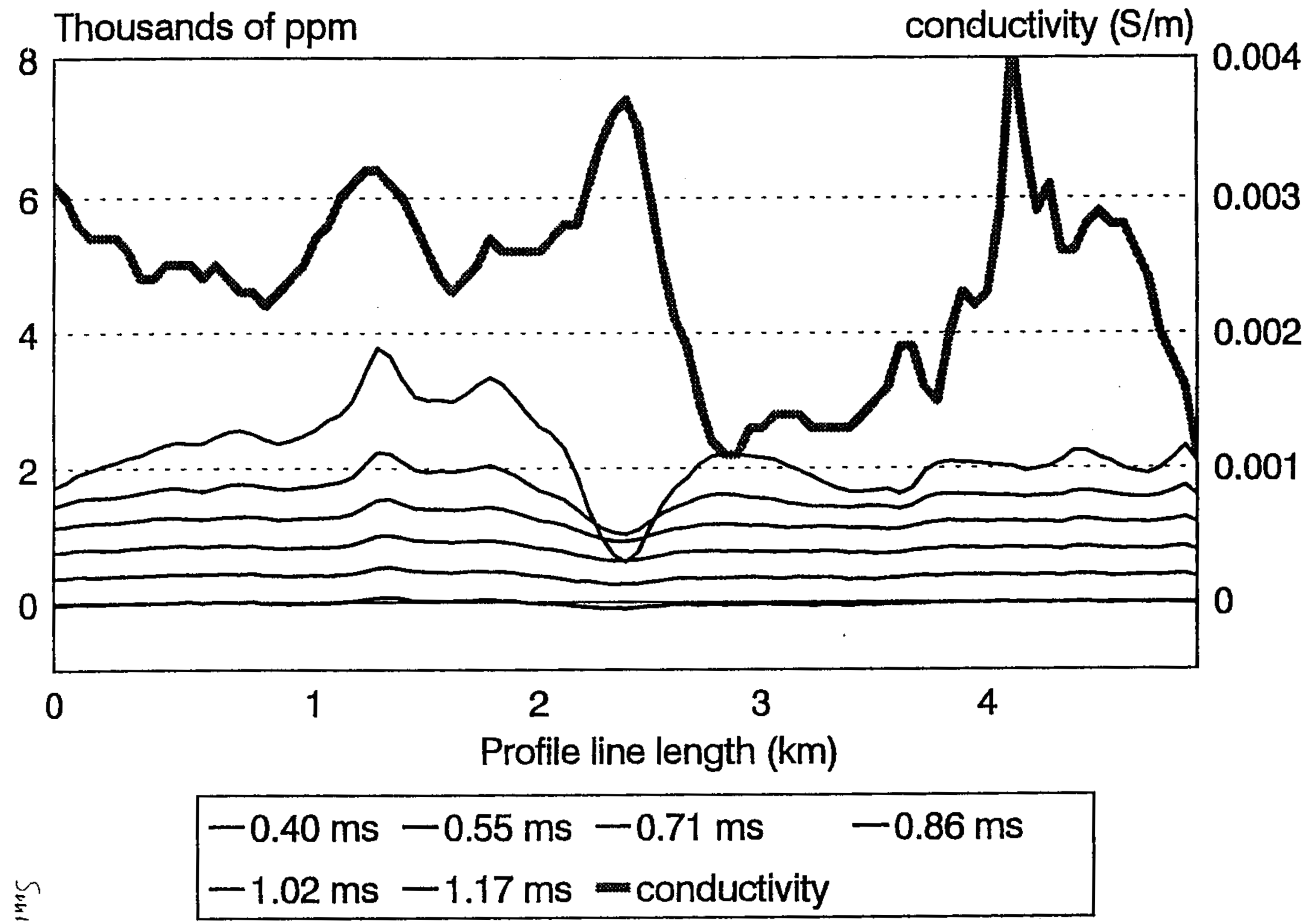
Smith & Klein
FIG 2

Line 46

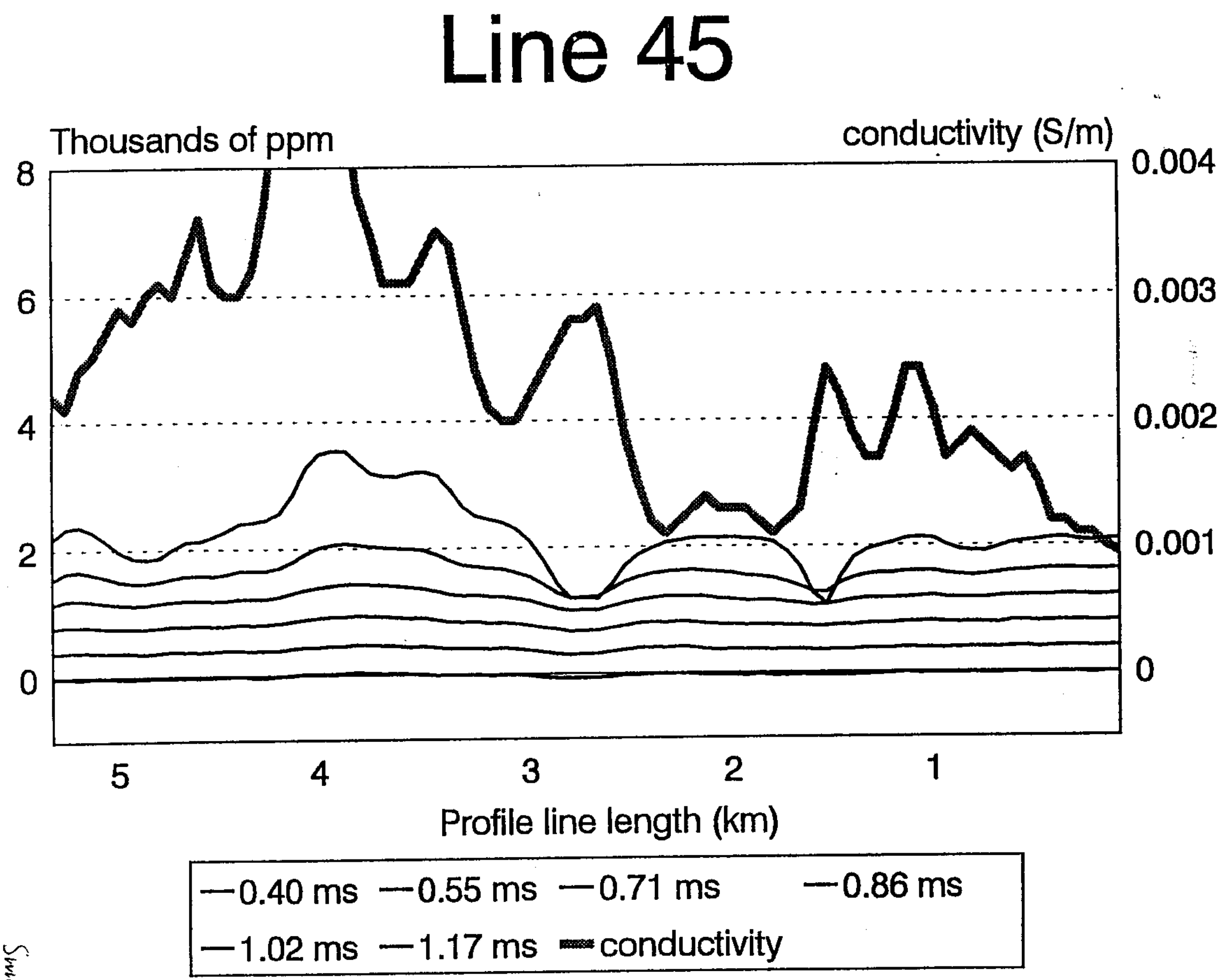


Smith & Klein Fig 3

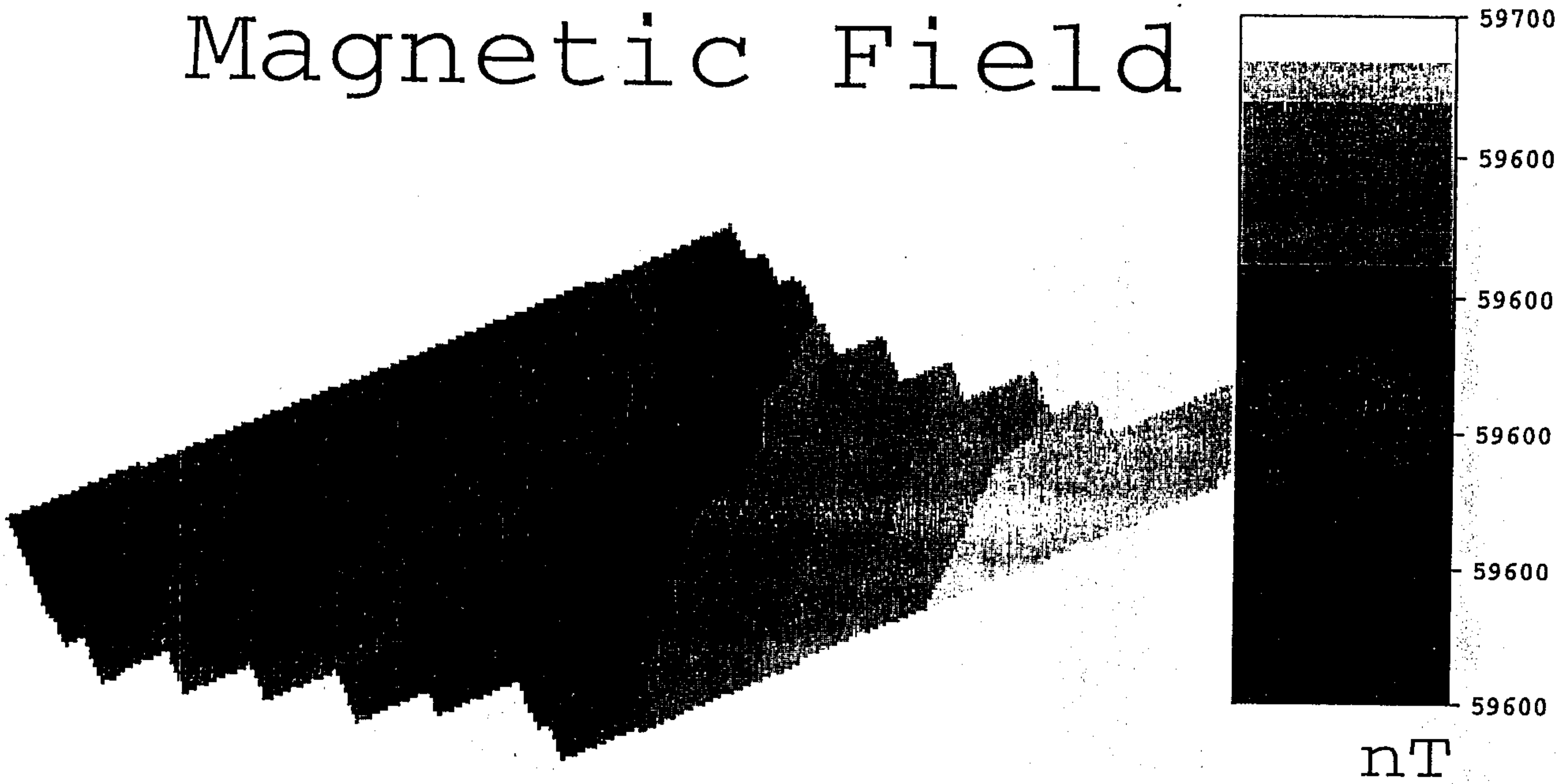
Line 46



Smith & Klein Fig 4

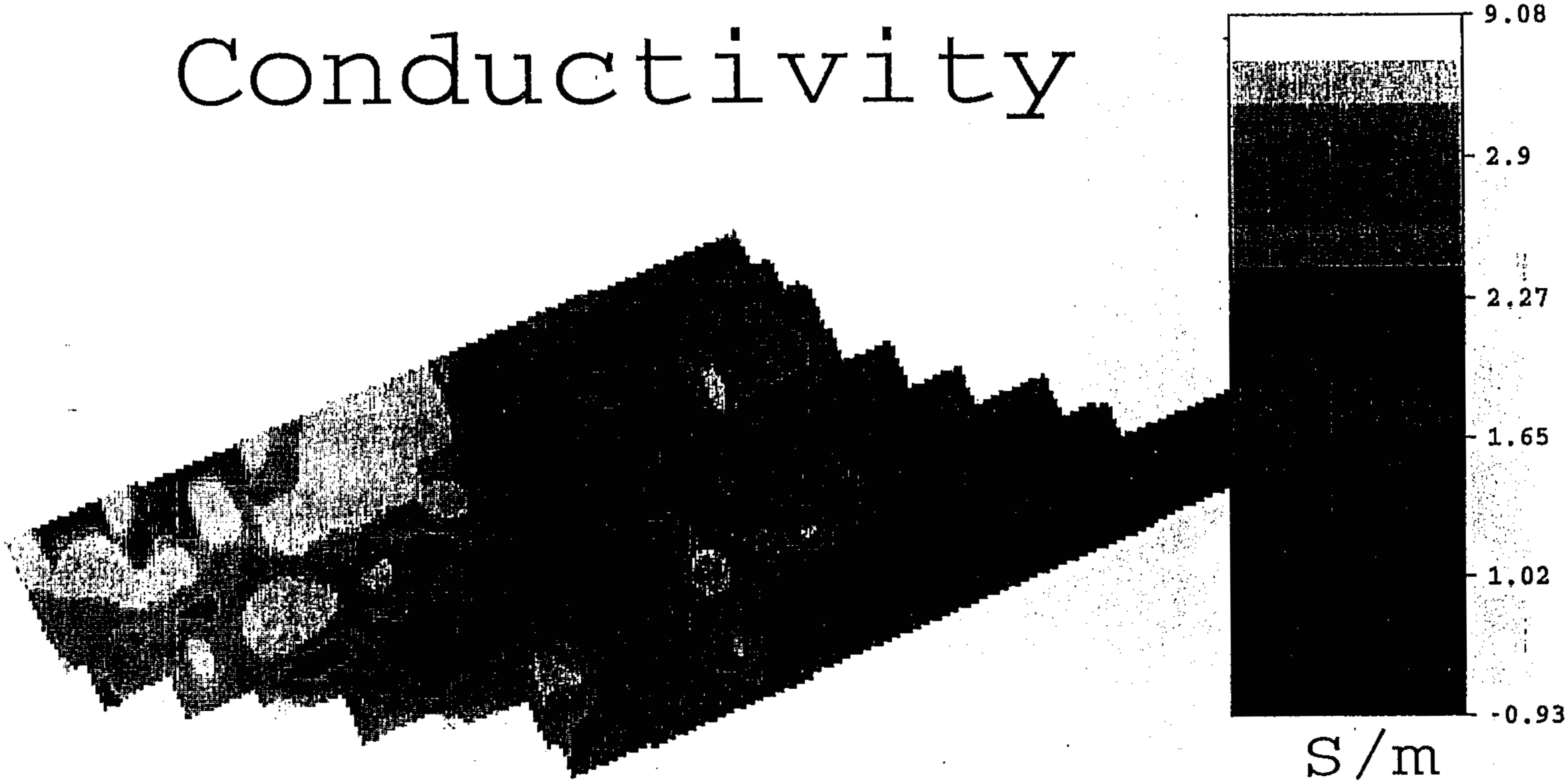


Smith & Klein Fig 5



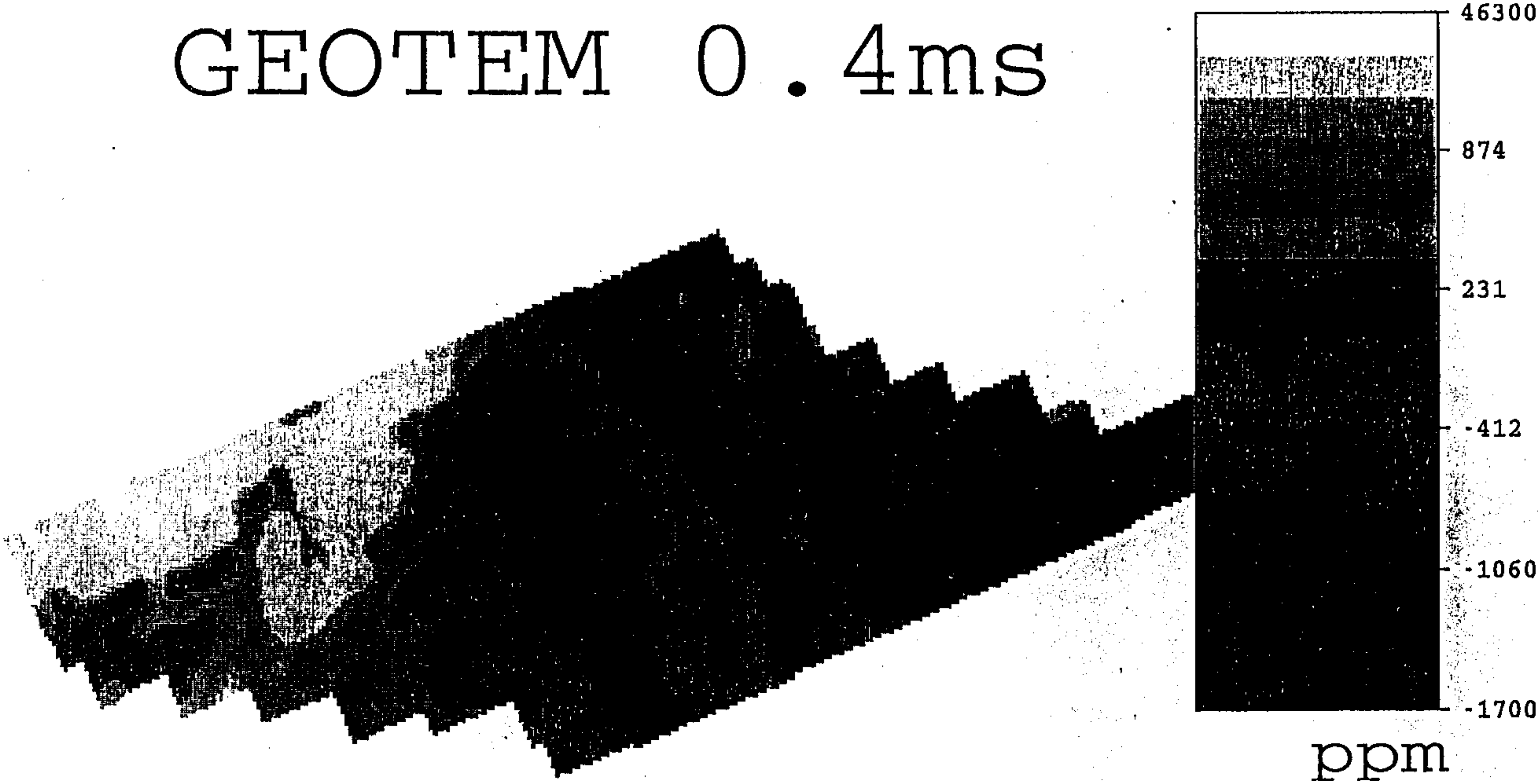
Smith & Klein Fig 6

Conductivity



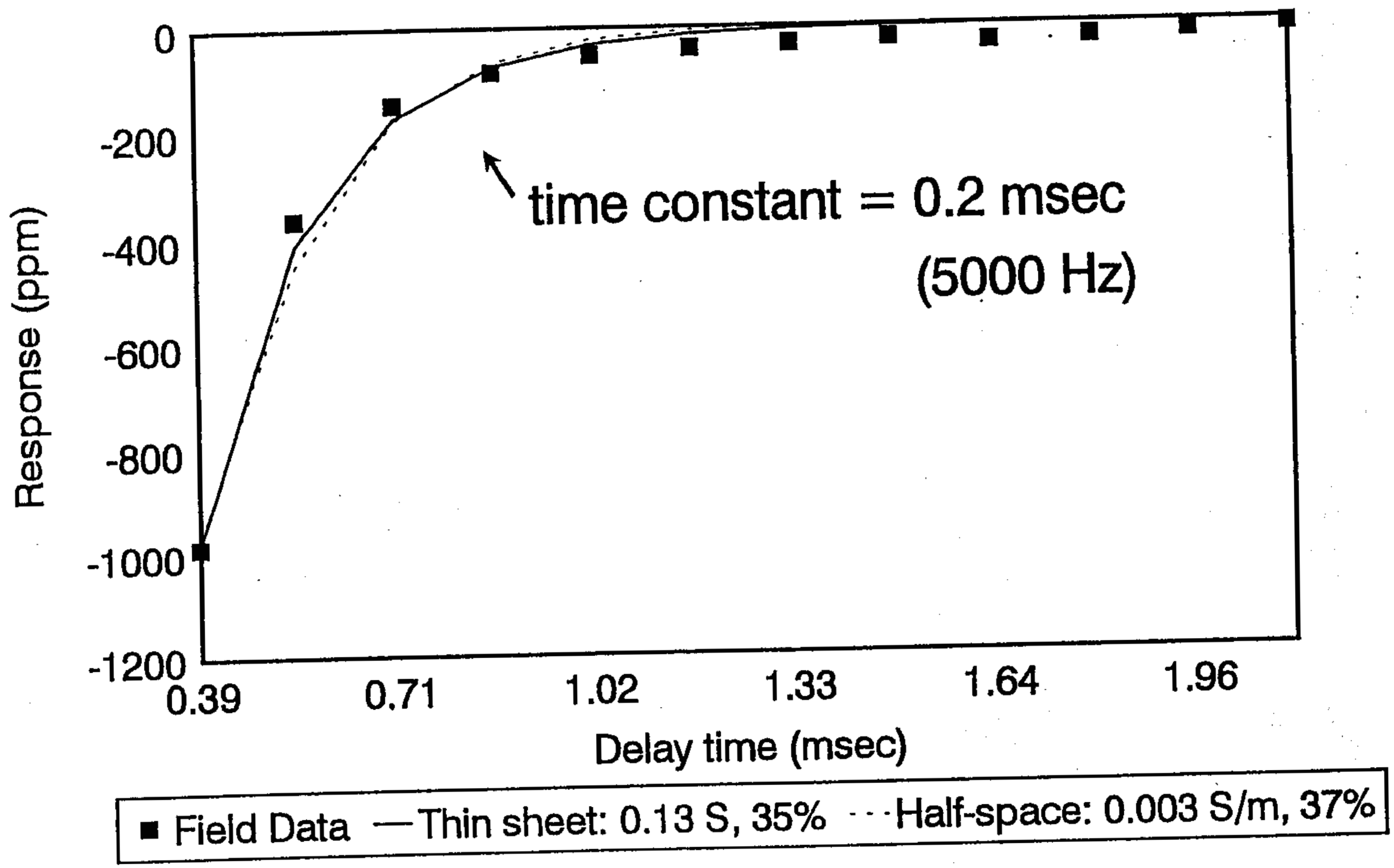
Smith & Klein Fig 7

GEOTEM 0.4ms



Smith & Klein Fig 8

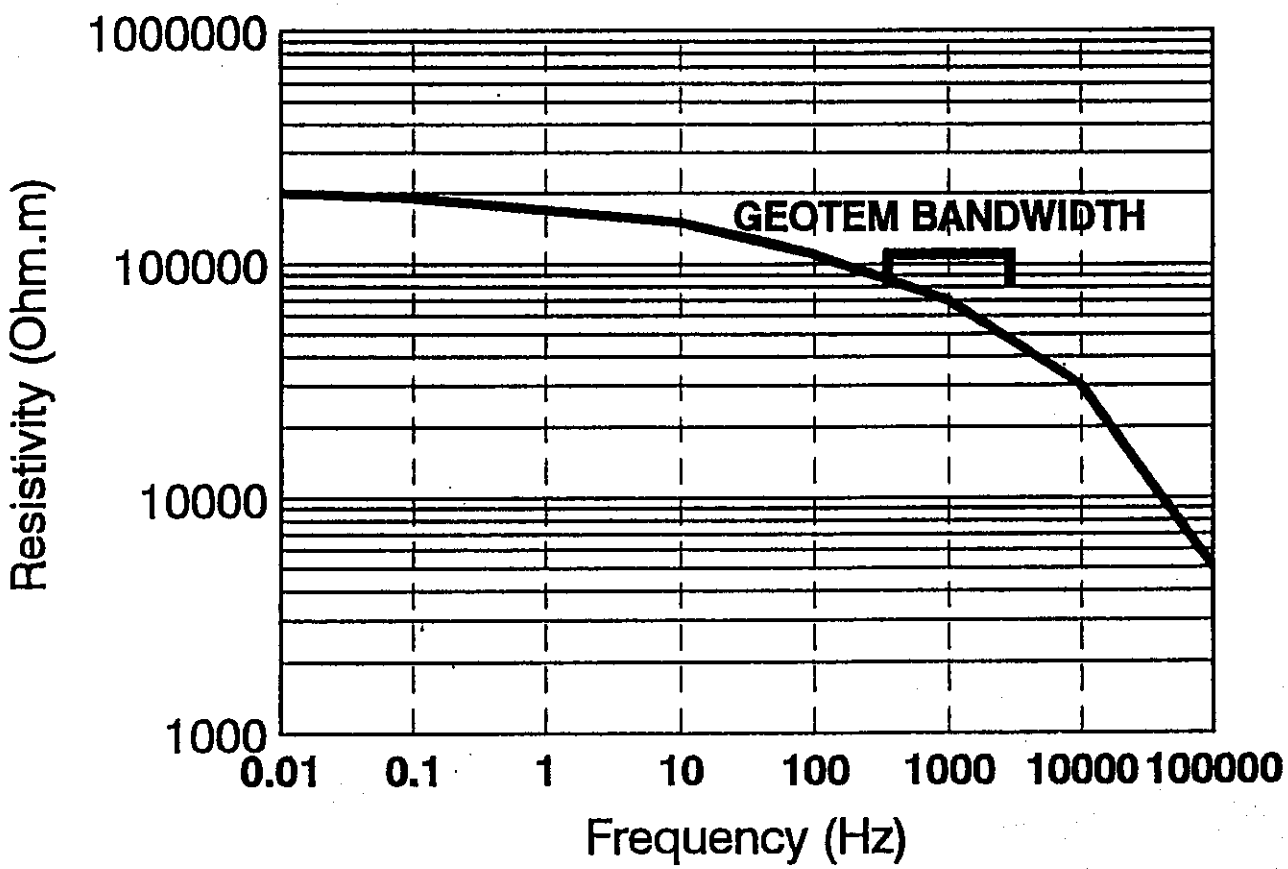
Fitted Decay



Smith & Klein
FIG 9

Kaolinite at -3 °C

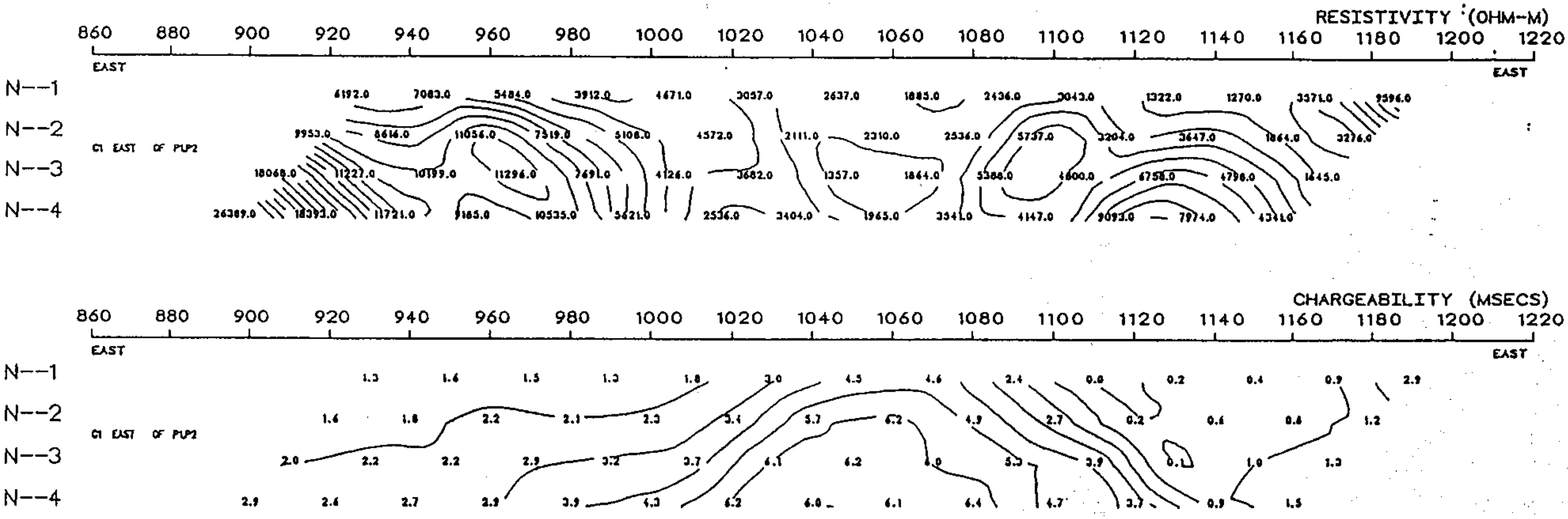
Sample API-K5 (Olhoeft, 1975)



Smith & Klein Fig 10

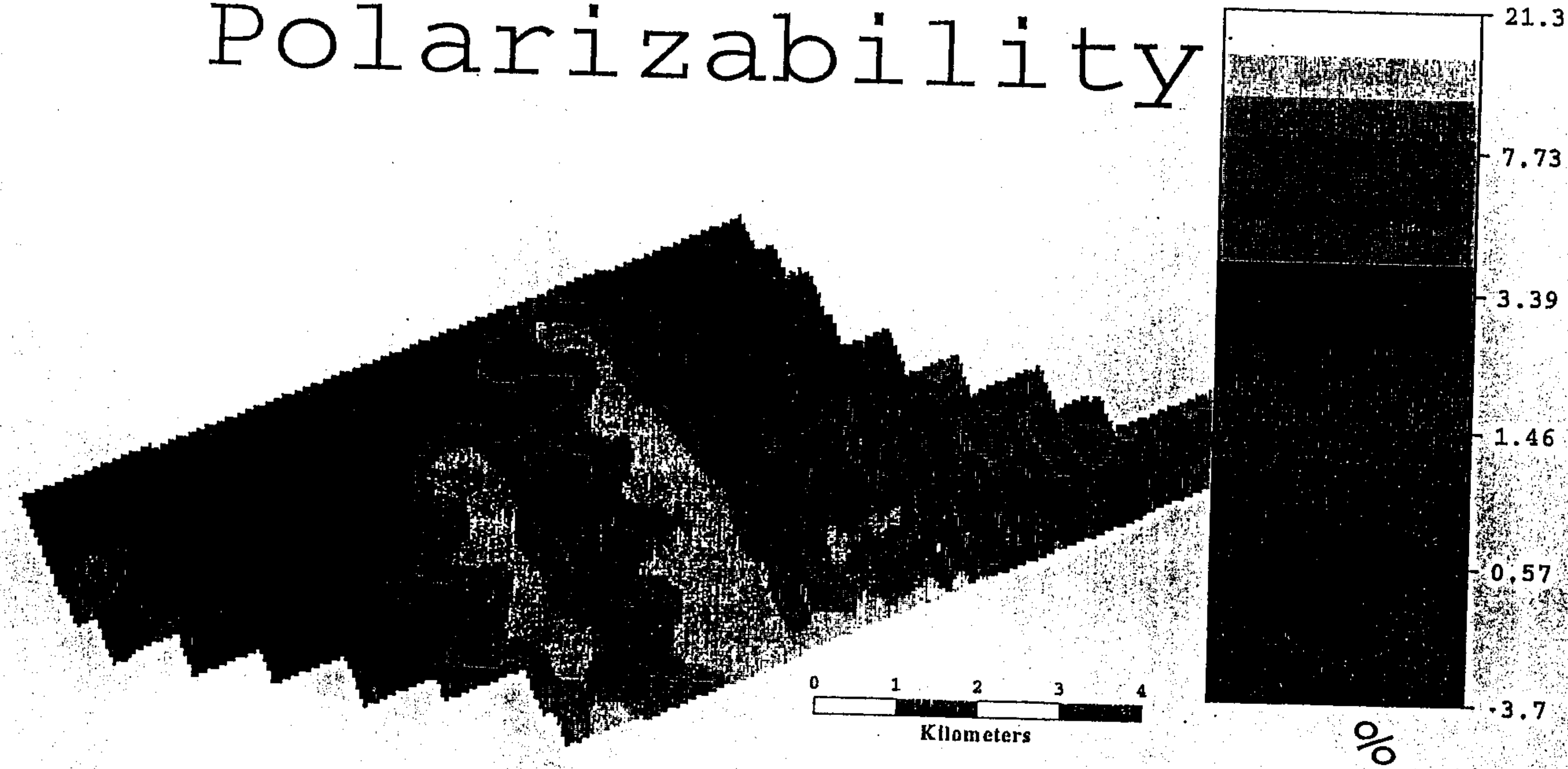
Pole-dipole IP Line 00N

LINE 00N a=20m C1 is EAST of P1

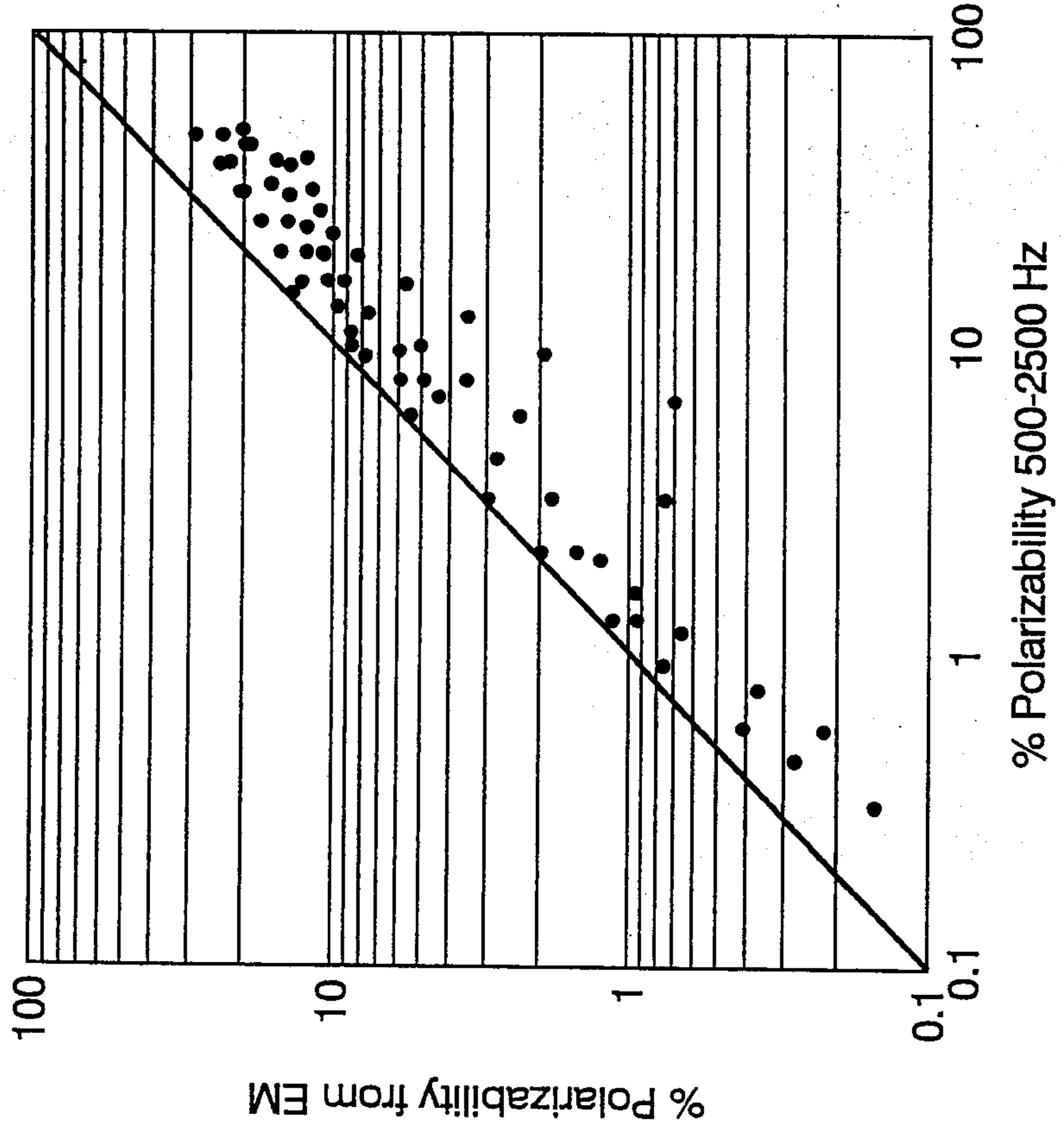


Smith & Klein
Fig 11

Polarizability



Smith & Klein Fig 13



Smith
& Klein
Fig 12