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Geophysical Atlas of Massive Sulphide Signatures Bathurst Mining Camp, New Brunswick

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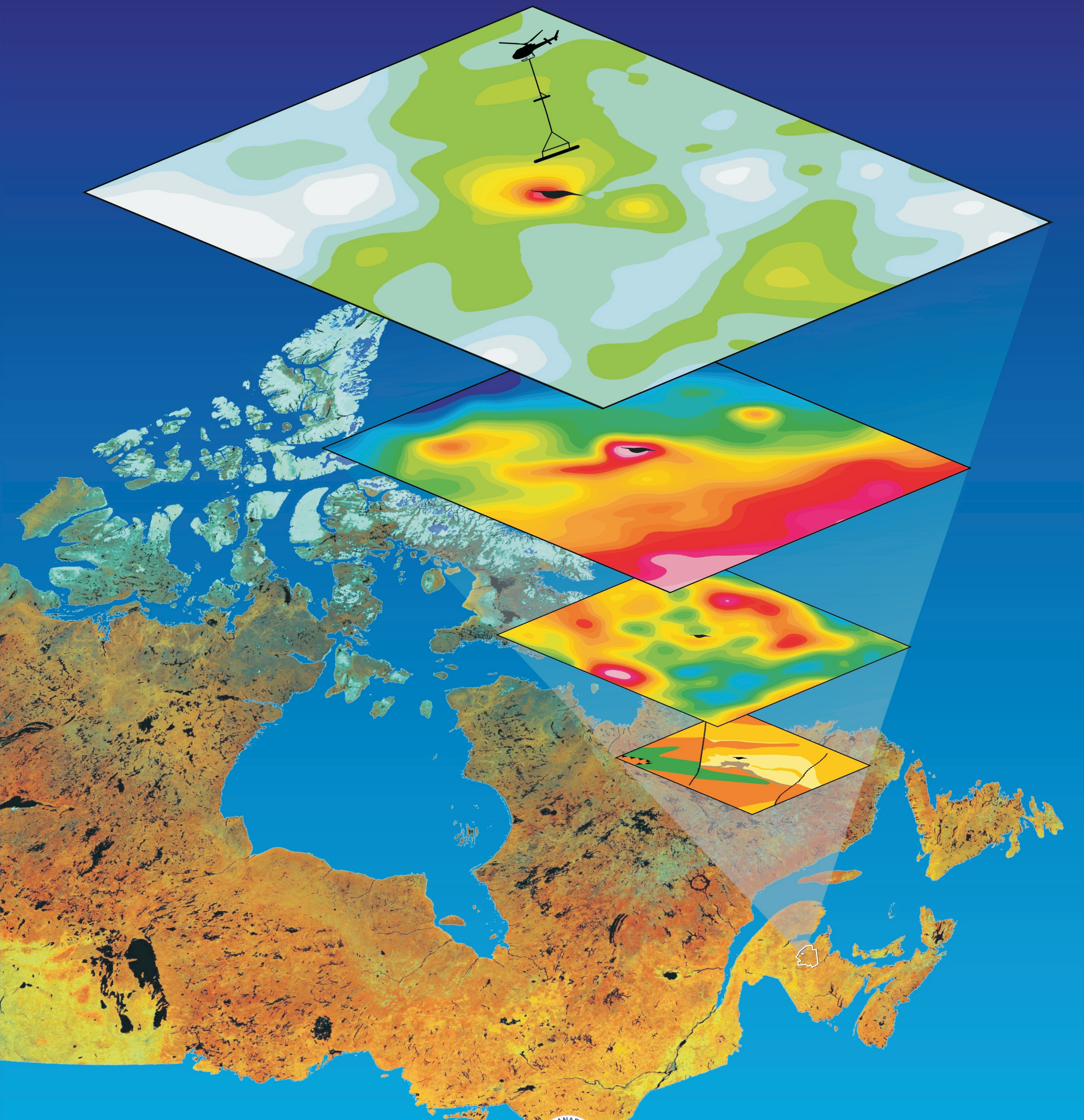

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CONTENTS

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PREFACE

This geophysical atlas is an important product of the Exploration and Technology Research (EXTECH-II) project that was undertaken in the Bathurst Mining Camp, northern New Brunswick in the period April 1994 to April 1999. EXTECH-II was a joint project between the Geological Survey of Canada and the New Brunswick Department of Natural Resources and Energy. It was carried out in close collaboration with the mining industry, other government agencies, such as the Atlantic Canada Opportunities Agency (ACOA) and the Research and Development Council (RDC) of New Brunswick, and the university community.

The principal objective of the EXTECH-II project was to enhance the potential for new mineral discoveries by updating the geoscience knowledge base, evaluating existing exploration techniques, and developing and testing new methods of detecting mineral deposits concealed at depth. The Bathurst Mining Camp is among Canada's most important mining camps, accounting for 25% of Canada's production of zinc, 30% of the lead, and 19% of the silver. The estimated value of production from the district in 1996 was $583 million, which constituted 63% of the total mineral production of New Brunswick. This geophysical atlas was produced in response to a request by the New Brunswick Prospectors and Developers Association for well illustrated case histories of the geophysical signatures associated with deposits of different size, geological setting and mineralogy in the Bathurst Mining Camp. The primary objective of this atlas is to assist the mineral exploration industry by providing a valuable reference of the types of geophysical anomalies associated with a variety of known volcanogenic massive sulphide (VMS) deposits. The large number of deposits with different geophysical properties, the excellent quality of the geophysical data, and the high level of understanding of the geological setting of these deposits, make the Bathurst Mining Camp an ideal subject for a geophysical atlas.

The atlas includes introductory sections containing brief descriptions of the geology of the Bathurst Mining Camp, the geophysical techniques used to obtain the illustrated data sets, the airborne survey, and regional (camp-wide) geophysical maps. Tables of physical properties of rocks and minerals are also included. Descriptions and graphic illustrations for 20 major sulphide deposits in the camp follow. The multiparameter geophysical characteristics of each deposit are described and portrayed in a four-page layout. Each layout includes a colour surface geological map and a cross-section showing the sub-surface distribution of the sulphide mineralization, and colour contour maps and profiles of magnetic, electromagnetic (EM), radiometric and gravity data. The magnetic, EM and radiometric data were collected by a helicopter-supported, high resolution airborne geophysical survey (200 m line spacing; 60 m mean terrain clearance) that was funded jointly by ACOA and RDC. The gravity data were obtained from ground surveys undertaken by private companies and the Geological Survey of Canada.

The suite of geophysical images illustrated in this atlas reflects the diverse mineralogical compositions, shapes, structural attitudes and geological settings of VMS deposits in the Bathurst Mining Camp. As such it provides a range of comparative geophysical fingerprints that should make important contributions to exploration programs, not only in the Bathurst Mining Camp, but also in other VMS camps having a similar geological setting.

Wayne D. Goodfellow
Coordinator
EXTECH-II Project

PRÉFACE

Cet atlas géophysique est un produit important d'EXTECH-II (projet quinquennal d'EXploration et de TECHnologie) réalisé dans le camp minier de Bathurst (nord du Nouveau-Brunswick) entre avril 1994 et avril 1999. La Commission géologique du Canada et le ministère des Ressources naturelles du Nouveau-Brunswick y ont participé en étroite collaboration avec l'industrie minière, d'autres organismes gouvernementaux, comme l'Agence de promotion économique du Canada atlantique (APECA) et le Conseil de recherche et de développement (CRD) du Nouveau-Brunswick, ainsi que le milieu universitaire.

Le projet EXTECH-II avait comme principal objectif d'accroître le potentiel de nouvelles découvertes de gîtes minéraux par la mise à jour des connaissances géoscientifiques, l'évaluation des techniques d'exploration actuelles et le développement et la mise à l'essai de nouvelles méthodes de détection des gîtes profonds. Le camp minier de Bathurst figure parmi les camps les plus riches du pays : 25% du zinc, 30% du plomb et 19% de l'argent extraits au Canada proviennent de ce camp. En 1996, la valeur de la production de ce district a atteint, selon les estimations, 583 millions de dollars, ce qui représentait 63% de la production minérale totale du Nouveau-Brunswick. Le présent atlas géophysique fait suite à une demande de la New Brunswick Prospectors and Developers Association qui souhaitait que l'on illustre de façon concrète les signatures géophysiques associées à des gîtes qui différaient par la taille, le cadre géologique et la minéralogie et qui étaient dans le camp minier de Bathurst. Le présent atlas vise surtout à venir en aide à l'industrie de l'exploration minérale en lui fournissant un outil de référence utile pour les types d'anomalies géophysiques associées à divers gîtes de sulfures massifs volcanogènes (SMV) connus. Le grand nombre de gisements possédant des propriétés géophysiques différentes, la très grande qualité des données géophysiques et la connaissance approfondie du cadre gîtologique contribuent à faire du camp minier de Bathurst un site idéal à cartographier.

L'atlas comprend en introduction de brèves descriptions de la géologie du camp minier de Bathurst, des techniques géophysiques utilisées pour obtenir les ensembles de données illustrés, du levé aérien et des cartes géophysiques régionales (à l'échelle du camp). Il contient également des tableaux de données sur les propriétés physiques des roches et des minéraux. Suivent des descriptions et des illustrations graphiques de 20 gîtes de sulfures massifs majeurs situés dans le camp. Les caractéristiques géophysiques multiparamétriques de chaque gisement sont décrites et illustrées sur un feuillet de quatre pages. Sur ces feuillets, on trouve une carte des dépôts superficiels en couleur, une coupe en profondeur de la minéralisation sulfurée ainsi que des cartes et des profils en couleur des isovaleurs magnétiques, électromagnétiques, radiométriques et gravimétriques. Les données magnétiques, électromagnétiques et radiométriques ont été recueillies par hélicoptère dans le cadre d'un levé géophysique haute résolution (selon un espacement de parcours de 200 m et une altitude moyenne de 60 m) financé conjointement par l'APECA et le CRD. Les levés gravimétriques ont été, pour leur part, exécutés au sol par des entreprises privées et la Commission géologique du Canada.

Les images géophysiques illustrées de l'atlas reflètent la diversité des minéralogies, des formes, des attitudes structurales et des cadres géologiques des gisements SMV du camp minier de Bathurst. Cet atlas constitue, par conséquent, un éventail de représentations géophysiques dont la comparaison devrait s'avérer très utile pour les programmes d'exploration, non seulement dans le camp minier de Bathurst, mais également dans d'autres camps de SMV possédant un cadre géologique semblable.

Wayne D. Goodfellow
Coordonnateur
Projet EXTECH-II

TECTONOSTRATIGRAPHIC AND STRUCTURAL FRAMEWORK OF MASSIVE SULPHIDE DEPOSITS IN THE BATHURST MINING CAMP

INTRODUCTION

The Bathurst Mining Camp, located in northern New Brunswick (Fig. 1), is a world-class base metal mining district that hosts over thirty volcanogenic massive sulphide (VMS) deposits, as well as dozens of lesser showings. The total sulphide production from the camp to the end of 1994 was 110,307,600 tonnes grading 3.01% Pb, 7.62% Zn, 0.49% Cu and 86.1 g/t Ag (Luff, 1995).

The first recorded observation of significant sulphides was in 1907 when several drill holes intersected and/or bottomed in pyrite during exploration drilling for iron ore by Drummond Iron Mines, on a property that would later become the Brunswick No. 6 Mine (Belland, 1992). In 1938 the Tetagouche Mining Company discovered the Orvan Brook deposit in outcrop in the bed of Orvan Brook. However, sulphide grades and/or thicknesses were not economical. The potential for economic sulphide mineralization was not fully appreciated until 1952 when the M.J. Boylen Company intersected ore-grade mineralization at the Brunswick No. 6 deposit during follow-up work on a ground electromagnetic anomaly. Most of the known deposits in the Bathurst Mining Camp were discovered during the initial staking rush of the 1950's, including the super-giant Brunswick No. 12 deposit that contained geological reserves in excess of 170 million tonnes of massive sulphides. Many of the deposits were discovered during follow-up work on airborne electromagnetic surveys.

The EXTECH (Exploration Technology)-II Project (1994-1999) was a Provincial-Federal-Industry initiative that focussed on the stratigraphy, structure and mineral deposits of the Bathurst Mining Camp. A fully-integrated, multiparameter airborne geophysical survey was conducted over the entire camp as part of this project. The purpose of this atlas is to show the results of the airborne geophysical survey over twenty known deposits (Fig. 1), and to integrate this information with compiled gravity data, regional stratigraphy and structure. It is worthy of note that the Camel Back deposit, included herein, was discovered by Noranda Exploration Company Limited (henceforth Noranda) during follow-up work on the airborne survey.

The following discussion of tectono-stratigraphy and structure is modified from McCutcheon *et al.* (1997), and reflects the understanding of the Bathurst Mining Camp at present. Although the rocks of the camp have been metamorphosed to greenschist grade and subjected to polyphase deformation, the rock descriptions in the following sections use protolith or assumed protolith names rather than metamorphic rock names. The reader should also keep in mind that the camp is made up of a number of structural nappes, which repeat stratigraphy.

STRATIGRAPHY

In simple terms the Bathurst Mining Camp consists of a Middle Ordovician felsic volcanic sequence overlain by interbedded Middle to Upper Ordovician mafic volcanic and sedimentary rocks. The felsic volcanic pile ranges in composition from dacite to rhyolite, whereas the mafic volcanic pile comprises alkalic to tholeiitic basalt (Whitehead and Goodfellow, 1978; van Staal, 1987; van Staal *et al.*, 1991; Rogers, 1995). This volcanic pile was erupted onto an older sequence of clastic sedimentary rocks (Miramichi Group) on the Gondwanan continental margin. Sedimentary rocks are intercalated with the volcanic rocks, and there is a distinctive post-volcanic sedimentary succession (Tomogonops Formation).

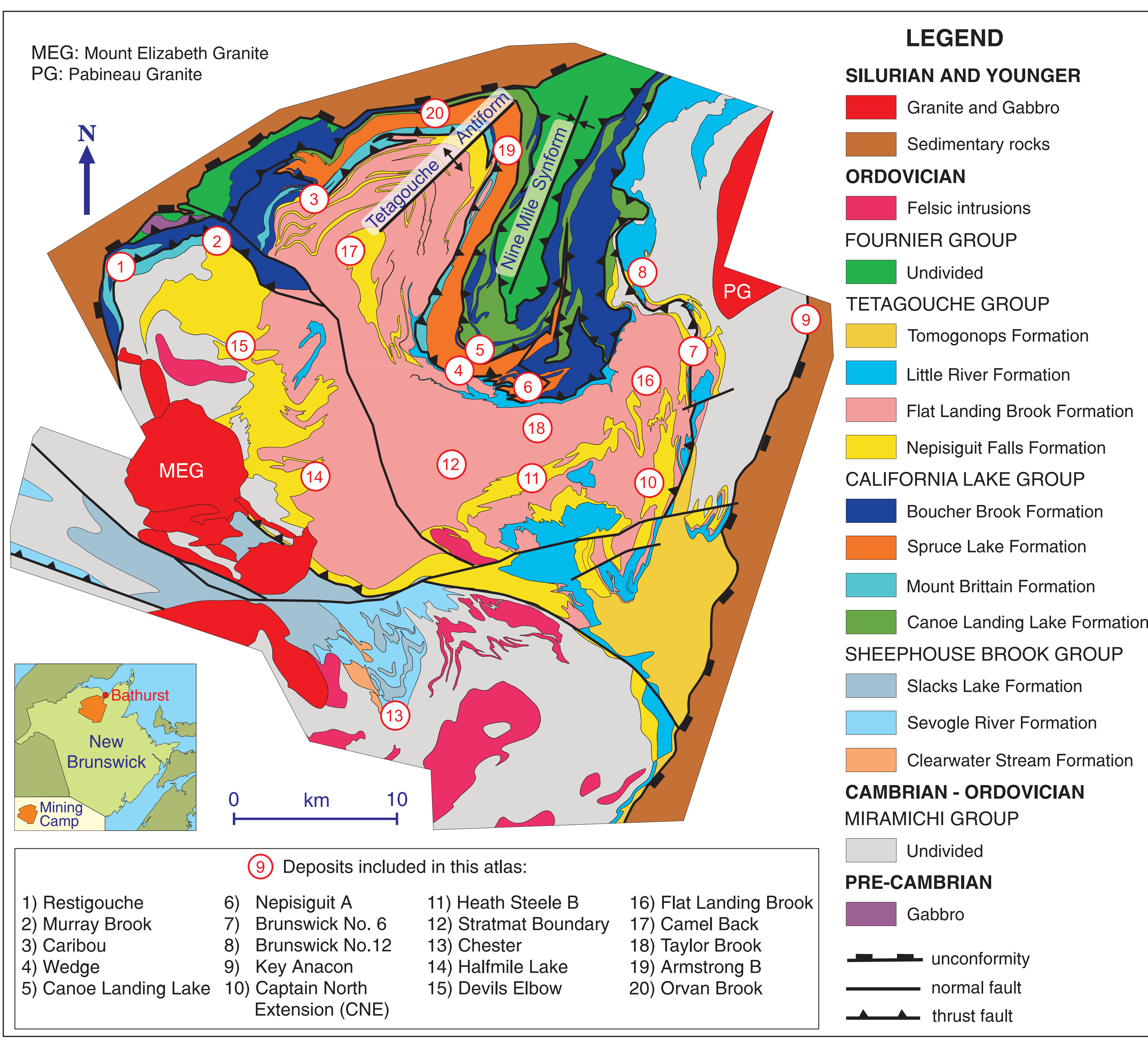


Figure 1: Geology map of Bathurst Mining Camp, modified from a map provided by Neil Rogers, Geological Survey of Canada. Locations of massive sulphide deposits illustrated in this atlas are indicated.

The rocks in the Bathurst Mining Camp, part of the northern Miramichi Highlands, were separated into the Miramichi, Tetagouche and Fournier groups by van Staal and Fyffe (1991). Recently the California Lake and Sheephouse Brook groups (Wilson *et al.*, 1998), which comprise some of the rocks formerly assigned to the Tetagouche Group, have been recognized. The Tetagouche, California Lake, Sheephouse Brook and Fournier groups constitute the Dunnage Zone in the northern Miramichi Highlands, whereas the Miramichi Group constitutes the Gander Zone (van Staal and Fyffe, 1991).

The stratigraphic subdivisions of the Bathurst Camp, as currently understood, are shown in Figure 2. Some of the units have not yet been formally described, but will appear in a paper by van Staal *et al.* (in preparation) in the forthcoming Economic Geology Monograph on the Bathurst Mining Camp. Each group, formation or map unit is briefly described below, beginning with the formation name, followed by the author(s) who introduced the name, and the description of the formation or corresponding map units(s) that appear on detailed maps in this atlas.

Miramichi Group

The Cambrian(?) to Lower Ordovician Miramichi Group, first defined by van Staal and Fyffe (1991), comprises a thick sequence of quartz wacke and shale of unknown thickness. These rocks have been interpreted as a flysch apron on the Avalon continental margin (Rast and Stringer, 1974; van Staal and Fyffe, 1991). This group underlies both the Sheephouse Brook and Tetagouche groups. The Miramichi Group comprises three formations that, in ascending stratigraphic order, are: Chain of Rocks, Knights Brook and Patrick Brook formations.

Chain of Rocks Formation (van Staal and Fyffe, 1991): Unit COCRs comprises fine- to coarse-grained, light greenish grey, quartzose sandstone with some interbedded light to dark greenish grey shale. Sandstone beds range from a few centimetres to greater than 1 m in thickness, whereas shale beds are from 1 to 10 cm thick (McCutcheon *et al.*, 1993).

Knights Brook Formation (van Staal and Fyffe, 1991): Unit COKBs contains interbedded quartzose sandstone, siltstone, shale and quartzose wacke. The shale is commonly pyritic, in places graphitic and has well developed cleavage. Shale is more abundant and graphitic in the upper part of this formation (McCutcheon *et al.*, 1993).

Patrick Brook Formation (van Staal and Fyffe, 1991): Unit OPBs consists of dark grey to black shale and dark grey volcaniclastic wacke that commonly contains clear quartz and/or plagioclase phenoclasts. These rocks were originally assigned to the Tetagouche Group (van Staal and Fyffe, 1991), but have been reassigned to the Miramichi Group (Fyffe *et al.*, 1996).

Tetagouche Group

The Tetagouche Group conformably to disconformably overlies the Miramichi Group and is structurally overlain by the California Lake Group. The Tetagouche Group hosts most of the Bathurst Camp deposits and comprises four formations that, in ascending stratigraphic order, are: Nepisiguit Falls, Flat Landing Brook, Little River and Tomogonops formations.

Nepisiguit Falls Formation (Saif, 1977): Unit ONF comprises massive, quartz-feldspar porphyritic (2 - 15 mm) tufflava, and medium- to coarse-grained, granular, quartz-feldspar-rich volcaniclastic rocks with minor intercalated ash tuff. The volcaniclastic rocks commonly become finer-grained near the top of the unit and are interlayered with light to dark greenish grey, chloritic mudstone that is locally iron-rich ("chloritic iron formation") and constitutes the "Brunswick Horizon". A U-Pb zircon age of 469 ± 2 Ma (Sullivan and van Staal, 1996) was obtained from this unit. The basal contact of the Nepisiguit Falls Formation is locally concordant with the underlying Knights Brook Formation.

There are three other mappable units that are also assigned to the Nepisiguit Falls Formation, which do not occur in the type area. These have been given member status and include the Lucky Lake, Little Falls and Vallee Lourdes members.

Lucky Lake Member (Wilson, pers. comm.): Unit ONFLL comprises felsic ash tuff, lapilli tuff and minor quartz-phyric tuff. These rocks are restricted to the northern part of the camp, *i.e.* the Tetagouche Antiform. A U-Pb zircon age of 470 ± Ma (van Staal *et al.*, in preparation) has been obtained from this unit.

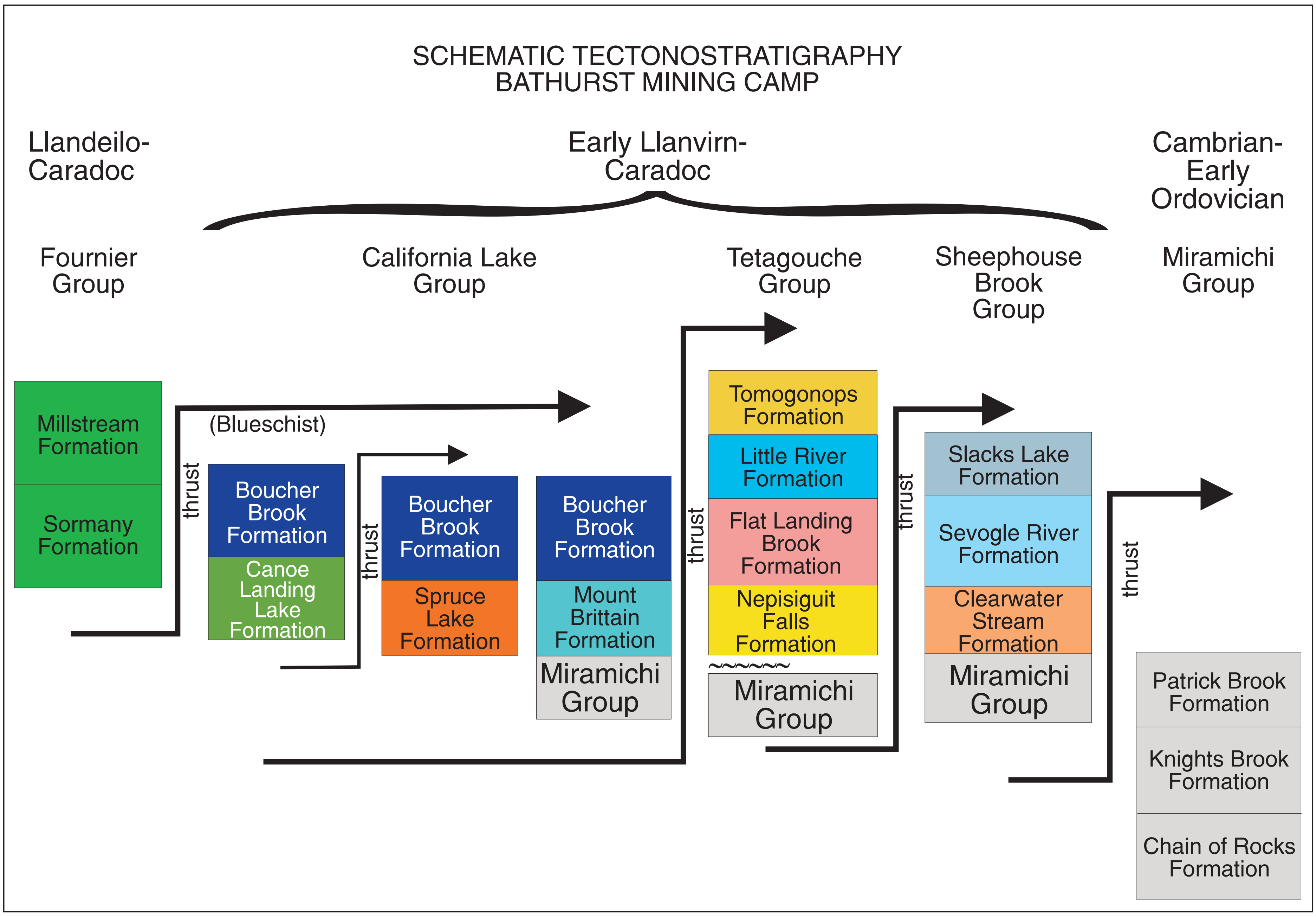


Figure 2: Tectonostratigraphic subdivisions of the Bathurst Mining Camp (modified from Wilson, unpublished).

Little Falls Member (Langton and McCutcheon, 1993): Unit ONFLF consists of greenish grey ash tuff and fine- to medium-grained, quartz-feldspar-phyric volcaniclastic rocks interbedded with dark greenish grey to black shale; tufflava is absent. A U-Pb zircon age of 471 ± 3 Ma was obtained from this unit (Sullivan and van Staal, 1996).

Vallee Lourdes Member (van Staal et al., 1988): This name was originally introduced as a formation, but it is clear that it should be reduced in rank (van Staal *et al.,* in preparation). Unit ONFVL comprises a thin unit of nodular to siliciclastic limestone (calcarenite of Rice and van Staal, 1992), calcareous sandstone and siltstone, which disconformably overlies the Miramichi Group. Brachiopods (Fyffe, 1976; Neuman, 1984) and conodonts (Nowlan, 1981) from this unit indicate a middle Arenigian to early Llanvirnian age, and confirm that the overlying felsic volcanic pile is mainly Llanvirnian, as elsewhere deduced from U-Pb geochronology.

Flat Landing Brook Formation (van Staal and Fyffe, 1991): Unit OFL comprises aphyric to feldspar-phyric (± quartz) rhyolite flows, hyaloclastite, pyroclastic rocks and minor sedimentary rocks, including some iron formation. Feldspar ± quartz phenocrysts are small (1 - 3 mm) and constitute less than 10% of the rocks; the matrix is cryptocrystalline. In the past, most of these rocks were interpreted as pyroclastic deposits, but many are now considered to be the products of mechanical/thermal fragmentation of lava flows, *i.e.* hyaloclastites (van Staal, 1987; Langton and McCutcheon, 1990; Wilson, 1993a). A U-Pb Zircon age of 466 ± 5.3 Ma was obtained from this unit (Sullivan and van Staal, 1990), and was subsequently refined to 466 ± 2 Ma (Rogers *et al.*, 1997).

Three other mappable units are also assigned to the Flat Landing Brook Formation, but do not occur in the type area. These have been given member status and include the Moody Brook, Forty Mile Brook and Roger Brook members.

Moody Brook Member (Wilson, 1993a): Unit OFLMB is characterized by fragmental rocks of pyroclastic origin, containing felsic clasts in a greenish grey to greenish black matrix of intermediate to mafic composition. The fragmental rocks apparently grade upward into mafic lavas of tholeiitic composition, which constitute part of the "Otter Brook tholeiite" of van Staal *et al.* (1991). They appear to be at or near the top of the Flat Landing Brook Formation and may occupy the same stratigraphic position as the Brunswick Mines Member of the Little River Formation (see below).

Forty Mile Brook Member (van Staal et al., 1991): Unit OFLFM consists of tholeiitic pillowed basalt flows and associated diabase and gabbro.

Roger Brook Member (Wilson, 1997): Unit OFLRB comprises felsic-crystal lithic tuff and minor rhyolite. These rocks appear to conformably overlie the Nepisiguit Falls Formation and, therefore, locally constitute the lower part of the Flat Landing Brook Formation.

Little River Formation (Wilson *et al.*, 1998): Unit OLR comprises mafic volcanic and associated sedimentary rocks that conformably overlie the Flat Landing Brook Formation. Many of these rocks had previously been assigned to the Boucher Brook Formation (van Staal and Fyffe, 1991). Unit OLRs comprises shale interstratified with siltstone and volcaniclastic sandstone. Two mappable units of mafic volcanic rocks are assigned to the Little River Formation, but do not occur in the type area. These have been given member status and include the Brunswick Mines and Beresford members.

Brunswick Mines Member (Wilson et al., 1998): This unit was originally introduced as the "Brunswick alkali basalt suite" by van Staal *et al.* (1991) and included in the Boucher Brook Formation. Wilson *et al.* (1998) reassigned some of the rocks belonging to this suite to the Little River Formation. Unit OLRBM consists of massive to pillowed basalt, breccia, hyaloclastite and interflow sedimentary rocks, including chert and red metalliferous shale. Basalts are characterized by Nb/Y ratios ranging between 0.65 and 1.0, with Cr not exceeding 200 ppm.

Beresford Member (van Staal et al., 1991): Originally introduced as the "Beresford alkalic basalt suite" by van Staal *et al.* (1991) and assigned to the Boucher Brook Formation. Wilson *et al.* (1998) reassigned this package of rocks to the Little River Formation. Unit OLRBE comprises alkalic basalt interlayered with black shale. It includes alkalic basalt with higher Nb/Y (>1) and lower Zr/Nb values than the Brunswick Mines Member (van Staal *et al.*, 1991).

Tomogonops Formation (Langton, 1994): Unit OT is a post-volcanic, upward-coarsening sequence that comprises light grey, thinly bedded, commonly calcareous siltstone (± limestone) and fine-grained sandstone. Toward the top, this unit grades into thick-bedded, non-calcareous, coarse-grained wacke and conglomerate. The Tomogonops Formation apparently conformably overlies early Caradocian shale and chert that mark the end of Ordovician volcanism. However, there is some evidence that the Tomogonops Formation may be unconformable on the underlying Little River Formation at the Key Anacon property (Lentz, 1995).

California Lake Group

The California Lake Group is approximately coeval with the Tetagouche Group, but occurs in a different structural nappe; consequently, its stratigraphic relationship to the latter is unknown. The California Lake Group comprises four formations: Canoe Landing Lake, Mount Brittain, Spruce Lake and Boucher Brook formations. The first three are more or less contemporaneous, because each is overlain by the Boucher Brook Formation.

Canoe Landing Lake Formation (van Staal and Fyffe, 1991): Unit OCL consists of high-chromium alkali basalt with intercalated red shale, chert and rare felsic volcanic rocks. Comendite from the type area yielded a U-Pb zircon age of 472 ± 4 Ma (van Staal *et al.*, 1991). Unit OCLs comprises interbedded black to grey shale and siltstone that conformably underlie the mafic volcanic rocks and host the Canoe Landing Lake deposit (Walker and McDonald, 1995).

Three other mappable units are also assigned to the Canoe Landing Lake Formation, but do not occur in the type area. These have been given member status and include the Nine Mile Brook, Orvan Brook and Spruce Lake members.

Nine Mile Brook Member (van Staal et al., 1991): Unit OCLNM is composed of tholeiitic pillow basalt with intercalated alkali basalt, red shale and chert. The contact between type-Canoe Landing Lake alkalic basalts and the Nine Mile Brook Member is marked by a broad zone of mélange, as shown by drilling north of Canoe Landing Lake (Brown, 1996). The Nine Mile Brook Member is overlain by sedimentary rocks of the Boucher Brook Formation.

Orvan Brook Member (Wilson et al., 1998): Unit OCLOB comprises basalts transitional between the alkalic and tholeiitic types.

Spruce Lake Member (Wilson, pers. comm.): Unit OCLSL comprises feldspar-phyric, locally amygdaloidal rhyolite that is similar to the feldspar-phyric rhyolite of the Spruce Lake Formation.

Mount Brittain Formation (Gower, 1996): Unit OMBfv comprises feldspar crystal-lithic felsic tuff that overlies less abundant, aphyric to sparsely feldspar-phyric dacitic lava. Quartz microphenocrysts (0.3 - 0.4 mm) are visible in thin sections, but are not obvious in the field. This unit contains rocks previously considered to be part of the Flat Landing Brook Formation (van Staal and Fyffe, 1991). The Mount Brittain Formation conformably overlies rocks of the Patrick Brook Formation and is overlain by sedimentary and mafic volcanic rocks that are assigned to the Boucher Brook Formation. A U-Pb zircon age of 468 ± 2 Ma was obtained for these rocks (Gower and McCutcheon, 1997a). One other mappable unit, which does not occur in the type area, has also been assigned to the Mount Brittain Formation, namely the Charlotte Brook Member.

Charlotte Brook Member (Wilson et al., 1998): Unit OMBCB comprises a predominantly sedimentary sequence of shale and siltstone with a few thin tuff beds. These rocks are transitional between the underlying Patrick Brook Formation and the overlying volcanic pile.

Spruce Lake Formation (Rogers and van Staal, 1996): Unit OSLfv comprises feldspar-phyric felsic lavas, autobrecciated lavas and pyroclastic rocks, including polymictic fragmental rocks and crystal tuff, with minor mafic volcanic rocks (part of the Forty Mile Brook tholeiite of van Staal *et al.*, 1991). This formation is exposed only in the Tetagouche Antiform and Nine Mile Synform. The characteristic K-feldspar phenocrysts, up to 1 cm in size, constitute up to 20% of many rocks, but they are virtually absent in some. Two U-Pb zircon ages, 471 ± 2 Ma (Walker and McCutcheon, 1996) and 471 +5/-3 Ma (Rogers *et al.*, 1997), from different parts of this formation, show that it is approximately coeval with, or slightly older than, the Nepisiguit Falls Formation. The apparent basal contact of the Spruce Lake Formation with other units is tectonic, and the upper contact is conformable with the Boucher Brook Formation.

Unit OSLs comprises fine-grained sedimentary rocks, that host the Caribou massive sulphide deposit. These rocks are provisionally assigned to the Spruce Lake Formation, because they underlie and/or are intercalated with feldspar-phyric lavas.

Two other mappable units are assigned to the Spruce Lake Formation, but do not occur in the type area. These have been given member status and include the Canoe Landing Lake and Shellalah Hill Brook members (Wilson, pers. comm.).

Canoe Landing Lake Member (Wilson, pers. comm.): Unit OSLCL comprises alkalic and tholeiitic mafic volcanic rocks in the Spruce Lake Formation. Many of these rocks were formerly included in the Forty Mile Brook tholeiite of van Staal *et al.* (1991).

Shellalah Hill Brook Member (Wilson, et al., 1998): Unit OSLSH comprises quartz-feldspar-phyric rhyolite and crystal tuff at the base of the Spruce Lake Formation.

Boucher Brook Formation (van Staal and Fyffe, 1991): As originally defined, this formation was areally extensive and consisted of a lower part dominated by sedimentary rocks, and an upper part dominated by mafic volcanic rocks. At the type section, the lower sedimentary rocks (shale and siltstone) are conformable on felsic volcanic rocks of the Spruce Lake Formation, but are separated from the mafic rocks by a high-strain zone. Because the stratigraphic relationship between the sedimentary rocks and the mafic volcanics is unknown, the name Boucher Brook is reserved for sedimentary rocks associated with the Spruce Lake Formation. Consequently most of the rocks originally included in the Boucher Brook Formation are now assigned to the Little River Formation (Tetagouche Group).

Unit OBBs comprises thinly bedded, bluish grey siltstone and greenish black shale with minor amounts of fine- to medium-grained quartz wacke. In the type area, near the conformable contact with the underlying Spruce Lake Formation, the wacke appears to be feldspathic but the "feldspars" actually are small fragments of white-weathering rhyolite. Radiometric ages from the Spruce Lake rhyolite (Walker and McCutcheon, 1996; Rogers *et al.,* 1997) indicate an Arenigian to Llanvirnian age, suggesting that the base of the lower Boucher Brook Formation is earliest Middle Ordovician.

Camel Back Member (Wilson et al., 1998): Originally introduced as the Camel Back alkalic basalt suite and assigned to the Boucher Brook Formation (*van Staal et al., 1991*), unit OBBCB comprises a lower part consisting of massive and pillowed alkali basalt and comendite, and an upper part containing shale and minor limestone that has yielded Caradocian fossils.

Sheephouse Brook Group

Volcanic and associated sedimentary rocks in the southern part of the Bathurst Camp are assigned to the Sheephouse Brook Group. The three formations that make up this group, in ascending stratigraphic order, are: Clearwater Stream, Sevogle River and Slacks Lake formations.

Clearwater Stream Formation (Fyffe, 1994): Unit OCWft consists of medium to dark greenish grey, plagioclase-phyric (30 - 50%), felsic to intermediate volcanic rocks that overlie the Patrick Brook Formation. Intense deformation and biotite-grade metamorphism have generally destroyed primary textures, but broken crystals and rare bedding features suggest a pyroclastic origin. Carbonate porphyroblasts (up to 3.5 mm) are a characteristic feature (Fyffe, 1995). U/Pb zircon dating indicates an age of 478 +3/-1 Ma (Wilson *et al.*, 1999).

Sevogle River Formation (Wilson and Fyffe, 1996): Unit OSRfv comprises schistose to massive felsic lavas containing up to 15% alkali feldspar phenocrysts ranging in size from 0.2 to 2.0 mm. The contact with the overlying Slacks Lake Formation is locally marked by a layer of cherty ironstone. A U/Pb zircon age of 466 ± 2 Ma suggests that the contact with the underlying Clearwater Stream Formation may be tectonic or disconformable (Wilson, 1999).

Slacks Lake Formation (Wilson, 1999): This formation comprises alkalic to tholeiitic basalts and interbedded sedimentary rocks. It includes dark grey, locally graphitic shale, and red and green chert as well as minor comendite.

Fournier Group

The Middle to Late Ordovician Fournier Group is divided into the Sormany and Millstream formations. The Fournier Group is completely allochthonous upon the California Lake Group. The contact between the Fournier and California Lake groups is a zone of high strain, which represents a ductile thrust characterized by blueschist (Fig. 2) along 70 km of its length (van Staal *et al.*, 1990).

Sormany Formation (van Staal and Fyffe, 1991): Unit OSO comprises pillow basalt and minor gabbro. The basalt is mainly primitive tholeiite with MORB-like compositions, but there are also compositions intermediate between MORB and oceanic-island basalt, reflecting the back-arc oceanic depositional setting (van Staal *et al.*, 1992).

Millstream Formation (van Staal *et al.*, 1988): Unit OM consists of lithic and feldspathic wacke and shale with minor intercalated limestone and basalt. The Millstream Formation conformably overlies the Sormany Formation.

STRUCTURE

The description of structure presented here is based to a large degree on the work of McCutcheon *et al.*, (1997). The structural geometry of the Bathurst Camp reflects an interference pattern produced by polyphase deformation, something that was first recognized by Skinner (1956). Helmstaedt (1973) recognized three, and locally four, phases of deformation in the camp, but detailed analysis by van Staal and co-workers has shown that there are five groups of folds, which have been designated F_1 to F_5 based on overprinting relationships. The first two groups of folds are responsible for most of the complex geometry (van Staal and Williams, 1984; van Staal *et al.*, 1988; de Roo *et al.*, 1990, 1991; de Roo and van Staal, 1991, 1994).

The earliest deformational event (D_1) is represented by steeply inclined to recumbent, non-cylindrical folds (F_1) with an axial-planar, layer-parallel transposition foliation (S_1), and generally a stretching lineation (L_1). The D_1 fabric elements are interpreted to have formed in the Late Ordovician to Early Silurian (van Staal *et al.*, 1992) as a result of underplating in a northwest-dipping subduction complex. They are typically concentrated in narrow ductile zones of high strain (phyllonites or mylonites) that cross-cut stratigraphy and represent major thrust faults (van Staal *et al.*, 1990; de Roo and van Staal, 1994) that formed in the subduction zone.

During the second phase of deformation (D_2), S_1 was re-oriented into a near-vertical attitude by tight to isoclinal F_2 folds, that were initially interpreted to have formed in the Late Silurian (de Roo and van Staal, 1994), but are now considered to be Early Silurian (Gower and McCutcheon, 1997b). The plunge of F_2 folds is generally shallow, but locally changes from shallow to steep, largely because of the influence of pre-existing F_1 closures. Thus, changes in attitude of F_2 hinges provide a method of detecting macroscopic F_1 folds. The S_2 cleavage is moderately to well developed and generally steeply-dipping. Along the limbs of the F_2 folds, S_1 and S_2 are sub-parallel and may form a composite S_1/S_2 cleavage (S_{MAIN}). The S_1 and S_2 cleavages are generally the dominant fabric elements throughout the area. In the latter stages of D_2, which is associated with obduction of the accretionary wedge onto the basin margin, out-of-sequence thrusts formed. These D_2 thrusts, which locally cut off F_2 folds, bound the major nappes and are commonly marked by zones of tectonic mélange.

The D_1 and D_2 structures are refolded by open to tight, recumbent F_3 folds that are probably related to extensional collapse (van Staal and Fyffe, 1991; de Roo and van Staal, 1994), which occurred in the Late Silurian (Gower and McCutcheon, 1997b). Where D_3 was intense, S_1 and S_2 are re-oriented to shallow-dipping attitudes, producing so-called flat belts (de Roo *et al.*, 1990; de Roo and van Staal, 1991). The areas that were relatively unaffected by F_3 folds are called steep belts. In the past, *i.e.* pre-1985, the D_3 fabric elements were considered to be part of the D_5 event (*cf.* van Staal and Williams, 1984). Thus, in the older literature, some large-scale F_5 folds, such as the Pabineau Synform, are called F_3 structures.

All earlier structures are refolded by F_4 and F_5 folds, but overprinting relationships between these two are rarely seen (van Staal, 1987). These folds range in scale from millimetres to kilometres, and produce dome and basin structures. They include the Pabineau Synform and Pabineau Antiform (van Staal and Williams, 1984), the Nine Mile Synform and the Tetagouche Antiform (van Staal 1986, 1987). F_4 and F_5 are interpreted to result from dextral transpression in the northern Appalachians during the Middle Devonian.

TECTONIC SETTING

The volcanic and associated sedimentary rocks of the Bathurst Mining Camp are considered to have been deposited in a back-arc-basin (van Staal, 1987). In this model (Fig. 3), felsic volcanic rocks of the Tetagouche, California Lake and Sheephouse Brook groups were emplaced during the continental extension stage of rifting, whereas the Fournier Group represents oceanic crust that formed during the spreading phase of basin development. Radiometric ages (Sullivan and van Staal, 1996) show that the Fournier oceanic crust is slightly younger (460 Ma) than the Tetagouche and California Lake groups, which in turn are younger than the Sheephouse Brook Group. Diachrony in the ages of the felsic volcanic rocks coupled with the ubiquitous presence of overlying mafic volcanic rocks is consistent with a propagating, ensialic back-arc environment.

The back-arc basin started to close in the Late Ordovician by northwest-directed subduction (van Staal, 1987) that lasted at least until the Early Silurian (van Staal *et al.*, 1990; van Staal, 1994a). The rocks of the northern Miramichi Highlands are thought to have been assembled in this subduction complex, *i.e.* Tetagouche rocks were underplated to the oceanic part (Fournier Group) of the accretionary wedge when the leading edge of the continental margin descended into the subduction zone. Closure of this basin culminated with the obduction of trench-blueschist rocks onto the former margin of the basin. The time of closure is

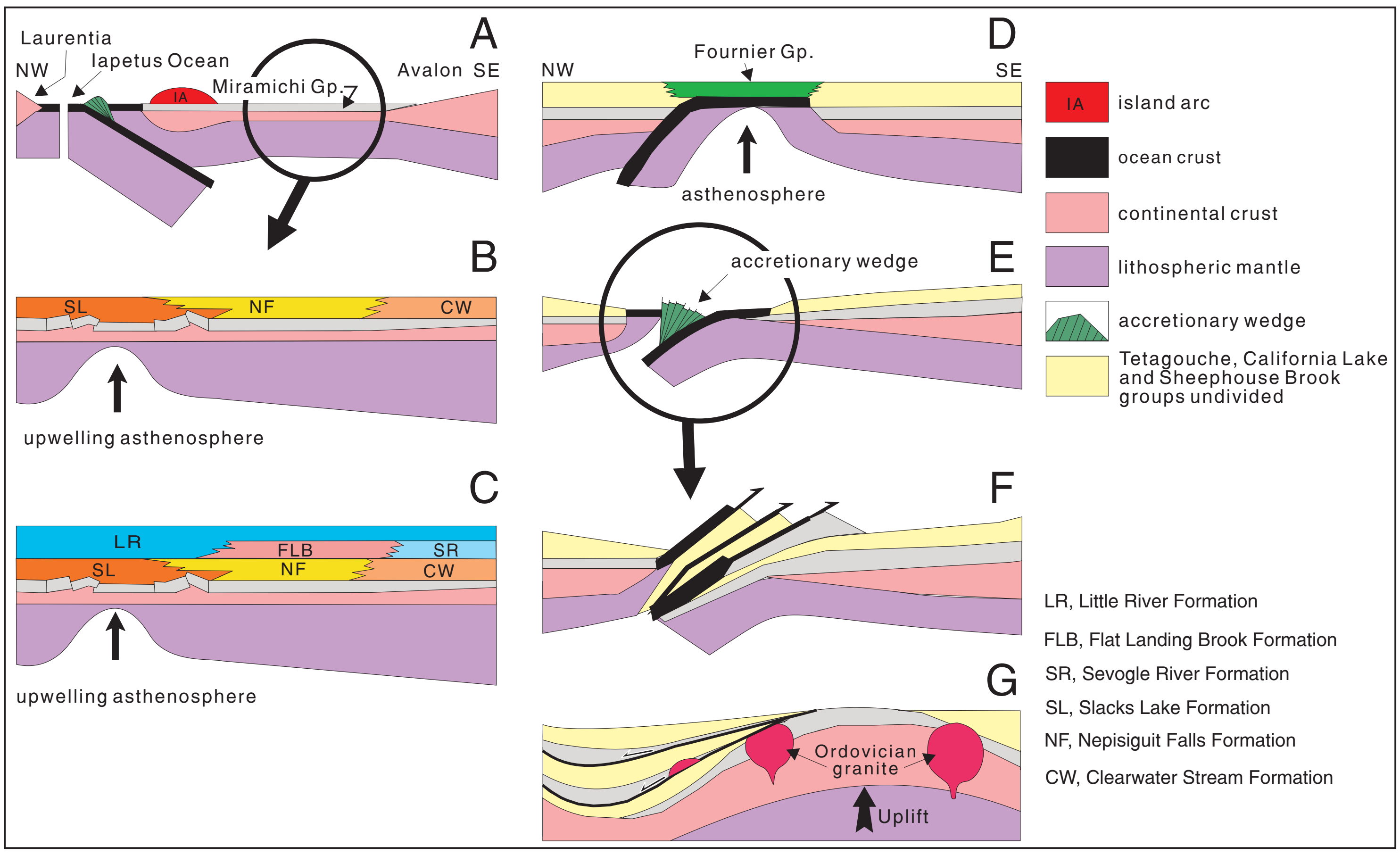


Figure 3: Tectonic model of the Bathurst Mining Camp (modified from McCutcheon et al., 1997).

constrained by the following: (1) Ar^{40}/Ar^{39} dating of crossite and phengite from blueschist facies rocks at the structural base of the Fournier Group yielded ages ranging from 453 ± 6 Ma to 416 ± 6 Ma, with the most precise age of blueschist metamorphism being 447 ± 6 Ma (van Staal *et al.*, 1990); (2) the youngest rocks of the Tetagouche Group involved in thrusting are late Caradocian (van Staal, 1994a); and (3) the Fournier Group is unconformably overlain by Lower Silurian (Llandovery) conglomerates of the Chaleurs Group. Within this tectonic scenario, D_1 is subduction-related and occurred in the accretionary wedge prior to closure of the oceanic basin, whereas D_2 is obduction-related and occurred when the accretionary wedge was thrust over the basin margin. Post-D_2 deformation resulted from the subsequent oblique, more or less continuous collision between Laurentia and Avalonia, which ended in the Middle Devonian.

MASSIVE SULPHIDE DEPOSITS

Massive sulphide deposits occur in several stratigraphic positions within the Tetagouche and California Lake groups, but the major ones occur in, or with, felsic volcanic rocks in the lower parts of these groups (Fig. 4). Many are closely associated with felsic volcaniclastic rocks of the Nepisiguit Falls Formation; a few are in the Clearwater Stream, Mount Brittain and Spruce Lake formations; others are in the lower (sedimentary) part of the Boucher Brook Formation and some are within the Flat Landing Brook Formation. Previously, three groups of deposits were recognized (van Staal and Williams, 1984; van Staal, 1986), but more recent work indicates that this is an over-simplification.

The Tetagouche Group is characterized by an anomalous abundance of Zn-Pb-Cu-Ag massive sulphide deposits. At least 35 deposits and about 100 occurrences are known (McCutcheon, 1992). At present the Brunswick No. 12 deposit is being mined for base metals by Brunswick Mining and Smelting; the Heath Steele mine closed in 1999. The Restigouche and Caribou deposits, which are operated by CanZinco Ltd., shut down in the summer of 1998 due to low metal prices. The Brunswick No. 6, Captain North Extension (CNE), Stratmat and Wedge deposits are past producers; Chester and Key Anacon deposits reached the bulk-sampling stage of development. Gold and silver were extracted from gossan overlying the Murray Brook, Caribou and Heath Steele deposits, and in the early part of this century (Belland, 1992) the iron formation in the hanging wall of the Austin Brook massive sulphide deposit was mined. Mineralogically, deposits in the Bathurst Mining Camp are typical of felsic volcanic-related VMS deposits worldwide, and may contain varying concentrations of pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, tennantite-tetrahedrite, as well as other sulphide and sulphosalt phases.

The largest deposits, *e.g.* Brunswick No. 12, have been classified as brine-pool type deposits whereas others, *e.g.* Chester, are more typical of sulphide-mound type deposits. Many of these deposits have an associated feeder zone that is manifested by intense chloritic alteration and stringer mineralization. However, polyphase deformation has caused many of these feeder zones to be transposed into the S_1 or S_1/S_2 schistosity so that they are now sub-parallel to the massive lenses. Some deposits, *e.g.* Canoe Landing Lake, do not have a recognized stringer zone and probably represent down-slope transport of sulphide debris or metalliferous brine away from the feeder zone (Walker and McDonald, 1995).

Within the Nepisiguit Falls Formation, stratiform deposits are associated with fine-grained rocks at or near the contact between porphyritic volcanic rocks and the underlying siltstone and shale (Little Falls Member), or between the Nepisiguit Falls and overlying Flat Landing Brook formations. The Heath Steele and Halfmile Lake deposits are examples of the former, and the Brunswick No. 6 and No. 12, and Key Anacon deposits (Lentz and Langton, 1993; Lentz, 1995) are examples of the latter. Typically, the host rocks are greenish grey to dark grey mudstones that are interbedded with fine- to medium-grained volcaniclastic rocks, in which feldspar has been destroyed by hydrothermal alteration (Lentz and Goodfellow, 1993). Algoma-type iron formation commonly caps and/or is laterally equivalent to the massive sulphides (Peter and Goodfellow, 1996). There are also some deposits that crosscut rocks belonging to the Nepisiguit Falls Formation, *e.g.* Devils Elbow (Walker, 1997), and presumably represent feeder zones to stratiform mineralization higher in the volcanic pile.

The overlying Flat Landing Brook Formation contains both stratiform and stratabound deposits. Examples of stratiform deposits include Headway and Stratmat, whereas Taylor Brook and Hartts Lake are examples of stratabound deposits. The stratiform deposits are hosted by ash tuff and/or fine-grained sedimentary rocks, but the stratabound deposits are within hyaloclastite and fragmental rocks; the former deposits may contain iron formation, particularly those near the base of the formation, but the latter never do.

With the exception of the Caribou deposit, most of the deposits in the Clearwater Stream, Mount Brittain and Spruce Lake formations, for example Chester, Restigouche, and Armstrong B, respectively, are all contained in volcanic rocks, and are devoid of an associated iron formation.

A number of stratiform massive sulphide deposits occurs entirely within sedimentary rocks; however, none has an associated iron formation, *e.g.* the Canoe Landing Lake deposit (Walker and McDonald, 1995). The Caribou deposit occurs in similar sedimentary rocks that appear to underlie the Spruce Lake Formation, based upon metal zoning (Cavelero, 1993). However, it seems more likely that these sedimentary rocks are intercalated with the Spruce Lake felsic volcanic rocks.

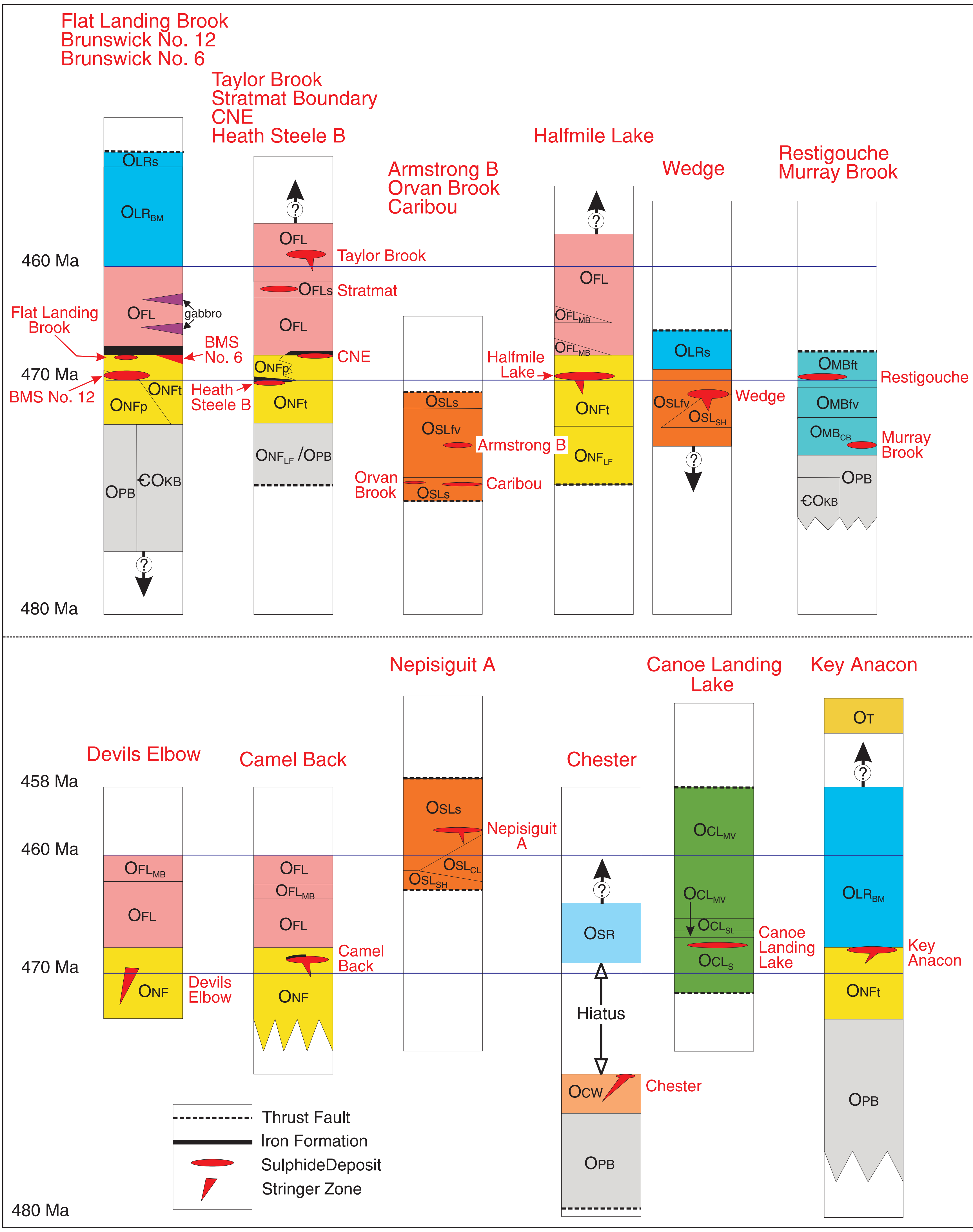


Figure 4: Stratigraphic setting of massive sulphide deposits in the Bathurst Mining Camp (see text (Stratigraphy) for unit descriptions).

HIGH RESOLUTION GEOPHYSICAL SURVEY AND MAPS OF THE BATHURST MINING CAMP

INTRODUCTION

Airborne geophysical surveys employing electromagnetic and magnetic methods have played a leading role in the discovery of volcanogenic massive sulphide deposits in the Bathurst Mining Camp. The first major airborne discovery is attributed to the magnetic method. In 1953, follow-up electromagnetic investigation of an anomaly outlined on aeromagnetic maps published by the Geological Survey of Canada in 1951 led to discovery of the Brunswick No. 12 deposit (Belland, 1992). In the same year, the Heath Steele sulphide horizon was detected by an airborne electromagnetic survey (Pemberton, 1989). The demonstrated success of these methods required their inclusion in the EXTECH-II initiative, directed at enhancing geoscientific knowledge, data bases and exploration methodologies in the camp. Airborne gamma-ray spectrometry was included to provide geochemical information, which has proven useful to geological mapping and mineral exploration in base metal camps elsewhere (Shives, 1996; Shives *et al*., 1995, 1997).

One of the principal objectives of EXTECH-II, therefore, was to obtain new, homogeneous, high-resolution geophysical data sets, using modern equipment and techniques. During July-November, 1995, a multisensor, helicopter-borne survey using a global positioning system (GPS) for navigation was completed over the entire Bathurst Mining Camp. The electromagnetic, magnetic and radiometric sensors were maintained at 30, 45 and 60 m above the ground, respectively, along flight-lines spaced at 200 m. The resulting data have been published in map format at 1:20,000 and 1:50,000 scales and are available digitally as grids or flight-line profiles.

A selection of images produced from the new data and covering all of the mining camp is included herein. These portray the total magnetic field, magnetic vertical gradient, apparent conductivity (4433 Hz) and thorium concentration. Results of deposit-specific ground gravity surveys carried out by exploration companies and as part of EXTECH-II are also included in this atlas. A map of the Bouguer gravity field based on data archived in the National Gravity Data Base maintained by Geomatics Canada, provides a regional context for the deposit-scale surveys. As a prelude to discussions of the airborne survey and its products, brief descriptions of the different geophysical methods, including gravity surveys, are presented.

GEOPHYSICAL METHODS

The utility of geophysics as a geological mapping and mineral exploration tool is dependent on the presence of measurable contrasts in the physical or chemical properties of the mineralized targets and their host rocks. In the case of sulphide deposits, strong contrasts in magnetic, electromagnetic and gravitational (density) properties provide direct exploration vectors. Gamma-ray spectrometry, however, provides indirect targeting based on chemical contrasts associated with near-surface alteration, within and surrounding the deposit, *e.g.* potassium enrichment or depletion. Where alteration extends beyond the limits of the sulphides, a much larger target may be presented. A list of magnetic susceptibilities, electrical conductivities and densities of sulphide minerals and minerals commonly found in association with them is presented in Table 1. A list of the same physical properties, measured on some sulphides and their host rocks from the Bathurst Mining Camp, are presented in Table 2. Radioelement concentrations for common rock types are provided in Table 3.

Magnetic Method

The magnetic method is the oldest and most widely used airborne geophysical exploration tool. The effectiveness of the method depends mainly on the distribution of magnetite in the rocks of the surveyed area. Other important magnetic minerals are pyrrhotite and hematite. The first aeromagnetic survey in Canada, flown by Gulf Corporation in 1947, resulted in the discovery of the Boston Township magnetite deposit in northern Ontario (Reford, 1980). One goal of magnetic surveys is direct detection of orebodies through delineation of associated anomalies, which are usually positive and intense. Another objective is to determine trends, extents and geometries of magnetic bodies in an area, and to interpret them in terms of geology. The technique is particularly useful, and can be highly effective, in areas where outcrop is limited. Structural trends are faithfully reproduced in magnetic patterns, but assignment of rock type is ambiguous, since ranges of values of magnetic susceptibilities of different rock types may overlap. Susceptibility may vary considerably, even within the same rock type. In general, sedimentary rocks have the lowest susceptibilities and mafic igneous rocks the highest.

In magnetic surveys the intensity or strength of the Earth's total magnetic field is measured. The unit of measurement is the nanotesla (nT). The intensity of the total magnetic field over Canada ranges from about 52,000 to more than 60,000 nT. The total field includes contributions from the Earth's core and crust. A third component, originating from electrical currents in the upper atmosphere, is normally eliminated from survey data during processing. It is common practice to subtract the component of the field attributed to the Earth's core, described mathematically by the International Geomagnetic Reference Field, from the total field. The resultant field, termed the residual total magnetic field, has both positive and negative values related principally to variation of crustal susceptibility. The residual total magnetic field is illustrated in this atlas, but for the sake of brevity it will be referred to as the total magnetic field.

A useful derivation from the total magnetic field is the vertical gradient, measured in nanotesla/metre (nT/m). The vertical gradient may be measured directly using a gradiometer, wherein two magnetometers are separated vertically by 2 to 3 m. Alternatively, as in the case of the survey of the Bathurst Mining Camp, the vertical gradient may be derived mathematically from the total magnetic field. Vertical gradient maps present a filtered picture of the magnetic field, emphasizing near-surface geological features. Gradient anomalies are narrower than corresponding total field anomalies, hence closely spaced geological units that produce distinct magnetic anomalies are better resolved by the vertical gradient. Steep contacts between geological bodies normally coincide with the zero contour of the vertical gradient.

Electromagnetic Method

Electromagnetic (EM) techniques are some of the most commonly used geophysical methods employed in mineral exploration. They are capable of direct detection of conductive base metal deposits, where large conductivity contrasts exist between the deposits and resistive host rocks or thin overburden cover. The techniques have been highly successful in North America and Scandinavia. A multitude of other conductive features, including swamps, shear and fracture zones, faults, and graphitic and barren metallic conductors, are causes of ambiguity in the interpretation of EM anomalies.

The conductivity of rocks and mineral deposits, commonly measured in milliSiemens per meter (mS/m), spans many orders of magnitude. For example, granite is essentially non-conductive, whereas the conductivity of shale ranges from 0.5 to 100 mS/m. Water content increases conductivity and may have a dramatic influence on its magnitude. For example, the conductivity of wet and dry tuffs may differ by a factor of 100 (Telford *et al.*, 1990). Different rocks have overlapping ranges of conductivity, for example the conductivities of massive sulphides may overlap those of non-mineralized materials such as graphite and clay. Conductive overburden, especially water-saturated clay, may generate EM anomalies that effectively mask the response of an underlying massive sulphide zone. Unequivocal identification of mineral deposits is, therefore, a difficult task. Where the conductivity of overburden is sufficiently uniform, EM responses can be interpreted in terms of overburden thickness.

Conductivities of common rocks and minerals are listed in Table 1. Massive sulphides, graphite and salt water have high conductivities (>500 mS/m). Intermediate values (1 - 500 mS/m) are typical of sedimentary rocks, glacial sediments, weathered rock, alteration zones and fresh water, whereas igneous and metamorphic rocks have low conductivities, generally less than 1 mS/m.

Electromagnetic systems operate in either the frequency- or the time-domain. Here, discussion will be restricted to the frequency-domain technique, used in the EXTECH-II survey. In frequency-domain systems, a transmitter generates an alternating EM field. This primary field produces eddy currents in a conductive medium, which in turn create a secondary EM field. This secondary field, detected by the receiver, is diagnostic of the electrical characteristics of the conductive medium excited by the primary field. In general, the secondary field is not in phase with the primary field. The EM receiver measures the in-phase and out-of-phase (quadrature) components of the secondary field, and the ratio of the secondary field to the primary field in parts per million (ppm).

As EM responses are frequency-dependent, modern helicopter-borne electromagnetic (HEM) systems use a wide range of frequencies to detect a large range of conductivities. A number of configurations for the transmitter and receiver coils are used to discriminate horizontal and vertical conductors. The horizontal coplanar coil pair is more sensitive to horizontal conductors, whereas the coaxial coil pair is more sensitive to vertical conductors. The geometry and attitude (dip) of conductors also influence the shape of the anomalies. A vertical conductor produces a double peak anomaly when detected by the coplanar coil pair, and a single peak anomaly when measured by the coaxial coil pair. These effects are illustrated in Figure 5.

Table 1: Density, Magnetic Susceptibility and Conductivity Values for Selected Rock Types and Minerals

Rock Type	Density g/cm^3			Magnetic Susceptibility SI x 10^{-3}			Conductivity mS/m		
	Min.	Max.	Average	Min.	Max.	Average	Minimum	Maximum	Average
Sediments and Sedimentary Rocks									
Overburden			1.92						
Soil	1.20	2.40	1.92	0.01	1.26				
Clay	1.63	2.60	2.21				10	300	
Glaciolacustrine Clay						0.25	10	200	
Gravel	1.70	2.40	2.00				0.1	2	
Sand	1.70	2.30	2.00				0.1	2	
Glacial Till							0.5	20	
Saprolite (mafic volcanic rocks, schist)							50	500	
Saprolite (felsic volcanic rocks, granite, gneiss)							5	50	
Sandstone	1.61	2.76	2.35	0	20	0.4	1	20	
Shale	1.77	3.20	2.40	0.01	18	0.6	30	200	
Argillite							0.07	83.3	
Iron Formation							0.05	3300	
Limestone	1.93	2.90	2.55	0	3	0.3	0.01	1	
Dolomite	2.28	2.90	2.70	0	0.9	0.1	0.01	1	
Conglomerate							0.1	1	
Greywacke	2.60	2.70	2.65				0.09	0.24	
Coal			1.35			0.025	2	100	
Red Sediments			2.24	0.01	0.1				
Igneous Rocks									
Rhyolite	2.35	2.70	2.52	0.2	35				0.04
Andesite	2.40	2.80	2.61			160			
Granite	2.50	2.81	2.64	0	50	2.5			
Granodiorite	2.67	2.79	2.73						
Porphyry	2.60	2.89	2.74	0.3	200	60			
Quartz Porphyry				0	33	20	0.04	1.7	
Quartz Diorite	2.62	2.96	2.79						
Quartz Diorite, Dacite				38	191	83			
Diorite	2.72	2.99	2.85	0.6	120	85			
Diabase	2.50	3.20	2.91	1	160	55			0.03
Olivine Diabase						25			
Basalt	2.70	3.30	2.99	0.2	175	70			0.2
Gabbro	2.70	3.50	3.03	1	90	70			0.02
Hornblende Gabbro	2.98	3.18	3.08						
Peridotite	2.78	3.37	3.15	90	200	250			
Obsidian	2.20	2.40	2.30						
Pyroxenite	2.93	3.34	3.17			125			
Monzonite, Latite				33	135	85			
Acid Igneous Rocks	2.30	3.11	2.61	0	80	8			
Basic Igneous Rocks	2.09	3.17	2.79	0.5	97	25			
Mafic Volcanic Rocks							0.09	0.27	
Dacite	2.35	2.80	2.58						
Phonolite	2.45	2.71	2.59						
Trachyte	2.42	2.80	2.60	0	111	49			
Nepheline Syenite	2.53	2.70	2.61						
Syenite	2.60	2.95	2.77	0	111	49			
Anorthosite	2.64	2.94	2.78						
Norite	2.70	3.24	2.92						
Metamorphic Rocks									
Quartzite	2.50	2.70	2.60			4			
Schist	2.39	2.90	2.64	0.3	3	1.4			
Marble	2.60	2.90	2.75						
Serpentine	2.40	3.10	2.78	3	17				
Slate	2.70	2.90	2.79	0	35	6			
Gneiss	2.59	3.00	2.80	0.1	25				
Amphibolite	2.90	3.04	2.96			0.7			
Eclogite	3.20	3.54	3.37						
Granulite	2.52	2.73	2.65	3	30				
Phyllite	2.68	2.80	2.74			1.5			
Quartz Slate	2.63	2.91	2.77						
Chlorite Schist	2.75	2.98	2.87						
Skarn	2.95	3.15				2.5			1.25
Hornfels	2.90	3.00				0.31			0.05
Sulphide Minerals									
Chalcopyrite			4.20	0.02	0.40		1.11 x 10^5	6.67 x 10^6	
Galena			7.50			-0.03	1.11 x 10^4	1.47 x 10^8	
Pyrite			5.02	0.03	5.30		1.67 x 10^3	8.33 x 10^5	
Pyrrhotite			4.62		3200		6.25 x 10^5	5.00 x 10^8	
Sphalerite			4.00	-0.03	0.75		0.08	3.70 x 10^5	
Other									
Magnetite			5.18	1000	5700				1.92 x 10^7
Graphite			2.16	-0.08	0.20		1.01 x 10^7	3.57 x 10^9	

Compiled from Carmichael (1982), Grant and West (1965), Hunt *et al.* (1995), Keller and Frischknecht (1966), Palacky (1986) and Telford *et al.* (1990).

Table 2: Selected Density, Magnetic Susceptibility and Conductivity Measurements on Core Samples from Sulphide Deposits and Host and Adjacent Country Rocks in the Bathurst Mining Camp

Deposit	Rock Type	Density (g/cm^3)		Magnetic Susceptibility (SI x 10^{-3})		Conductivity (mS/m)
		Range	Mean & S.D.	Range	Mean & S.D.	
Sulphides						
Brunswick No. 12	massive sulphide	3.16 - 4.86	4.31 ± 0.34	0.20 - 962	51 ± 124	590 - 3330
Brunswick No. 12	semi-massive sulphide	2.97 - 4.20	3.58 ± 0.45	0.30 - 14	5.1 ± 3.76	145 - 205*
Caribou	massive sulphide	3.04 - 4.75	4.34 ± 0.46	0.30 - 223	17 ± 57	330 - 1000
Caribou	stringer sulphide	2.76 - 4.40	3.55 ± 0.49	0.15 - 85	12.7 ± 32	
Halfmile Lake	massive to semi-massive sulphide	3.05 - 4.29	3.75 ± 0.33	0.55 - 66	13.4 ± 20	
Heath Steele B	massive sulphide	3.43 - 4.70	4.21 ± 0.35	5.38 - 339	138 ± 94	
Murray Brook	massive sulphide		4.42			
Host and Adjacent Rocks						
Brunswick No. 12	iron formation	3.09 - 3.97	3.58 ± 0.20	15.4 - 3700	990 ± 967	0.045-6.67*
Key Anacon	argillite, quartz wacke, siltstone	2.47 - 2.94	2.74 ± 0.07	0.02 - 9.20	1.11 ± 1.78	
Canoe Landing Lake	argillaceous sedimentary rocks	2.77 - 2.92	2.82 ± 0.04	0.31 - 0.75	0.47 ± 0.13	
Heath Steele B	rhyolite, tuff	2.65 - 2.90	2.70 ± 0.05	0.10 - 2.07	0.26 ± 0.36	
Canoe Landing Lake	acid tuff, rhyolite porphyry	2.67 - 2.78	2.73 ± 0.03	0.21 - 0.43	0.26 ± 0.06	
Key Anacon	felsic volcanoclastics	2.68 - 2.90	2.80 ± 0.05	0.27 - 12.22	4.1 ± 3.05	
Brunswick No. 12	crystal tuff	2.74 - 3.26	2.84 ± 0.12	0.02 - 0.40	0.01 ± 0.01	0.61*
Brunswick No. 12	quartz eye schist	2.72 - 2.97	2.81 ± 0.07	0.05 - 2.70	0.39 ± 0.82	135*
Brunswick No. 12	massive basalt	2.73 - 3.16	2.98 ± 0.09	0.72 - 41.6	10 ± 13.4	
Key Anacon	mafic tuffs, volcanoclastics	2.81 - 3.17	2.91 ± 0.09	0.40 - 191.7	30.4 ± 58.0	
Caribou	felsic volcanics					0.02 - 1.39
Caribou	carbonaceous argillite					0.3 - 11.1
Brunswick No. 12	gabbro					0.02
Brunswick No. 12	mafic volcanic flow, basalt					0.10 - 0.27
Brunswick No. 12	laminated maroon sedimentary rock					0.05 - 0.15
Brunswick No. 12	chloritic sedimentary rock					0.08 - 1.04
Brunswick No. 12	quartz-feldspar porphyry					0.06 - 1.08
Brunswick No. 6	iron formation					0.05 - 3330
Heath Steele	lapilli tuff					0.04 - 0.54
Heath Steele	quartz-feldspar porphyry					0.16 - 1.69
Heath Steele	carbonaceous sedimentary rock					12 - 320
Heath Steele	porphyritic rhyolite					0.04 - 0.16
Orvan Brook	carbonaceous shale/schist					0.6 - 21.7

* These conductivity measurements were made on samples from same sections of core used for density and magnetic susceptibility measurements (conductivity data from Katsube *et al.* (1997) and Katsube *et al.* (1998a, 1998b)).

Density and magnetic susceptibility measurements were made by the authors on the same section of drill core.

Table 3: Radioelement Concentrations in Different Classes of Rocks (Killeen, 1979)

	Potassium (%)		Uranium (ppm)		Thorium (ppm)	
Rock Type	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Acid Extrusives	3.1	1.0 - 6.2	4.1	0.8 - 16.4	11.9	1.1 - 41.0
Acid Intrusives	3.4	0.1 - 7.6	4.5	0.1 - 30.0	25.7	0.1 - 253.1
Intermediate Extrusives	1.1	1.1 - 2.5	1.1	0.2 - 2.6	2.4	0.4 - 6.4
Intermediate Intrusives	2.1	0.1 - 6.2	3.2	0.1 - 23.4	12.2	0.4 - 106.0
Basic Extrusives	0.7	0.06 - 2.4	0.8	0.03 - 3.3	2.2	0.05 - 8.8
Basic Intrusives	0.8	0.01 - 2.6	0.8	0.01 - 5.7	2.3	0.03 - 15.0
Ultrabasic	0.3	0 - 0.8	0.3	0 - 1.6	1.4	0 - 7.5
Alkali Feldspathoidal Intermediate Extrusives	6.5	2.0 - 9.0	29.7	1.9 - 62.0	133.9	9.5 - 265.0
Alkali Feldspathoidal Intermediate Intrusives	4.2	1.0 - 9.9	55.8	0.3 - 720.0	132.6	0.4 - 880.0
Alkali Feldspathoidal Basic Extrusives	1.9	0.2 - 6.9	2.4	0.5 - 12.0	8.2	2.1 - 60.0
Alkali Feldspathoidal Basic Intrusives	1.8	0.3 - 4.8	2.3	0.4 - 5.4	8.4	2.8 - 19.6
Chemical Sedimentary Rocks	0.6	0.02 - 8.4	3.6	0.03 - 26.7	14.9	0.03 - 132.0
Carbonates	0.3	0.01 - 3.5	2.0	0.03 - 18.0	1.3	0.03 - 10.8
Detrital Sedimentary Rocks	1.5	0.01 - 9.7	4.8	0.01 - 80.0	12.4	0.2 - 362.0
Metamorphosed Igneous Rocks	2.5	0.1 - 6.1	4.0	0.1 - 148.5	14.8	0.1 - 104.2
Metamorphosed Sedimentary Rocks	2.1	0.01 - 5.3	3.0	0.1 - 53.4	12.0	0.1 - 91.4

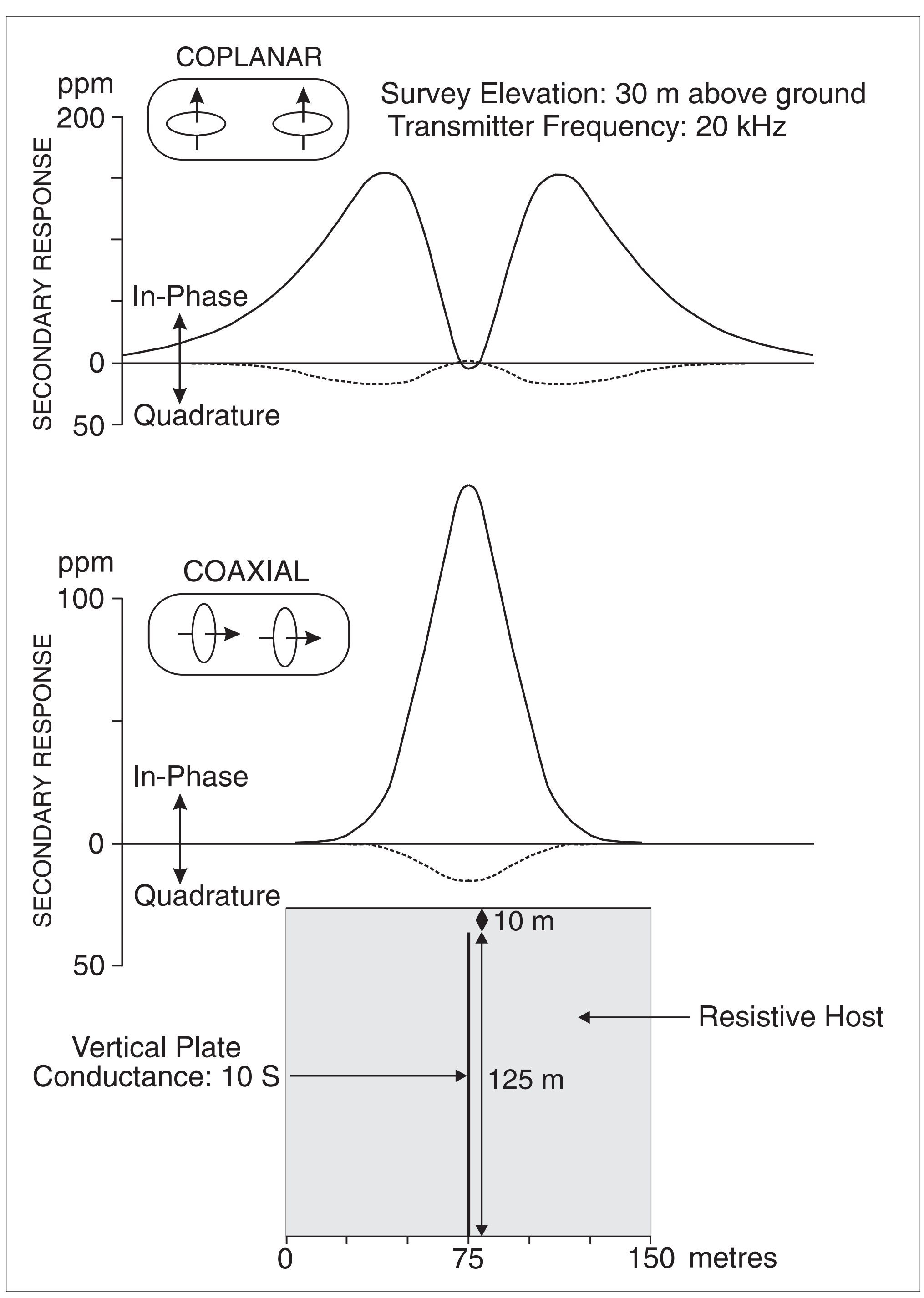


Figure 5: Electromagnetic in-phase and quadrature responses for a conductive thin vertical plate (conductance = 20 S; strike length = 250 m) hosted by a resistive (unresponsive) medium. Computation of the profiles assumes a transmitter frequency of 20 kHz and a survey elevation of 30 m above ground surface; the top of the plate is 10 m below surface. Transmitter-receiver coil separation is 10 m. Figure is modified from Figure 30 of Palacky and West (1989).

A geological unit that has high magnetic susceptibility and low conductivity will generate a strong in-phase EM response that is opposite to the polarity of the response of a conductive body. Units with high susceptibility produce an in-phase response and a strong magnetic anomaly. In this situation, the HEM response is likely to reflect a shallower portion of the causative body than the magnetic response. It is also possible to determine the magnetic susceptibility of a rock and evaluate its magnetite content from airborne EM data (Fraser, 1973, 1981).

Airborne EM data can be converted into ground conductivities to produce a conductivity map. To obtain stable results, a number of simplifying assumptions or models must be employed. The homogeneous half-space model assumes that the conductivity of the ground is uniform and that the Earth is flat and bottomless. This model is robust and generally provides realistic results. A second model is the one-layer earth, where a homogeneous conductive layer of uniform thickness overlies a homogeneous half-space. However, when the top layer is conductive and relatively thin, only the conductivity-thickness product can be determined. In the Bathurst Camp, the simple and robust half-space model was adopted and applied to process the EM survey data to produce conductivity maps.

Apparent conductivity was calculated for all frequencies measured. Only the conductivities calculated from the mid-frequency (4433 Hz) coplanar EM data, normalized to 7 m coil spacing, were published in map form. This apparent conductivity map is illustrated in this atlas and is the one that best reflects the bedrock geology of the area. The apparent conductivity calculations were executed using a homogeneous half-space model (Seigel and Pitcher, 1978), which is essentially independent of survey altitude. Initially, the EM data were levelled using values obtained during high-altitude nulling procedures. Further levelling was achieved by visual inspection of the line data. The apparent conductivity values were subsequently interpolated to a 50 m square grid. The coplanar mid-frequency data have a better signal to noise ratio than the mid-frequency coaxial data. Conductivities calculated from the low-frequency data (853 and 914 Hz) mostly reflect lithologies that have high conductivity contrasts, whereas conductivities calculated from the high-frequency EM data (32290 Hz) usually contain significant overburden responses.

Bedrock conductors were interpreted by examining the in-phase and quadrature responses of anomalies and their variation with frequency. Although the procedure was somewhat automated, the final selection was completed by an experienced geophysicist. Conductance was determined using a vertical half-plane model in free space (Ghosh, 1972), using coaxial data recorded at 4786 Hz.

Radiometric Method

All rocks are naturally radioactive, containing various proportions of a variety of radioactive elements measured in radiometric surveys (Table 4). Early instruments measured only the total radioactivity from all sources, and were used primarily for uranium exploration. In the 1960's, gamma-ray scintillation spectrometers were developed, and calibrated to measure discrete windows within the spectrum of gamma-ray energies. This permitted determination of concentrations of individual radioelements. At least 20 naturally occurring elements are known to be radioactive (Telford *et al*., 1990). Potassium (K), uranium (U) and thorium (Th) are the three most abundant of these elements measured in radiometric surveys (Table 4). All three elements occur in various concentrations in rocks and soils (Table 3). Their different chemical properties provide useful characterization of normal and anomalous chemical or mechanical (transport) processes. K is a major constituent of most rocks and is a dominant alteration element in many mineral deposits; U and Th are present in trace amounts, as relatively mobile and usually immobile elements, respectively. For this reason, for geological mapping and exploration purposes, the technique should be considered and interpreted in geochemical terms.

Table 4: Radioelements Used for Geoscientific Purposes

Potassium	K	K^{40} represents 0.012% of total K; measured directly at 1.46 MeV
Equivalent Uranium	eU	U^{238} represents 99.3% of total U; measured indirectly via daughter Bi^{214} at 1.76 MeV; assumes parent-daughter equilibrium, hence "equivalent" prefix "e"
Equivalent Thorium	eTh	Th^{232} represents 100% of total Th; measured indirectly via daughter Tl^{208} at 2.61 MeV; assumes parent-daughter equilibrium, hence "equivalent" prefix "e"

The attenuation of gamma-rays by rock or soil prevents their emanation from a depth of greater than, approximately, the top 20 to 60 cm of the Earth's surface. This has profound implications for the interpretation of gamma-ray spectrometric surveys. Whereas magnetic, electromagnetic, gravimetric or seismic sensors may detect features located at depths of tens or hundreds of metres below the mappable near-surface geology, gamma-ray data are interpreted in terms of surface chemistry. Properly conducted surveys produce accurate maps of the K, eU and eTh distribution at the Earth's surface. Poor correlation with other data, such as magnetic or geological, is a consequence of the inherently different sampling methods, and can usually be explained through a better understanding of the media sampled.

A gamma-ray detector does not have a fixed field of view. The volume and shape of the detector, and the distribution of ground sources, will influence the size and shape of the sampled area. Thus, a highly radioactive point source may be detected even when it lies outside some nominal field of view. In airborne surveys, a single measurement provides an estimate of the average surface concentration for an area of several thousand square metres. This single sample comprises variable proportions of exposed bedrock (fresh or weathered), overburden (including glacial till, glacio-fluvial sediment, colluvium, alluvium, loess, soil (clay, sand, loam, *etc.*), soil moisture, standing water (lakes, rivers, swamps, bogs) and vegetation. In almost all cases, the inhomogeneous nature of the surface (and therefore each sample) introduces variability, such that the absolute value of K, eU or eTh may be less significant than the radioelement patterns.

The effects of variations in soil moisture, amount of bedrock exposure, or source geometry, can be minimized through the use of radioelement ratios. In mineralized systems, all three radioelements may be enriched or depleted relative to unaltered, equivalent host rocks. However, one or more of the radioelements may be preferentially affected, for valid geochemical reasons. In these cases, the ratios offer very sensitive alteration vectors, which may point directly or indirectly to mineralization, even where the individual radioelement patterns are ambiguous.

Gravity Method

Gravity observations provide a measure of the Earth's gravity field, which is sensitive to variations in rock density. The unit of measurement used in geophysical studies is the milligal (mGal). The gravity technique is commonly applied in follow-up investigations of magnetic, electromagnetic or geochemical anomalies. The method can detect excess mass, providing information on the size of a potential orebody, and it is particularly useful in assessing whether a conductivity anomaly is related to low-density graphite or a high-density sulphide deposit. Gravity surveys also contribute to exploration programs when used to map geology and structure that may favour the presence of ore deposits. Surveys over many properties in the Bathurst Mining Camp have delineated discrete gravity highs related to sulphide deposits.

Gravity measurements are influenced by variations in latitude and elevation. These effects must be removed if the data are to have geological application. Variations related to elevation are removed by applying two separate corrections, known as the free-air and the Bouguer corrections, which are applied relative to a vertical datum, commonly sea level.

The free-air correction (0.3086 mGal/m) is added to the observed value, and compensates for the greater distance of the measurement point from the Earth's centre of mass. The Bouguer correction, which removes the gravity effect of the rock mass between the observation point and the datum, is subtracted from the observed value. This correction assumes that the mass is approximated by an infinite slab of rock, whose lower surface coincides with sea level and upper surface passes through the observation point. This approximation introduces little error into Bouguer anomalies where the terrain is reasonably flat, but where terrain is rugged, corrections for terrain should be applied. A density of 2.67 g/cm^3 is traditionally assigned to the slab, resulting in a Bouguer correction equal to 0.1119 mGal/m. More exactly, the density used for the Bouguer correction should be the average density of rocks between the observation point and the datum. Effectively, the reduction procedure produces gravity values, known as Bouguer anomalies, which are equivalent to the gravity values that would have been observed had it been possible to remove the topography and make the observations at sea level.

The effect of latitude is eliminated in the final step of computing a Bouguer anomaly at a gravity station, when the theoretical value of gravity on the reference ellipsoid at the station is subtracted from the observed value, corrected for elevation, terrain, earth tides and instrumental drift.

AIRBORNE SURVEY SPECIFICATIONS AND INSTRUMENTATION

The EXTECH-II geophysical survey, carried out by Aerodat Inc., was conducted from a helicopter flown at a mean terrain clearance (MTC) of 60 m. Flight-elevation was maintained to within 5 m of this specified MTC. The magnetic and electromagnetic sensors were suspended by cable at flight-elevations of 45 m and 30 m above ground, respectively. The radiometric system was housed within the helicopter. Flight-lines were 200 m apart and oriented perpendicular to the geological strike, resulting in four sub-areas with different flight directions (Fig. 6). Control lines were spaced 7 km apart, perpendicular to the flight-lines. Differential GPS navigation was used and the accuracy of the flight-path is estimated to be within 10 m. A video camera was used for verification of the flight-path.

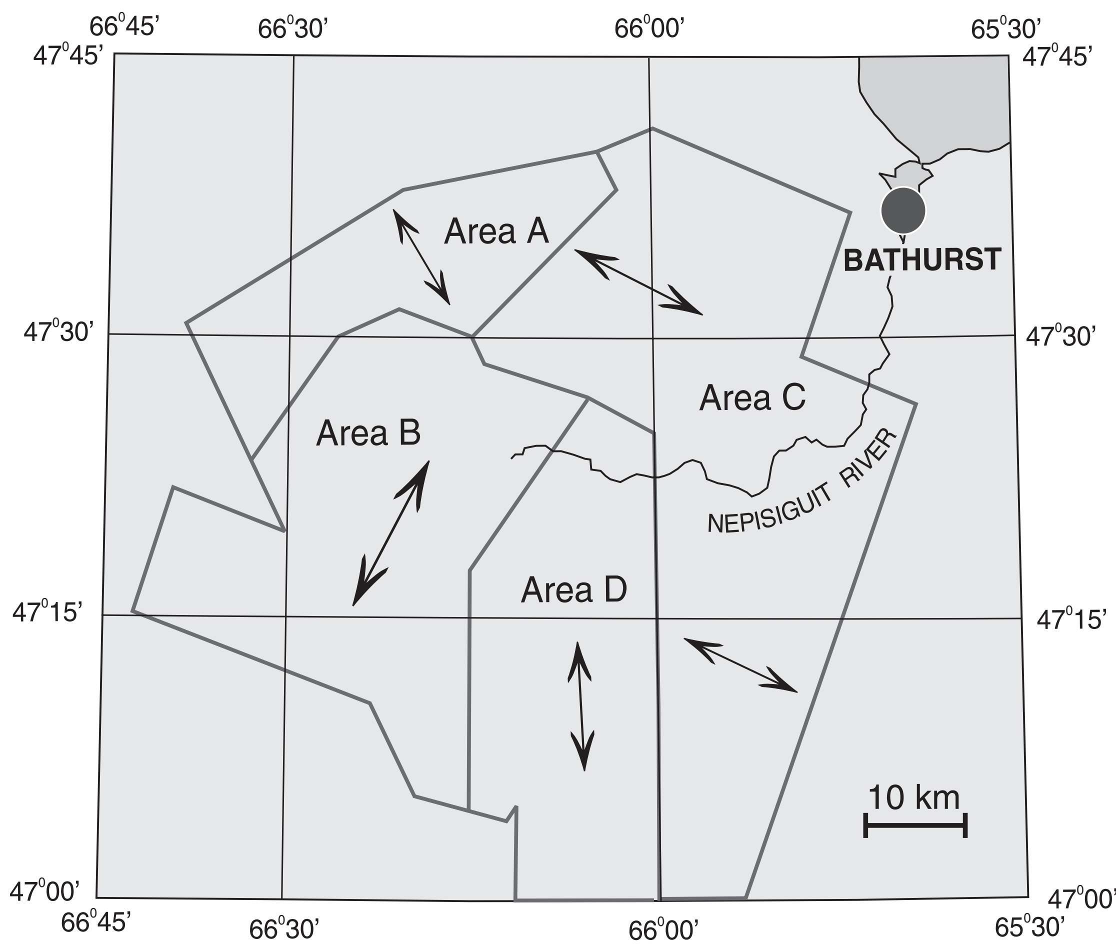


Figure 6: Map showing area of Bathurst Mining Camp covered by the EXTECH-II high resolution geophysical survey. Sub-areas (A-D) with respective flight-line orientations are also indicated.

Magnetometer System

A Scintrex H-8 split beam cesium vapour magnetometer with a sensitivity of 0.005 nT was mounted in a bird towed 15 m below the helicopter. Magnetic data were recorded every 0.1 second. The control-line magnetic data were corrected for temporal variations in the magnetic field using magnetometer data recorded at ground stations. After editing the survey data, differences in magnetic values between traverse and control lines, established at intersections, were computer-analyzed to obtain the levelling network. The magnetic data were then interpolated to a 50 m square grid.

Electromagnetic System

The electromagnetic sensor, designed by Aerodat Inc., comprised three coplanar coils operating at frequencies of 853, 4433 and 32290 Hz, and two coaxial coils operating at 914 and 4786 Hz. The sensor was housed in a an 8.4 m long EM bird, towed 30 m below the helicopter. The in-phase and quadrature components of the secondary field were recorded at a 0.1 second sampling rate with a time constant of 0.1 second.

Radiometric System

An Exploranium GR-820 spectrometry system was used for the radiometric measurements. This gamma-ray system included a 256-channel spectrometer sampling data at 1 second intervals with a 16 litre main NaI detector and a 4 litre upward-looking NaI detector. After energy calibration of the spectra, counts from the main detector were recorded in five windows corresponding to thorium (2410-2810 keV), uranium (1660-1860 keV), potassium (1370-1570 keV), total radioactivity (400-2815 keV) and cosmic radiation (3000-6000 keV). Radiation in the upward-looking detector was recorded in a radon window (1660-1860 keV). The system was calibrated following methods outlined in IAEA Report 323 (Grasty *et al.*, 1991). After removal of background radiation, the data were corrected for spectral interference, changes in temperature and pressure, and departure from the desired 60 m survey elevation. The data were then converted to standard concentration units, which were interpolated to a 50 m square grid.

DESCRIPTIONS OF REGIONAL GEOPHYSICAL MAPS

A map of principal geological boundaries and faults in the Bathurst Mining Camp, conforming to those on the geological map of Figure 1, is superposed on regional geophysical maps of the Bathurst Mining Camp to provide a reference framework (Figs. 7-11). The lines represent formation and intrusion contacts, unconformities and faults (normal and thrust). Five geophysical maps are presented: total magnetic field (Fig. 7), vertical magnetic gradient (Fig. 8), apparent conductivity (Fig. 9), thorium concentration (Fig. 10) and Bouguer gravity field (Fig. 11). Various geological features are reflected in all of the airborne maps. Relative to previously published airborne magnetic and gamma-ray spectrometric maps, the new data provide significantly better resolution of signatures associated with bedrock and surficial features. This is a function of closer flight-line spacing, better line orientation and lower sensor heights. The survey also benefitted from improved positioning provided by GPS navigation.

Among the most noticeable geophysical expressions are those for the Nine Mile Synform and Tetagouche Antiform (Fig. 1). The elongate, oval shape of the synform is outlined in the magnetic maps (Figs. 7, 8) by strong magnetic highs related to mafic volcanics of the Canoe Landing Lake Formation and Fournier Group. On the conductivity map (Fig. 9) it is outlined by narrow strips of elevated conductivity values occurring on its western flank and nose, and by broader strips on its eastern flank and within its axial region. These correlate mainly with sedimentary rocks of the Little River and Boucher Brook formations and Fournier Group. Excellent correlations observed between conductivity maps and the vertical magnetic gradient map provide a means of distinguishing between overburden and bedrock conductivity responses. Linear conductive features are often closely associated with certain geological formations containing horizons of black shale and/or argillite. Geophysical logs indicate high conductivity bands in a number of tuffaceous (rhyolite and crystal) and argillitic units. These findings are confirmed by laboratory measurements yielding relatively high conductivities (1-10 mS/m) for mudstone in tuffaceous units within the Tetagouche Group. These rocks have electrical anisotropies as high as 35:1 (Katsube *et al.*, 1998b), with the highest conductivity in the direction parallel to the foliation, which is often parallel to the unit contacts. Consequently, units containing horizons of highly anisotropic mudstone are most likely the source of highly conductive linear EM features. Chemical differences between felsic and mafic intrusions are reflected in the radioelement patterns through variation in potassium, equivalent uranium and equivalent thorium concentrations, and their ratios. The Nine Mile Synform stands out on the thorium map (Fig. 10) as an area of generally subdued values over

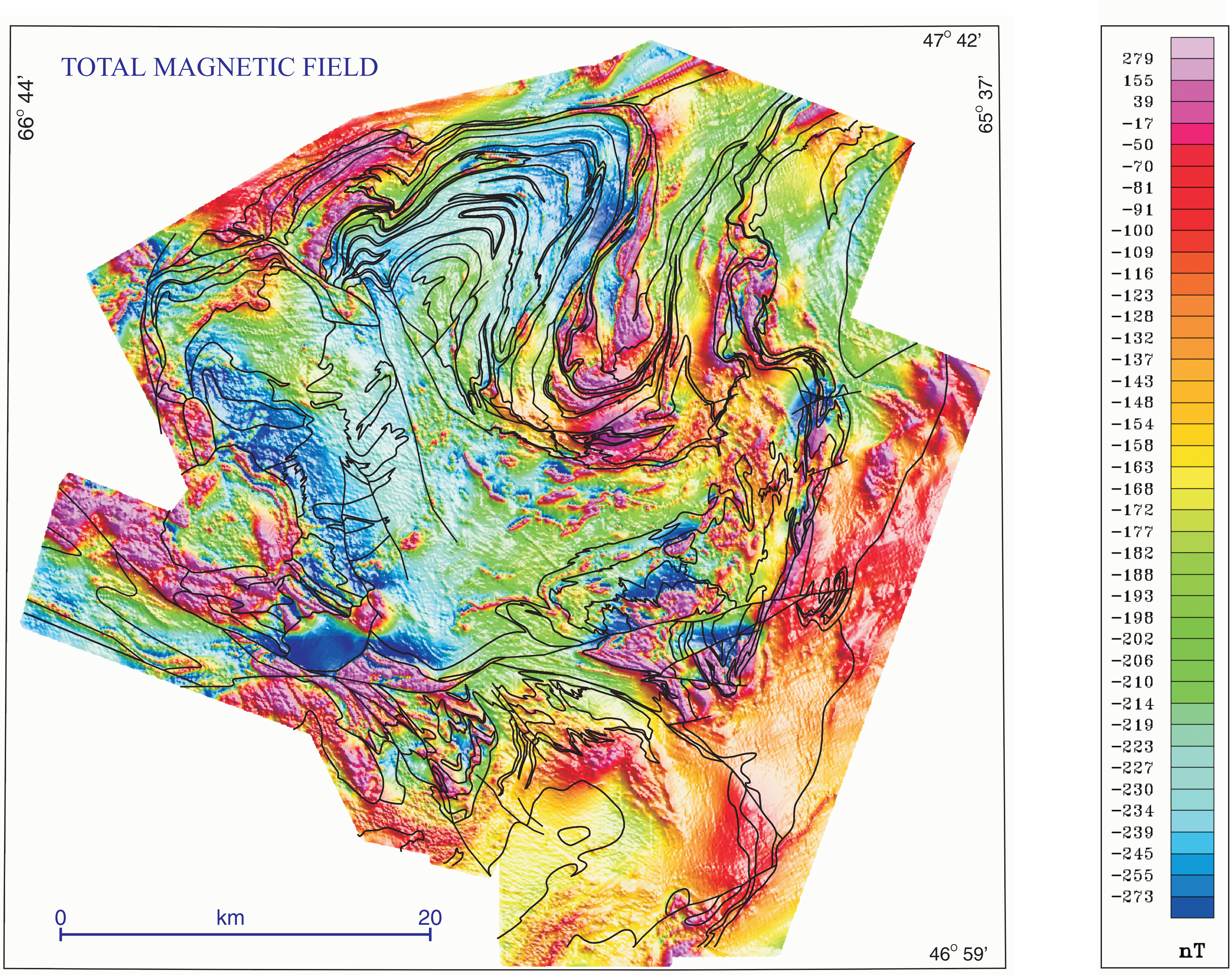


Figure 7: Total magnetic field with geological boundaries superposed.

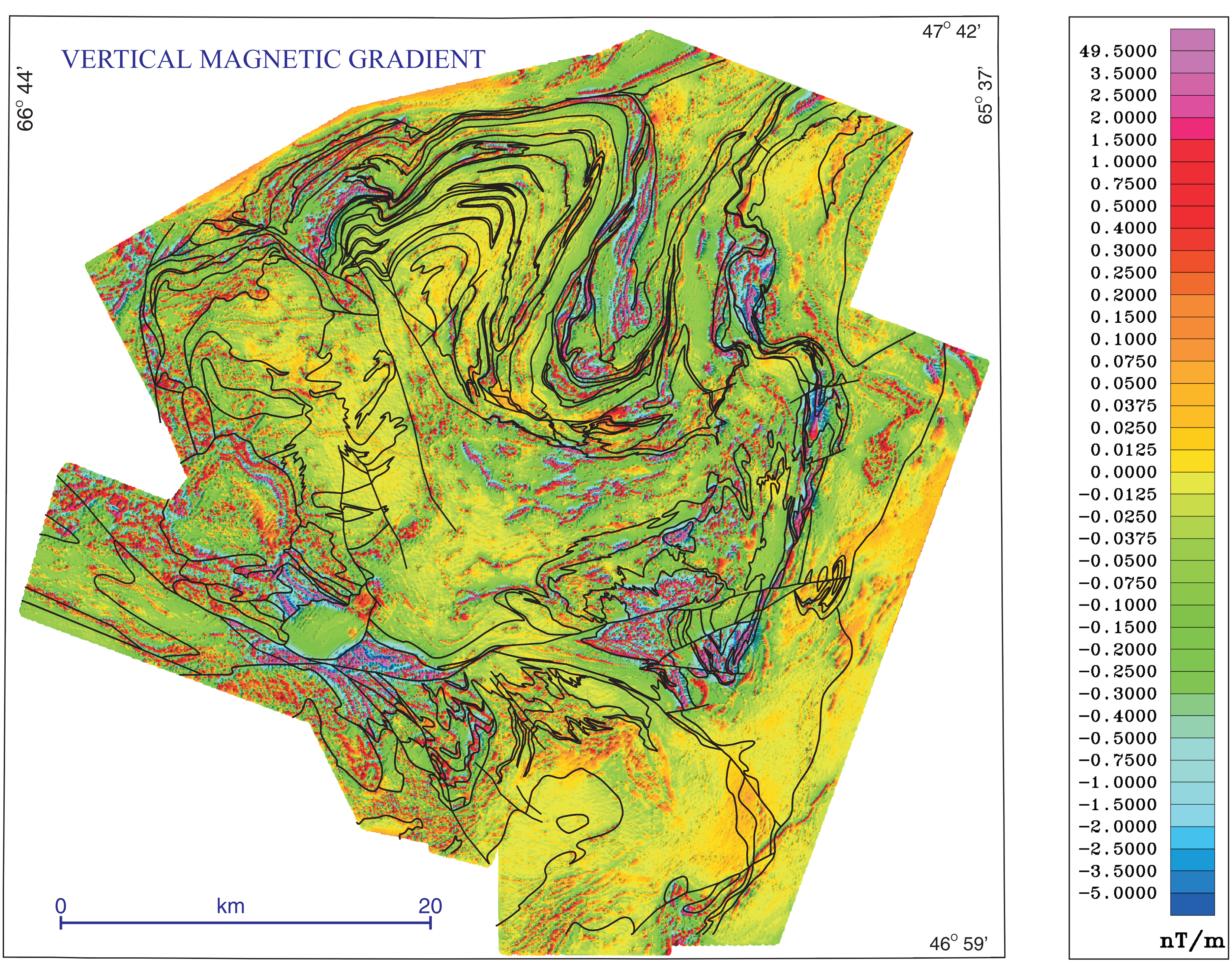


Figure 8: Vertical magnetic gradient with geological boundaries superposed.

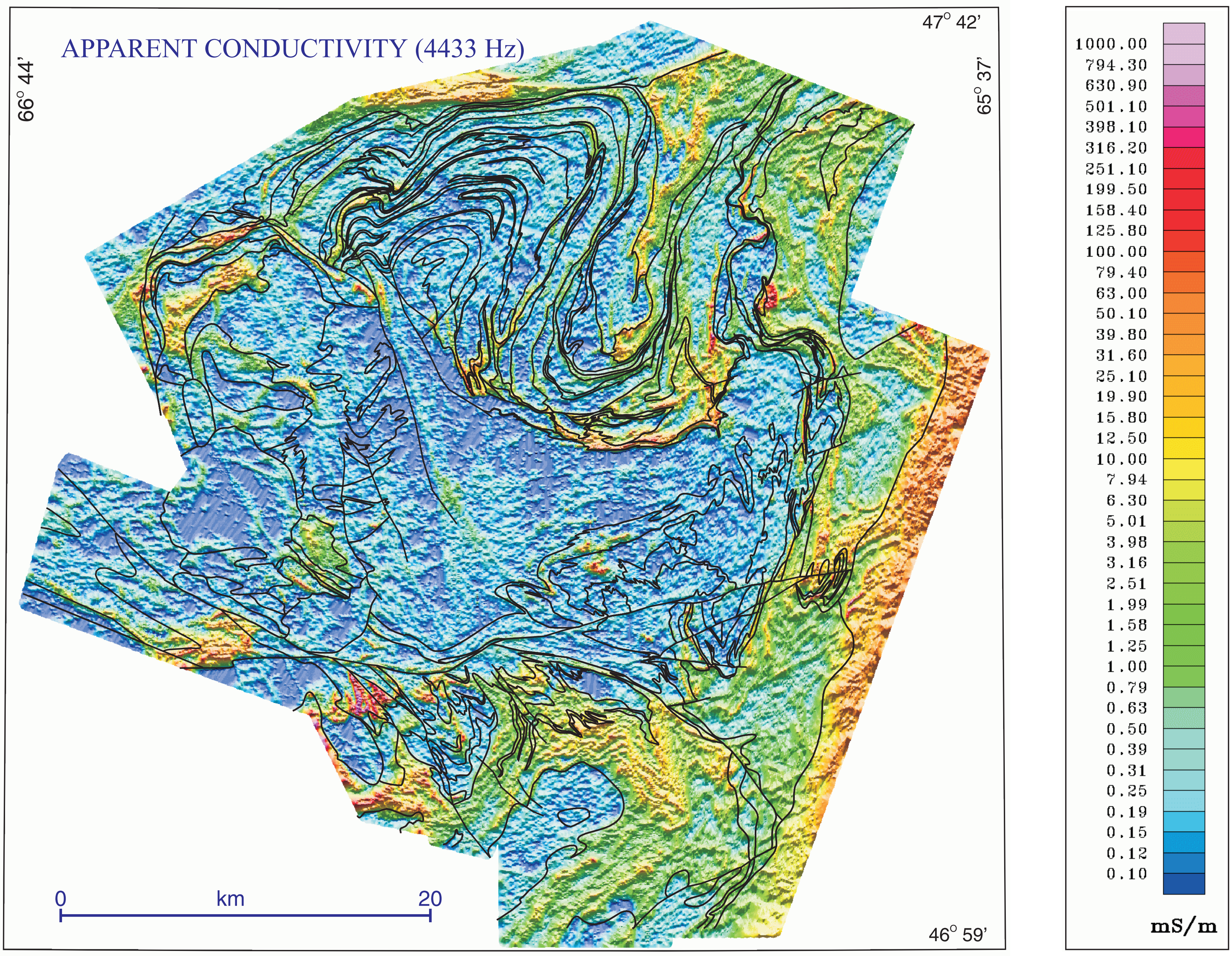


Figure 9: Apparent conductivity (4433Hz) with geological boundaries superposed.

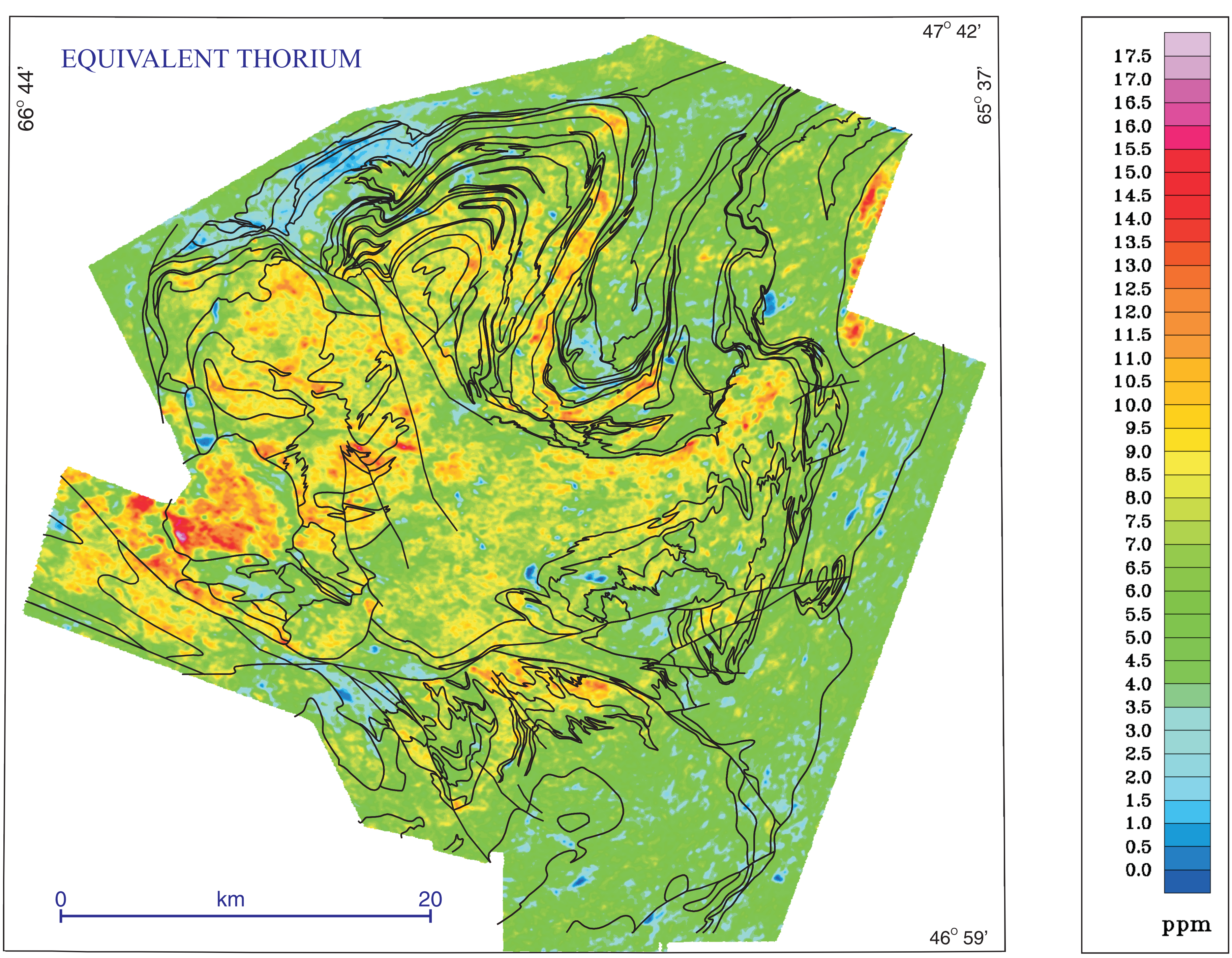


Figure 10: Thorium concentration with geological boundaries superposed.

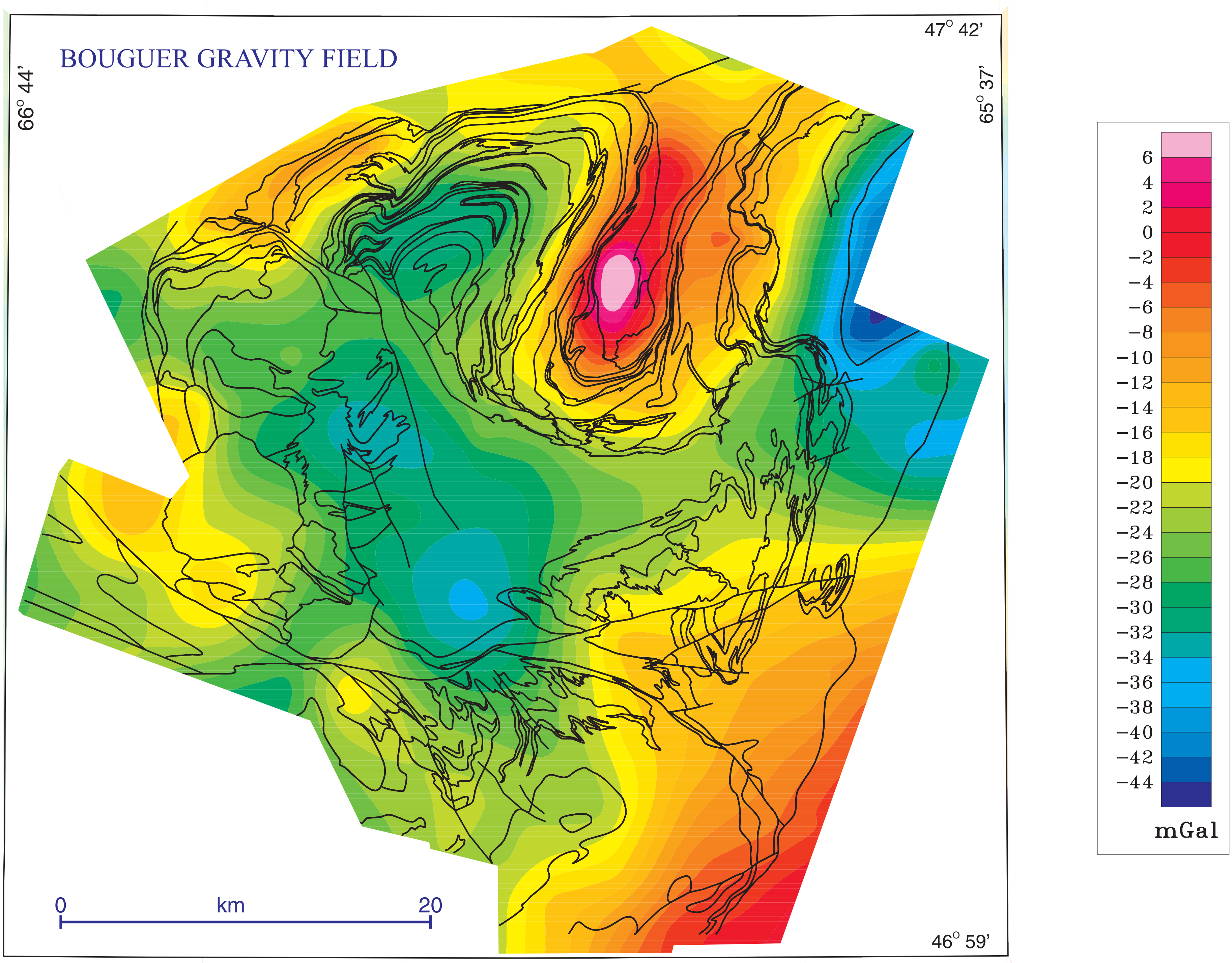


Figure 11: Bouguer gravity field with geological boundaries superposed.

the mafic volcanic and sedimentary rocks, fringed by bands of elevated eTh values over mainly felsic volcanic rocks of the Spruce Lake and Flat Landing Brook formations.

The Tetagouche Antiform is cored by felsic volcanics of the Tetagouche and California Lake groups and is characterized on the total magnetic field map by a relatively subdued magnetic field. This generally featureless field is punctuated, however, by several distinct elongate magnetic highs, that collectively mimic the tight arc-shape of the antiform, open to the southwest. These are particularly evident in the magnetic vertical gradient map. These features are related to horizons of mafic rocks. A similar pattern of anomalies, controlled principally by sedimentary horizons, is observed on the conductivity map. The magnetic field over the Tetagouche Antiform is conspicuous by the sharp contrast it makes with the strong positive signatures of the Nine Mile Synform (previously described) and the northwest margin of the camp, which is underlain by mafic volcanics of the Boucher Brook Formation and Fournier Group. The thorium map exhibits elevated concentrations over the antiform compared to lower values over mafic volcanics of the Nine Mile Synform and northwest margin of the antiform.

South of the Tetagouche Antiform and the Nine Mile Synform, the central part of the Bathurst Mining Camp is underlain by a broad expanse of felsic volcanic rocks belonging mainly to the Flat Landing Brook and Nepisiguit Falls formations. This felsic belt has expression in all of the airborne geophysical images, but is best expressed, perhaps, in the conductivity map, where it is characterized by very low values. What makes the area particularly noticeable, is the sharp change to higher values along many parts of its perimeter, where it is flanked by sedimentary rocks. This is best developed along the eastern and southeastern margins of the region where sedimentary rocks of the Miramichi Group and Tomogonops Formation have significantly higher conductivity values. The contrast also occurs intermittently along the northwest and western margins, where rocks of the Miramichi Group are present, and along the southeast flank of the Nine Mile Synform. Because of the low values and scale of presentation, it is difficult to discern an internal pattern of conductivities, although there is a suggestion of north-northwest trends in the west, and east-northeast trends in the east. The felsic belt is distinguished on the thorium map (and potassium and uranium maps) by generally higher values that peak in a number of fairly small, roughly circular to elongate oval-shaped areas, distributed in somewhat irregular patterns. These probably indicate the presence of local geological units in several locations, such as high-silica rhyolites within the Flat Landing Brook Formation. These chemical variations can be used to improve the detail of bedrock mapping in these areas.

Outside the Tetagouche Antiform and central felsic belt, with rare exception, thorium values are noticeably lower. Noteworthy exceptions occur over the Pabineau Granite near the northeast margin of the Bathurst Mining Camp, and over felsic volcanic rocks of the Clearwater Stream Formation and Ordovician felsic intrusions in the south. Higher thorium values coincide also with portions of the Slacks Lake Formation, just south of the Mount Elizabeth Granite on the western margin of the camp. This granite produces some of the highest thorium values and exhibits strong internal magmatic zonation. Southwest of the granite, high values over a region of Miramichi Group sedimentary rocks indicate an assemblage that differs in some way from sedimentary sequences elsewhere in the group. This is substantiated by the conductivity map, which show generally lower conductivities over this region, compared to the generally higher values recorded elsewhere over the Miramichi Group.

Although the potential of the new high resolution data sets for geological mapping may be readily appreciated from the regional maps, their utility for direct detection of sulphide deposits is less obvious. This is a consequence of the small scale of presentation. However, larger scale maps clearly exhibit distinctive anomalies over several known sulphide deposits, both on the magnetic and apparent conductivity maps. This is demonstrated particularly well in northwest and central regions of the Bathurst Mining Camp, where felsic volcanic rocks having low magnetic susceptibilities and conductivities predominate. Here, sulphide deposits such as Devils Elbow, Camel Back and Armstrong B are associated with conspicuous, coincident, circular to oval, positive magnetic and conductivity anomalies. Many other sulphide deposits featured in this atlas exhibit similar characteristics. In parts of the camp where mafic igneous rocks are present, as in the Brunswick belt, their geophysical signatures are cause for interference, making discrimination of signatures related to sulphide deposits more difficult. The Brunswick 12 deposit is an example where the magnetic signature of the deposit is overshadowed by a magnetic high related to basaltic rocks, and its conductivity anomaly competes with an adjacent anomaly coinciding with sedimentary rocks. Nevertheless, the association of a magnetic and conductivity anomaly would be sufficient indication to target the anomalies for further exploration.

There are no airborne radioelement signatures directly associated with the sulphide mineralization in the Bathurst Camp. Few of the deposits or related alteration zones crop out, subcrop or are overlain by sufficiently altered overburden to produce airborne anomalies. Where mineralization is exposed in outcrop at the Brunswick No. 6 and No. 12 deposits and Heath Steele B Zone, local K depletion caused by albitization and chloritization of alkali feldspar has been recognized in proximity to ore, based on ground investigations incorporating spectrometry (Lentz, 1994; Rickard, 1998; Shives and Ford, in press). This trend has also been found at other deposits in the Bathurst Mining Camp, but the contrast between altered (K-depleted) and unaltered stratigraphy is not observed in the airborne patterns. At several of the deposits, eTh variations in both airborne and ground radiometric data reflect contrasts between hanging wall and footwall units, or other units in the local succession. These patterns can be used to improve geological mapping in the vicinity of known deposits or exploration targets. Specific examples are presented in the following deposit descriptions.

Where airborne gamma-ray spectrometric surveys have been conducted over VMS deposits in other geological settings, such as Pilleys Island and the Tulks Volcanic Belt in Newfoundland, direct detection of the sulphides is made possible by associated, intense potassium enrichment. At Snow Lake, Manitoba, direct detection of suphide deposits is problematical, but airborne and ground spectrometry successfully outlined subvolcanic intrusions and related extrusive units that host the deposits. Although the contribution of airborne gamma-ray spectrometry to exploration in the Bathurst Mining Camp has been evaluated in terms of massive sulphide exploration, there are other deposit-types in the region, which may benefit more directly from the data.

The nature of rock density variations and the relatively wide spacing of gravity stations combine to produce a picture of the gravity field of the Bathurst Camp lacking the details seen in the airborne data sets. The principal utility of this regional map is, therefore, in modelling studies of large scale structures. Close correlations are observed between positive anomalies and the Nine Mile Synform and the belt of basaltic rocks along the northwestern margin of the camp, and between a pronounced negative anomaly and the Pabineau Granite at the northeastern extremity of the camp. The Tetagouche Antiform and the broad belt of dominantly felsic rocks stretching laterally across the camp, are imaged as an area of relatively low gravity. Another use of the gravity map is in providing a wider reference framework for examining the more detailed gravity data at specific deposits.

GEOPHYSICAL SIGNATURES OF MASSIVE SULPHIDE DEPOSITS IN THE BATHURST MINING CAMP

INTRODUCTION

Twenty massive sulphide deposits in the Bathurst Mining Camp were selected for inclusion in this atlas (Table 5). In order to illustrate the geophysical signature of each deposit within the broader context of the respective surrounding geophysical field, an area measuring 2 seconds of longitude by 1 second of latitude (approximately 2.53 km by 1.85 km), centred approximately on the deposit, has been defined for all but one deposit. The area for the Orvan Brook deposit is slightly larger, to accommodate its considerable strike-length. The names of the deposits, bounding latitudes and longitudes of their map-areas, principal commodities, reserve tonnages and host rocks are listed in Table 5. Each deposit is described and illustrated using a four-page format.

First Page

The **first page** provides descriptions of the geology, magnetic data, electromagnetic data, gravity data and radiometric data, and concludes with a brief summary. The description of the electromagnetic data for a deposit (apparent conductivity and electromagnetic profiles/anomalies) may contain reference to a specific flight-line number. This flight-line corresponds in all but one case to the flight-line displayed on the **fourth** page for that deposit. The exception is in the case of the Chester deposit, in which reference is made to one other specific flight-line (440130). This line is labelled on the image of electromagnetic profiles/anomalies for the Chester deposit.

Second Page

The **second page** contains 8 coloured panels that display a geological map, a geological legend, and maps of topography/airborne survey flight-lines, gravity field, magnetic field (total magnetic field and magnetic vertical gradient), apparent conductivity (4433 Hz) and electromagnetic profiles/flight-lines. The scale of presentation of the maps is approximately 1:22,790, to allow optimum use of space on the page. All maps were prepared using a Universal Transverse Mercator projection referenced to the North American Datum 1983 (NAD83). Production of airborne geophysical maps in NAD83 was a straightforward process, since no transformation from an older or different datum was required. Some geological maps produced by the Geological Survey of Canada were transformed digitally from an original NAD27 datum to NAD83. No transformation was applied to geological maps produced by the New Brunswick Department of Natural Resources and Energy, which uses the ATS77 datum. This differs from NAD83 by no more than 4.3 m in terms of horizontal position, a distance which translates into a mere line-width at the scale of presentation. The greatest cause for concern in georeferencing data in NAD83 space was in regard to geological features and gravity data obtained from assessment report maps. Many of the maps do not display latitude/longitude or UTM coordinates. In these cases NAD83 control points were assigned to the maps by visually fitting topographic (streams, lakes) or cultural (roads, railways) features on the maps to their equivalents on a NAD83 map at the same scale. In qualitative terms, the fits were generally good. In spite of these shortcomings, the accuracy of absolute position in most cases is estimated to be better than a few tens of metres. This estimate is supported by the close match in position of several sulphide deposits and their attendant gravity highs, in most cases where gravity data were obtained from assessment reports.

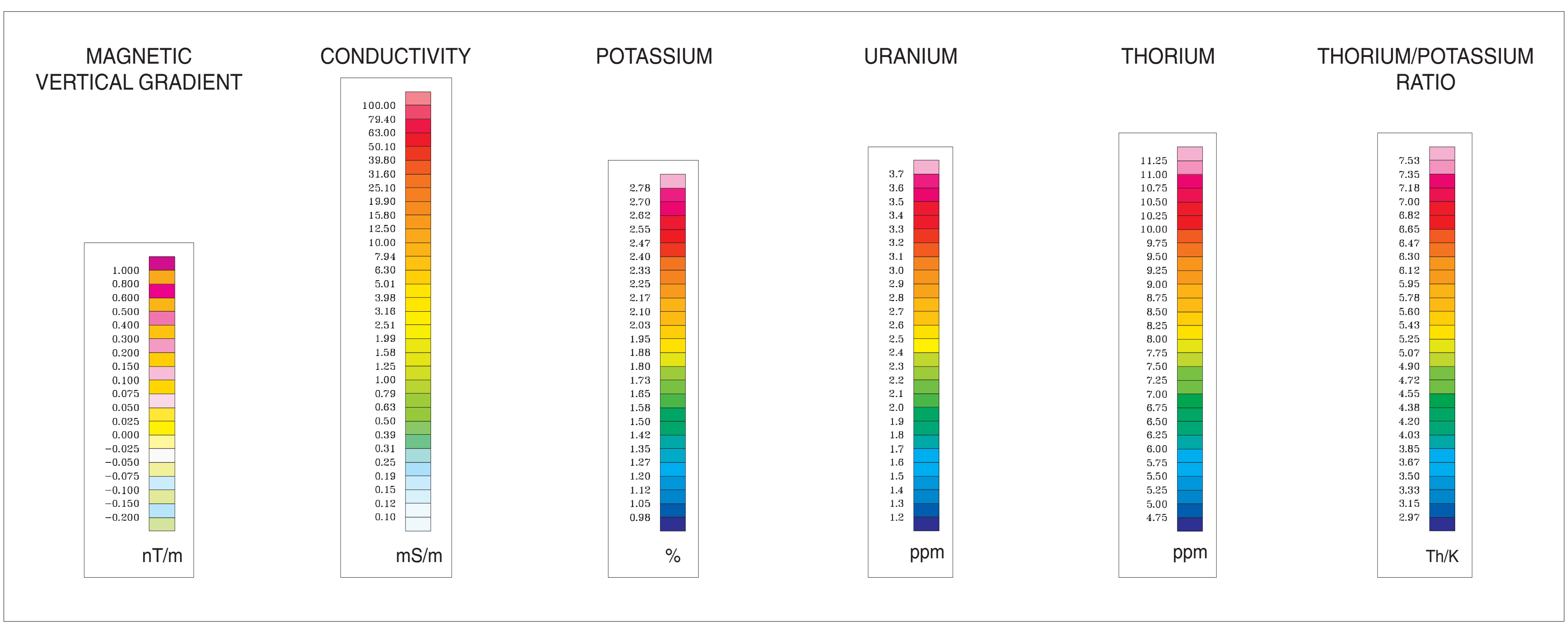


Figure 12: Scale bars for various geophysical maps illustrated on the second and third pages of individual deposit presentations.

The geophysical maps, with the exception of the electromagnetic profiles/anomalies map, are presented as coloured contoured maps with labelled contours. The magnetic, conductivity and radiometric maps were produced from gridded data (50 m interval), interpolated from the flight-line data. The gravity maps were produced from gridded data (20 to 50 m intervals) supplied by companies, or interpolated from data along ground survey lines, or obtained by the digitization of contour lines on maps. A colour scale bar accompanies each of the gravity and magnetic field maps, since the range of values for these fields can vary significantly. Scale bars for the magnetic vertical gradient and conductivity maps, and also for the four radiometric maps on the **third page** of each deposit, are constant and hence are shown only once in Figure 12. Short descriptions of each of the map-panels follow:

GEOLOGY: The main sources of geological information were maps produced by the Geological Survey of Canada or the New Brunswick Department of Natural Resources and Energy. Modifications based on more detailed industry mapping may be incorporated. Formations or units are identified by a unique colour and a label, which are keyed to the geological legend. A line A-A’, marking the position of the geological section crossing the sulphide deposit (shown on the **third page**), and structural features such as faults, thrusts, unconformities and fold axes are indicated. The sulphide deposit and line A-A’ have been superposed on each of the geophysical images (except the radiometric images) so that geological-geophysical correlations can be readily observed. Because of the limited development of radiometric signatures over the deposits, profiles were not extracted for inclusion in the series of profiles illustrated above the geological section on the **third page**, and thus A-A’ is not included on radiometric images. Line A-A’ and the sulphide deposit are also included on the image of topography/flight-lines; on a few images where buildings (black) occur the deposit is coloured red to distinguish them from the buildings.

GEOLOGICAL LEGEND: The legend applies both to the geological map and to the geological section A-A’. Ordovician sedimentary and volcanic assemblages, which together form most of the Bathurst Mining Camp, are divided on the basis of groups and formations. The ages of geological groups and formations, and of other geological units, in the legend are denoted by the following abbreviations: Є, Cambrian; O, Ordovician; S, Silurian; D, Devonian; C, Carboniferous.

TOPOGRAPHY/FLIGHT-LINES: The topographic bases reproduced in these maps were prepared by the Minerals and Energy Division of the New Brunswick Department of Natural Resources and Energy from digital files provided by the New Brunswick Geographic Information Corporation, Fredericton. The map displays elevation contours (in metres), streams and lakes, and a variety of cultural features, including roads, tracks, power transmission lines and buildings. These are distinguished on the basis of line colour and pattern, and colour of fill for solid symbols. A legend for topographic and cultural features is shown in Figure 13. Superimposed on the topographic base map are the positions of survey flight-lines. The flight-line selected for the production of the stacked geophysical profiles shown on the **fourth page** for each deposit is marked by a heavier line-weight. Generally, the closest flight-line to the centre of the deposit was chosen.

GRAVITY FIELD: Unit of measurement is the milligal (mGal). The sources of gravity data include assessment report maps archived by the New Brunswick Department of Natural Resources and Energy, digital files provided by exploration companies, and data collected by the Geological Survey of Canada. In many cases it was necessary to position survey grid lines in NAD83 space, previously described. Once positioned, the gravity field was digitized, either by tracing contours or digitizing individual station values. Positions of digitized points are superposed on the gravity map to indicate the degree of control on the map. In some cases, gravity data were supplied in the form of grids. In such cases it has not been possible to provide original station positions. Information on

Table 5: Location, Tonnage, Grade and Geological Data for the Twenty Sulphide Deposits Described in this Atlas

Deposit	Bounding Latitudes	Bounding Longitudes	Tonnage and Grade	* Status	IF	Host Rocks**	Alteration	Deposit Character #
Armstrong B	47.5767(S) 47.5933(N)	66.0750(W) 66.0417(E)	Resource - 537,400 t grading 0.23% Pb, 1.10% Zn, 0.67% Cu and 14 g/t Ag	R	No	FW and HW: ash tuff, feldspar crystal tuff, and lapilli tuff	sericite-chlorite	P, SF, ST
Brunswick No. 6	47.4000(S) 47.4167(N)	65.8375(W) 65.8042(E)	Total resource 18.5 Mt grading 1.59% Pb, 4.08% Zn, 0.45% Cu and 55 g/t Ag; including production of 12.97 Mt grading 5.43% Zn, 2.15% Pb, 0.4% Cu and 67 g/t Ag	PP	Yes	FW: crystal tuff and shale, HW: aphyric to sparsely feldspar-phyric rhyolite	chlorite, sericite	P, SF, ST
Brunswick No. 12	47.4667(S) 47.4833(N)	65.9083(W) 65.8750(E)	Production to end of 1998 - 88.8 Mt grading 8.81% Zn, 3.49% Pb, 0.34% Cu and 99.9 g/t Ag; remaining resource - 40.7 Mt grading 3.42% Pb, 8.57% Zn, 0.37% Cu and 93 g/t Ag	P	Yes	FW: crystal tuff with minor ash tuff and epiclastic rocks, HW: hyalotuff and fine-grained clastic rocks	chlorite-sericite, siliceous	P, SF, ST
Captain North Extension (CNE)	47.2867(S) 47.3033(N)	65.9000(W) 65.8667(E)	Production of 39,000 t grading 4.42% Pb, 9.97% Zn, and 134.7 g/t Ag; remaining resource - 0.236 Mt grading 2.74% Pb, 7.64% Zn, 89 g/t Ag, and 0.03 Mt grading 1.3% Cu	PP	No	FW: massive chloritic ash tuff and quartz-feldspar crystal tuff, HW: siliceous exhalite overlain by aphyric rhyolite	chlorite	SF
Canoe Landing Lake	47.4042(S) 47.4208(N)	66.1250(W) 66.0917(E)	20.6 Mt of sulphides grading 0.61% Pb, 1.71% Zn, 0.57% Cu and 32 g/t Ag; includes a resource of 3.456 Mt grading 0.65% Pb, 2.48% Zn, 0.65% Cu, and 44 g/t Ag	R	No	FW: shale and wacke, HW: shale and wacke	none	D, SF
Camel Back	47.4972(S) 47.5139(N)	66.2833(W) 66.2500(E)	200,000 t of 5 - 7% combined Pb + Zn	R	Yes	HW and FW: felsic tuff and epiclastic rocks	chlorite	P, SF, ST
Caribou	47.5583(S) 47.5750(N)	66.3125(W) 66.2792(E)	Production - 1.34 Mt grading 3.72% Pb, 6.78% Zn, 0.32% Cu, 97 g/t Ag; remaining resource - 3.6 Mt grading 3.22% Pb, 6.77% Zn, 98 g/t Ag, and 0.21 Mt grading 3.82% Cu	PP	No	FW: phyllite, wacke and ash tuff, HW: aphyric to feldspar-phyric rhyolite	chlorite	P, SF, ST
Chester	47.0917(S) 47.1083(N)	66.2417(W) 66.2083(E)	Production - 3000 t grading 1.46% Cu; resource - 1.019 Mt grading 1.58% Pb, 3.95% Zn, 0.67% Cu and 12 g/t Ag; copper zone contains 6.4 Mt grading 1.22% Cu	R	No	FW: feldspar crystal tuff, HW (?)	chlorite	P, ST, SF
Devils Elbow	47.4217(S) 47.4383(N)	66.4167(W) 66.3833(E)	Resource - 0.362 Mt grading 1.2% Cu	R	No	FW: quartz-feldspar crystal tuff	chlorite	P, ST
Flat Landing Brook	47.3750(S) 47.3917(N)	65.8958(W) 65.8625(E)	Resource - 1.27 Mt grading 5.62% Zn, 1.29% Pb and 0.3% Cu	R	Yes	FW: quartz-feldspar crystal tuff and ash tuff, HW: aphyric to feldspar- phyric rhyolite	chlorite and siliceous	P, SF, ST
Halfmile Lake	47.2972(S) 47.3139(N)	66.3375(W) 66.3042(E)	Resource - 8.528 Mt grading 0.1% Cu, 2.83% Pb, 8.94% Zn and 39 g/t Ag	R	No	FW and HW: felsic ash and lapilli tuff and related epiclastic rocks	chlorite-sericite	P, SF, ST
Heath Steele B Zone	47.2889(S) 47.3056(N)	66.0583(W) 66.0250(E)	Production - 20.723 Mt grading 1.75% Pb, 4.79% Zn, 0.98% Cu and 65.5 g/t Ag	PP	Yes	siltstone and ash tuff	chlorite-sericite	P, SF, ST
Key Anacon	47.4292(S) 47.4458(N)	65.7167(W) 65.6833(E)	Resource - 1.86 Mt grading 0.16% Cu, 2.63% Pb, 6.93% Zn and 84 g/t Ag	R	Yes	FW: felsic ash and crystal tuff, HW: mafic flows and related sedimentary rocks	chlorite-sericite	SF
Murray Brook	47.5167(S) 47.5333(N)	66.4458(W) 66.4125(E)	Production from gossan - 1.01 Mt grading 82.98 g/t Ag and 2.39 g/t Au; remaining resource - 4.6 Mt 0.22% Cu, 1.8% Pb, 4.73% Zn and 64 g/t Ag, plus 3.59 Mt grading 1.88% Cu	R	No	shale-siltstone and lithic tuff	chlorite	P, SF, ST
Nepisiguit A	47.3694(S) 47.3861(N)	66.0500(W) 66.0167(E)	Resource - 1.54 Mt grading 0.4% Cu, 0.6% Pb, 2.8% Zn	R	No	HW: shale and wacke, FW: mafic volcanic rocks	weak chlorite	P, SF
Orvan Brook	47.6188(S) 47.6396(N)	66.1500(W) 66.1083(E)	2.687 Mt grading 0.37% Cu, 1.732% Pb, 5.95% Zn, and 72 g/t Ag	R	Yes (?)	FW and HW: feldspar-phyric to aphyric micaceous sericite tuffs and dark grey, locally graphitic shale	chlorite	SF
Restigouche	47.4917(S) 47.5083(N)	66.5667(W) 66.5333(E)	Production - 0.231 Mt grading 5.49% Pb, 6.34% Zn, 132.9 g/t Ag; remaining resource - 2 Mt containing 0.3 Mt grading 5.27% Pb, 6.56% Zn, 72 g/t Ag	R	No	FW and HW: crystal lithic tuff, ash tuff, feldspar-phyric rhyolite	silicic chlorite	SF
Stratmat Boundary	47.2972(S) 47.3139(N)	66.1500(W) 66.1167(E)	Production - 1.1 Mt grading 2.98% Pb, 8.11% Zn, 0.35% Cu, and 44 g/t Ag	PP	No	argillaceous to cherty sedimentary rocks	chlorite-sericite-talc	SF(?)
Taylor Brook	47.3383(S) 47.3550(N)	66.0278(W) 65.9944(E)	Resource - 325,000 t grading 2 - 3% (Pb + Zn) and 0.4 oz/ton Ag; this does not include results from most recent drilling	R	No	FW: aphyric rhyolite and related rocks, HW: aphyric rhyolite, crystal tuff and minor siltstone	chlorite, sericite	P, SF, ST
Wedge	47.3875(S) 47.4042(N)	66.1458(W) 66.1125(E)	Remaining resource - 1.8 Mt grading 1.04% Pb, 2.87% Zn, 2.9% Cu and 35 g/t Ag; production - 1.5 Mt grading 2.88% Cu, 0.65% Pb, 1.61% Zn, and 20.6 g/t Ag	PP	No	FW: quartz-feldspar- phyric tuff and epiclastic rocks	chlorite	P, SF, ST

IF Iron Formation
* P-producer, PP-past producer, R-resource
** FW-footwall, HW-hanging wall
\# P-proximal, D-distal, SF-strataform, ST-stringer

Tonnages and grades in this table are compiled from data presented in various assessment reports and by Luff (1995), and include some values based on recent estimations by Luff and McCutcheon (in preparation).

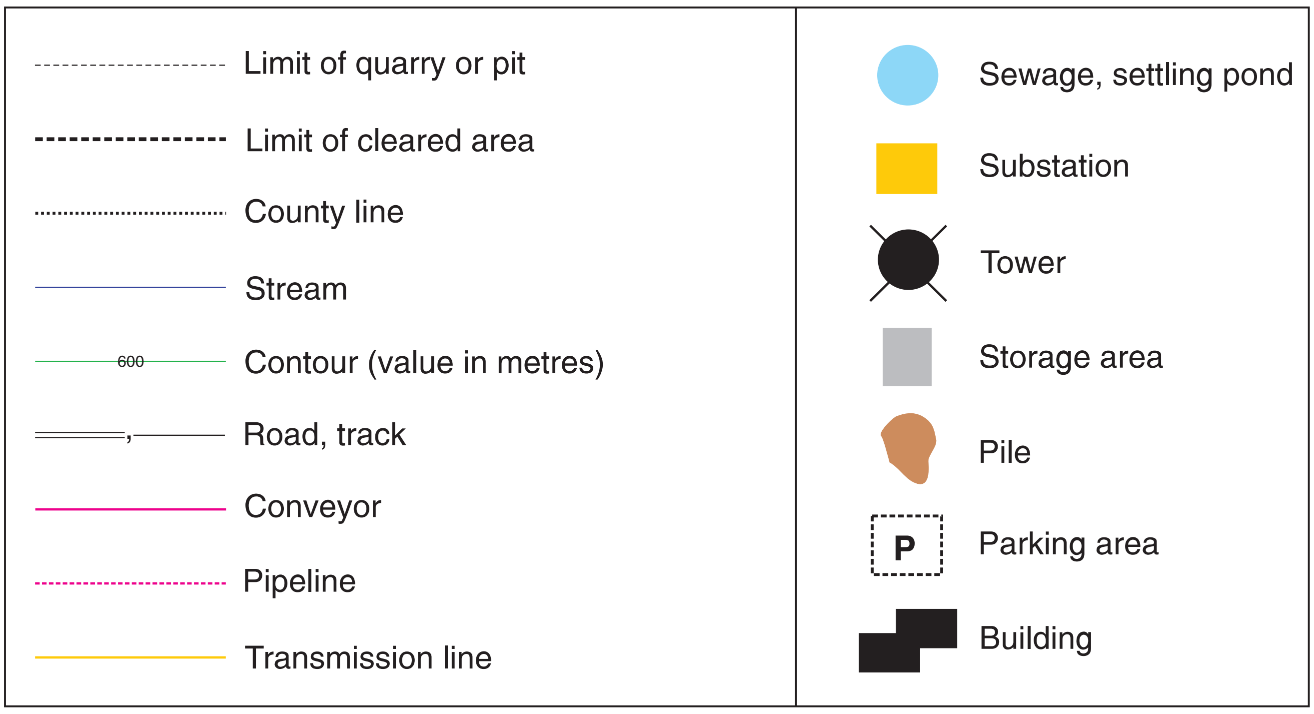


Figure 13: Legend for lines and symbols on the map of topography and flight-lines illustrated on the second page of individual deposit presentations.

certain parameters used in the processing of gravity observations is not always available, and hence the Bouguer anomaly values have been accepted on an "as is" basis. Specifically, documentation of the density and vertical datum (commonly sea level) used in the Bouguer correction, and the nature of the gravity base station (whether or not it is part of the national gravity network), may be missing. Also, in most cases it is unknown whether the data have been corrected for effects of terrain.

MAGNETIC FIELD: Unit of measurement is the nanotesla (nT). The magnetic map represents a histogram-equalized version of the the residual total magnetic field (the total magnetic field minus the International Geomagnetic Reference Field as defined at the time of the survey).

APPARENT CONDUCTIVITY: Unit of measurement is millisiemens/metre (mS/m). The apparent conductivity map was calculated from data obtained by the 4433 Hz frequency coplanar coils of the HEM system. This frequency represents a mid-frequency in this survey.

ELECTROMAGNETIC PROFILES/ANOMALIES: The vertical scale for profiles represents a measure of the ratio of the secondary electromagnetic field to the primary electromagnetic field, expressed as parts per million/millimetre (ppm/mm), where millimetres are measured at the scale of presentation. In-phase (IP) and quadrature (Q) profiles are shown for all flight-lines in the map-area for a coplanar (CP) coil arrangement of the transmitter-receiver couple for frequencies of 4433 Hz and 835 Hz. For flight-lines oriented in a north-south direction, the positive axis for the profiles is to the west of the lines. For lines oriented northwest to southeast, and southwest to northeast, the positive axis is to the northeast and northwest of the lines, respectively. Large red dots represent the positions of interpreted conductivity anomalies. The flight-line selected for illustration on the **fourth page** is identified by black triangles at its extremities. Because of the strong responses on several adjacent lines on the Brunswick No. 12 image, the selected flight-line and its electromagnetic responses are highlighted by suppressing the "brightness" of the other lines.

Third Page

The **third page** portrays 4 panels of radiometric images, the geological section along A-A', and selected geophysical profiles along A-A' derived from gridded data. The parameters shown in the radiometric images are concentrations of potassium, equivalent uranium and equivalent thorium and the equivalent thorium/potassium ratio.

POTASSIUM: Unit of measurement is percent (%).
eURANIUM: Unit of measurement is parts per million (ppm).
eTHORIUM: Unit of measurement is parts per million (ppm).
eTHORIUM/POTASSIUM RATIO: expressed in parts per million times 10^4 (ppm x 10^4).

The geological sections along A-A' are constructed from drill-hole logs, and where available, data provided by mining operations. Where information permits, an overburden layer is presented. The vertical scale is sometimes exaggerated; the amount of exaggeration is noted on all sections. Geological units are coloured and labelled in accordance with the geological legend. Geophysical profiles of the total magnetic field, magnetic vertical gradient, apparent conductivity (coplanar 4433 Hz) and gravity field (where available) along section A-A' are illustrated. These are derived from data gridded at 50 m spacing for the airborne data sets, and at 25 to 50 m spacing for the gravity data sets.

Fourth Page

The **fourth page** for each deposit illustrates profiles of the flight-elevation (radar height and barometric altitude) and a series of geophysical profiles selected along a specific flight-line (the line number is indicated), whose position is highlighted on the panel showing topography and flight-lines **(second page)**. The position of the sulphide deposit, extrapolated in some cases, is indicated by a vertical grey bar(s), the width(s) of which is equivalent to the width(s) of intersection(s) of the deposit on that flight-line. The flight-line profiles (radiometric profiles excepted) are derived from data collected every 0.2 seconds, equivalent to a distance of less than 10 m (distance will vary depending on helicopter speed). Radiometric parameters were measured every 1 second. Hence, the flight-line profiles provide significantly higher resolution than do the profiles of corresponding parameters based on gridded data along the geological section A-A'. The longer length of the flight-line profiles also enables the signature of the sulphide deposit to be viewed in a more regional setting. The geophysical profiles include those for: total magnetic field, in-phase and quadrature pairs (for different frequencies for coaxial and coplanar arrangements of the transmitter-receiver), 60 Hz power line response, potassium concentration, equivalent thorium/potassium ratio, equivalent thorium concentration, equivalent uranium/equivalent thorium ratio and equivalent uranium concentration. Each profile extends across the entire map-area and its length is determined by the orientation of the flight-line. The absolute scale of each profile is different, since all profiles are assigned identical widths on the printed page. A scale bar for the profiles is shown at the bottom of the page, distance increasing in the direction of flight. This scale bar is derived by computing distances based on elapsed time intervals of 20 seconds. Since survey speed is variable, distances are also variable for the 20 second intervals.

ARMSTRONG B DEPOSIT

GEOLOGY

The Armstrong B deposit was discovered in 1956 by Anaconda American Brass as a result of follow-up work on an airborne electromagnetic anomaly, and was subsequently drilled in 1958 (Morrison, 1960). The deposit comprises disseminated to massive sulphides hosted by a mixed sequence of ash, feldspar-crystal and lithic-lapilli tuffs that are assigned to the Spruce Lake Formation.

Sulphide mineralization occurs in a north-striking, steeply east-dipping (65°) lens on the east limb of the Tetagouche Antiform. According to Williams (1974a) the deposit contains a drill-indicated resource of 250,000 tonnes grading 0.80% Cu and is divisible into two zones, (1) the copper zone, which is 244 m long, 2 m thick and extends to a depth of 183 m, and (2) the Pb-Zn zone, which is 6 m thick, 61 m in length and extends downward for 30 m. Like other deposits in the northwest part of the Bathurst Mining Camp, there is no evidence of an exhalative unit (iron formation) along strike from the sulphide lens.

Metal zonation is manifested by a Cu-enriched zone to the east and a Pb-Zn zone to the west, which supports the interpretation that the deposit is overturned to the west. Pyrrhotite is present throughout the deposit, and is particularly abundant in the Cu zone. Intense, feldspar-destructive, chloritic and sericitic alteration is conformable with mineralization and is ubiquitous in the footwall of the deposit. Chlorite and sericite are less well developed in the hanging wall.

The rocks hosting this deposit have been subjected to intense strain as evidenced by numerous feldspars exhibiting brittle deformation. A well developed cleavage is present and probably represents a composite S_1/S_2 fabric.

MAGNETIC DATA

The Armstrong B sulphide deposit generates a conspicuous oval-shaped, total magnetic field anomaly, which is much broader than the narrow surface trace of the deposit. The anomaly is but one of several positive features on the total field magnetic map, but its amplitude, about 100 nT, is by far the largest of any of them. The prominence of the anomaly can be attributed to the strong contrast between the magnetic susceptibilities of the sulphide body, which contains abundant pyrrhotite, and the surrounding felsic tuffs of the Spruce Lake Formation. The susceptibility of the hosting felsic tuffs is very weak with in situ measurements at two sites near the deposit yielding values less than 0.2×10^{-3} SI. These are comparable to values obtained for similar rocks elsewhere in the mining camp. The low susceptibility of the Spruce Lake Formation is reflected in the generally lower values of the magnetic field over the formation. The magnetic field over units of dominantly sedimentary rocks of the Spruce Lake Formation is noticeably stronger, particularly in the northwest. These rocks are commonly pyritic, and the presence of pyrite with a susceptibility of 5×10^{-3} SI is consistent with the higher values. A mean susceptibility value of 0.42×10^{-3} SI was obtained at one site on sedimentary rocks near the deposit. On the eastern margin of the area, alkali basalts of the Canoe Landing Lake Formation are characterized by a variable magnetic signature that includes oval-shaped magnetic highs.

ELECTROMAGNETIC DATA

Armstrong B deposit provides a typical example of an EM response of a small massive sulphide deposit. Apparent conductivity is more than 250 mS/m at low and mid frequencies. Coaxial and coplanar EM responses are easy to identify. The maximum of the coplanar responses are shifted about 45 m relative to the maximum of the coaxial responses, indicating a dipping conductor. The shoulder on the coplanar responses is also an effect of dip. The axis of the conductor is located under the maximum of the coaxial response. At low frequency, the coplanar in-phase and quadrature responses are 64 ppm and 22 ppm, respectively, and corresponding coaxial responses are 28 ppm and 9 ppm. At mid frequencies, the coplanar responses are 60 ppm and 20 ppm, and the coaxial responses are 36 ppm and 10 ppm. At high frequency, the in-phase and quadrature responses are 112 ppm and 64 ppm. These strong responses make the anomaly readily identifiable. The EM anomaly can be modelled by a 60 x 60 m square, thin plate dipping 60° and located 30 m below the EM bird. The interpreted conductivity-thickness product is 30 S.

Because the deposit has a strike-length of about 240 m, only slightly longer than the 200 m distance between flight-lines, it is detected on only one flight-line (330611), where it produces a distinct positive response at all frequencies. There are no responses on adjacent flight-lines.

GRAVITY DATA

The gravity map of the Armstrong B map-area is based on measurements along seven profiles spaced approximately 90 to 175 m apart, three of which cross the deposit (Mersereau, 1985). Gravity observations were made at intervals of 100 ft (~30 m), and were reduced to Bouguer anomalies using a density of 2.67 g/cm^3. The anomaly values along the profiles were digitized to produce the map displayed here. A distinct, elongate local gravity high is associated with the sulphide deposit, and is observed on two of the profiles. Its amplitude on the profile crossing the widest part of the deposit is about 0.4 to 0.45 mGal, and that on the adjacent line to the north is roughly 0.2 to 0.25 mGal. The anomaly is superposed on a gentle, uniform gradient that increases from west to east, which probably reflects the influence of dense mafic volcanics forming much of the Nine Mile Synform to the east (Thomas *et al.*, 1991). No other anomalies, such as might have been observed had mafic igneous rocks been present, conflict with the sulphide anomaly.

RADIOMETRIC DATA

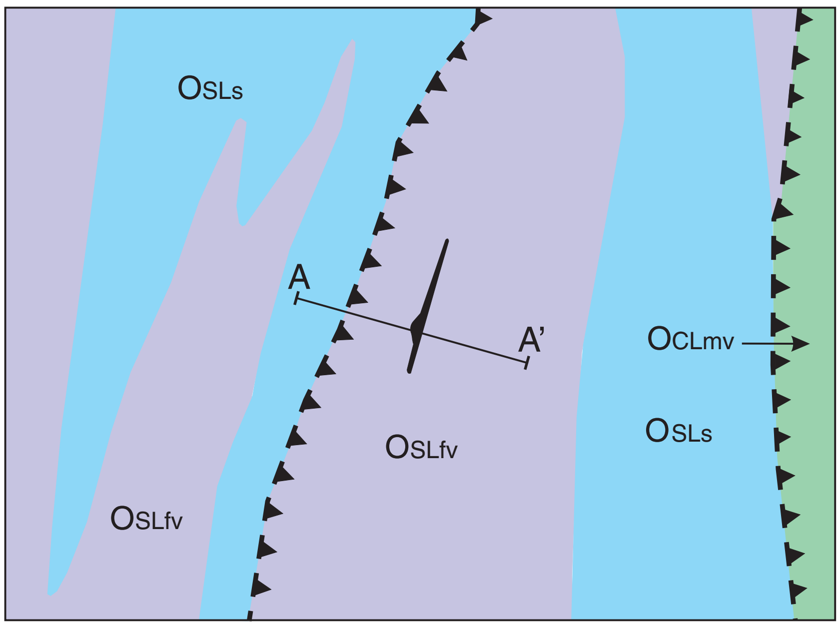
The radioelement patterns generally reflect geochemical contrasts between felsic volcanic and sedimentary units within the Spruce Lake Formation. Approximately 230 m west of the deposit, breaks in eTh and eTh/K patterns overlie the north-northeast-trending, east-dipping thrust fault which separates felsic, feldspar-phyric crystal tuffs and ash tuffs from thinly bedded shale, sandstone and siltstone. Radioelement concentrations over the felsic units are 1.6 - 1.8% K, 1.8 - 2.1 ppm eU and 7 - 8 ppm eTh. Over the sedimentary units these values are lower, ranging from 1.3 - 1.6% K, 1.4 - 1.8 ppm eU and 5 - 7 ppm eTh. The surface projection of the deposit correlates with weak highs in all three radioelements. Low K and eTh values along the north and northeast parts of the map-area overlie low, swampy terrain. Southeast of the deposit, an area mapped as metasediments yields moderately low K (less than 1.4%) but elevated eU (2.4 ppm), eTh (10.25 ppm) and eTh/K (7.6×10^{-4}), suggesting the presence of an unrecognized unit. Regionally (camp-scale maps), the relatively higher eU and eTh patterns form a series of spotty highs which broadly delineate the Spruce Lake Formation, lying along the flanks of the Tetagouche Antiform and Nine Mile Synform. These relationships suggest that revisions to existing geology maps may be locally possible, using the radioelement maps as guides.

SUMMARY

The Armstrong B deposit produces coincident "bull's-eye" positive magnetic and conductivity anomalies, which are the most prominent features on the respective maps. A small, yet distinct gravity anomaly is also present, and stands out within the context of the local gravity field. The deposit is located within areas of weak radiometric highs for each of the radioelements, though these are considerably more extensive than the deposit and cannot be ascribed directly to it.

ARMSTRONG B

GEOLOGY



Modified from van Staal (1994d)

GEOLOGICAL LEGEND

CALIFORNIA LAKE GROUP

Canoe Landing Lake Formation

OCLmv alkalic basalt

Spruce Lake Formation

OSLs laminated to thinly bedded shale interbedded with feldspathic sandstone & siltstone

OSLfv felsic feldspar-phyric crystal tuff & ash tuff

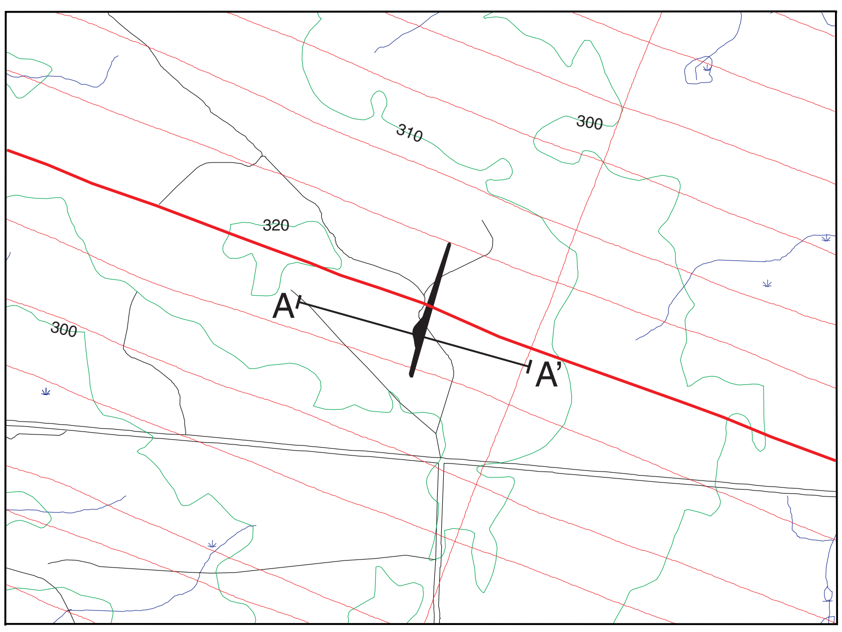
massive sulphides

stringer zone mineralization

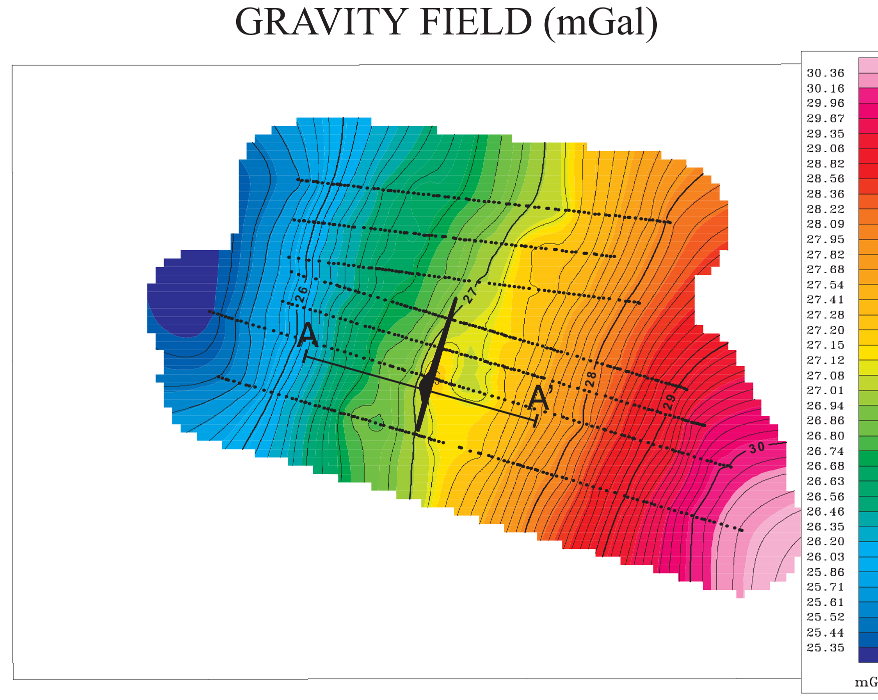
normal fault

thrust fault

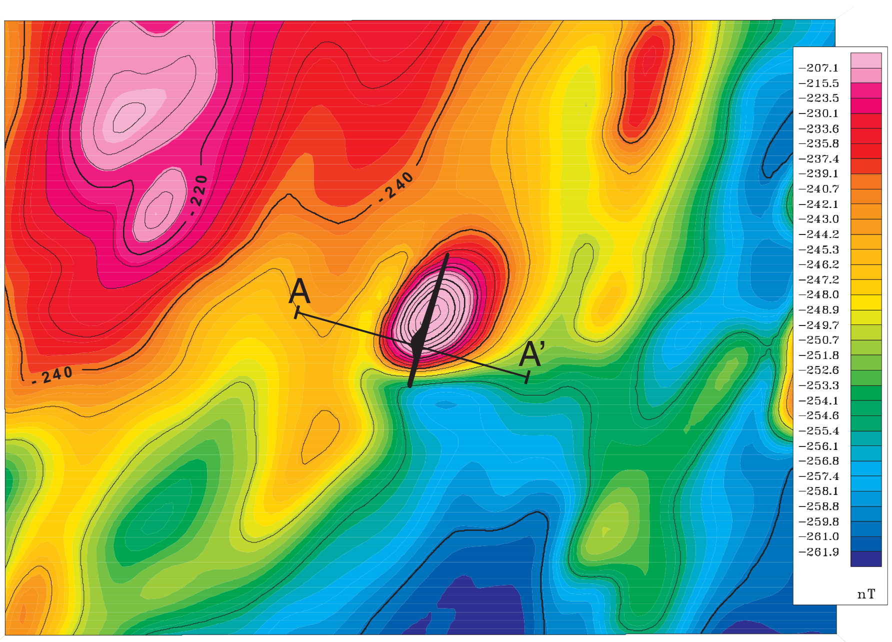
TOPOGRAPHY/FLIGHT LINES



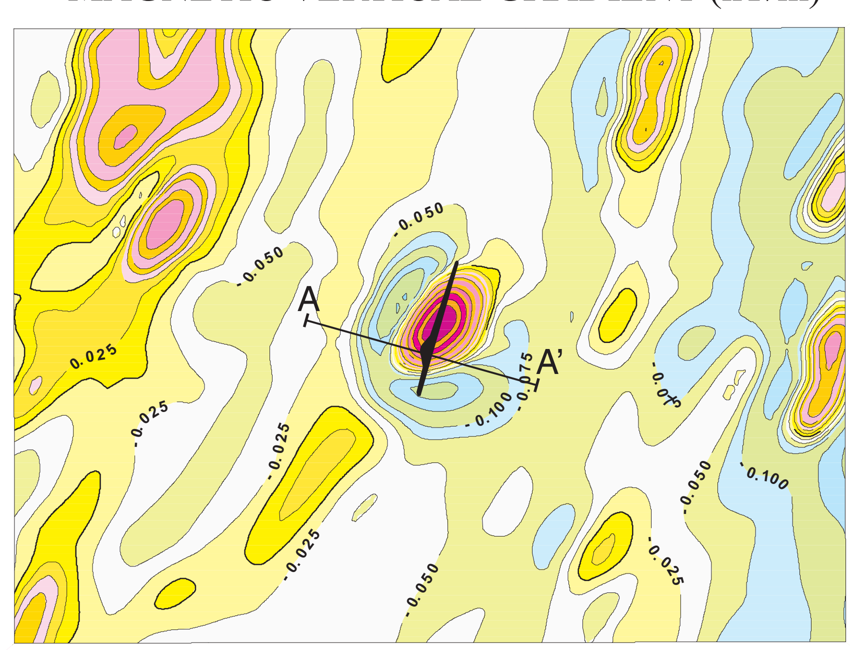
GRAVITY FIELD (mGal)



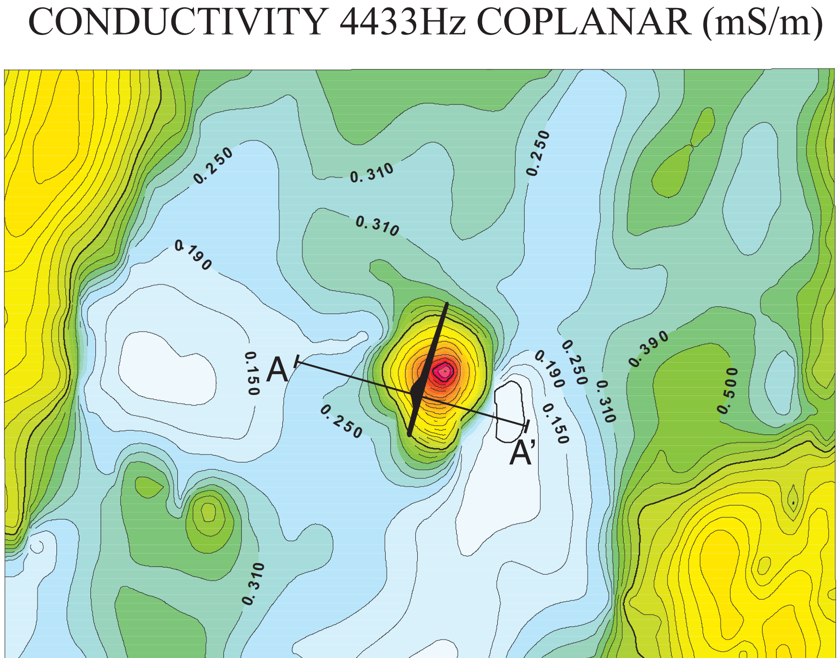
MAGNETIC FIELD (nT)



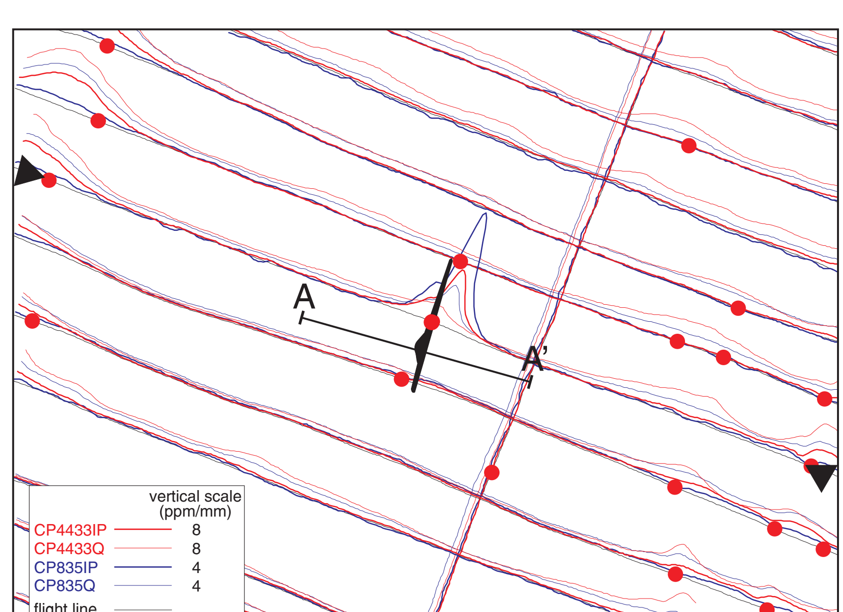
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



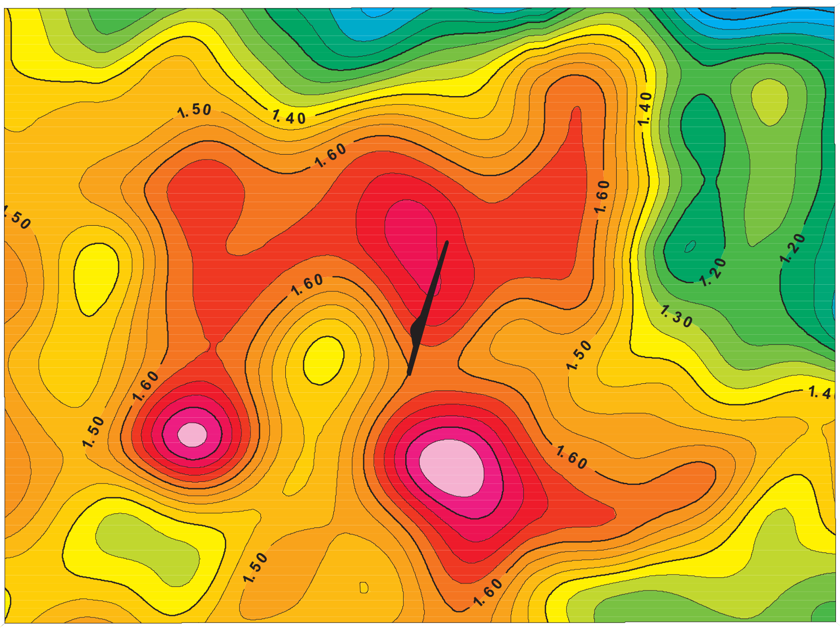
ELECTROMAGNETIC PROFILES/ANOMALIES



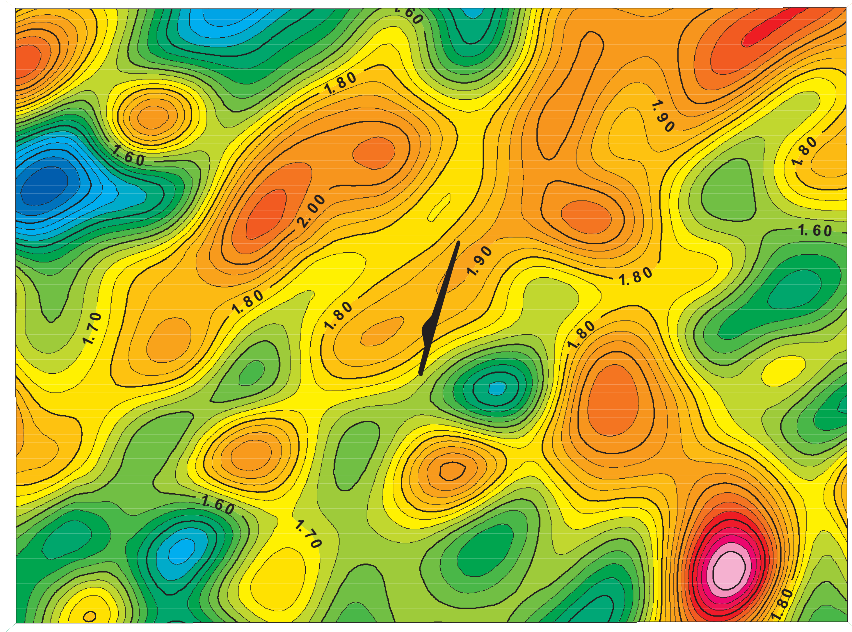
1000 m

ARMSTRONG B

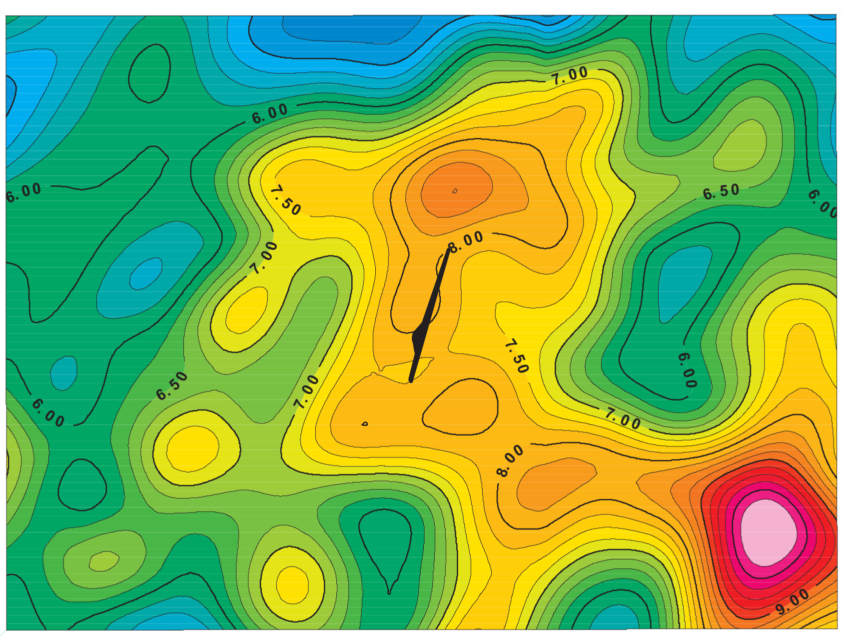
POTASSIUM (%)



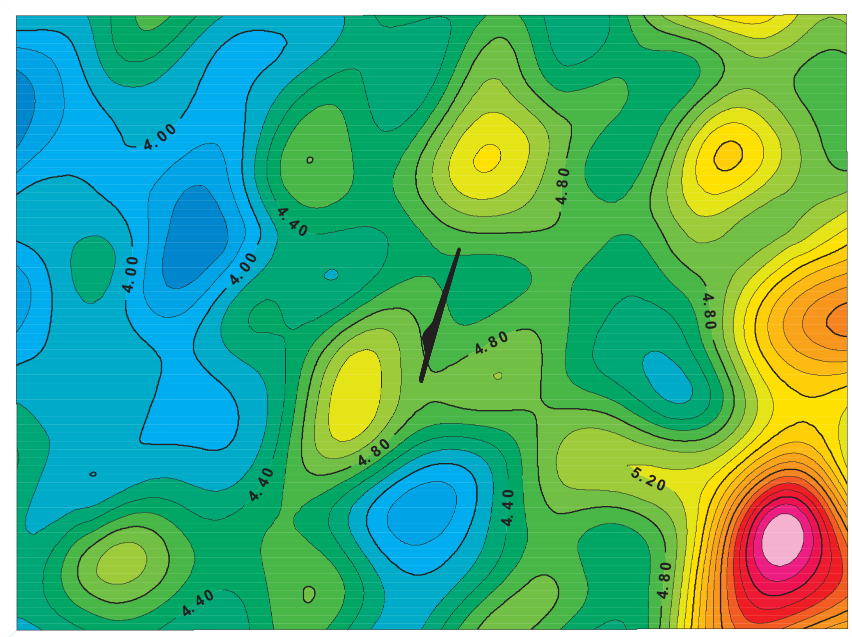
URANIUM (ppm)



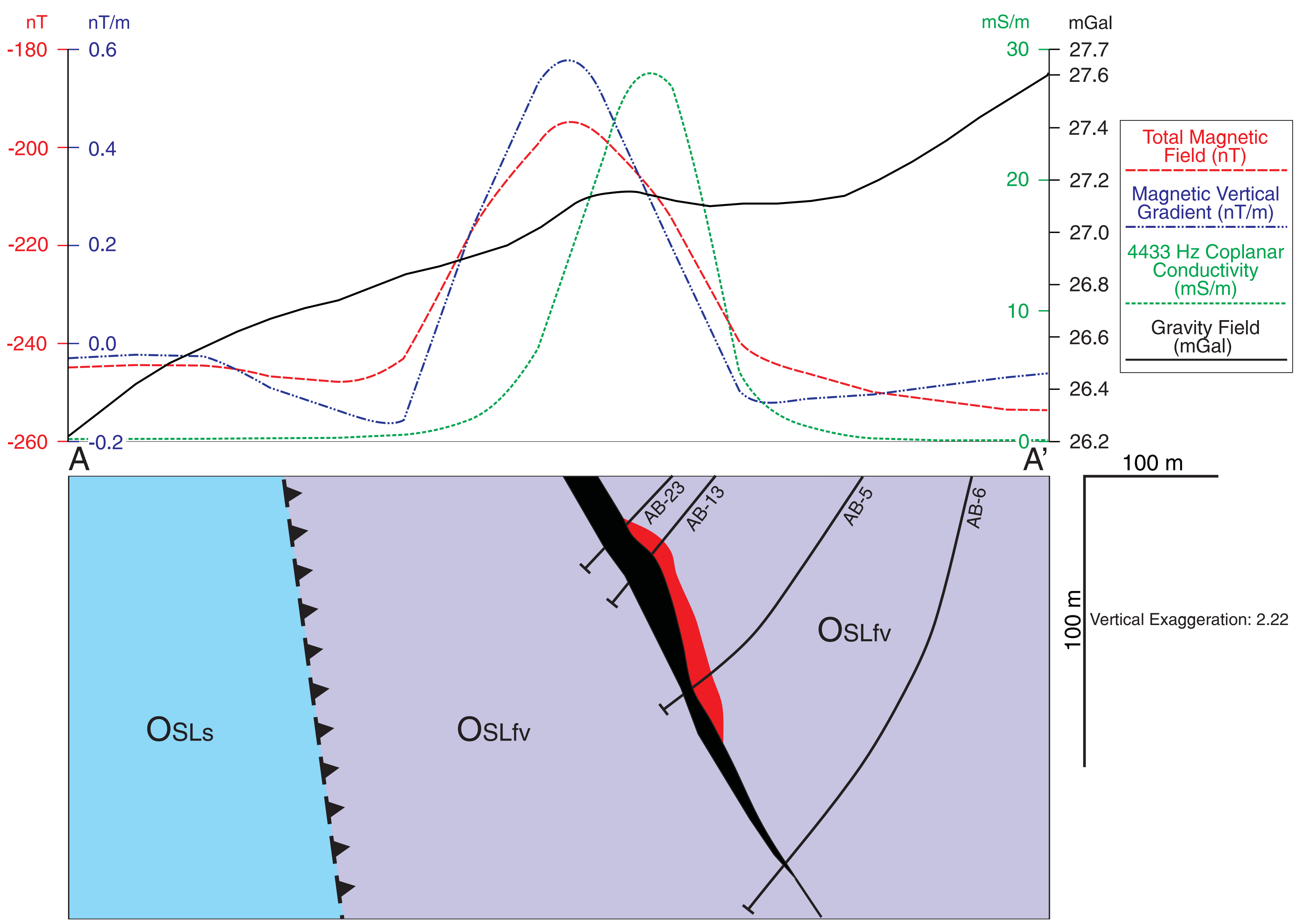
THORIUM (ppm)



THORIUM/POTASSIUM RATIO (x 10^{-4})



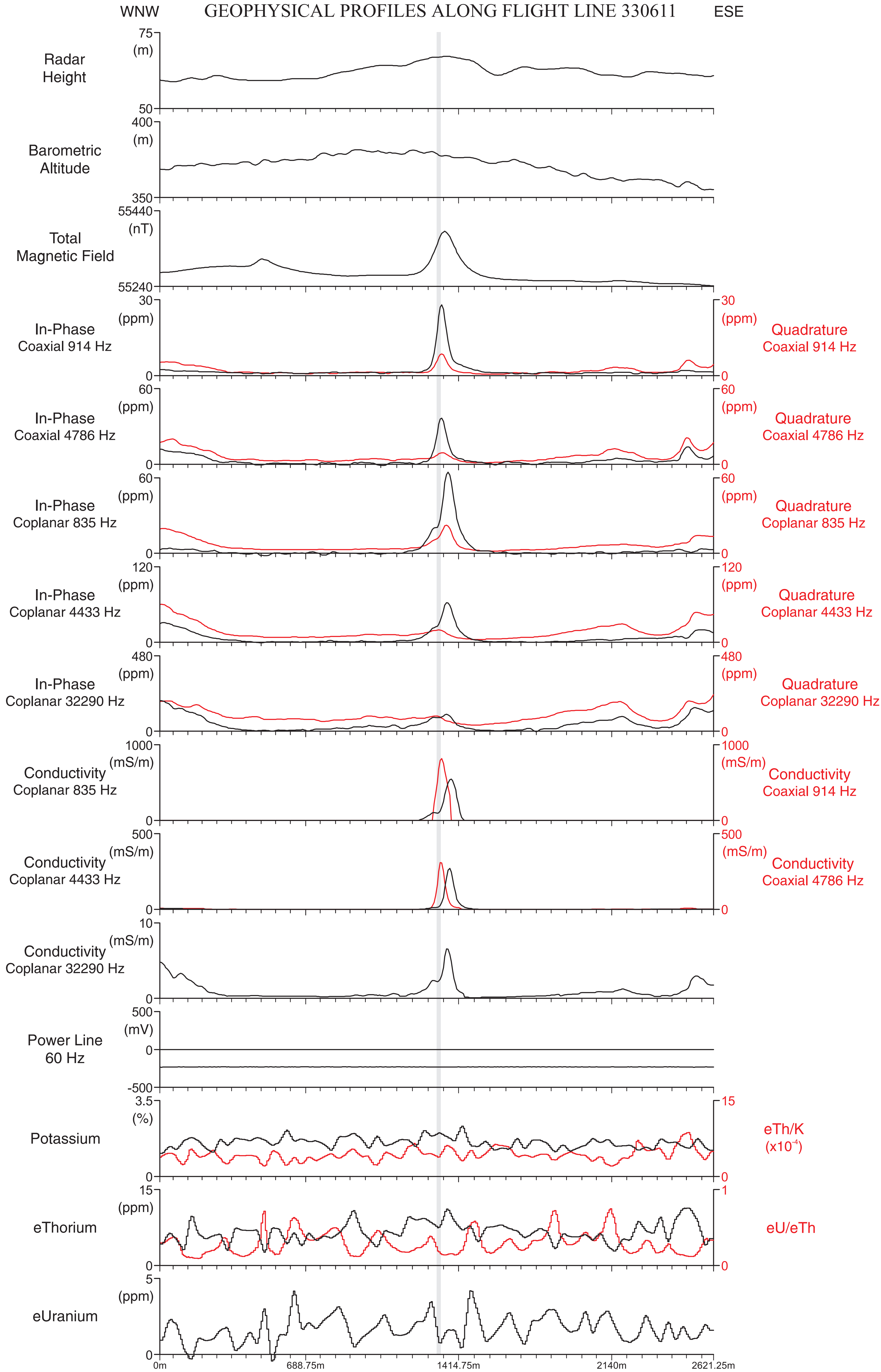
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’



Walker (Unpublished)

ARMSTRONG B

GEOPHYSICAL PROFILES ALONG FLIGHT LINE 330611



BRUNSWICK NO. 6 DEPOSIT

GEOLOGY

The Brunswick No. 6 deposit was discovered and intersected in drilling conducted by Drummond Iron Mines in 1907, but was not recognized as a potential producer of base metals until 1952, when follow-up drilling on an electromagnetic anomaly was conducted by the M.J. Boylen Prospectors Group (Belland, 1992). The deposit was mined by the open pit method from 1966 to 1980 and by underground methods from 1980 to 1983. During this time 12,125,000 tonnes grading 5.43% Zn, 2.16% Pb, 0.39% Cu and 67 g/t Ag were produced (Luff, 1995). The remaining inferred resource is calculated to be 980,200 tonnes grading 2.94% Pb, 7.97% Zn, and 0.17% Cu (Rutledge and Brooks, 1982).

The Brunswick No. 6 orebody lies at the contact between the Nepisiguit Falls Formation and overlying Flat Landing Brook Formation. The footwall rocks comprise crystal tuff with minor interbedded sedimentary material. Deeper in the footwall and along strike from the deposit, quartz and quartz-feldspar porphyritic rocks of the Nepisiguit Falls Formation lie on sedimentary rocks of the Knights Brook Formation (Miramichi Group). Intense chloritic and sericitic alteration, together with Cu-rich stringer-type mineralization, are present in the footwall of the deposit, whereas the hanging wall is relatively unaltered. The stratiform part of the deposit comprises galena, sphalerite and pyrite with infolded iron formation, and is overlain by, and laterally equivalent to, an Algoma-type iron formation that has oxide, silicate, carbonate and chert facies; the iron formation can be traced along strike for at least 20 km. A disconformable pyrrhotite-chalcopyrite stringer zone occurs at the northeast end of the deposit. Aphyric- to sparsely feldspar-phyric rhyolite flows and domes assigned to the Flat Landing Brook Formation immediately overlie the iron formation. The deposit occurs in a F_1 fold nose on the west limb of the north-trending Brunswick Antiform, which is a major F_2 fold (van Staal, 1985). These early folds are refolded by the northeast-trending F_4 Pabineau Synform.

MAGNETIC DATA

The area around the Brunswick No. 6 sulphide deposit is dominated by a strong, north-trending positive magnetic anomaly, that is roughly 700 m wide and extends laterally across several geological units. The massive sulphides, themselves, do not produce a separate, distinct magnetic signature, although they coincide with a slight eastward bulging of the magnetic contours near their northeastern extremity. This bulging becomes more pronounced farther to the northeast, and is manifested on the vertical gradient map as a subsidiary anomaly that branches off the main anomaly. The southwestern part of this branch exhibits a close correlation with the northeastern part of the deposit. The branch terminates northeastward in a distinct oval magnetic high, which can be attributed to a stringer zone containing magnetic chalcopyrite and pyrrhotite, and/or to discarded waste rock containing iron formation, extracted from the open pit (Lentz, pers. comm.). The lack of a stronger expression over the main part of the deposit itself may be attributed to two main factors: (1) the mineralogy of the deposit is dominated by relatively non-magnetic sphalerite and galena, and associated weakly magnetic pyrite (McAllister and Lamarche, 1972), and (2) removal of the shallower part of the deposit by open pit mining places the residual ore mass about 180 m below ground surface, resulting in attenuation of magnetic signal. It is speculated that the principal dominating magnetic high, which is underlain mostly by relatively non-magnetic felsic rocks, has a source in oxide-predominant facies (magnetite- and hematite-rich varieties) of iron formation in the area (Peter and Goodfellow, 1996). Even though the iron formation is restricted to a narrow band running along the axis of the anomaly, it may be more widely distributed at depth as a result of folding, and could have sufficient volume to generate the observed anomaly. The abrupt termination of the anomaly at its south end is difficult to explain in terms of the mapped geology, although a northwest-trending fault may play a role.

ELECTROMAGNETIC DATA

The HEM response of the deposit is complex and is the result of the superposition of the individual responses of the orebody, waste rock piles and cultural effects (?). The strong apparent conductivity anomaly of about 250 mS/m observed over the open pit is caused by massive sulphides. However, a strong apparent conductivity anomaly of similar amplitude located northeast of the mine corresponds to mine tailings. The north-trending conductivity anomaly in the western part of the map-area is caused by conductive shales of the Patrick Brook Formation. In general, the Flat Landing Brook Formation has no conductivity response except northwest of the open-pit mine.

Profiles of the HEM response of the deposit detected in a survey carried out in 1956 are illustrated by Pemberton (1989). The deposit produces an easily identifiable EM target. At 390 Hz the in-phase response is 550 ppm and the quadrature response is 60 ppm. The response consists of a broad, single peak anomaly, as expected from a thick orebody. The EM anomaly is caused mainly by the massive sulphides, massive pyrite and sphalerite, with little contribution from the iron formation (Brant *et al.*, 1966).

GRAVITY DATA

Gravity data illustrated here are provided courtesy of Noranda. Coverage is limited to roughly the southern third of the area and a strip along the western margin. There are no data available directly over the Brunswick No. 6 deposit. However, it is known from a gravity profile and geological section presented in Figure 19a by Slichter (1955) that the deposit produced a large pre-mining gravity anomaly of about 4.5 mGal amplitude. This anomaly is the largest sulphide-related anomaly in the Bathurst Mining Camp, although it included a small gravity effect of about 0.5 mGal amplitude caused by iron formation. The large size reflected essentially two characteristics of the body: (1) it was exposed at surface, and (2) it was relatively wide (maximum width >100 m). Its down-dip extent was about 250 m. The gravity profile was fairly symmetrical and superposed on a gentle, eastward-decreasing gradient. This aspect of the gravity field is observed on the gravity map, where Bouguer anomaly values decrease by about 4.5 mGal from west to east. Alkali basalt and gabbroic intrusions along the western margin of the area are probably the main contributors to the higher field in the west. Sedimentary rocks of the Patrick Brook Formation may also contribute. Elsewhere, the area is dominated largely by a variety of felsic rocks, which are expected to have significantly lower densities. A gabbroic intrusion, lying east of the deposit near the axis of the Brunswick Synform, has little effect on the gravity field, producing an anomaly of just a few tenths of a milligal in amplitude.

RADIOMETRIC DATA

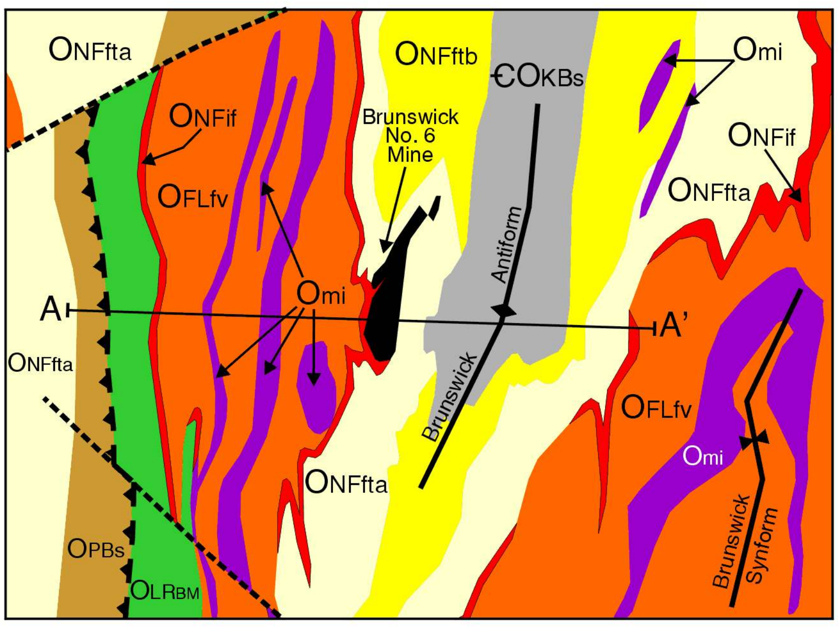
The airborne gamma-ray spectrometry patterns are strongly influenced by topography, with prominent lows on the K, eU and eTh maps corresponding to low, wet ground. This includes the elliptical low caused by the water-filled open pit, overlying the southern two-thirds of the surface projection of the massive sulphides. West of the deposit, low K and moderate eTh values produce a prominent high eTh/K ratio "bull's-eye", unrelated to mapped bedrock geology. Felsic units within Nepisiguit Falls and Flat Landing Brook formations generally produce elevated airborne K, eU and eTh values, with highs of 1.8%, 2.7 ppm, and 9 ppm, respectively, related to increased bedrock exposed by mining/exploration activities. Alkali basalts within the Little River Formation are coincident with the north-trending, eTh (<6 ppm) and eTh/K ratio ($<5 \times 10^{-4}$) lows west of the deposit. Low, wet ground in this area may also contribute to the lower concentrations. Ground spectrometry (Lentz, 1994; Shives and Ford, in press) clearly reflects known K depletion in proximity to massive sulphides, due to the progressive albite-sericite-chlorite alteration of alkali feldspar in the footwall of the Brunswick No. 6 deposit. However, this alteration signature is not apparent in the airborne data.

SUMMARY

The Brunswick No. 6 deposit correlates closely with the southwestern part of a prominent axial region of a broad conductivity anomaly. Tailings from the open pit correspond with the offset northeastern extension of the axis. The deposit produced a very large 4 mGal amplitude gravity anomaly before it was mined. Although positioned on a major magnetic anomaly it appears to lack its own magnetic signature, though its northeast extremity is associated with a small magnetic high, that continues beyond the deposit, where it may be related to stringer mineralization, and/or waste rock and/or tailings. Any radiometric signatures that might be present are masked by the signature of water in the open pit, and are potentially affected by excavation of overburden within and around the pit.

BRUNSWICK No. 6

GEOLOGY



Modified from van Staal (1994c)

GEOLOGICAL LEGEND

Omi gabbro

TETAGOUCHE GROUP

Little River Formation

OLRBM Brunswick Mines Member: alkali basalt

Flat Landing Brook Formation

OFLfv rhyolite domes, flows & related pyroclastic rocks

Nepisiguit Falls Formation

ONFif iron formation

massive sulphides

ONFfta crystal tuffs

ONFftb quartz-eye schist

MIRAMICHI GROUP

Patrick Brook Formation

OPBs shale & quartzose-feldspathic sandstones

Knights Brook Formation

ЄOKBs sandstone & siltstone interlayered with black shale

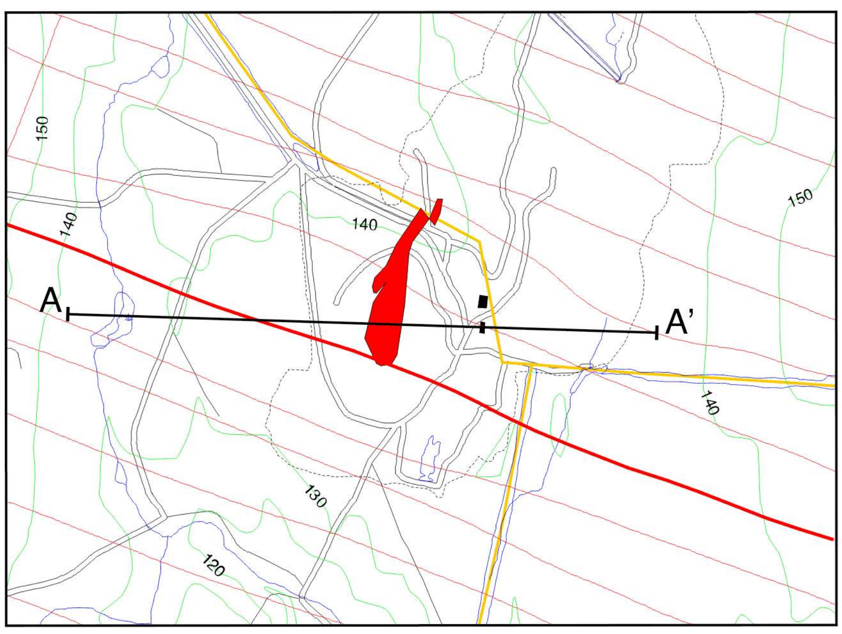
thrust fault

normal fault

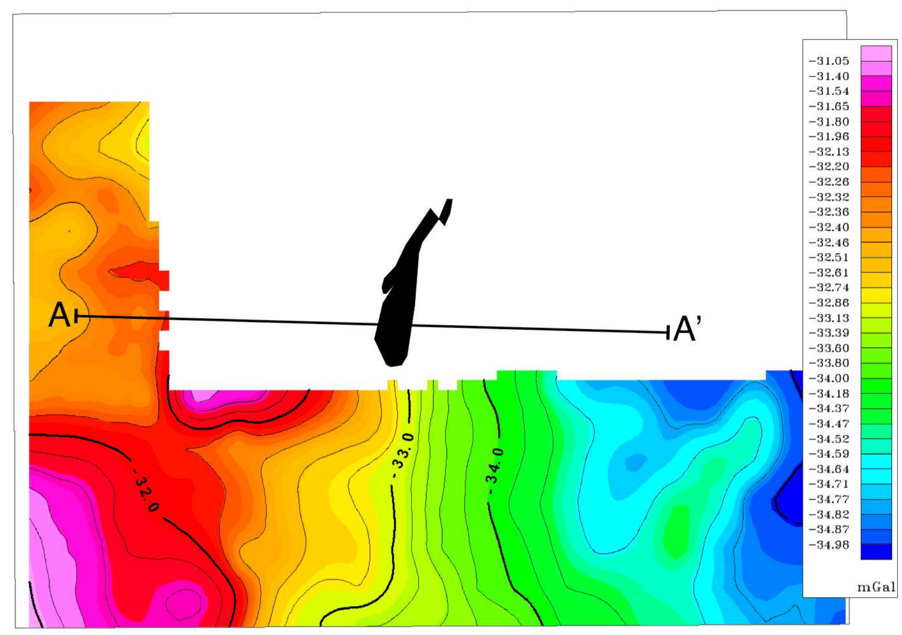
antiformal fold axis

synformal fold axis

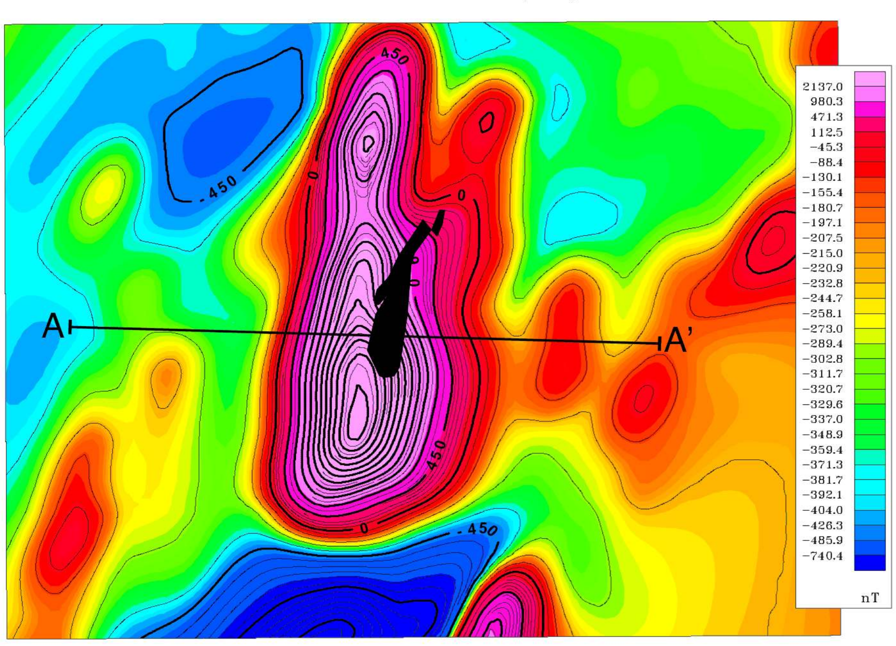
TOPOGRAPHY/FLIGHT LINES



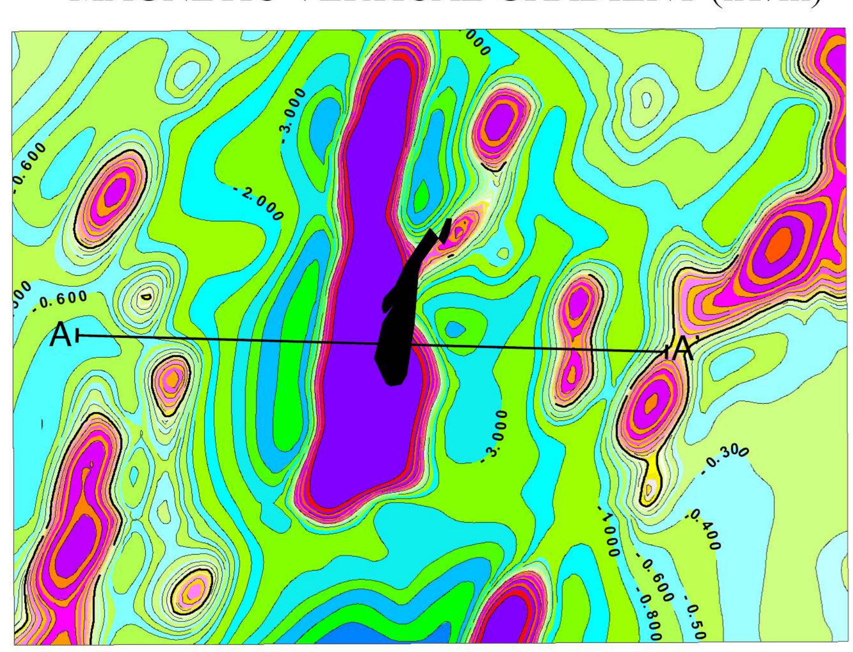
GRAVITY (mGal)



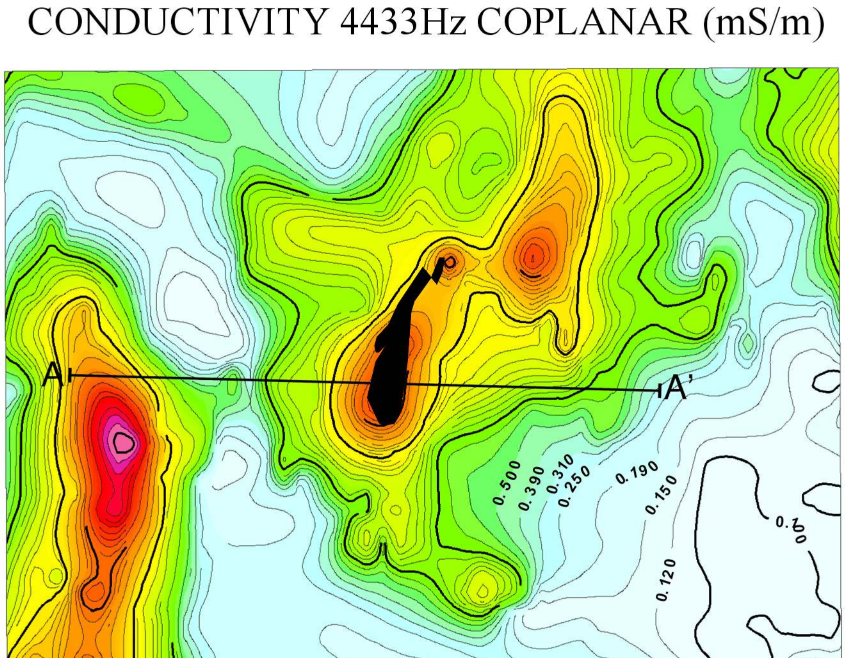
MAGNETICS (nT)



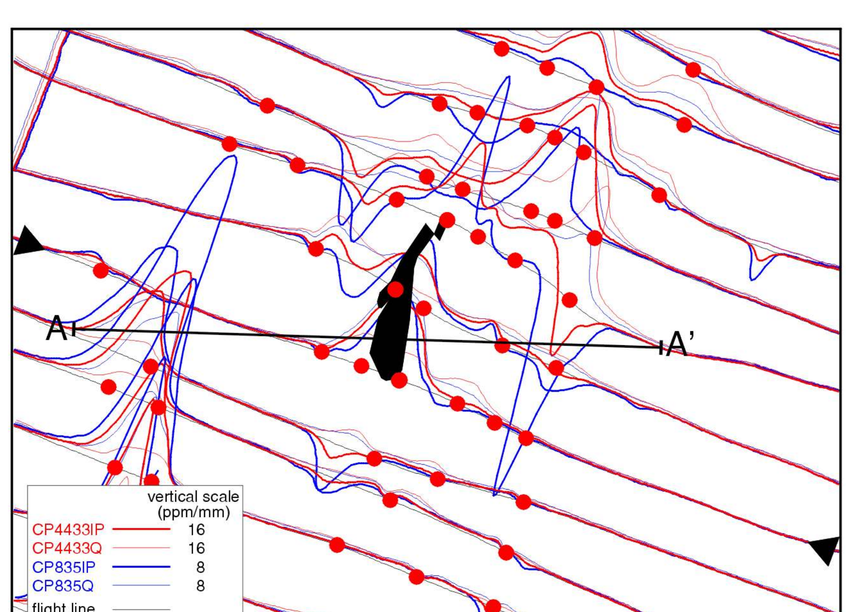
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



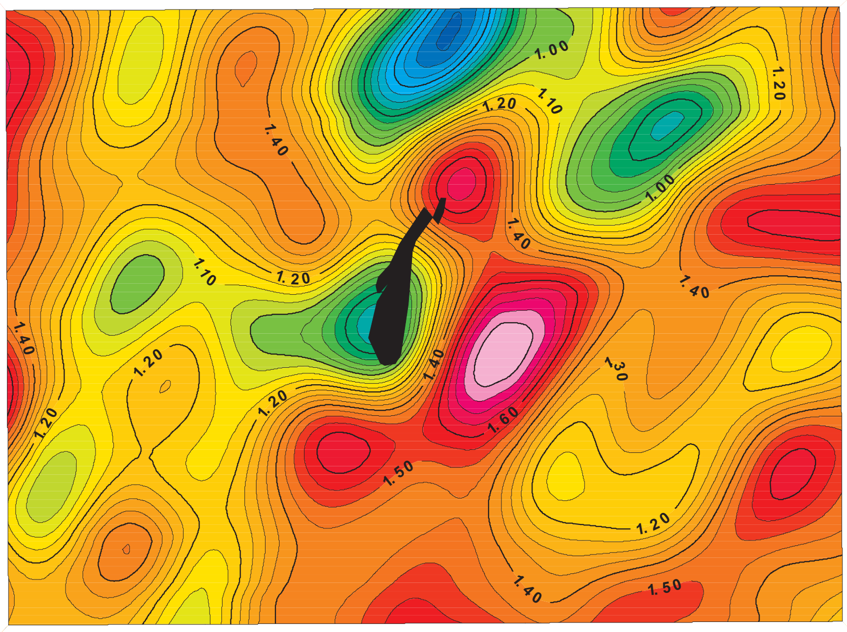
ELECTROMAGNETIC PROFILES/ANOMALIES



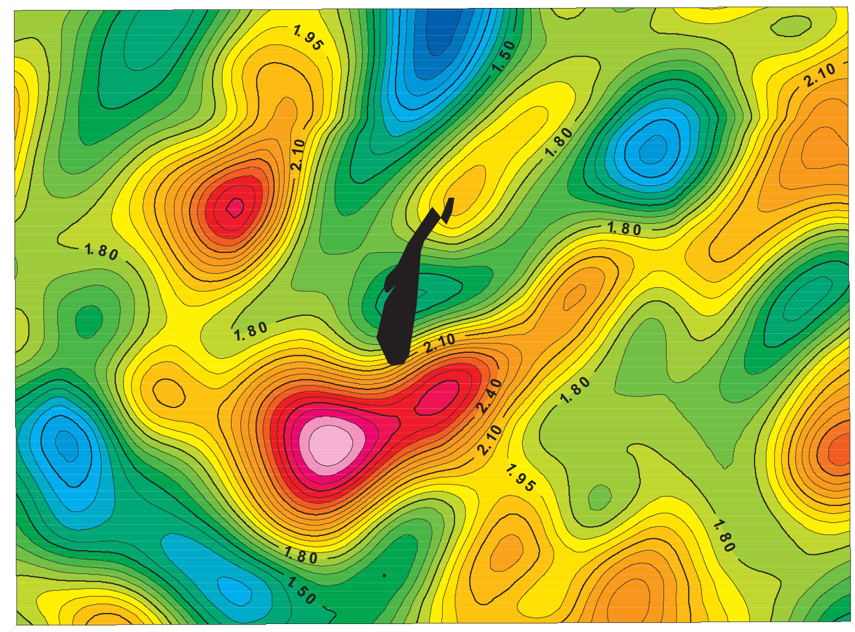
1000 m

BRUNSWICK No. 6

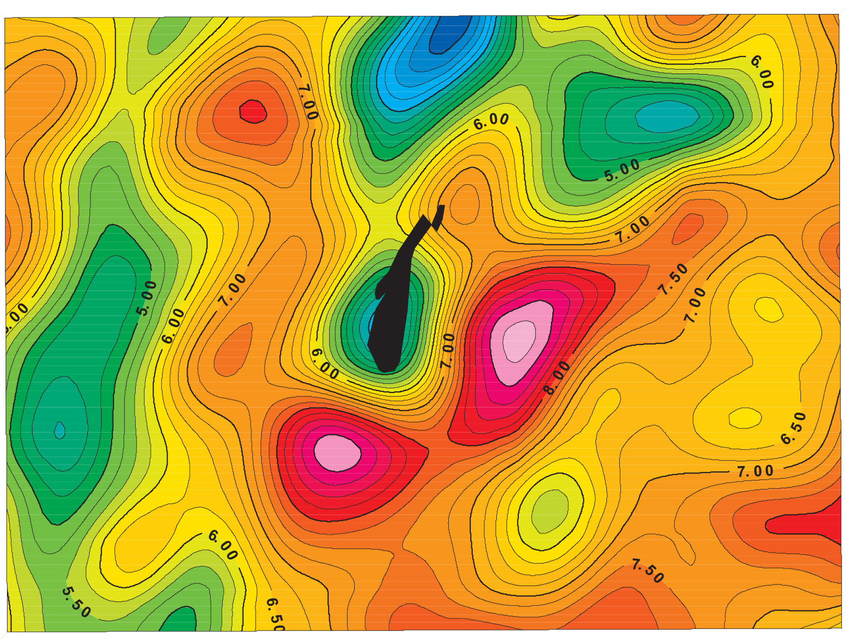
POTASSIUM (%)



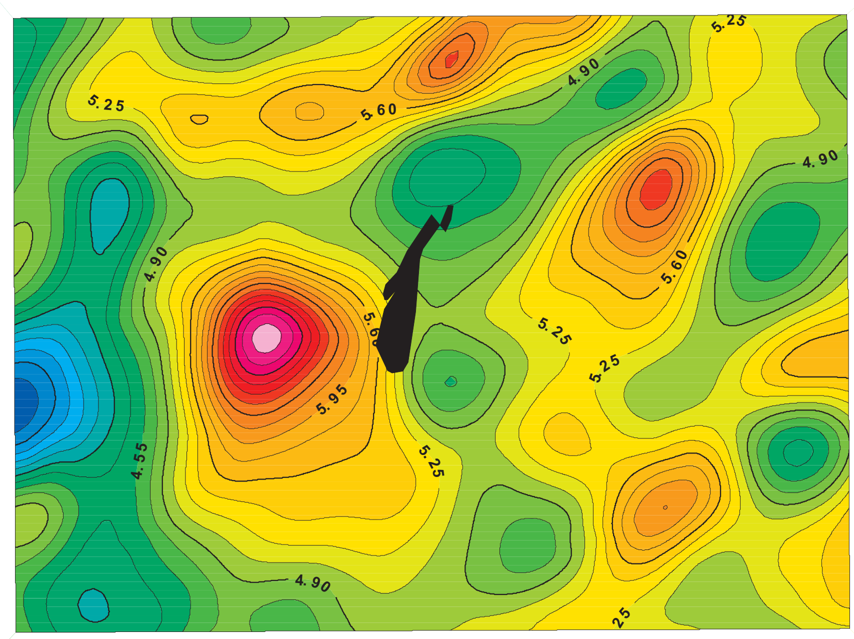
URANIUM (ppm)



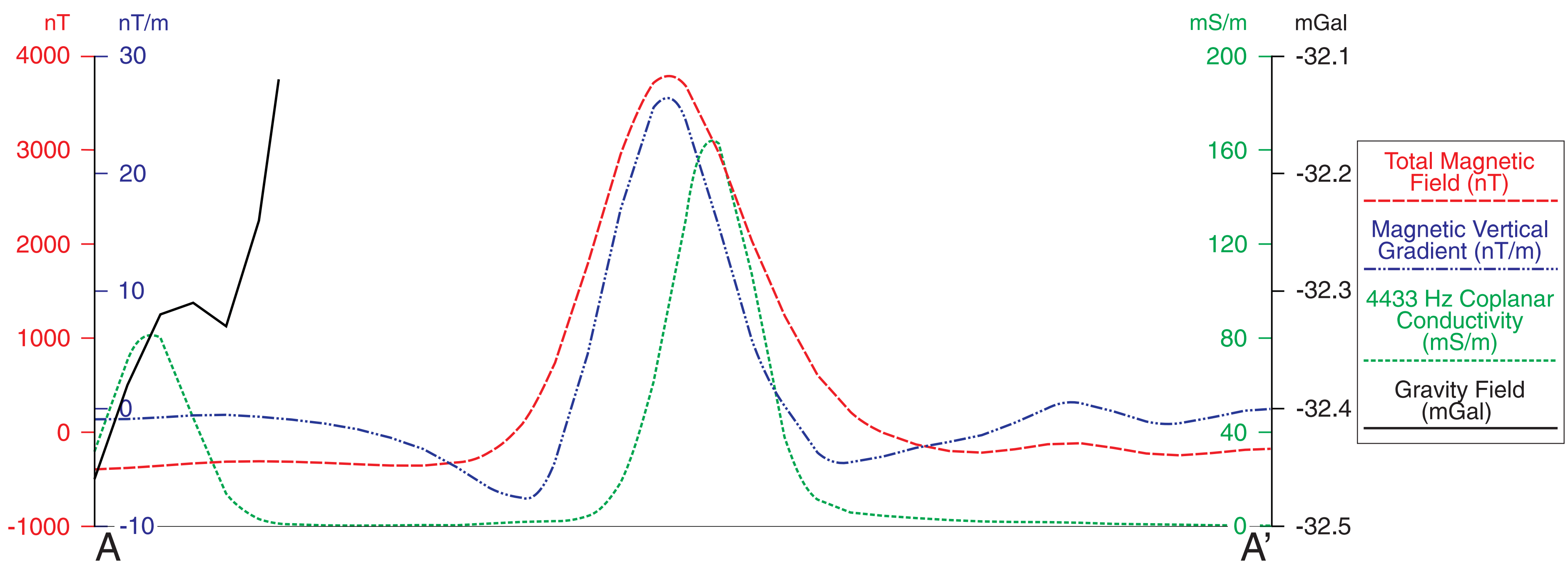
THORIUM (ppm)

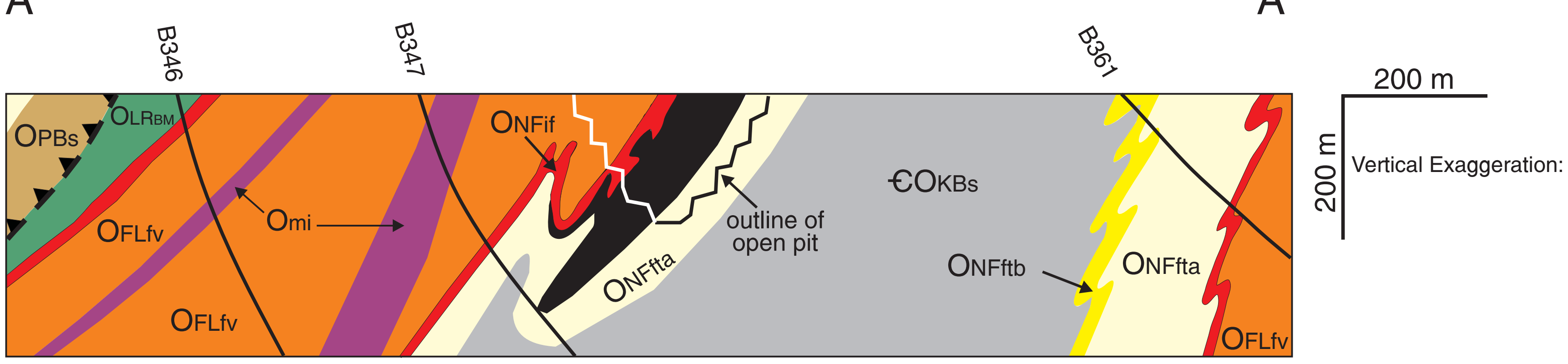


THORIUM/POTASSIUM RATIO (x 10^{-4})



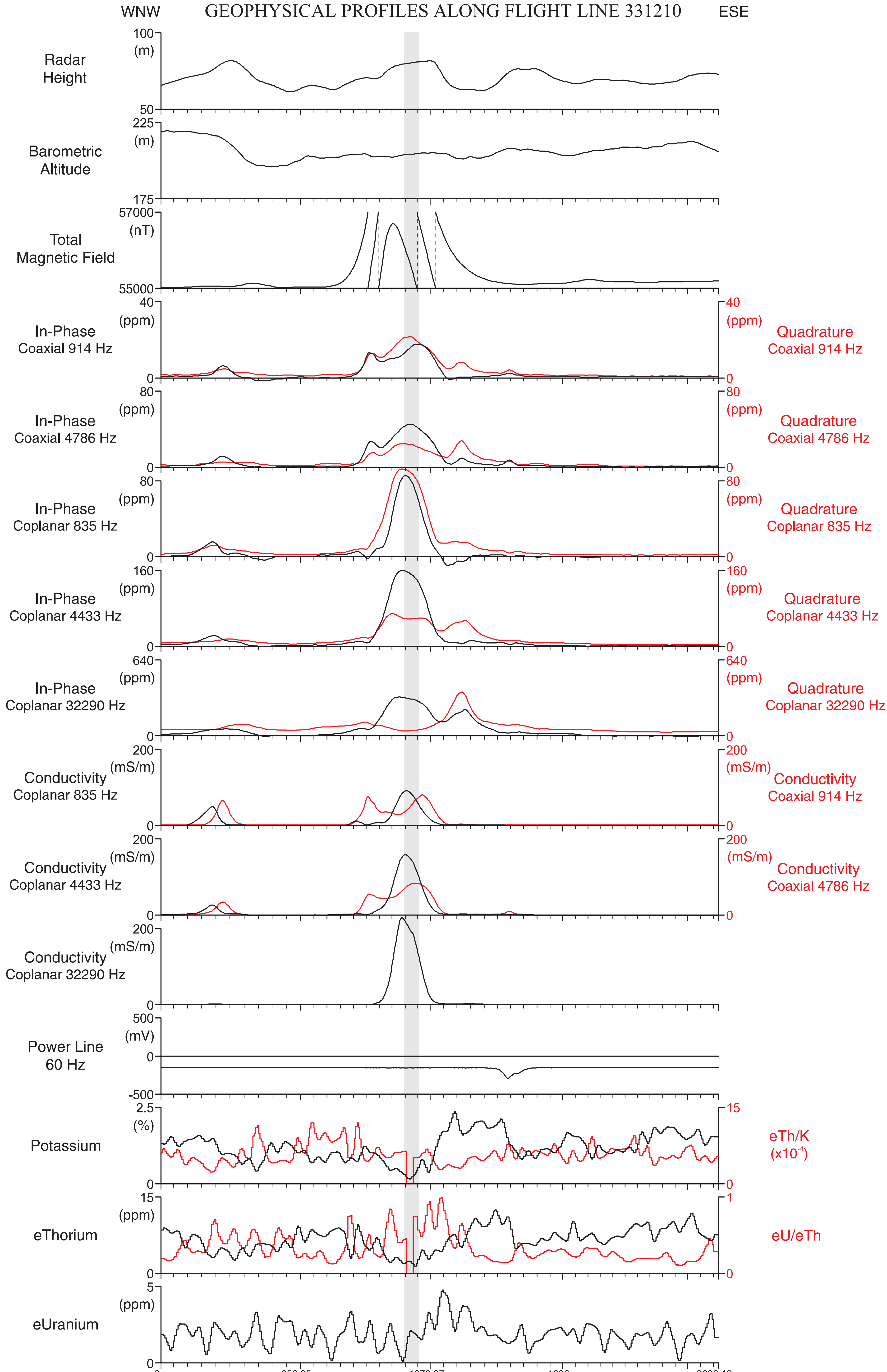
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’





McCutcheon (Unpublished)

BRUNSWICK No. 6



BRUNSWICK NO. 12 DEPOSIT

GEOLOGY

The Brunswick No. 12 orebody was discovered by the M.J. Boylen Company in 1953 during follow-up work on airborne EM anomalies (MacKenzie, 1958). The deposit is presently controlled by Noranda and has been in production since 1964. To 1994 total production from Brunswick No. 12 has been 75,169,000 tonnes grading 8.81% Zn, 3.51% Pb, 0.33% Cu and 98 g/t Ag (Luff, 1995). According to Noranda's 1997 annual report, remaining drill-indicated reserves at the No. 12 mine are 46.65 million tonnes grading 3.61% Pb, 9.08% Zn and 0.33% Cu.

The deposit lies just below the contact between the Nepisiguit Falls Formation and overlying Flat Landing Brook Formation. Footwall rocks comprise crystal tuff with minor interbedded ash tuff and epiclastic rocks. Deeper in the footwall and along strike from the deposit, quartz and quartz-feldspar porphyritic rocks of the Nepisiguit Falls Formation overlie Miramichi Group rocks, *i.e.* sedimentary rocks of the Knights Brook Formation. The massive sulphide lens is capped by and laterally equivalent to an Algoma-type iron formation, which to the north is overlain by fine-grained clastic rocks (Nepisiguit Falls Formation), and to the south is overlain by hyalotuff of the Flat Landing Brook Formation. The Flat Landing Brook Formation passes upward into alkalic basalts (Brunswick Mines Member, Little River Formation).

A footwall feeder zone has been recognized by Luff *et al.* (1992), but intense deformation has transposed the stringer zone so that it is subparallel to the massive sulphide lens. In proximity to this feeder zone, chloritic alteration is intense and feldspar has been completely destroyed. The Brunswick No. 12 orebody has been structurally thickened because of the interference of D_1 and D_2 folds. The result of this fold interference is that the plunge direction of the orebody reverses at depth.

MAGNETIC DATA

Two conspicuous, roughly oval-shaped magnetic highs occur in the vicinity of the Brunswick No. 12 sulphide deposit, along the eastern margin of a major, north-trending positive anomaly associated with a broad unit of alkali basalt. These three anomalies are particularly well distinguished on the vertical gradient map. Where it intersects ground-surface, much of the deposit coincides with the south end of the northern oval anomaly, which has an amplitude of about 350 nT. Belland (1992) notes that discovery of the Brunswick No. 12 deposit is related to staking of a magnetic anomaly outlined on maps published by the Geological Survey of Canada in 1951. A buried extension of the deposit towards the south-southeast is generally associated with more subdued values of the magnetic field, though it does touch on the southern oval anomaly. Depth of burial, roughly 60 m deep in section A-A', probably contributes to attenuation of the magnetic signal. Changes in sulphide mineralogy may also be an influence, since minerals such as pyrite, chalcopyrite, pyrrhotite, sphalerite and galena are present in varying concentrations, depending on the zone (Luff *et al.*, 1992). Magnetite has also been noted in one zone, and is present in an iron formation that overlies the sulphide horizon. The iron formation occurs in a narrow band extending south and north from the deposit, yet with the possible exception of a positive anomaly near the northern border of the map-area, it does not appear to have a positive magnetic expression. Notwithstanding the partial correlation of the deposit with a distinct magnetic high, the full significance of the two oval highs, whose axes tend to lie east of the deposit over predominantly felsic volcanic rocks having low magnetic susceptibility, remains to be determined. The southern oval anomaly embraces an area of mining operations that includes buildings and holding tanks, raising the possibility of magnetic contributions from cultural sources.

ELECTROMAGNETIC DATA

The Brunswick No. 12 HEM response is influenced by the tailings ponds, to the east of the deposit, and the mine installations. The conductivity of the tailings ponds attains more than 100 mS/m, and the conductivity anomaly clearly outlines their limits. A strong conductivity anomaly, greater than 100 mS/m, is observed over, and is attributed to, the mine installations. The in-phase and quadrature traces at low frequencies and at coplanar mid frequency are noisy, due to 60 Hz contamination from the neighbouring power lines. There is, nevertheless, a sharp conductivity response at all frequencies directly over the orebody. In-phase responses are sharp and strong, conductive responses are slightly above background level. The offset between the conductivity maxima calculated from the co-axial and coplanar coils is diagnostic of a dipping orebody. Negative in-phase responses are observed at all frequencies west of the mine, their locations corresponding to a strong magnetic anomaly located within the Brunswick alkali basalt. Such responses are indicative of a high magnetite content, which is corroborated by the presence of the magnetic high.

GRAVITY DATA

Gravity data displayed here are provided courtesy of Noranda. The Brunswick No. 12 deposit sits on the eastern flank of a prominent north-trending gravity high that is clearly related to alkalic basalt of the Brunswick Mines Member. Density measurements on drill core from the vicinity of the deposit indicate sections of basalt having average densities ranging typically from about 2.90 to 2.98 g/cm^3. These contrast with much lower values, ranging from 2.75 to 2.85 g/cm^3, for a variety of sedimentary rocks, crystal tuff, quartz-porphyry and quartz-eye schist logged in core extracted east of the basalt unit. Average densities for sections of massive sulphides forming the Brunswick No. 12 deposit range from about 3.90 to 4.35 g/cm^3. The effect of this dense mass on the gravity field is to produce a discernible local anomaly on the flank of the basalt-related gravity high, manifested in a distinct eastward bulging and a local closure of the contours. The anomaly is restricted to the immediate area around the surficial configuration of the orebody, and has limited extent along geological strike. High-pass filtering of the Bouguer gravity map produces a roughly oval-shaped residual gravity high, coincident with the deposit, and having an amplitude of approximately 1 mGal. In this type of geological setting, where mafic igneous rocks may produce pronounced positive gravity anomalies, discrimination of those anomalies likely to have an association with sulphide mineralization may prove difficult.

RADIOMETRIC DATA

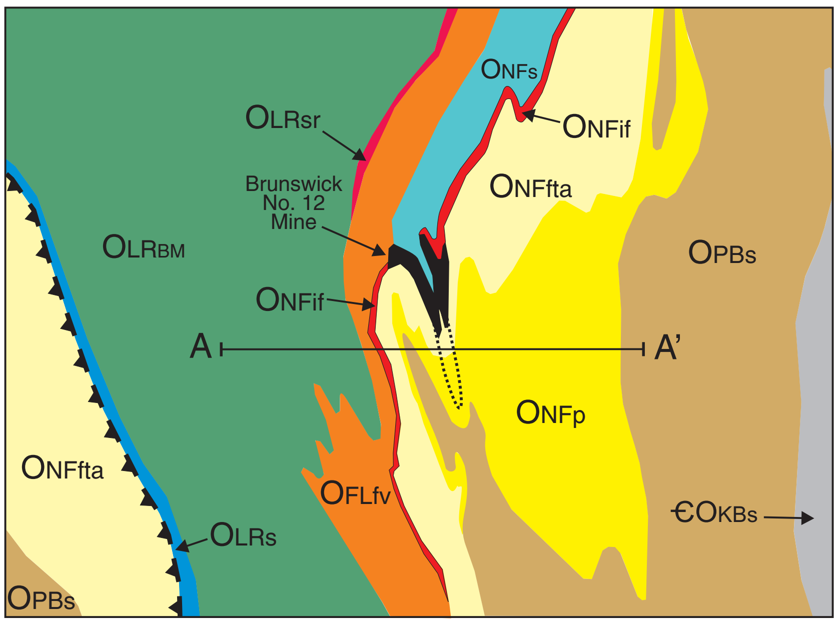
Airborne radioelement patterns in the vicinity of the Brunswick No.12 mine reflect regional scale contrasts between mafic and felsic volcanic units. West of the deposit, alkali basalts assigned to the Brunswick Mines Member (Little River Formation) produce lows on all three radioelement maps (<1.2 %K, <1.6 ppm eU, <6.0 ppm eTh). In contrast, felsic rocks to the east and west of the basalts are associated with increased radioelement concentrations (1.2 - 1.8% K, 1.6 - 2.3 ppm eU, 6.0 - 7.8 ppm eTh). Although K and eTh patterns over the Flat Landing Brook and Nepisiguit Falls formations are similar, the former formation appears to be associated with slightly lower eU values. Water within a settling/tailings pond produces a large low in the northeast corner of all radioelement maps. Poor counting statistics in these very low-count areas prevents calculation of reliable ratio values, thus data have been removed from the eTh/K ratio map in this area. Other low, swampy areas produce low radioelement patterns and a related eTh/K high, which extends southward from the northwest corner of the map area.

SUMMARY

The surface distribution of the Brunswick No. 12 deposit is marked by discrete local magnetic and gravity highs, though in both cases these are overshadowed by larger and more extensive anomalies related to alkalic basalt. Filtering of the respective fields is required to bring them into focus. The deposit sits on a much broader and extensive conductivity anomaly that probably includes responses from several sources: the deposit itself, tailings ponds east of the deposit, the mine installations and sedimentary rocks of the Patrick Brook Formation. Deposit-related radiometric signatures, apparently, are not present.

BRUNSWICK No. 12

GEOLOGY



Modified from van Staal (1994c)

GEOLOGICAL LEGEND

TETAGOUCHE GROUP

Little River Formation

- OLRs — mainly shale interstratified with feldspathic sandstone & siltstone
- OLRBM — Brunswick Mines Member: alkalic basalt; OLRsr - red shale

Flat Landing Brook Formation

- OFLfv — mainly felsic hyaloclastites, minor domes & sills

Nepisiguit Falls Formation

- ONFif — iron formation
- massive sulphide (> 6% Pb+Zn)
- massive pyrite (pyrrhotite +/- Cu)
- ONFfta — crystal tuff

Nepisiguit Falls Formation Ctd.

- ONFs — chloritic siltstone & ash-tuff
- ONFp — quartz-feldspar porphyry

MIRAMICHI GROUP

Patrick Brook Formation

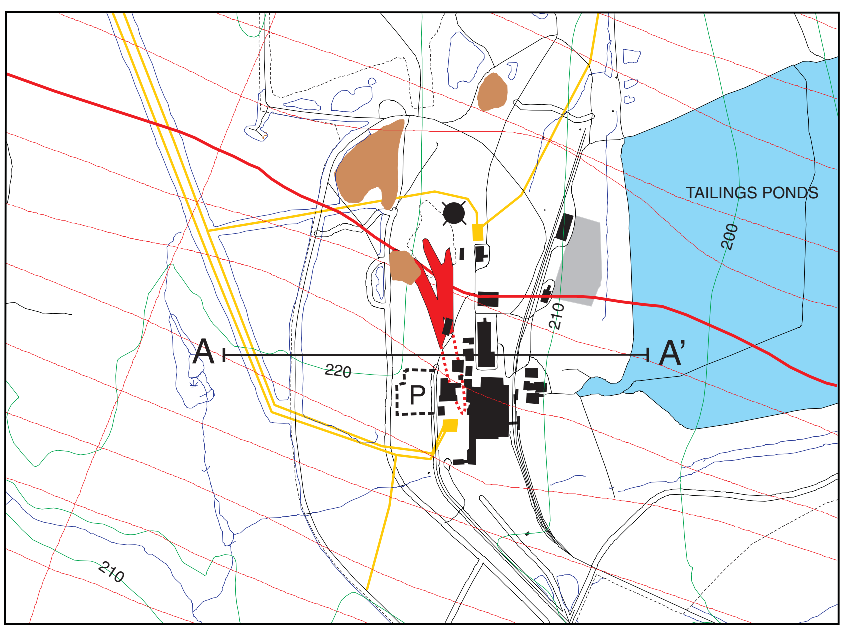
- OPBs — shale & quartzose-feldspathic sandstone

Knights Brook Formation

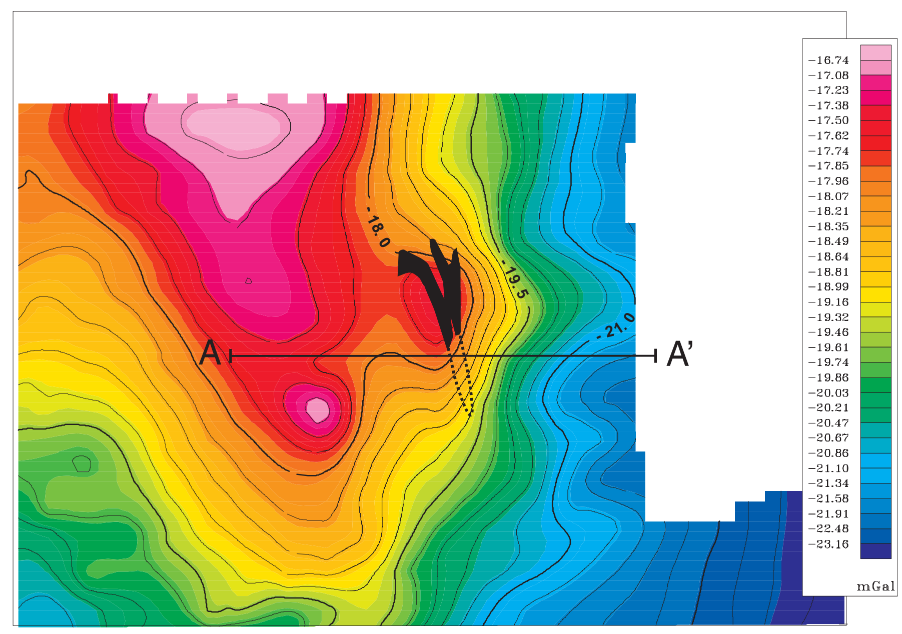
- €OKBs — mainly quartz-rich sandstone &/or siltstone interstratified with shale

- normal fault
- thrust fault
- fold axis
- sulphides projected to surface

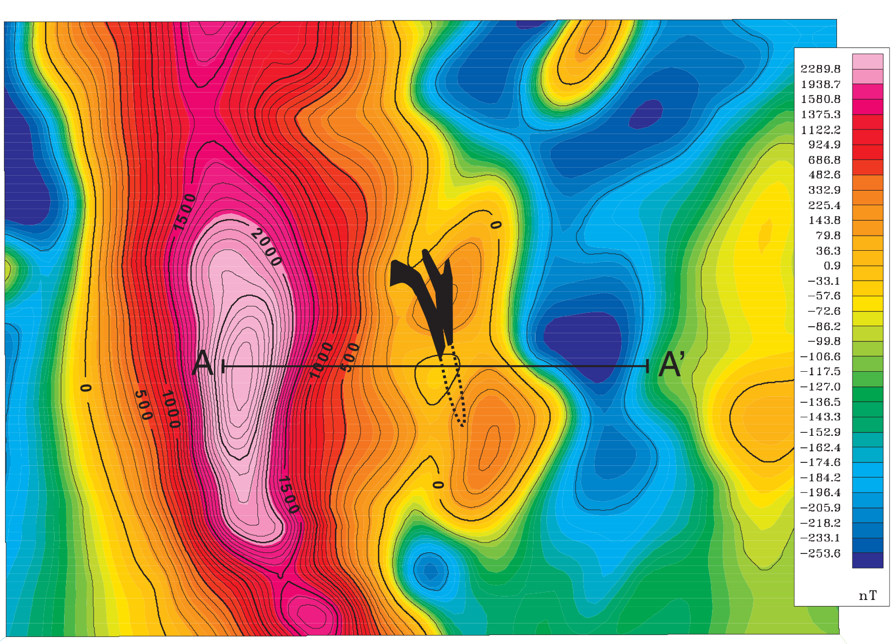
TOPOGRAPHY/FLIGHT LINES



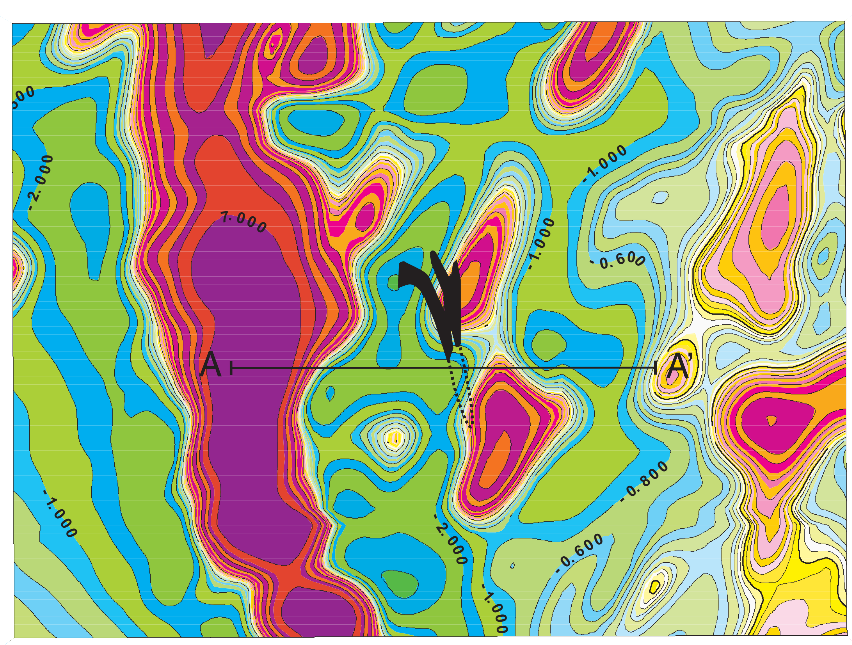
GRAVITY (mGal)



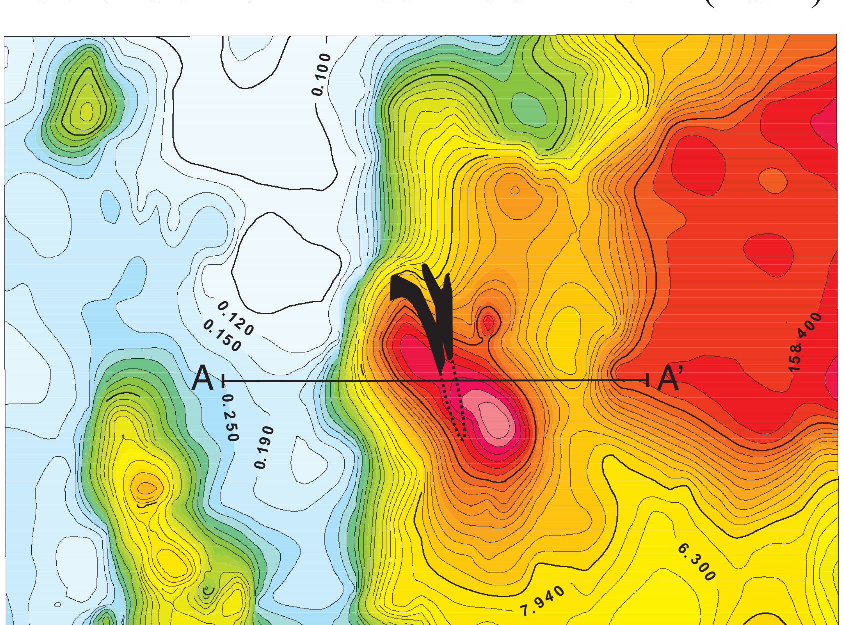
MAGNETICS (nT)



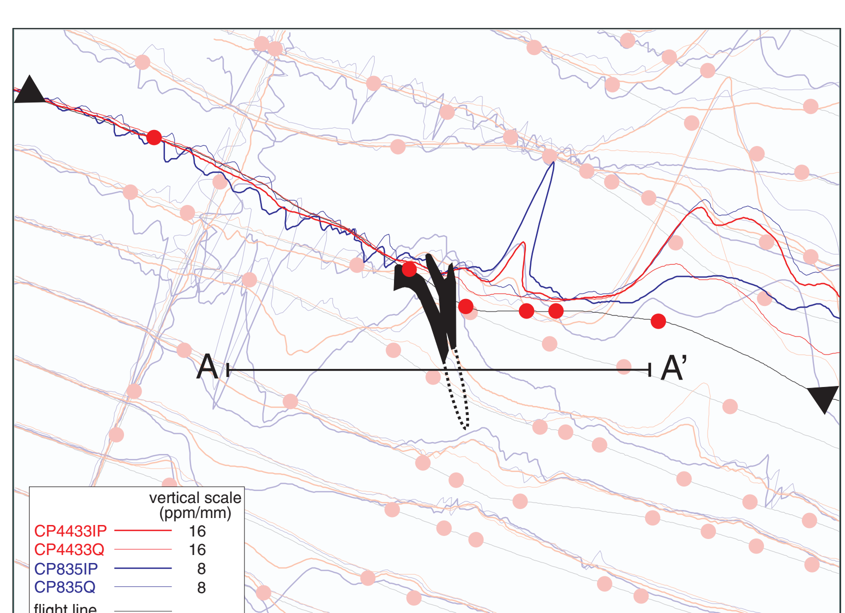
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



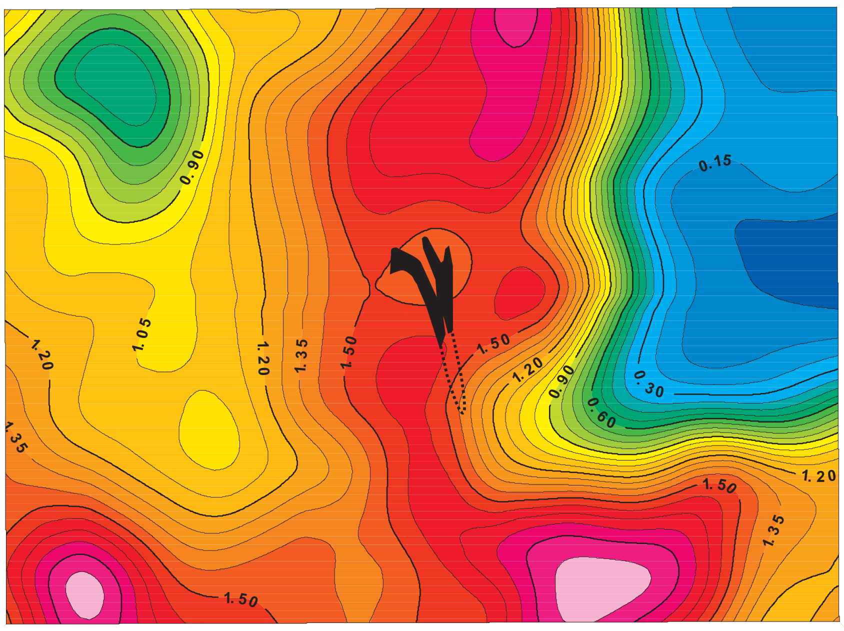
ELECTROMAGNETIC PROFILES/ANOMALIES



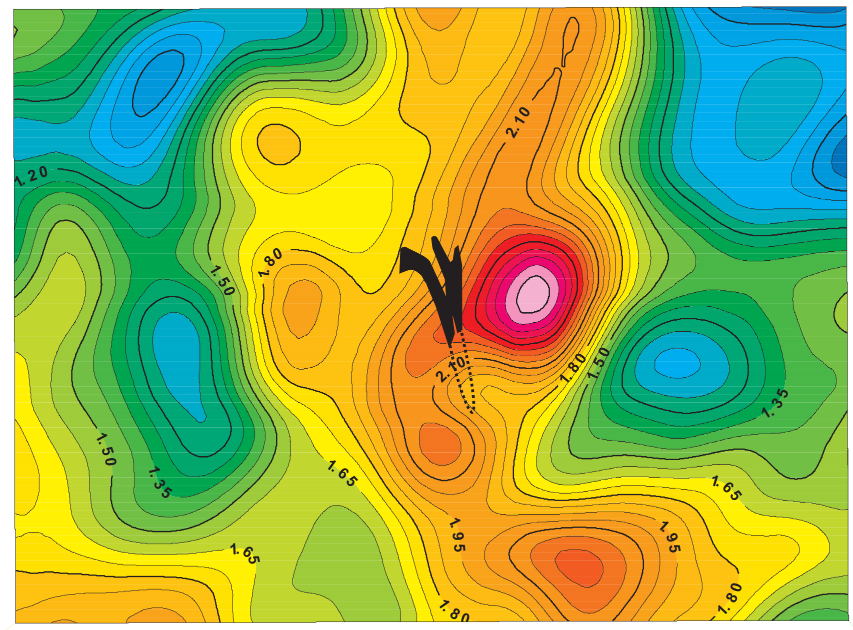
1000 m

BRUNSWICK No. 12

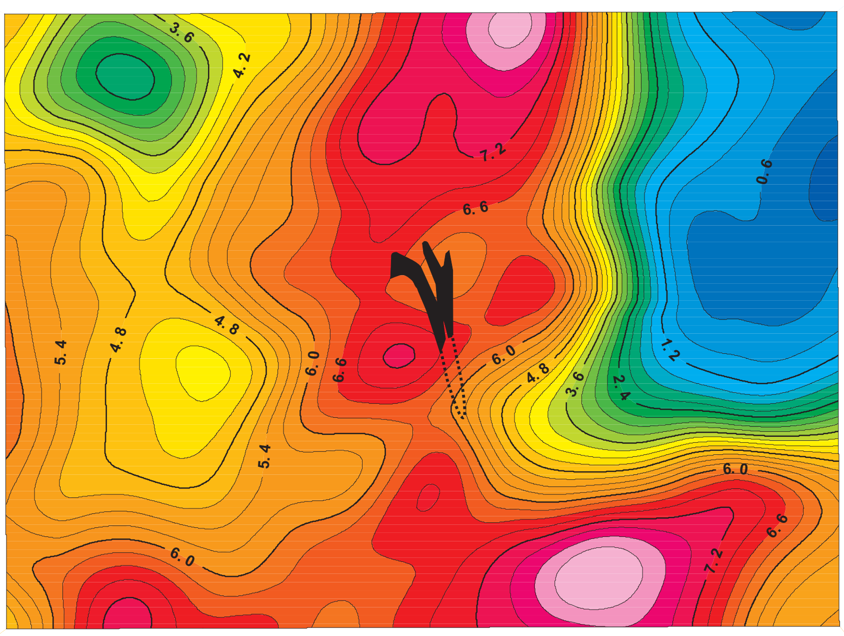
POTASSIUM (%)



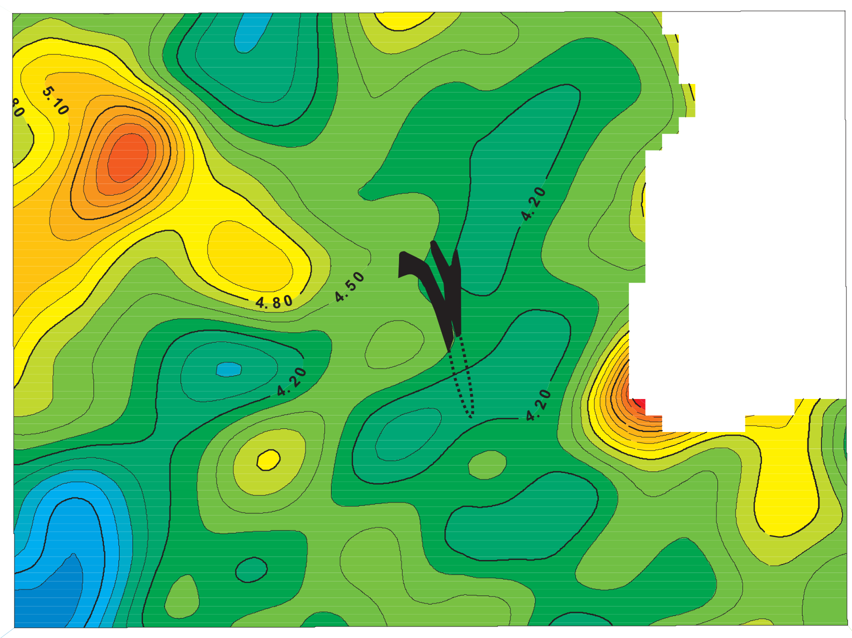
URANIUM (ppm)



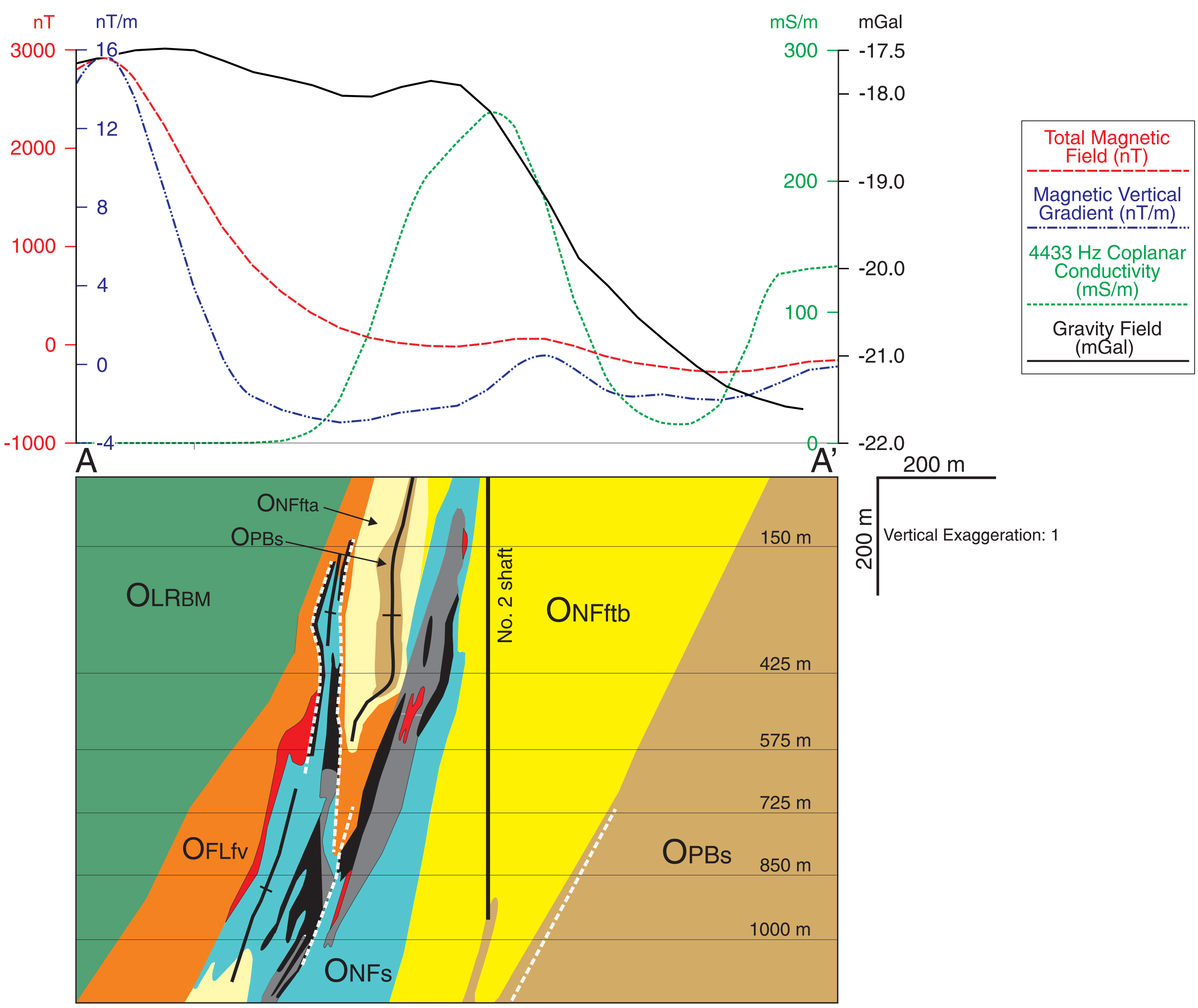
THORIUM (ppm)



THORIUM/POTASSIUM RATIO (x 10^{-4})

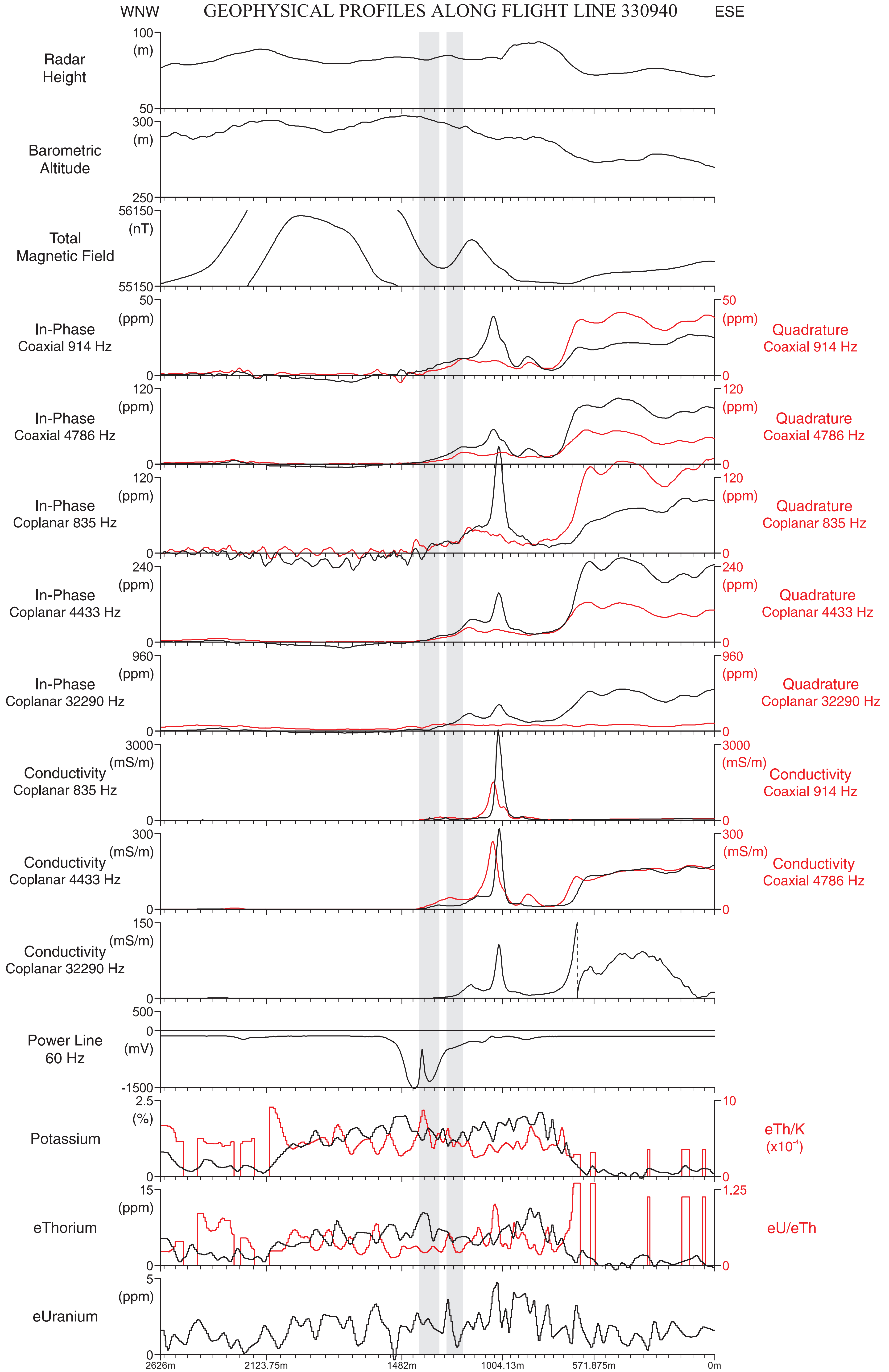


GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’



Modified from Luff et al. (1992)

BRUNSWICK No. 12



CAMEL BACK DEPOSIT

GEOLOGY

The Camel Back deposit was discovered by Noranda in 1997 during follow-up work on conductivity and magnetic anomalies outlined by the EXTECH-II airborne geophysical survey. The deposit is located approximately 7 km south of the Caribou deposit, near the axis of the Tetagouche Antiform. Rough estimates based on a 125 m strike length, 100 m down-dip extent and average thickness of 4 m, suggest a 200,000 tonne massive sulphide body grading between 5 and 7% Zn (Carroll, pers. comm.).

The deposit is hosted by felsic tuffs and epiclastic volcanic rocks that are interpreted to belong to the upper part of the Nepisiguit Falls Formation, although they are difficult to distinguish from the lower part of the Flat Landing Brook Formation in this area. Like other deposits at the boundary between the Nepisiguit Falls and Flat Landing Brook formations an Algoma-type iron formation is spatially associated with this deposit, at least locally, and was exposed in one or two trenches by Noranda (Carroll, pers. comm.). The deposit is deformed by tight to isoclinal (F_2) folding, and recumbent F_3 folding. The deposit may also be affected by late normal faulting. The sulphide mineralogy in order of decreasing abundance comprises pyrite, sphalerite, chalcopyrite, galena and minor pyrrhotite. Intense chloritic alteration containing chalcopyrite-pyrite ± pyrrhotite stringer mineralization envelops the massive sulphide lens, and is interpreted to represent a cross-cutting feeder zone that has been transposed by folding.

MAGNETIC DATA

The Camel Back deposit sits in the centre of a conspicuous, roughly circular, positive total magnetic field anomaly, which is superposed on a gently sloping background field that increases by about 30 nT from west to east across the area. The amplitude of the anomaly is about 14 nT. The anomaly is generated, most probably, by magnetite iron formation, with a possible contribution from pyrrhotite in stringer mineralization. A small "tail" trending initially south and then southwest from the anomaly is attributed to magnetite-bearing, hydrothermally-altered, fine-grained volcanic and volcaniclastic rocks (Carroll, pers. comm.). Most of the area surrounding the deposit is dominated by a variety of felsic volcanic rocks that are very weakly magnetic and do not cause significant perturbations in the magnetic field. Nevertheless, some influence is indicated by magnetic contours that trend northeast-southwest, parallel to geological strike, in the northwest part of the area. Mafic volcanic rocks of the Moody Brook Member, apparently, are virtually non-magnetic, the single unit in the area showing no compatibility with the pattern of magnetic contours. Two other "bull's-eye" magnetic highs occur near the deposit, one to the north, the other to the southwest. Their amplitudes are estimated to be about 10 nT and 8 nT, respectively. From an exploration perspective, their potential as signatures of sulphide mineralization seems somewhat limited, since there are no coincident conductivity anomalies.

ELECTROMAGNETIC DATA

No EM response is observed on the low-frequency coaxial coils, and weak in-phase and quadrature responses of about 4 ppm above the background are observed on the mid-frequency coaxial coils. On the coplanar coils, at low frequency, there is no in-phase response, but a quadrature response of about 10 ppm is readily identifiable. Mid-frequency in-phase and quadrature coplanar responses are 17 and 28 ppm, respectively. At high frequency there is a strong and broad response clearly related to the deposit, however, part of this response is also caused by the overburden. The EM anomaly can be modelled by a thin plate having a conductance of 3 S and dipping 45° south. The axis of the conductor is oriented at an angle of 30° to the flight-line. The plate has a strike-length of 125 m and a depth extent of 100 m. A host rock conductivity of 0.33 mS/m was used in the model. There is a clear association between the EM and magnetic anomalies. A smaller EM anomaly located about 150 m to the southwest of the discovery anomaly has no associated magnetic anomaly and remains unexplained.

GRAVITY DATA

The gravity data for the area of the Camel Back deposit were acquired from Noranda, and are based on measurements made at intervals of 25 m along sixteen lines spaced generally about 100 m apart. The deposit coincides with the peak of a relatively broad, arcuate gravity high located approximately between the two northwest-trending faults. Inspection of adjacent gravity coverage to the north reveals that the anomaly is superposed on a broad gradient defined by contours striking roughly north-northeast, across which the gravity field increases from west to east. The overall trend of the gravity high is similar to that of the local northeast-southwest geological strike. The gravity high falls mainly over felsic crystal tuff and quartz-feldspar porphyry of the Nepisiguit Falls Formation. These rocks are flanked on three sides by rhyolitic rocks of the Flat Landing Brook Formation. In detail, the axis of the gravity high swings from a north-northeast trend near the western fault, to northeast near the deposit, to east-southeast to the east of the deposit.

Gravity profiles crossing the high illustrate, more clearly than does the map, the presence of a localized peak coincident with the Camel Back deposit or its along-strike extension. The amplitude of this shorter wavelength component of the overall gravity high is estimated to be about 0.7 mGal. Model calculations indicate that this amplitude is about twice as large as that expected for an anomaly produced exclusively by the sulphide deposit. It is conjectured that a chloritic chalcopyrite-pyrite ± pyrrhotite stringer zone associated with the deposit makes a significant contribution to the peak. Local developments of iron formation would also contribute. The broader aspects of the gravity high are more difficult to explain, since densities of the predominantly felsic rocks of the area are probably quite similar. Possibly, an unrecognized facies within the Nepisiguit Falls Formation, which may be denser than adjacent felsic volcanic rocks is a contributor. It is conceivable, also, that felsic volcanic rocks adjacent to the stringer zone contain low levels of sulphide mineralization, that would enhance their density. The Camel Back deposit is estimated to have a strike-length of about 125 m, but the distribution of the associated gravity anomaly indicates that rocks affected by a sulphide-producing event may extend over some 800 m along strike.

It is noted that the only mafic rocks in the map-area, belonging to the Moody Brook Member, do not produce a positive gravity signature, and fall partially within a broad negative gravity anomaly. Gravity coverage of these rocks is incomplete and is restricted to the eastern part of their mapped distribution.

RADIOMETRIC DATA

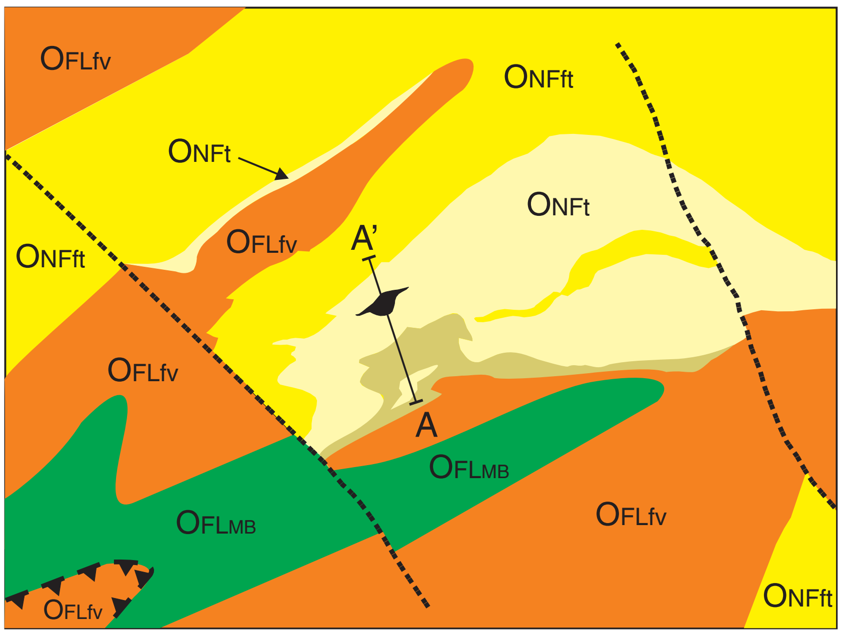
The radioelement patterns are relatively weak, with low concentration ranges in all three elements. Subtle east-southeast trends, defined by K and eTh, cross the northeast-trending bedrock units. Potassium ranges from 1.5% over low ground east of the surface projection of the deposit, to 2.3% over high ground to the north and south. Similar patterns appear on the eTh map, ranging from 6.6 to 10.6 ppm. Weak correlation between geology and eTh/K patterns suggest the ratio may be responding to subtle relative concentration variations between felsic (higher ratio values) and mafic units (lower values over Moody Brook mafic tuff, for example). Overall, the weak gamma-ray spectrometric patterns appear to reflect variations in surficial materials and topographic effects.

SUMMARY

The Camel Back deposit is an example of a deposit marked by coincident circular to oval magnetic and conductivity anomalies. Even though their amplitudes are relatively small, the geophysically quiet background provided by the ubiquitous felsic host rocks makes them conspicuous features on the respective maps. A distinct gravity anomaly is also present, though it represents a significantly broader signature of the deposit. The deposit itself does not appear to be reflected in patterns of radiometric variations, which are considered to be controlled by surficial materials and topography.

CAMEL BACK

GEOLOGY



Modified from Carroll (unpublished)

GEOLOGICAL LEGEND

TETAGOUCHE GROUP

Flat Landing Brook Formation

- OFLfv: mainly rhyolite flows, domes & sills
- OFLMB: Moody Brook Member: mafic tuff & hyaloclastite

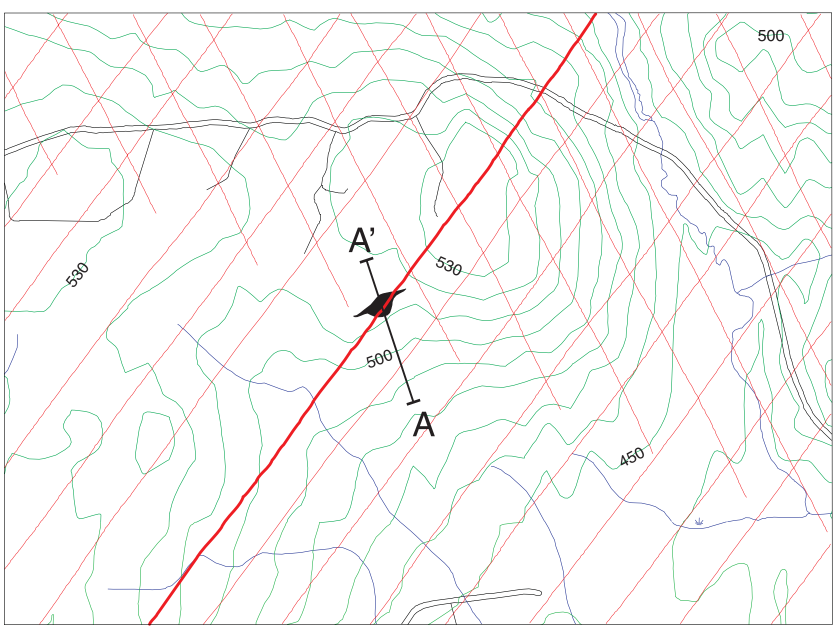
Nepisiguit Falls Formation

- ONFt: quartz-feldspar porphyry
- ONFt: crystal tuff
- massive sulphide
- quartz-sericite schist
- chloritic pyrite-, pyrrhotite- & chalcopyrite-rich stringer zone

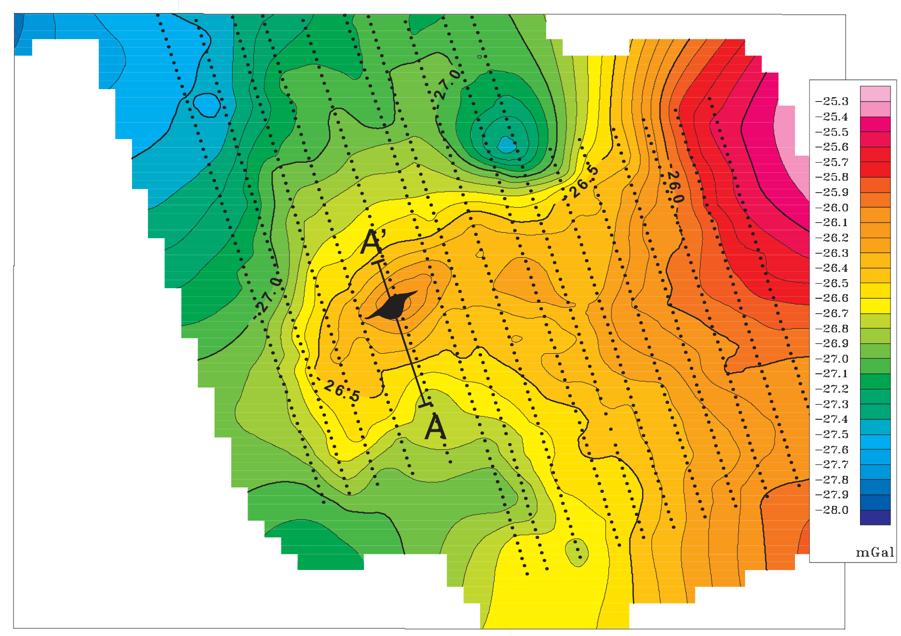
normal fault

thrust fault

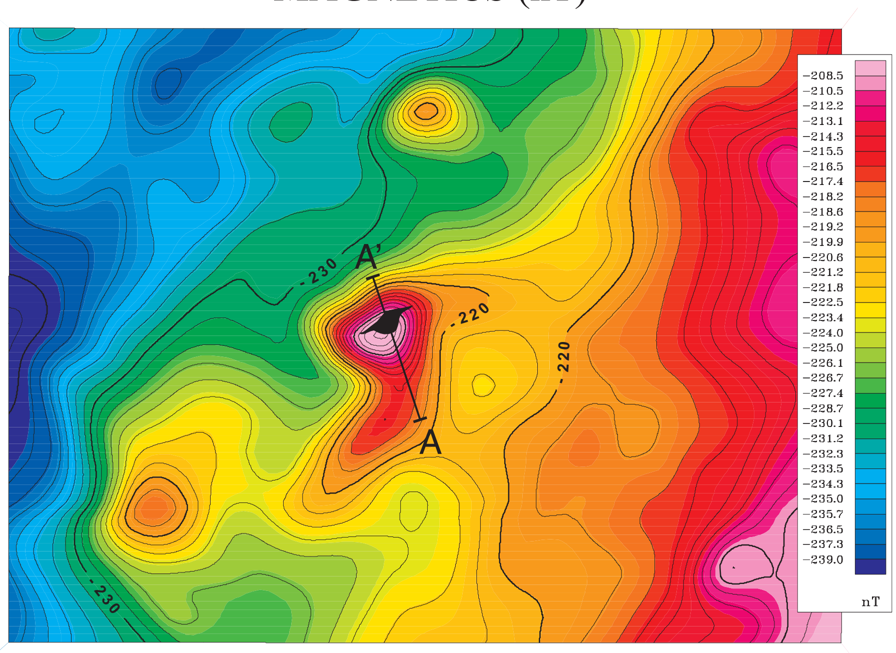
TOPOGRAPHY/FLIGHT LINES



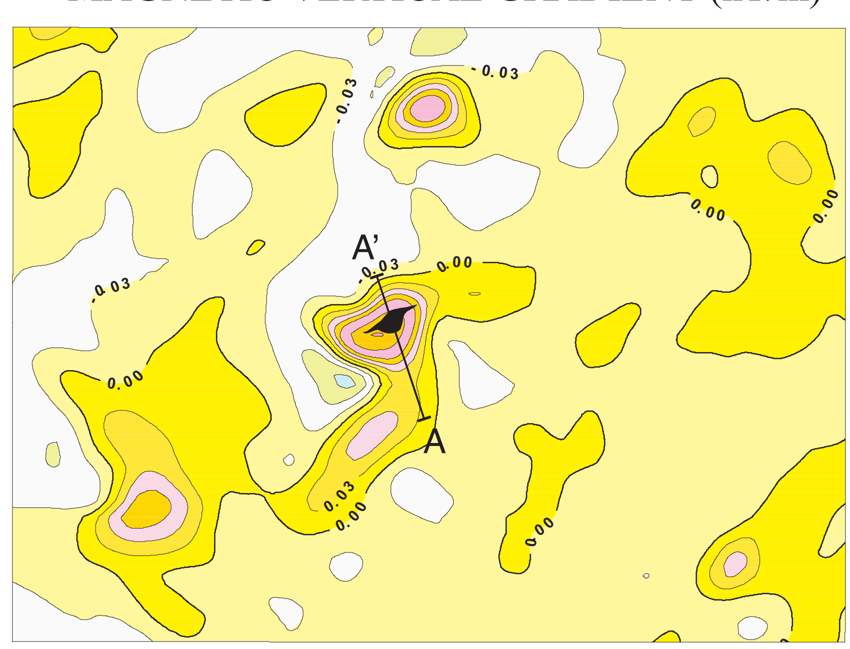
GRAVITY (mGal)



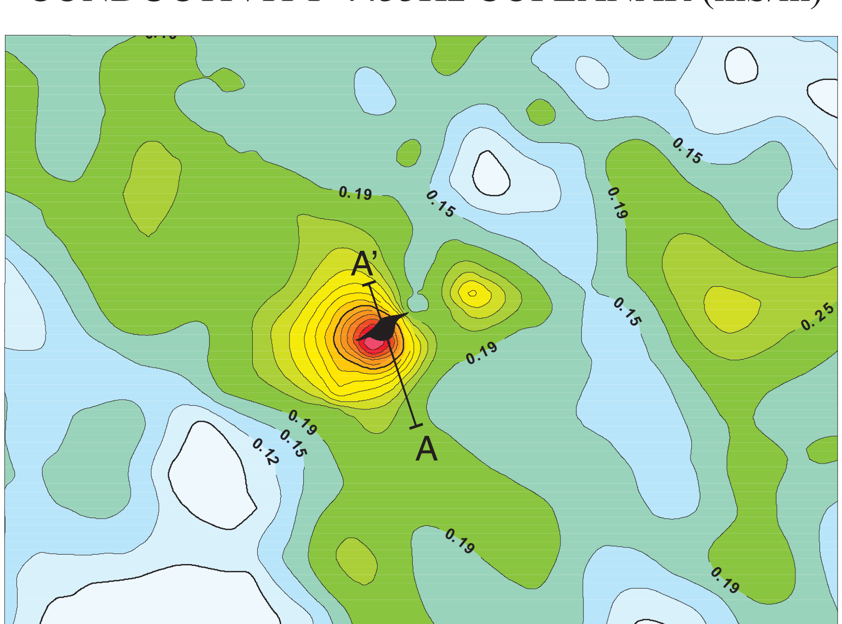
MAGNETICS (nT)



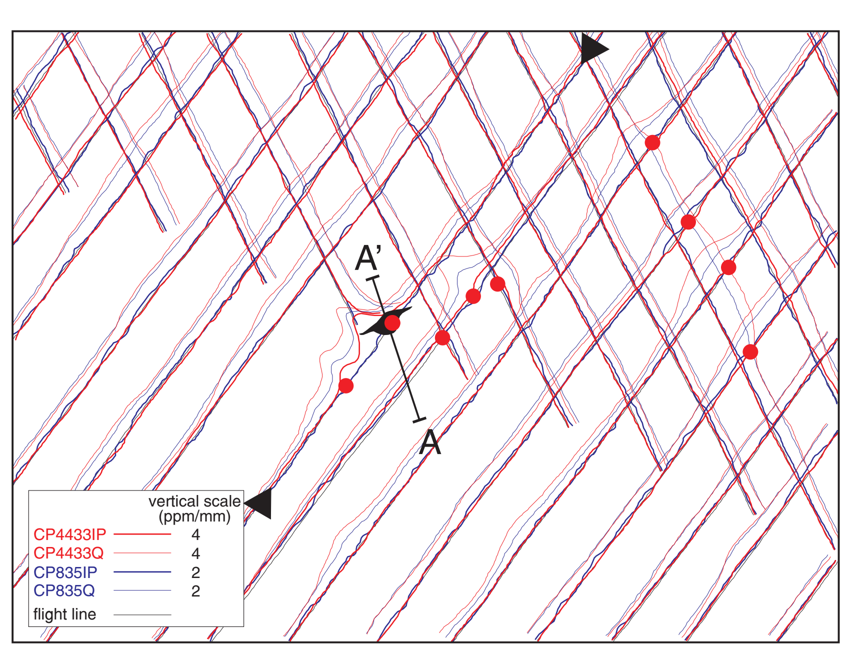
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



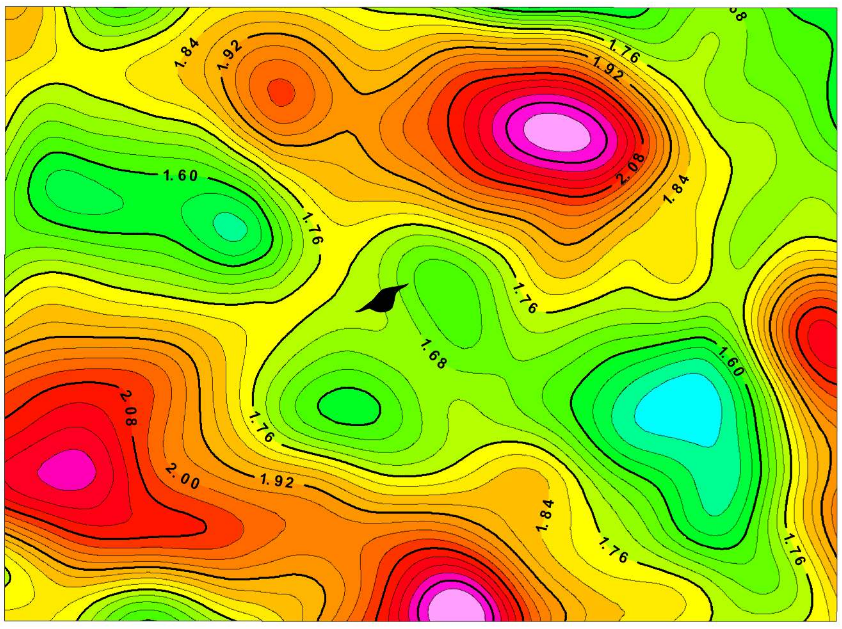
ELECTROMAGNETIC PROFILES/ANOMALIES



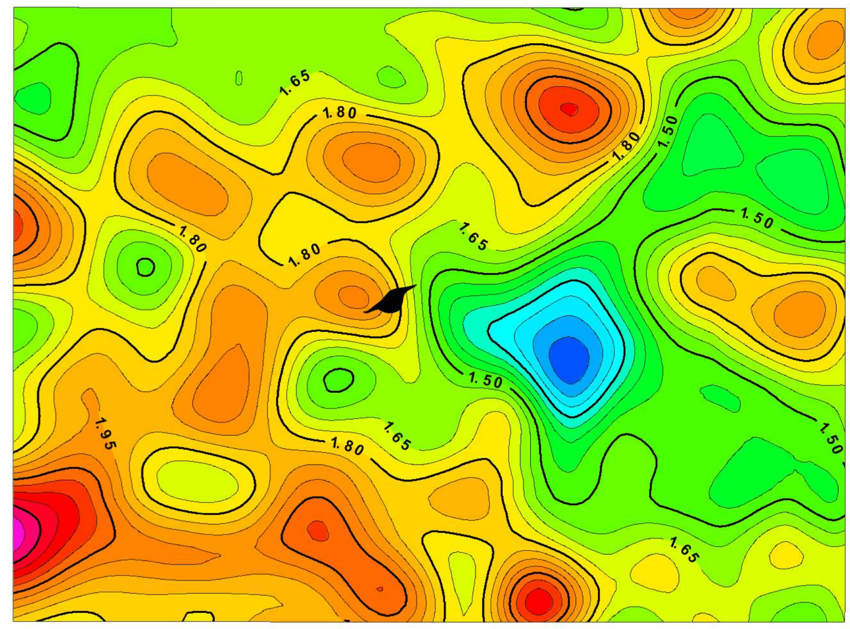
1000 m

CAMEL BACK

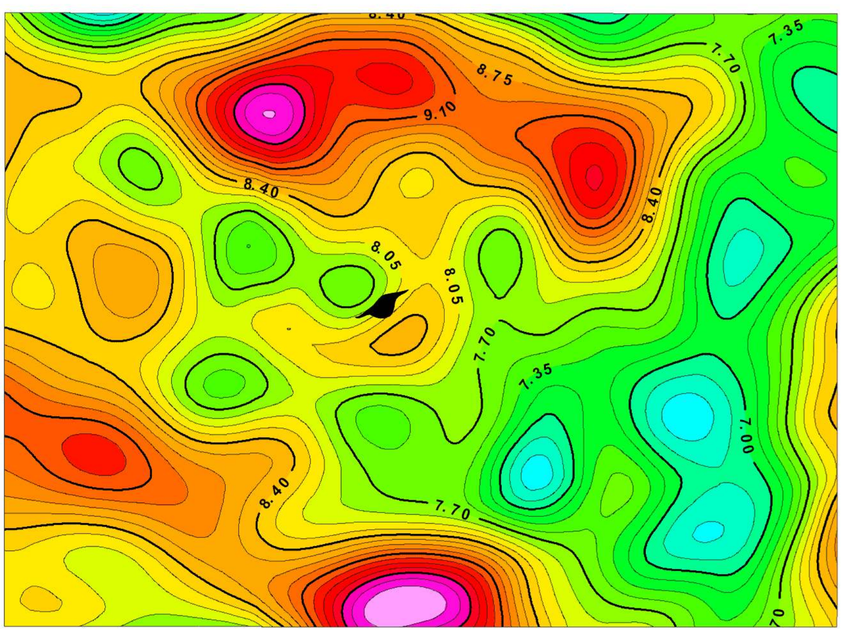
POTASSIUM (%)



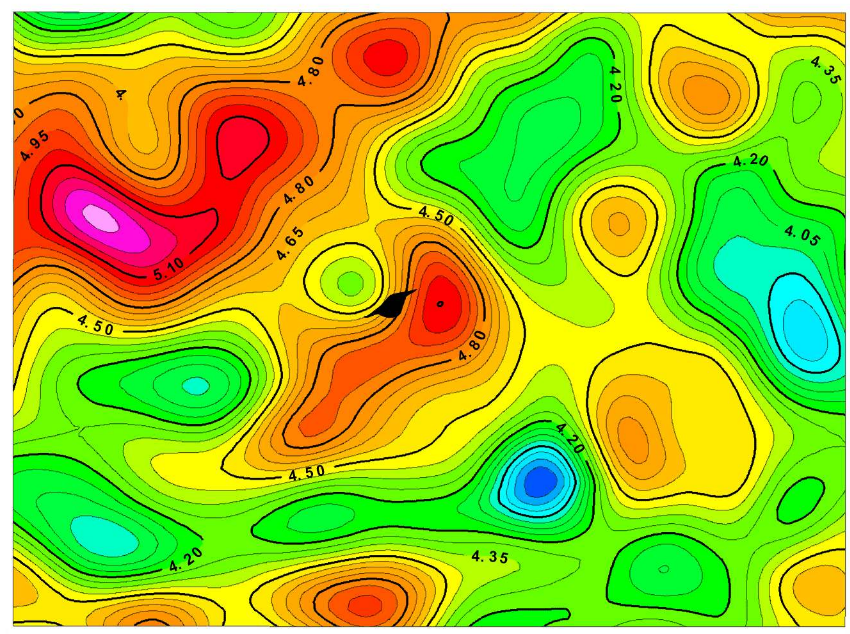
URANIUM (ppm)



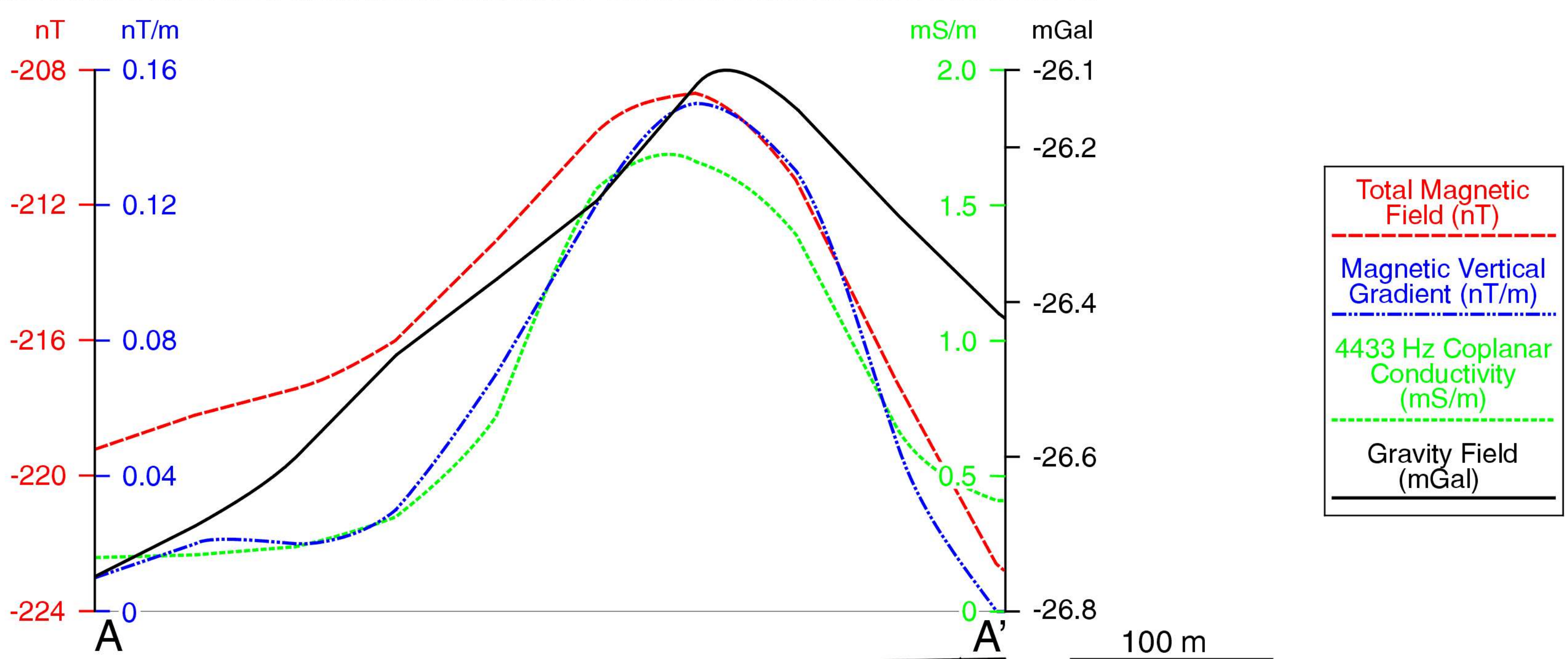
THORIUM (ppm)

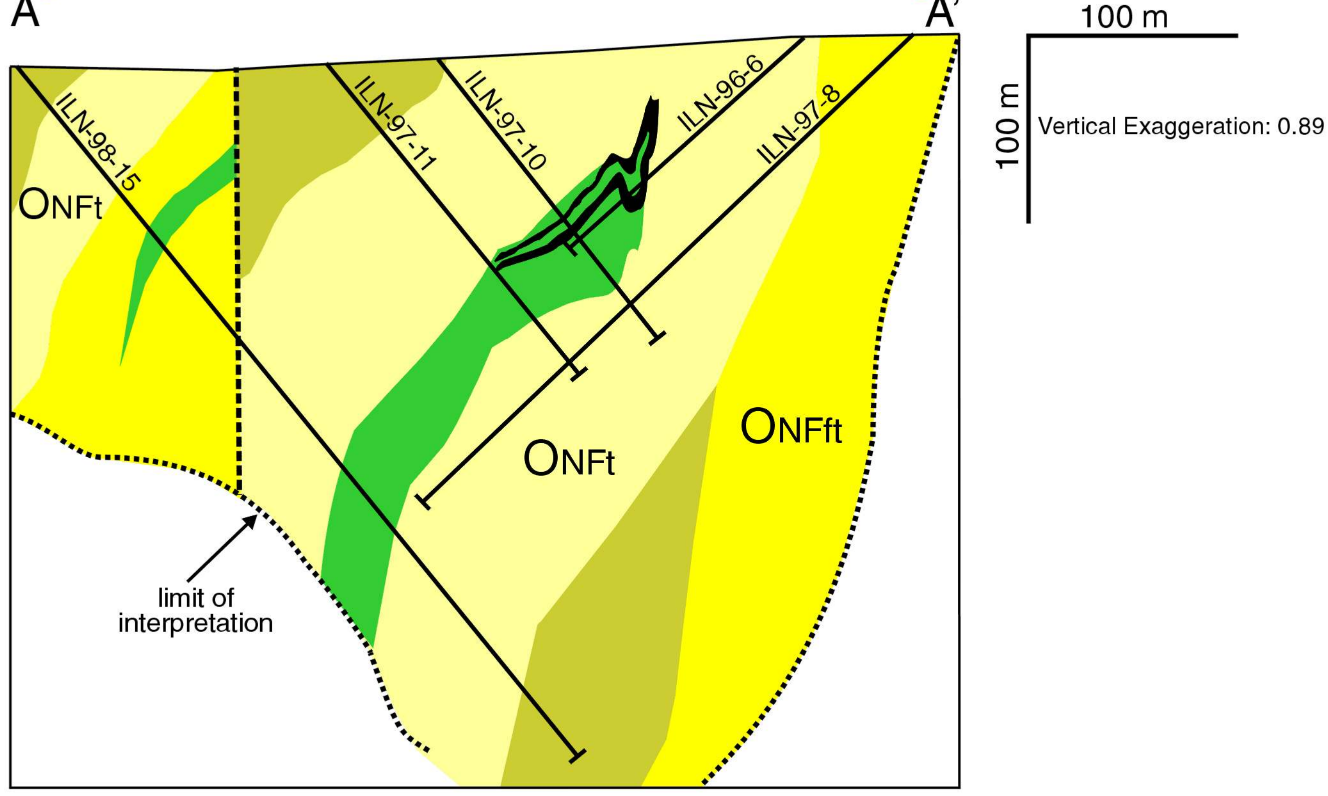


THORIUM/POTASSIUM RATIO (x 10^{-4})



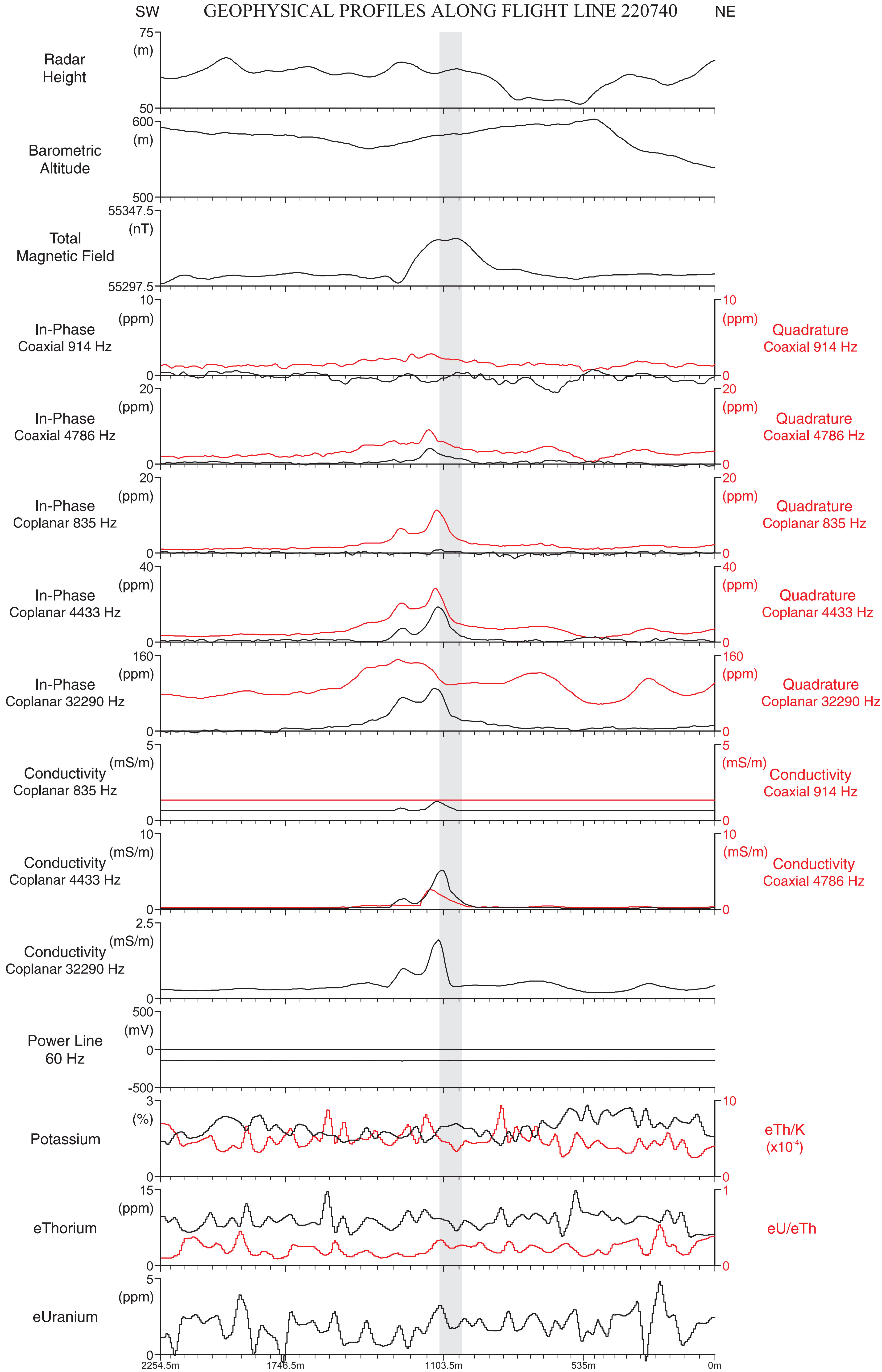
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'





Modified from Carroll (Unpublished)

CAMEL BACK


SW
GEOPHYSICAL PROFILES ALONG FLIGHT LINE 220740
NE
Radar Height
75
(m)
50
Barometric Altitude
600
(m)
500
Total Magnetic Field
55347.5
(nT)
55297.5
In-Phase Coaxial 914 Hz
Quadrature Coaxial 914 Hz
10
(ppm)
0
In-Phase Coaxial 4786 Hz
Quadrature Coaxial 4786 Hz
20
(ppm)
0
In-Phase Coplanar 835 Hz
Quadrature Coplanar 835 Hz
20
(ppm)
0
In-Phase Coplanar 4433 Hz
Quadrature Coplanar 4433 Hz
40
(ppm)
0
In-Phase Coplanar 32290 Hz
Quadrature Coplanar 32290 Hz
160
(ppm)
0
Conductivity Coplanar 835 Hz
Conductivity Coaxial 914 Hz
5
(mS/m)
0
Conductivity Coplanar 4433 Hz
Conductivity Coaxial 4786 Hz
10
(mS/m)
0
Conductivity Coplanar 32290 Hz
2.5
(mS/m)
0
Power Line 60 Hz
500
(mV)
0
-500
Potassium
3
(%)
0
eTh/K (x10⁻⁴)
10
0
eThorium
15
(ppm)
0
eU/eTh
1
0
eUranium
5
(ppm)
0
2254.5m
1746.5m
1103.5m
535m
0m

CANOE LANDING LAKE DEPOSIT

GEOLOGY

The Canoe Landing Lake massive sulphide deposit was discovered by Baie Holdings Ltd. in 1960 during follow-up work on coincident soil-geochemical and ground electromagnetic anomalies. The sulphides are hosted by grey to black, locally graphitic shale, and fine-grained wacke at or near the contact with conformably overlying mafic volcanic and epiclastic rocks. Both sedimentary and volcanic rocks are assigned to the Canoe Landing Lake Formation (van Staal, 1994b; Walker and McDonald, 1995). The Canoe Landing Lake Formation is in tectonic contact with sedimentary rocks of the Boucher Brook Formation to the south.

Mineralization occurs at one horizon that strikes between 110° and 140° and dips northward between 70° and 90°. The sulphide lens has a sheet-like morphology with a strike-length of 1200 m, thickness of 2 - 18 m, and a down-dip extent of greater than 925 m. The deposit has an indicated resource of 20.7 million tonnes grading 0.64% Pb, 1.82% Zn, 0.56% Cu, 0.94 oz/ton Ag and 0.034 oz/ton Au (Brooks, 1985), and a simple mineralogy comprising pyrite, minor pyrrhotite, galena, sphalerite and chalcopyrite. In most drill intersections the sulphide lens is massive to semi-massive and has sharp hanging wall contacts. Footwall contacts can be sharp or gradational into disseminated pyrite that appears to be in part diagenetic. Locally, the sulphides appear to be clastic, and mixed with unmineralized lithic fragments. These clastic rocks are interpreted to represent intraformational conglomerates (Walker and MacDonald, 1995). There is no obvious metal zonation, alteration or stringer-type mineralization in either the footwall or hanging wall rocks, suggesting that the sulphides were transported and deposited distal to the vent complex. Structurally the deposit is quite simple. The mafic volcanic rocks display two weakly developed cleavages, whereas the sedimentary rocks have two well developed cleavages. The first trends east-west and is probably a composite S_1/S_2 fabric, and the later cleavage S_4 strikes northeast and is axial-planar to the Nine Mile Synform (Walker and McDonald, 1995).

MAGNETIC DATA

The long trace of the Canoe Landing Lake sulphide deposit is nowhere associated with an obvious magnetic signature in the total magnetic field. However, a more subtle magnetic expression presents itself as a southwestward bulging of total field contours near the centre of the deposit. This is transformed into a distinct oval-shaped high on the vertical gradient map. Its position is consistent with an observed slight local enrichment of pyrrhotite in the same area (Walker and McDonald, 1995). The field immediately around the deposit and over much of the area to the southwest is characterized by gentle to moderate fluctuations. This is a reflection of the low magnetic susceptibilities ($<1 \times 10^{-3}$ SI) of the sedimentary rocks of the Canoe Landing Lake and Boucher Brook formations and felsic volcanic rocks of the Spruce Lake Formation. Reasons for a lack of signature over the deposit itself are: (1) the combination of its narrow width (2 - 18 m) and its depth of burial, tens of metres below surface (roughly 50 m in section A-A'), and (2) the fact that it is comprised largely of pyrite (Walker and McDonald, 1995), which has low magnetic susceptibility (up to 5.3×10^{-3} SI); two small intersections (both <3 m thick) of massive sulphide encountered in one borehole yielded mean magnetic susceptibilities of 0.8 and 0.9×10^{-3} SI. Northeast of the deposit, the magnetic field takes on the character of a broad, west-northwest- to northwest-trending band of relatively elevated values, containing several discrete highs that are particularly well delineated on the vertical gradient map. These correlate mainly with mafic volcanic and related epiclastic rocks of the Canoe Landing Lake Formation. Measurements of susceptibility by the authors, on drill core, indicate that mafic units may be very weakly magnetic (susceptibility $<1 \times 10^{-3}$ SI), or moderately strongly magnetic ($\sim 40 \times 10^{-3}$ SI), with individual values as high as 135×10^{-3} SI.

ELECTROMAGNETIC DATA

The coaxial responses of the steeply dipping Canoe Landing Lake massive sulphide deposit show a single maximum over the orebody, whereas the coplanar responses show two maxima having almost equal amplitudes. These are the expected HEM responses of a vertically-dipping thin plate. The apparent conductivity map calculated from the mid-frequency coplanar coils shows a single low amplitude conductivity anomaly (about 2 mS/m) to be associated with the sulphide deposit. This has a strike-length of about 500 m and is located above the eastern part of the orebody. The EM anomaly can be modelled by a thin plate having a strike-length of 600 m and a depth-extent of 300 m. The plate has a dip of 60°, a strike angle of 60° relative to the flight-line, and a conductivity-thickness product of 1 S.

GRAVITY DATA

The gravity map of the Canoe Landing Lake map-area has been compiled from detailed gravity surveys carried out on behalf of Brunswick Mining and Smelting Corporation Limited (Brooks, 1982, 1983, 1984) and as part of EXTECH-II (Thomas *et al.*, 1996). Most of the data were collected along lines spaced generally 200 ft (~60 m) apart at intervals of 50 ft (~15 m). Further details on the surveys may be found in the aforementioned reports. The deposit sits on a uniform gravity gradient that increases from southwest to northeast, and strikes subparallel to the gravity contours. The gradient is attributed to the change from lower density sedimentary and felsic volcanic rocks in the south to denser mafic volcanic rocks in the north. The deposit has no obvious expression in the gravity map, which is contoured at 0.25 mGal interval. However, gravity profiles along individual lines reveal several small positive departures from the estimated background gradient, which have amplitudes that range from about 0.1 to 0.3 mGal. Brooks and Macintosh (1982) related one such small anomaly, attaining 0.3 mGal amplitude, to the Canoe Landing Lake deposit. Thomas *et al.* (1996) suggested that this particular anomaly might be located some 80 to 130 m north of the surface position of the sulphide horizon as portrayed on a geological map compiled by Nebex Resources Limited (Johnson, 1995), and that it could have an alternative source. Some small anomalies have been explained by pyritic sediments flanked by less dense acid volcanics (Brooks, 1982) or by stringer pyrite (up to 10%) in graphitic argillite (Brooks and Macintosh, 1982). The apparent lack of a gravity signature over the Canoe Landing Lake deposit is ascribed to the small width of the deposit and the fact that it is probably buried some tens of metres below surface. Surface showings of the deposit, apparently, are limited to mineralized boulders, and the shallowest intersection in a borehole is at a vertical depth of 100 m (Johnson, 1995). Thus, the deposit could thin significantly and/or become lower grade near surface, resulting in marked attenuation of any associated signal. The mineralized boulders may signify the intersection of the sulphide-mineralized horizon at surface, but do not necessarily imply the development of significant thicknesses of sulphides.

RADIOMETRIC DATA

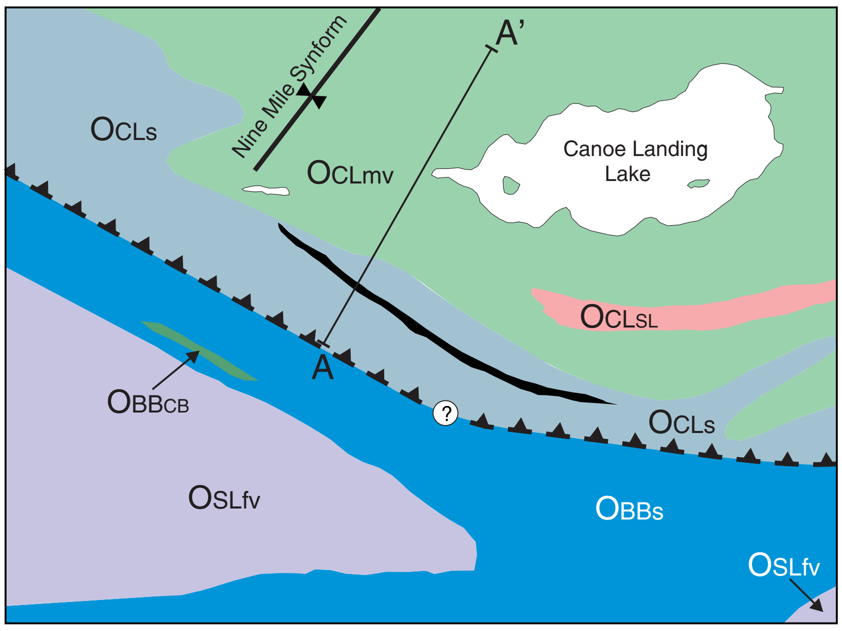
Airborne gamma-ray spectrometry patterns reflect the southeast to east trends of the geological units. Maximum K, eU and eTh concentrations (2.4%, 3.3 ppm and 11.5 ppm, respectively) occur southwest of the deposit and are associated with aphyric and feldspar-phyric rhyolites of the Spruce Lake Formation. Similar concentrations are associated with parts of the Boucher Brook Formation west of the deposit, but generally the shales and siltstones of this formation yield values of 1.2 - 1.7% K, 1. 5 - 2.4 ppm eU and 6.0 - 8.0 ppm eTh. East of the deposit, a zone of elevated K, eU and eTh coincides with feldspar-porphyritic felsic flows of the Spruce Lake Member of the Canoe Landing Lake Formation. Low radioelement concentrations are associated with Canoe Landing Lake, and with swamps in the southeast corner of the map area. The Canoe Landing Lake deposit coincides with a west- to northwest-trending Th/K low, and to a lesser extent with a K high of approximately the same trend.

SUMMARY

The best developed geophysical signature of the Canoe Landing Lake deposit is the linear conductivity anomaly that coincides with the eastern half of the deposit. It stands out from a generally quiet background, even though its amplitude (2 mS/m) is quite small. A weak magnetic high coincides with the central part of the deposit and is attributed to pyrrhotite enrichment. A perceptible gravity signature is lacking, probably because the deposit is extremely thin at shallow depths.

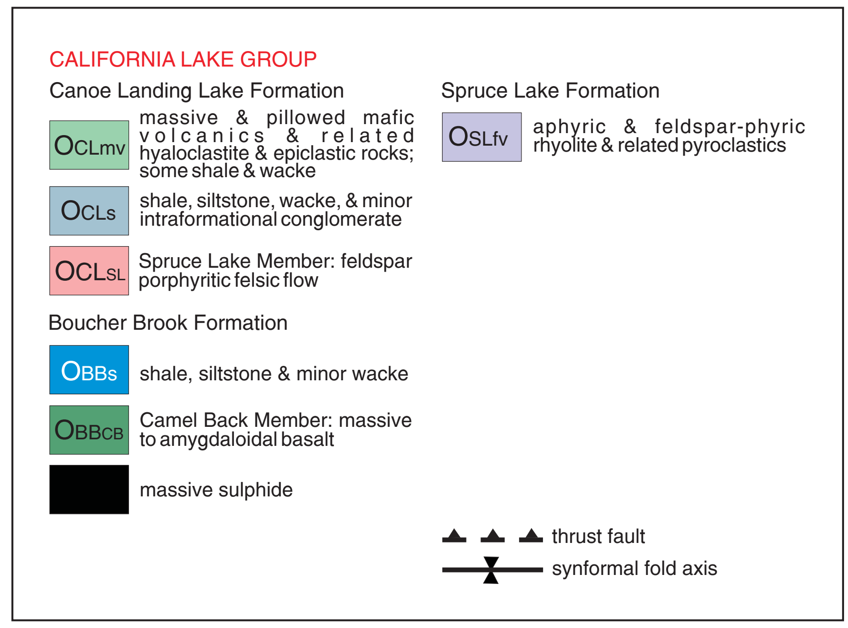
CANOE LANDING LAKE

GEOLOGY

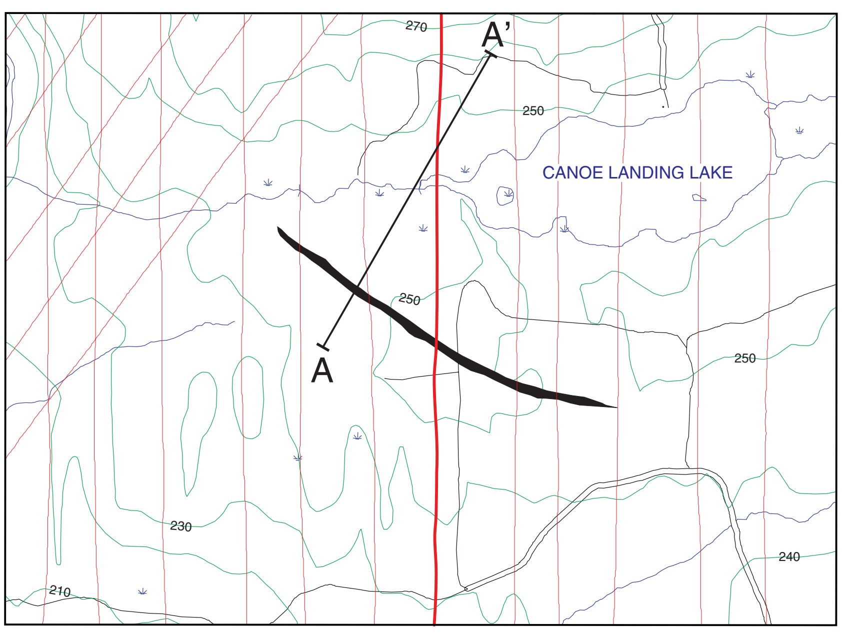


Modified from Walker and McDonald (1995)

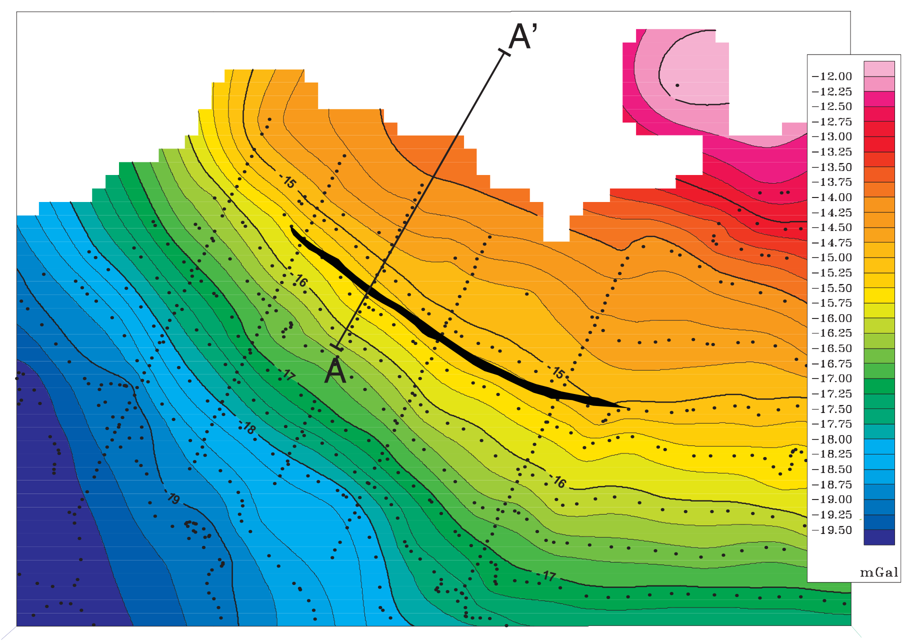
GEOLOGICAL LEGEND



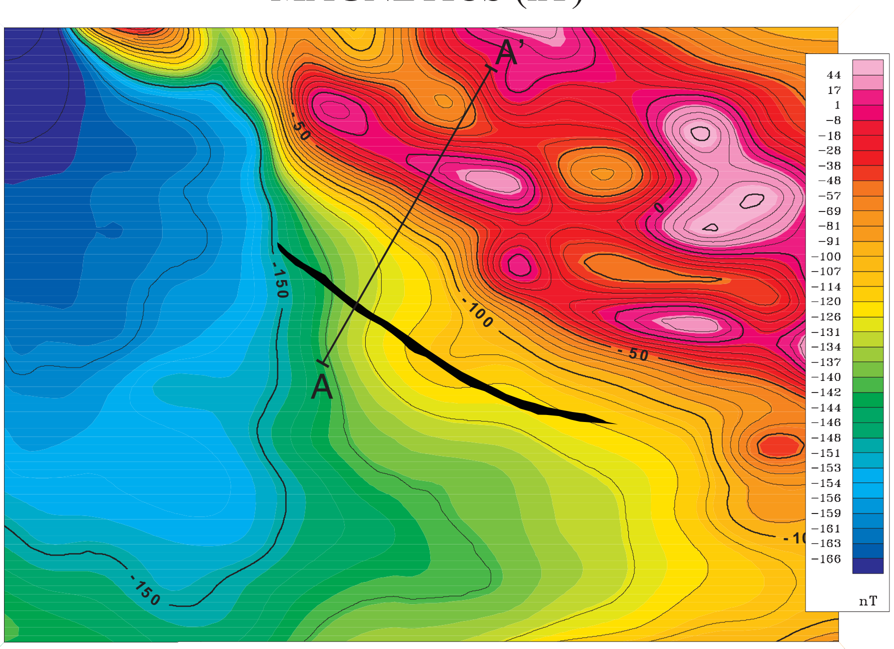
TOPOGRAPHY/FLIGHT LINES



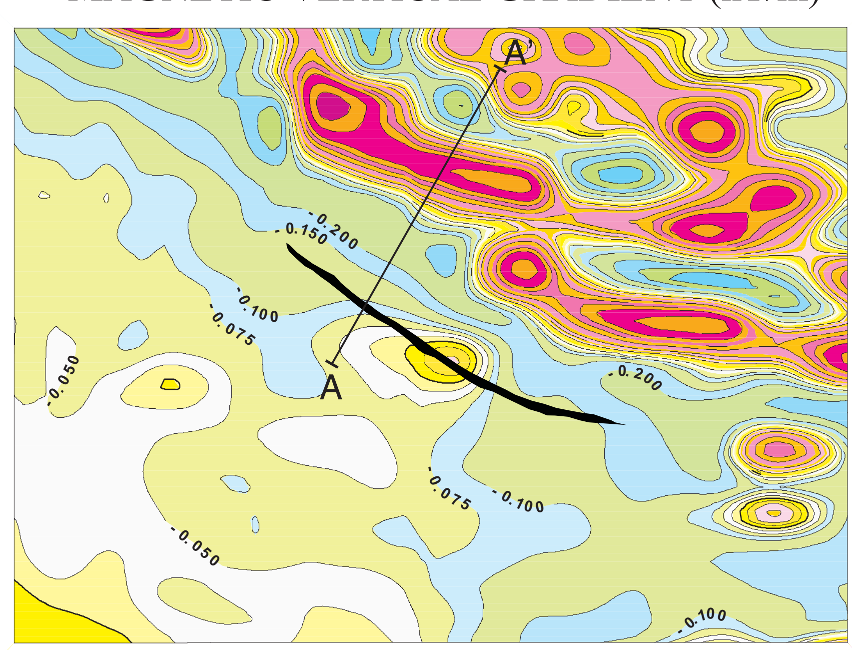
GRAVITY (mGal)



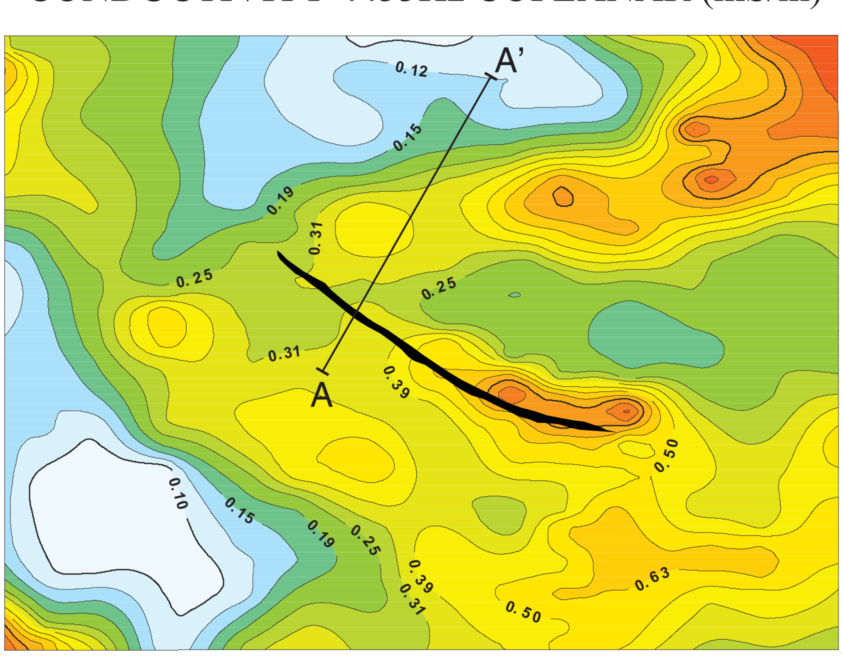
MAGNETICS (nT)



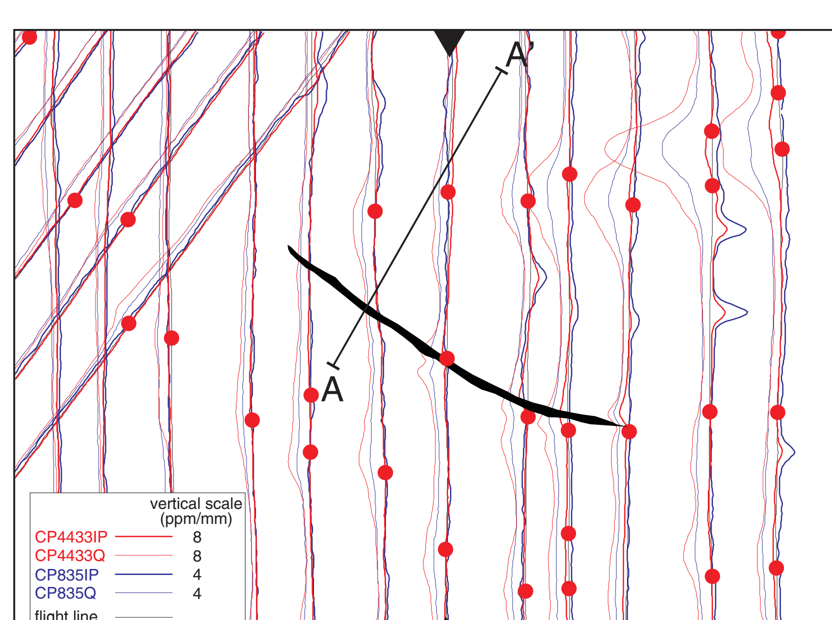
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



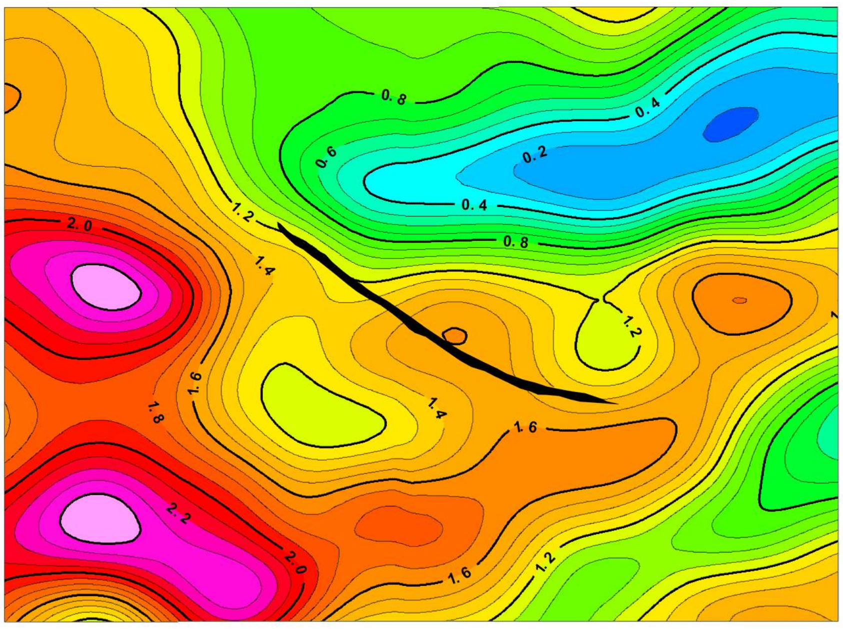
ELECTROMAGNETIC PROFILES/ANOMALIES



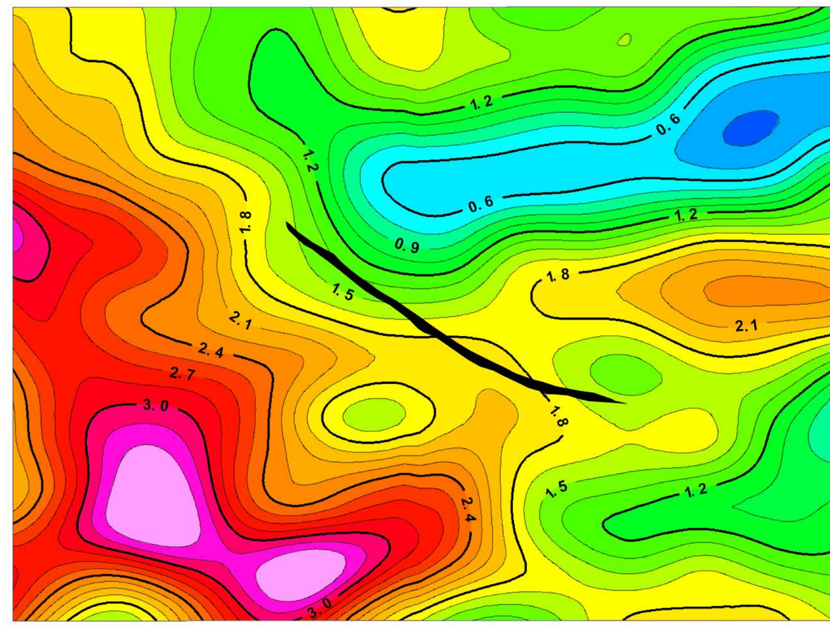
1000 m

CANOE LANDING LAKE

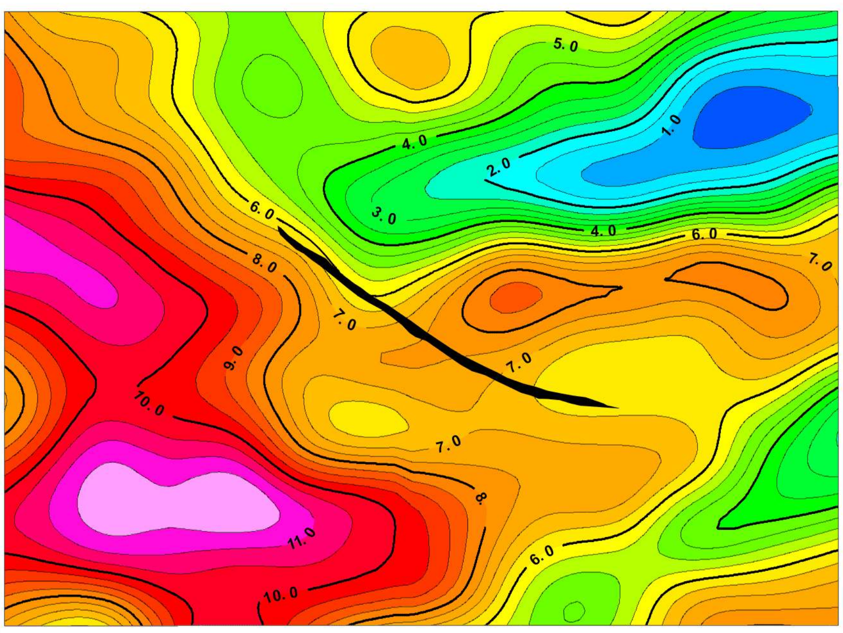
POTASSIUM (%)



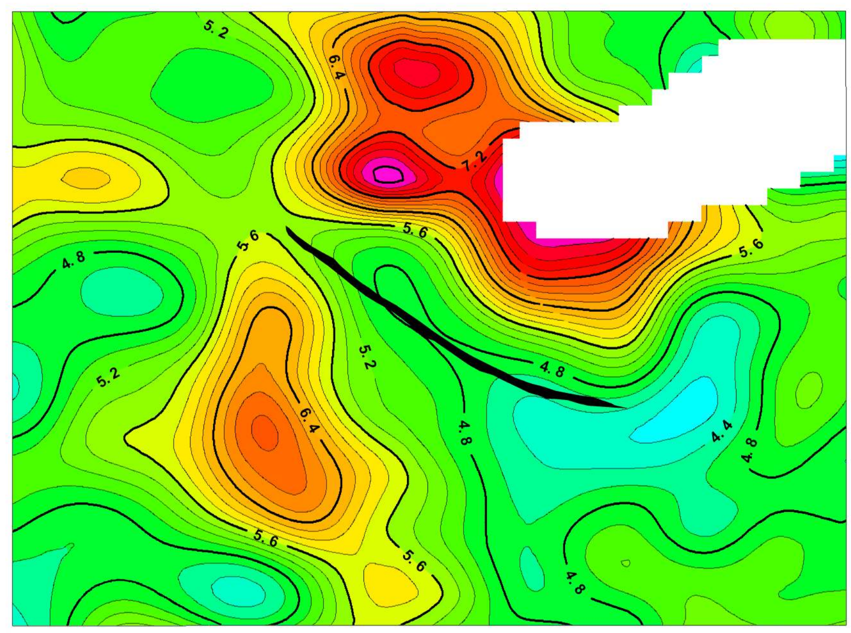
URANIUM (ppm)



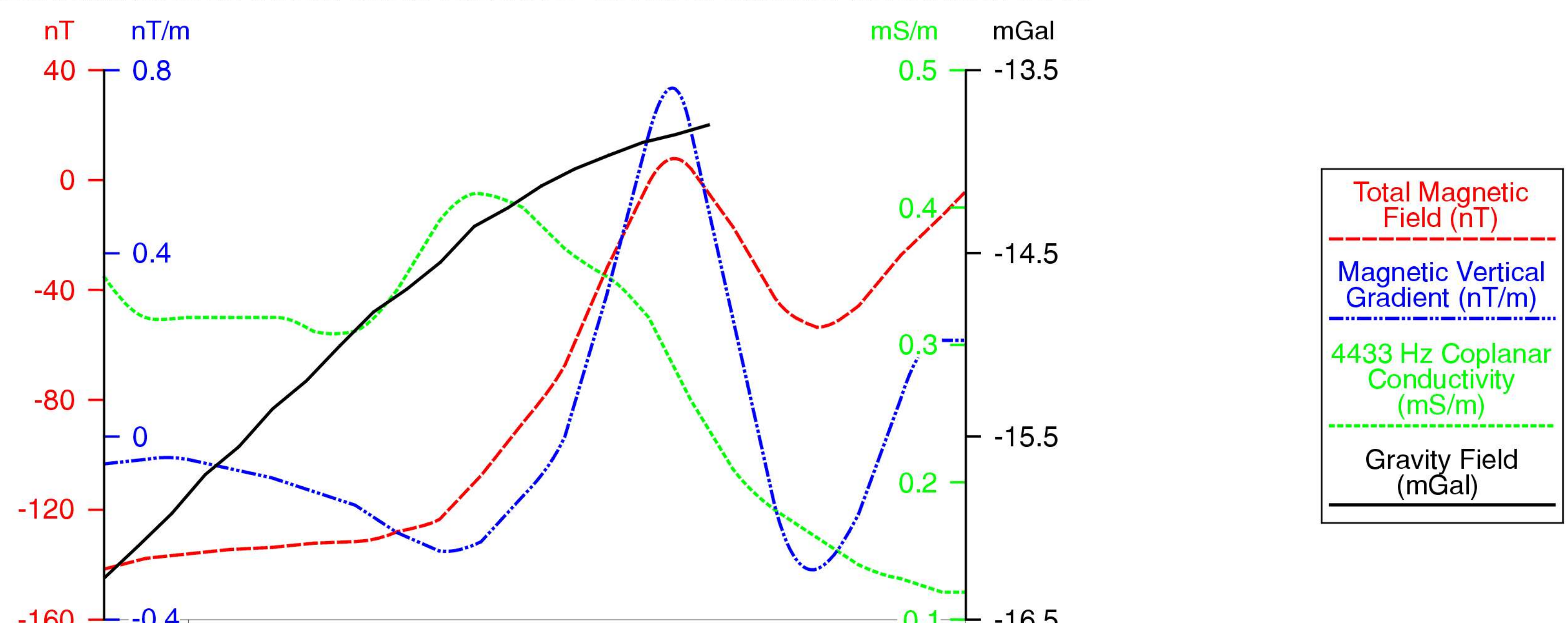
THORIUM (ppm)

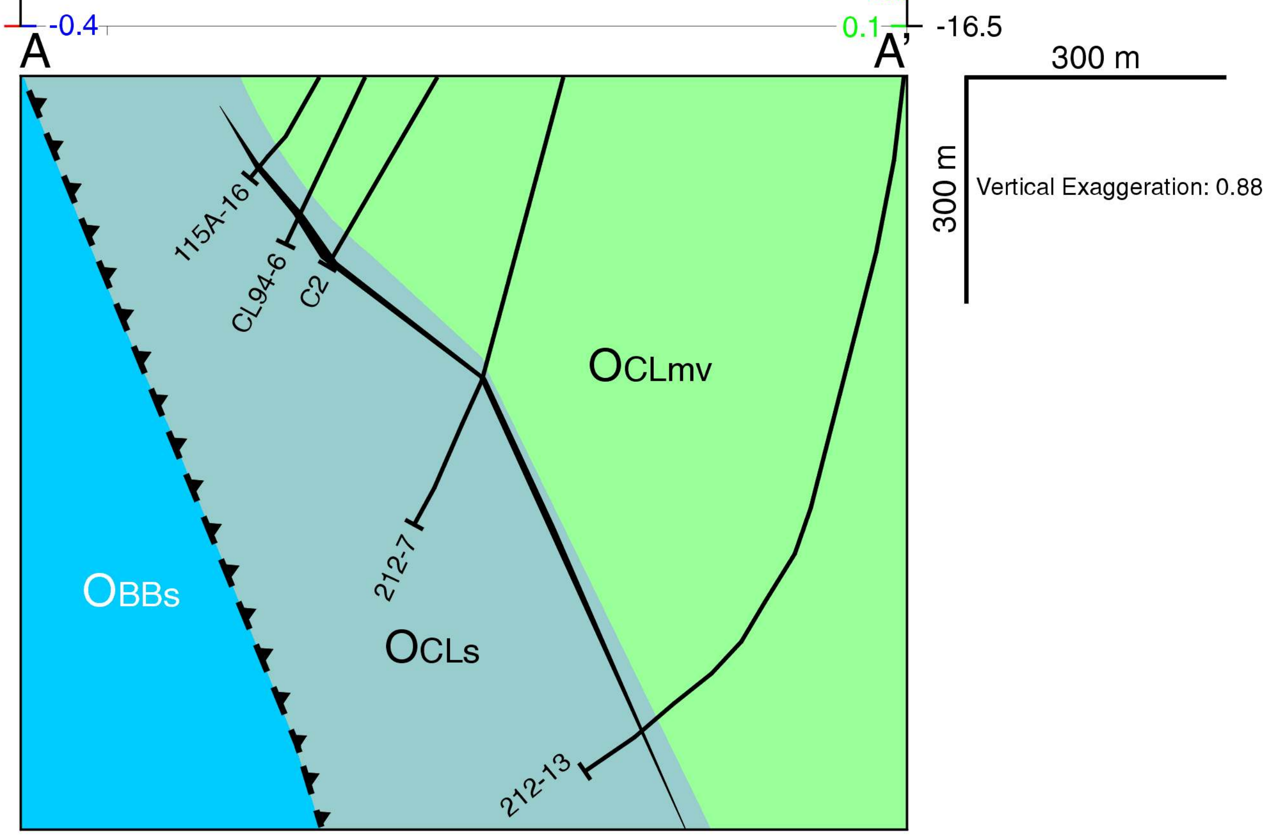


THORIUM/POTASSIUM RATIO (x 10^{-4})



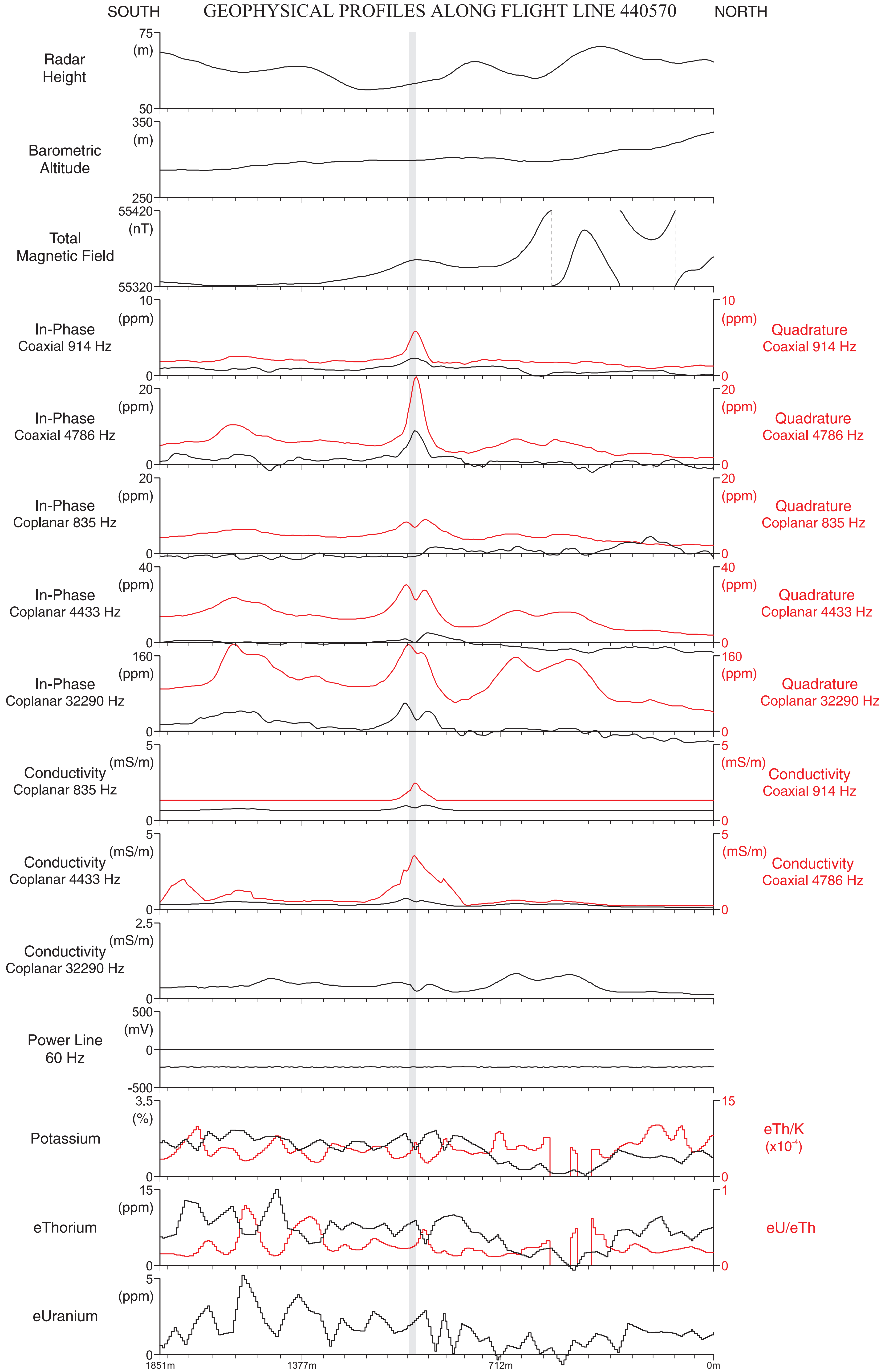
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'





Modified from Walker and McDonald (1995)

CANOE LANDING LAKE



CAPTAIN NORTH EXTENSION (CNE) DEPOSIT

GEOLOGY

The Captain North Extension (CNE) deposit was discovered in 1978 by a consortium comprising Metallgesellschaft (Canada) Ltd., Sabina Industries Ltd. and others, during follow-up drilling of a stream sediment geochemical anomaly. It is worth noting that glacial till over the deposit is greater than 5 m thick and that soil geochemical and till geochemical sampling 60 cm above the bedrock-till interface did not reveal mineralization.

The deposit occurs at the contact between the Nepisiguit Falls and Flat Landing Brook formations, *i.e.* Brunswick Horizon. The immediate footwall comprises mudstone, fine-grained wacke, and quartz-feldspar crystal-rich epiclastic rocks. Quartz-feldspar crystal tuffs occur deeper in the footwall. The hanging wall sequence comprises a siliceous exhalative sedimentary unit that is overlain by aphyric- to feldspar-phyric rhyolitic flows, tuffs and related pyroclastic rocks.

CNE occurs on the east limb of a north-trending synform, the core of which is occupied by rocks of the Flat Landing Brook Formation. The deposit is isoclinally folded, strikes north-northeast, dips steeply west, plunges 50° to the south and is cut out by a fault to the north. Probable reserves are estimated at 207,555 tonnes grading 7.38% Zn, 2.76% Pb, and 91.81 g/t Ag, whereas the total probable geological resource is approximately 425,000 tonnes grading 5.6% Zn, 2% Pb and 68.5 g/t Ag (Whaley, 1992 and references therein). During the period 1990-1992 the deposit produced 39,000 tonnes grading 9.97% Zn, 4.22% Pb and 134.7 g/t Ag (Luff, 1995). Metal zoning is evident according to Whaley (1992), with Cu concentrated in the east and Pb-Zn in the west. This supports the westward-younging direction inferred by regional stratigraphy. Chloritic and sericitic alteration are locally well developed in the footwall.

MAGNETIC DATA

The total magnetic field over and around the immediate area of the CNE sulphide deposit varies by no more than 1 nT. There is no indication of any response from the deposit, either in the total field or vertical gradient maps. However, Whaley (1992) reports that a ground magnetic survey defined an anomaly, 100 nT amplitude, over a pyrite-rich lens that included chalcopyrite. Another anomaly, 50 nT amplitude, was detected over a high-grade Zn-Pb lens in which sphalerite and galena were the main minerals (pyrite <10%). The discrepancy may be explained by the fact that the deposit lies roughly midway between flight-lines which are about 240 m apart in this locale, remaining essentially undetected by the airborne system. On a more regional scale, the horizon of the deposit, near the boundary of the Nepisiguit Falls and Flat Landing Brook formations, lies along the axis of a very broad and low amplitude, north-northeast-trending magnetic low overlying the central part of the map-area, which is dominated by felsic volcanic rocks.

Magnetic susceptibility measurements on core samples from the vicinity of the ore deposit indicate average values for sections of felsic volcanic rocks and siltstones ranging from 0.15 to 0.35 x 10^{-3} SI, values which are probably characteristic of much of the map-area, and are consistent with the low magnetic field. The highest mean value, 0.42 x 10^{-3} SI was obtained for a section of chloritic schists and tuffaceous sedimentary rocks in the footwall of the deposit, and can be attributed to 5% disseminated and stringer pyrite (Teck Exploration Ltd. drill log). Individual susceptibility values within sections of sulphide lenses generally range from about 0.2 to 0.5 x 10^{-3} SI Exceptionally, one 5-metre section yielded a mean value of 45 x 10^{-3} SI with a maximum >200 x 10^{-3} SI. The magnetic field increases progressively towards the western and eastern margins of the map area, reasons for which are not apparent in the surface geology. About 700 m due north of the CNE deposit a conspicuous circular magnetic high and coincident weak conductivity high may hold some potential for exploration.

ELECTROMAGNETIC DATA

The CNE deposit does not produce an HEM response, the absence of which is probably related to one or both of two principal factors: (1) the location of the deposit between adjacent flight-lines, and (2) the nature of the sulphides, which are predominantly sphalerite and zinc. Lens No. 2, which has 55% of the reserves, is a massive body of sphalerite and galena, grading up to 25% Zn+Pb (Whaley, 1992). Although no conductivity measurements are available from this deposit, sphalerite and galena can have very low conductivities. It is worthwhile to note that the deposit has a weak response on the 3555 Hz Max-Min II ground EM system and a good IP response (Whaley, 1992). The disseminated nature of the zinc-rich sulphides and their low conductivity explain the lack of significant EM response at the sensor height of about 30 m.

GRAVITY DATA

Gravity surveys over the CNE deposit are described in reports for Teck Exploration Limited by Brace (1992) and Brace and Miller (1993). A test survey conducted along three lines over and adjacent to the deposit revealed a small associated gravity high, amplitude 0.25 mGal, on the one line crossing directly over the deposit (Brace, 1992). The lines and gravity observations were spaced roughly 65 m and 25 m apart, respectively. The anomaly was not present on the two adjacent lines, which were both south of the deposit. An expanded gravity survey, north and south of the deposit (Brace and Miller, 1993), did not reveal any continuation of the high encountered on the test line (Brace, 1992). According to Brace and Miller (1993), observations in the extended survey were made at intervals of 50 m along lines spaced 60 m to 150 m apart, though a map accompanying their report shows line spacing to average about 180 m near the deposit. The map displayed here is based on those observations. On this, the gravity high over the deposit is expressed as a distinct bulging of the -21.5 mGal contour, which partially encloses a small closure of the -21.4 mGal contour. An estimate of its amplitude, based on a profile passing directly through the deposit, is 0.34 mGal, which is higher than the 0.15 to 0.20 mGal amplitude estimated by Brace and Miller (1993). The high is superimposed on a uniform gravity gradient, across which values increase from west to east. Lower values correlate with felsic volcanics of the Flat Landing Brook Formation, whereas higher values to the east are associated mainly with quartz-feldspar crystal tuffs and less abundant sedimentary rocks of the Nepisiguit Falls Formation. Brace and Miller (1993) reported that, apparently, there is no density contrast between the felsic rocks of the aforementioned formations, yet the gravity pattern suggests otherwise. Possibly, sedimentary units within the Nepisiguit Falls Formation are the main influence on the higher gravity field to the east. Brace and Miller (1993) noted the association of weak gravity highs with sedimentary rocks, a particularly good example being a north-south gravity high near the eastern margin of the map-area, which correlates with one section of a narrow sedimentary unit.

RADIOMETRIC DATA

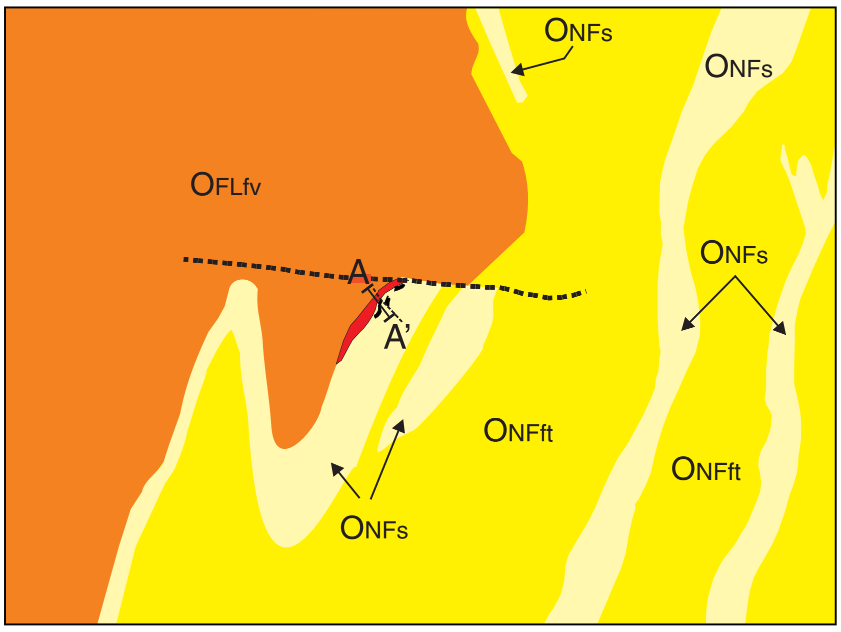
Spectrometric patterns reflect drainage-enhanced, north-northeast geological trends. Areas of low K, eU and eTh concentrations are associated with swamps east of the deposit. Two areas of low K occur west of the deposit. The southern low has coincident low eU and eTh, suggesting wet, saturated ground not indicated on the topographic map. The northern area of low K is associated with moderate eU and high eTh concentrations, which may reflect chemical variation within aphyric to feldspar-phyric felsic volcanic flows and tuffs of the Flat Landing Brook Formation. Potassium is highest (1.95%) immediately west of the deposit, over hanging wall units of the Flat Landing Brook Formation. High K also occurs north of the deposit in the same unit and to the east and south, over porphyritic quartz-feldspar crystal tuff within the Nepisiguit Falls Formation. Immediately east of the deposit, potassium decreases slightly (1.50%). Although this may reflect K-depletion, as documented in the footwalls of other deposits in the Bathurst area (Lentz, 1994; Rickard, 1998; Shives and Ford, in press), ground studies are required to verify this. Airborne eTh concentrations are highest (7.25 - 8.75 ppm) 600 - 1400 m northwest of the deposits, over aphyric to feldspar-phyric felsic volcanic flows of the Flat Landing Brook Formation. These are associated with low K and moderate eU concentrations. Equivalent thorium concentrations decrease progressively to the southeast towards the deposit and the contact between the Flat Landing Brook (6.0 - 7.25 ppm) and Nepisiguit Falls (5.5 - 7.25 ppm) formations. Equivalent uranium concentrations are high (2.25 ppm) immediately southeast of the deposit and along strike from it to the south, over felsic volcanics and related sedimentary rocks of the Nepisiguit Falls Formation. A broad zone of low eTh/K almost completely surrounds the deposit, interrupted only by a local high immediately southeast of the deposit. The pattern is mimicked in the potassium map, except the role of lows and highs is reversed.

SUMMARY

No magnetic or conductivity responses are observed over the CNE deposit, probably because the deposit is small and also located between flight-lines, where it produces little effect on the geophysical sensors. Furthermore, the sulphide mineralogy in this deposit is not conducive to generating sizable magnetic and conductivity signals. However, a small, yet distinct, gravity anomaly (~0.34 mGal amplitude) is associated with the deposit, and is clearly visible, even though it is superposed on a background gradient. No radiometric signature can be linked to the deposit, although low potassium immediately east of the deposit may signify potassium depletion related to alteration in the footwall.

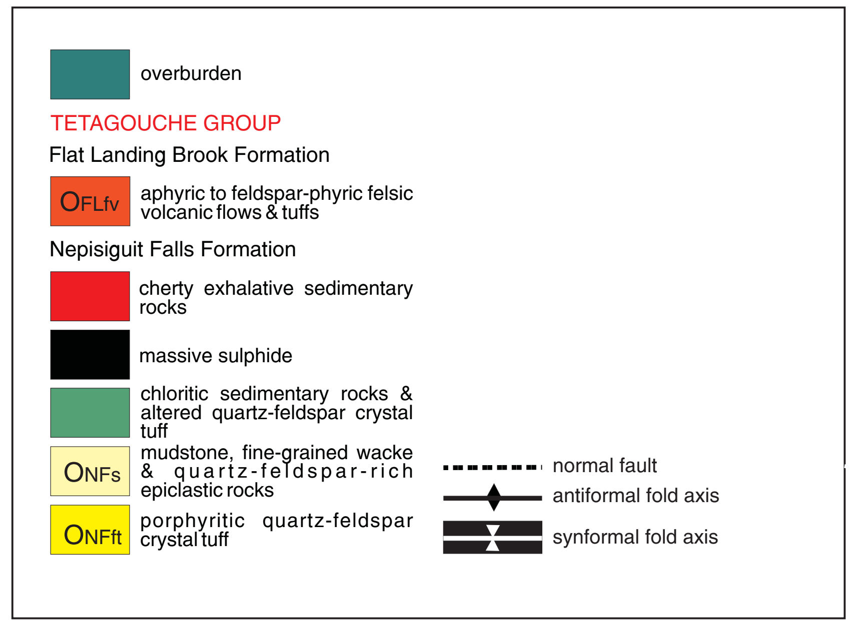
CAPTAIN NORTH EXTENSION (CNE)

GEOLOGY

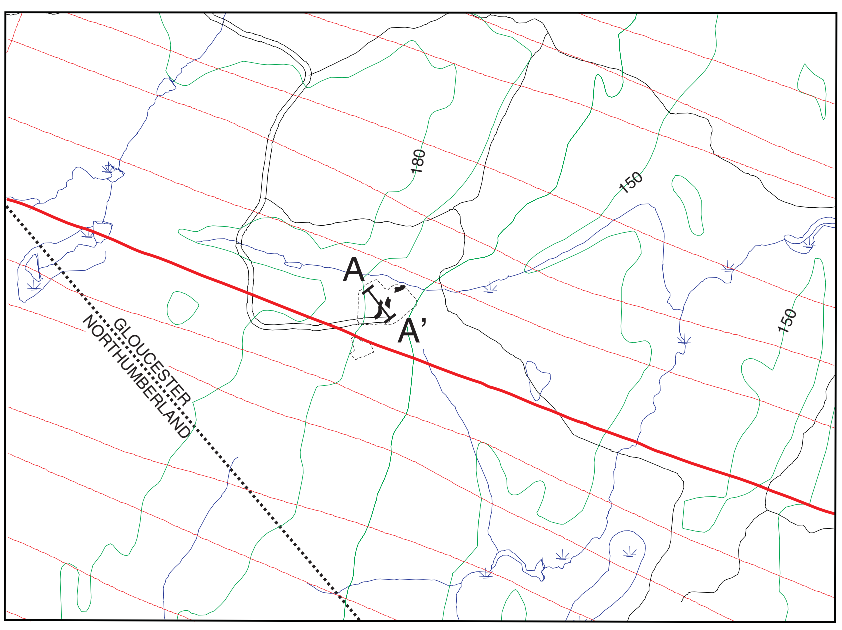


Modified from Langton (1996)

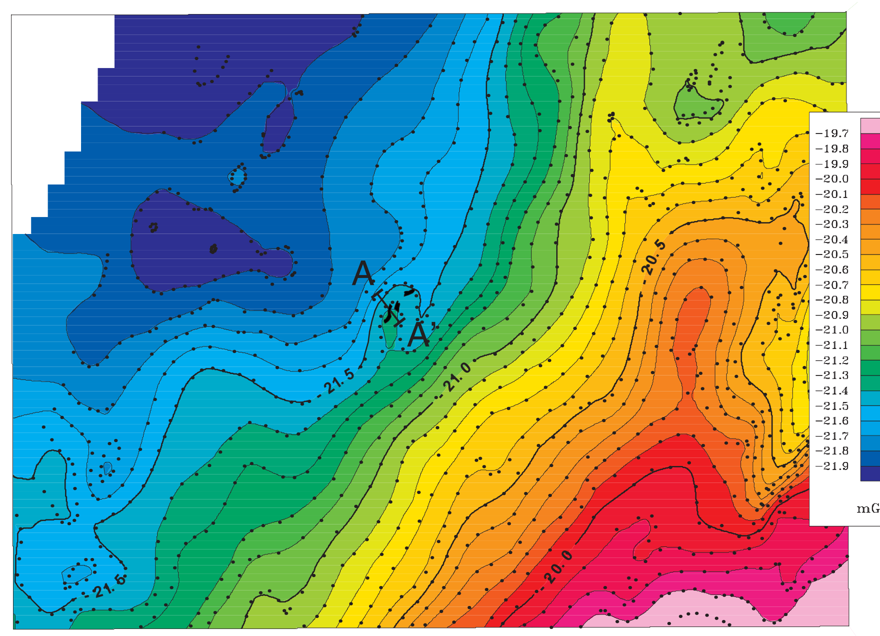
GEOLOGICAL LEGEND



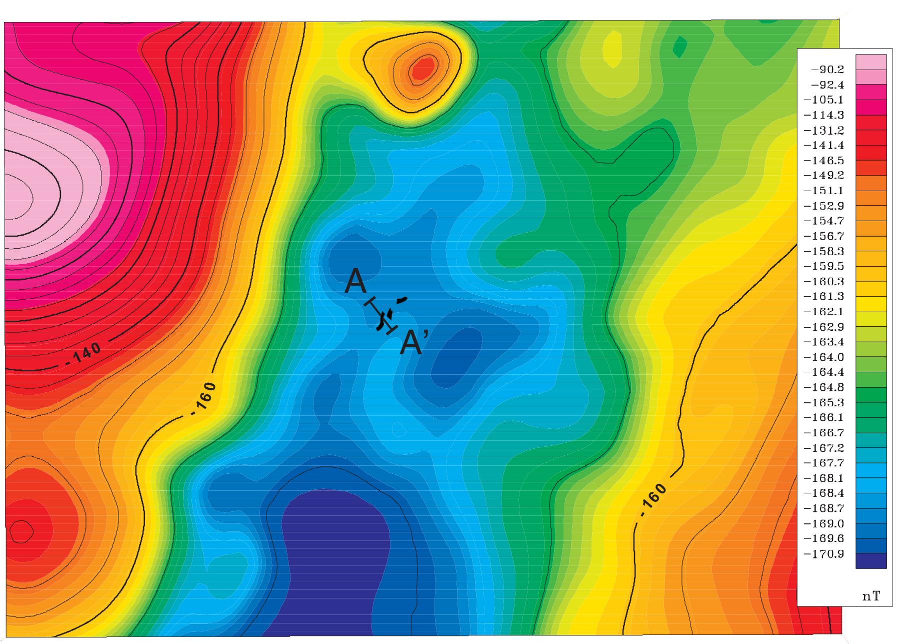
TOPOGRAPHY/FLIGHT LINES



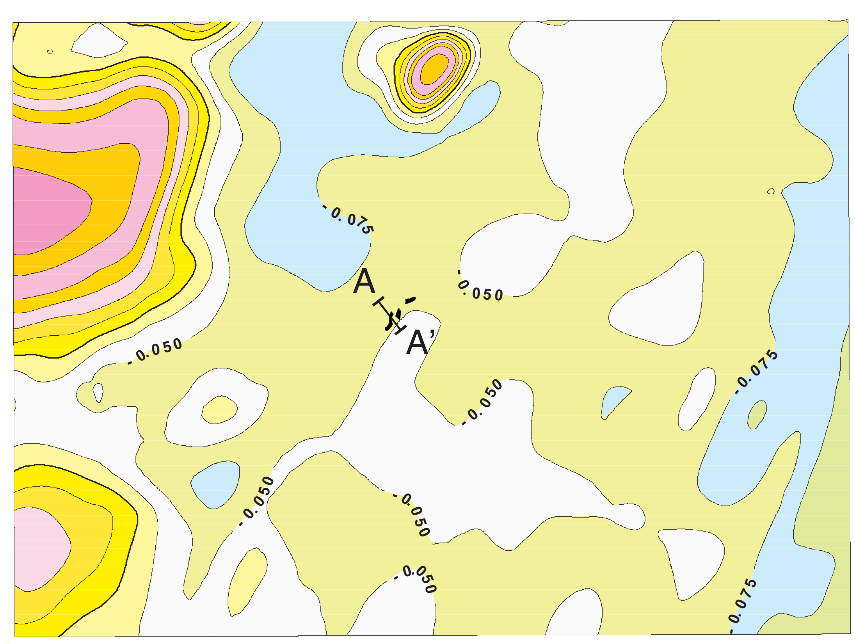
GRAVITY (mGal)



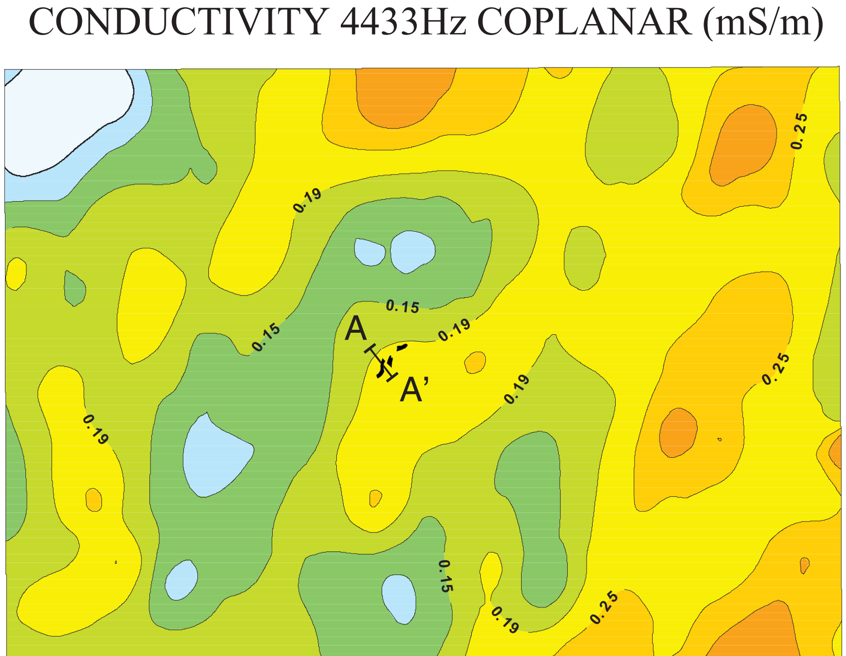
MAGNETICS (nT)



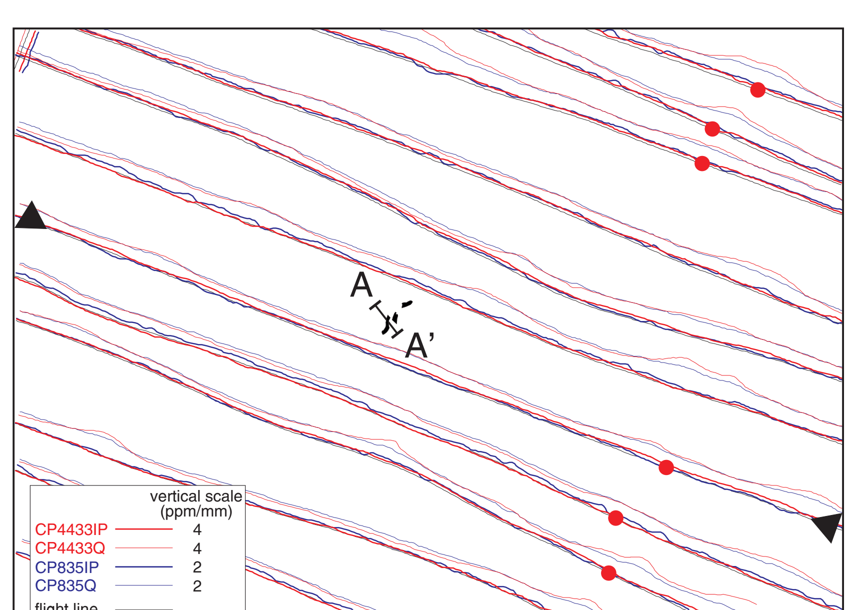
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



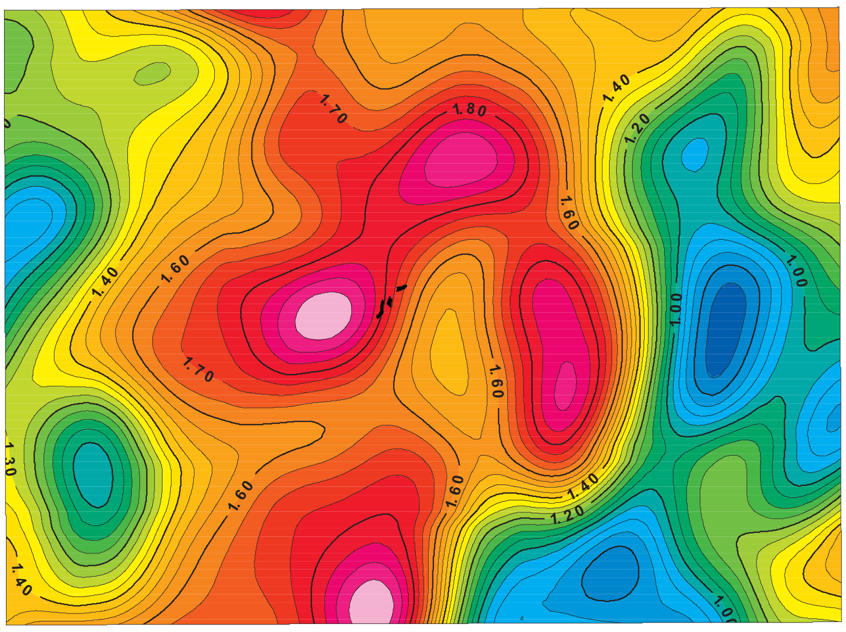
ELECTROMAGNETIC PROFILES/ANOMALIES



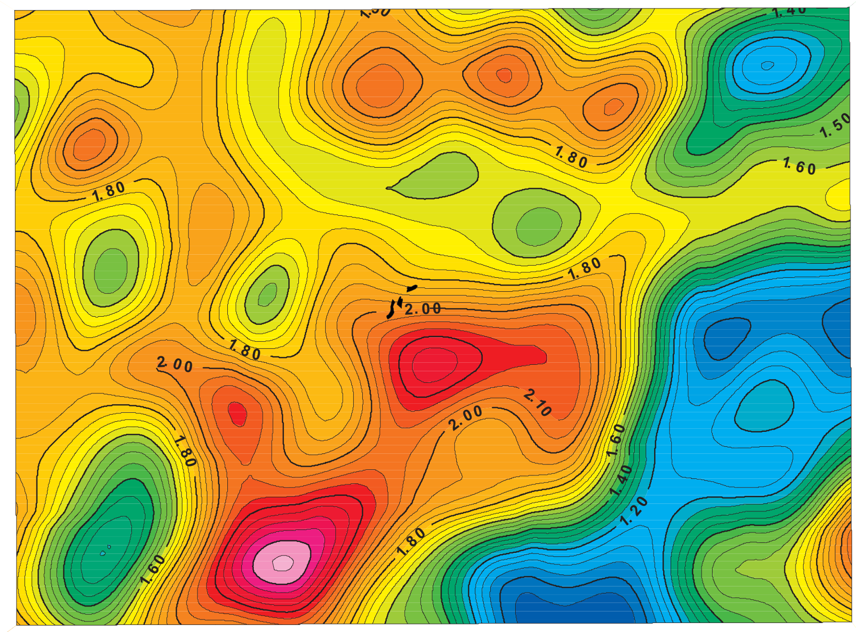
1000 m

CAPTAIN NORTH EXTENSION (CNE)

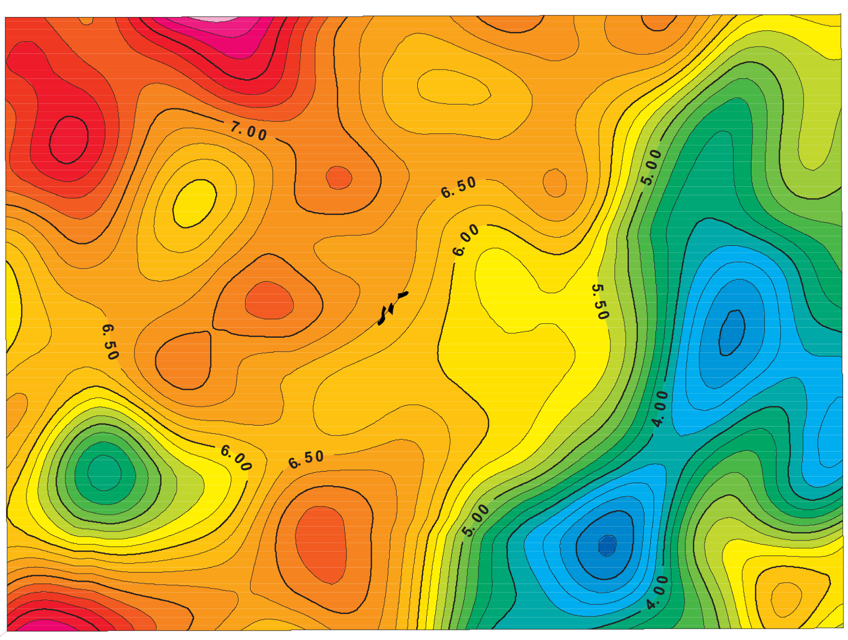
POTASSIUM (%)



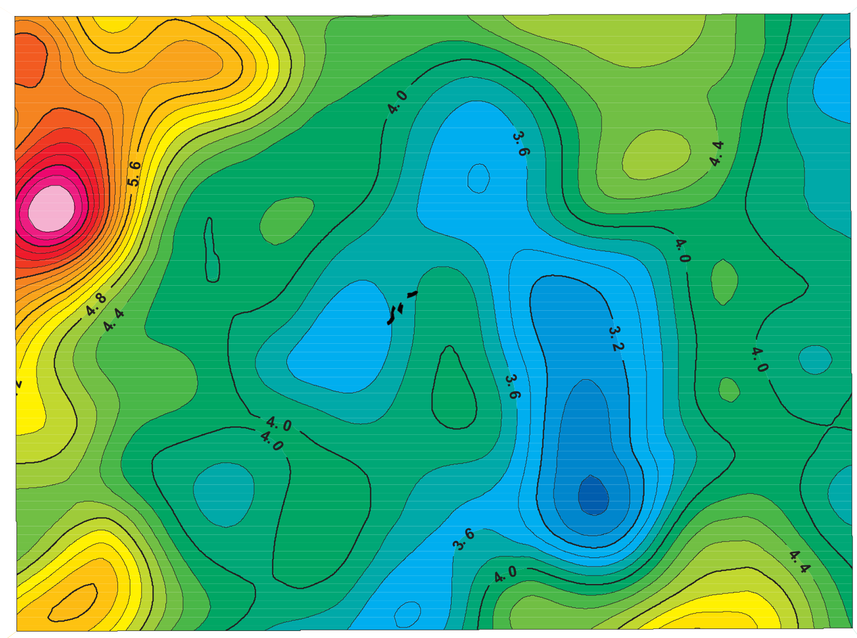
URANIUM (ppm)



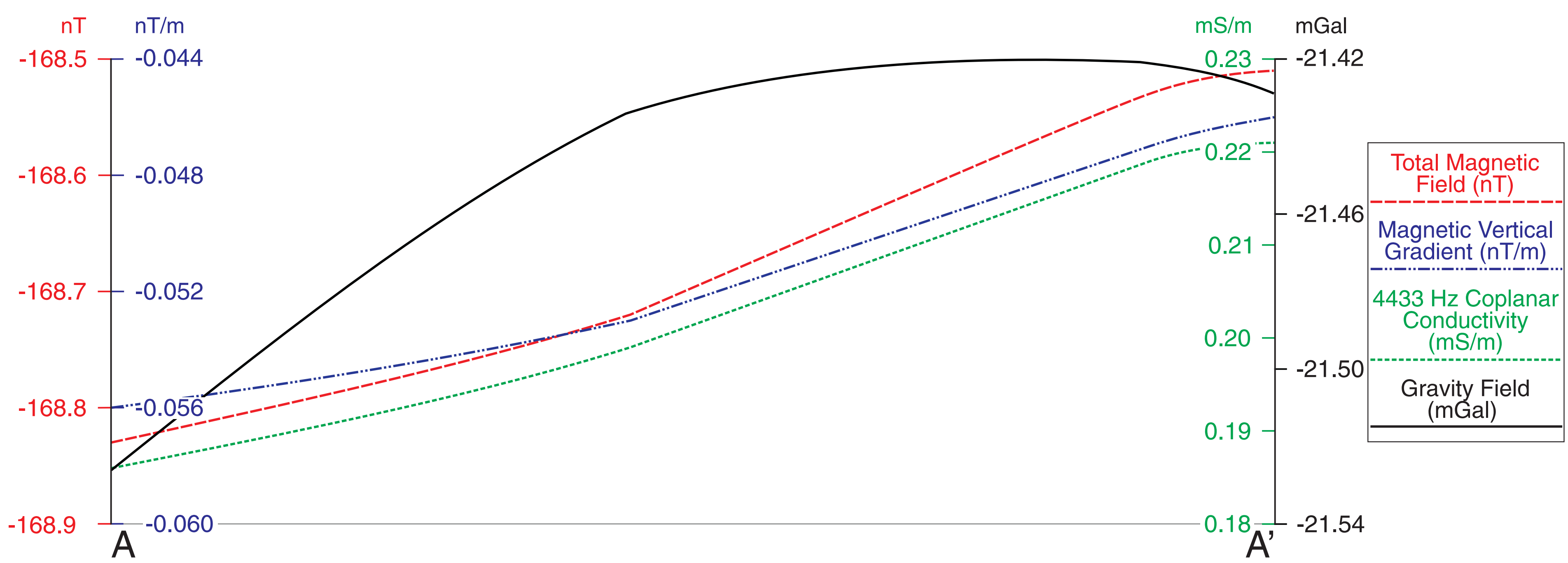
THORIUM (ppm)

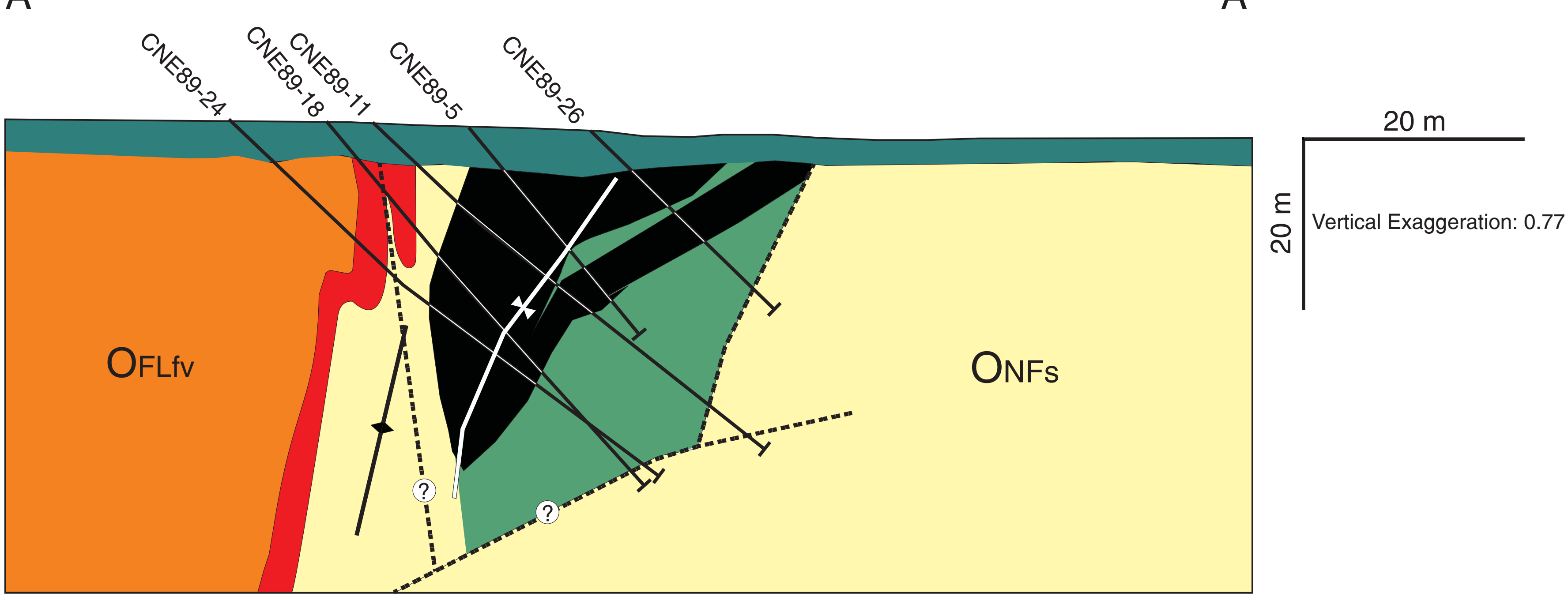


THORIUM/POTASSIUM RATIO (x 10^{-4})



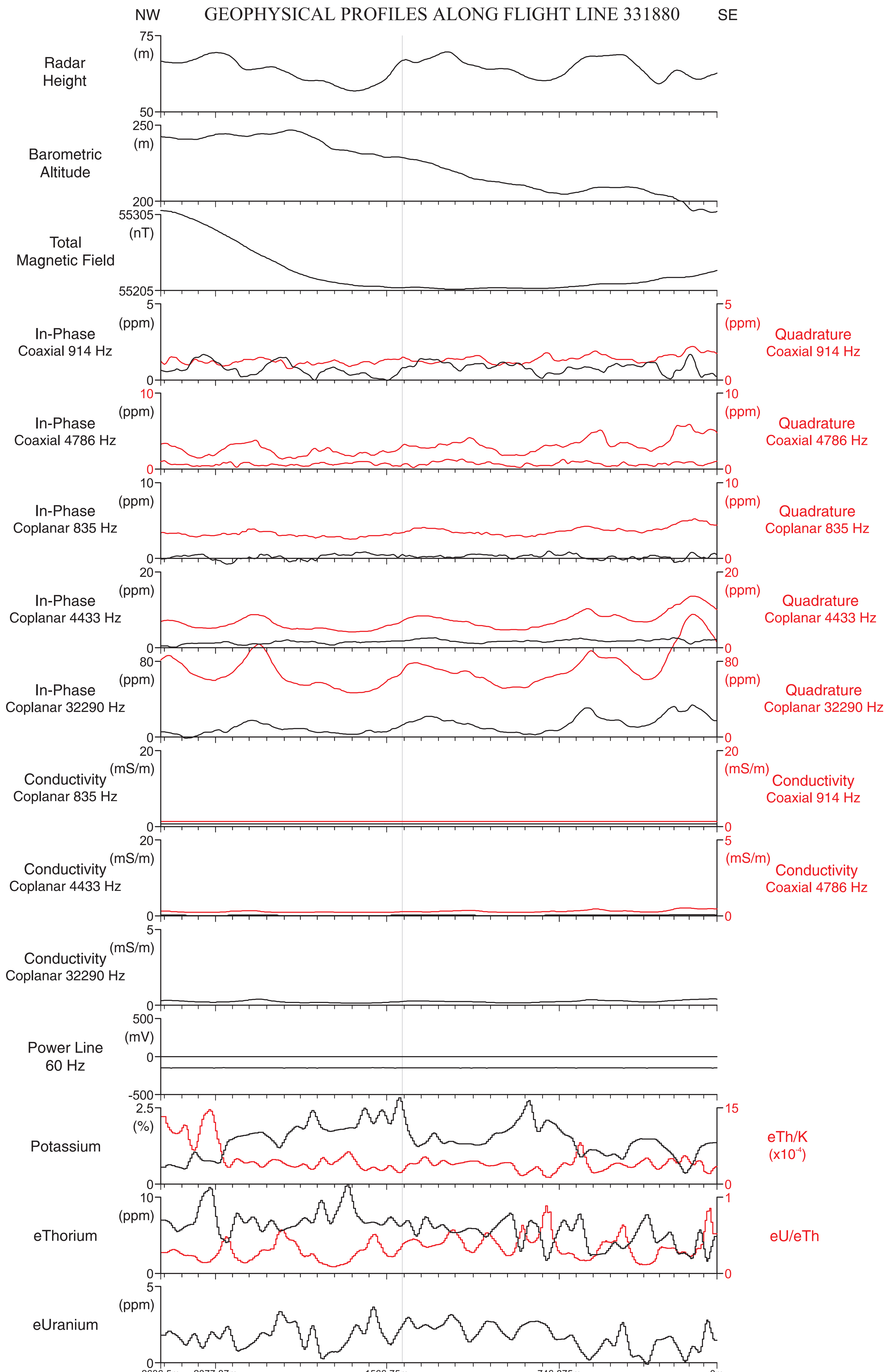
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'





Modified from Whaley (1992)

CAPTAIN NORTH EXTENSION (CNE)



CARIBOU DEPOSIT

GEOLOGY

The Caribou massive sulphide deposit is the second largest deposit in the district with total reserves to a depth of 1200 m estimated at 70 million tonnes of 0.5% Cu, 1.6% Pb, 4.3% Zn, 51.3 g/t Ag and 1.715 g/t Au (Cavelero, 1993). The deposit occurs in the core of an F_4 synform on the north limb of the Tetagouche Antiform (Cavelero 1990, 1993; Roscoe, 1971), and is hosted by sedimentary and felsic volcanic rocks of the Spruce Lake Formation (Rogers and van Staal, 1996).

The Spruce Lake Formation, in the vicinity of the mine, in ascending order comprises: (1) pale grey phyllite, greywacke and chloritic schist with interbedded highly altered pale green felsic tuff, (2) stratiform massive sulphides, and (3) green aphyric to feldspar-phyric rhyolite. The contact between the hanging wall rhyolite and massive sulphides is very sharp, and the contact area is commonly altered to chlorite. To the south, the mine sequence is in tectonic contact with the Boucher Brook Formation, which comprises alkalic basalt and grey to maroon shale and chert, interbedded with dark grey to black carbonaceous shale.

The Caribou deposit consists of an en-echelon array of four steeply-dipping stratiform massive sulphide lenses that extend over 1500 m (Cavelero, 1990, 1993; Roscoe, 1971). Mineralogically the sulphide lenses are dominated by pyrite, magnetite, sphalerite, galena, chalcopyrite, tetrahedrite, marcasite and arsenopyrite. Like most other deposits hosted by the Spruce Lake Formation, a laterally extensive Algoma-type iron formation is absent. The massive sulphides consist of two major hydrothermal facies: vent complex and bedded sulphide facies (Goodfellow, in prep.). The vent complex is restricted mostly to lens 2, whereas the bedded sulphide facies occurs throughout the Caribou deposit. The northwest sulphide lenses are underlain by a sulphide stringer zone that intersects chloritized sedimentary and volcanic rocks in the stratigraphic footwall (Goodfellow, in prep.).

MAGNETIC DATA

The U-shaped pattern of the narrow Caribou sulphide deposit is replicated by a much broader positive magnetic anomaly characterized by three circular to oval-shaped culminations. The deposit contains magnetite as a major component on the west limb of the Caribou synform, and magnetite is present on the east limb (Cavelero, 1993). This is probably the principal source of the anomaly. There is little evidence for alternative sources within the adjacent footwall and hanging wall rocks, which are mainly fine-grained sedimentary and felsic volcanic rocks, respectively. However, a possible additional source may contribute to the northernmost peak of the U-shaped magnetic high, which extends well to the east of the deposit. It is similar to anomalies over basaltic and sedimentary rocks to the northwest, and it is speculated that sub-thrustal equivalents may contribute to the high in this area. If the high is indeed a product of the massive sulphide, it may be poorly-defined, because the flight-line orientation (~N25°W) is subparallel to the west limb of the sulphide deposit, which lies between adjacent flight-lines. The two circular maxima on this portion of the magnetic high lie either side of the deposit and fall on flight-lines. Had flight-line orientation been east-west and/or line spacing smaller, better definition of the magnetic high and a closer correlation between peaks and the trace of the deposit would probably have been achieved. On the east limb, where flight-lines are practically perpendicular to the strike of the sulphide body, the peak of the anomaly has better correspondence with the deposit. The U-shaped anomaly is flanked to the northeast by a relatively quiet magnetic field over felsic volcanics, whereas to the west and southeast, where there are units of basalt, the field is much stronger and varied, several positive features being resolved in the vertical gradient map.

ELECTROMAGNETIC DATA

The HEM response of the Caribou sulphide deposit is caused mostly by tailings and contamination generated by heap-leaching of its gossan between 1982 and 1983. However, geophysical surveys done in the 1950's and the 1960's provide an idea of its EM response. Corbett (1961) describes the response of the deposit to various ground geophysical methods: horizontal and vertical loop EM, self-potential, resistivity and AFMAG. In all cases, this massive sulphide deposit gave a good response. The conductor was originally discovered by an airborne EM survey and later investigated by a vertical loop EM ground survey (Corbett,1961). Conductivity is said to be due essentially to sulphide mineralization, with no contribution from the adjacent shale, since the ground EM response is restricted to the length of the mineralization.

Electrical characteristics of mineralized and non-mineralized rocks at the Caribou deposit have been studied by Katsube *et al.* (1998a). They found that the massive sulphides have high conductivities, ranging from 330 to 10,000 mS/m. Volcanic tuffs have very low conductivities in the direction perpendicular to the foliation (0.07 mS/m to 0.15 mS/m) and significantly higher conductivities parallel to the foliation (0.37 mS/m to 6.6 mS/m). These conductivities are two order of magnitudes lower than the conductivity of the massive sulphides, and confirm that massive sulphides were the source of the original EM anomalies.

GRAVITY DATA

Gravity data for this deposit are unavailable.

RADIOMETRIC DATA

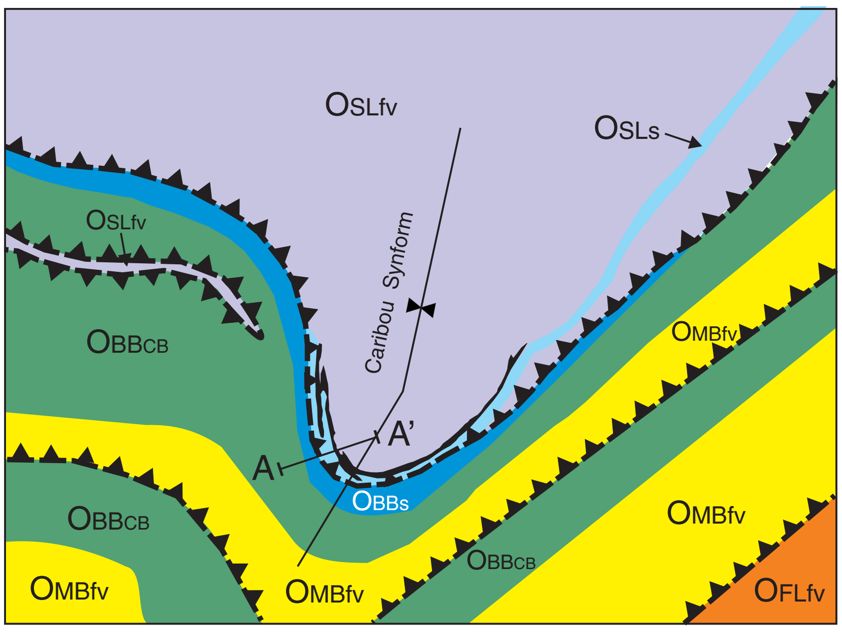
Airborne gamma-ray spectrometric patterns in the area of the Caribou deposit reflect regional geological trends. In the Spruce Lake Formation, feldspar-phyric crystal tuff and ash tuff within the core of the Caribou Synform produce elevated radioelement patterns (1.8 - 2.3% K, 2.0 - 2.6 ppm eU, 7.0 - 10 ppm eTh). Highest values in all three radioelements occur at the eastern end of the deposit, perhaps enhanced due to mine development. South of the deposit, alkali basalt, graphitic shale, siltstone and chert of the Boucher Brook Formation are associated with low radioelement concentrations (<1.2% K, <1.5 ppm eU, <6 ppm eTh). Ground spectrometry confirms that the prominent eTh/K ratio low “bull's-eye” is related to variations in bedrock chemistry, rather than surficial geological sources or mine development.

SUMMARY

Three local magnetic highs are distributed along or adjacent to the U-shaped Caribou deposit. Discontinuity between the highs is probably a result of the flight-line pattern, which did not intersect the western limb of the U. Magnetite within the sulphide lenses is likely the principal control on the magnetic highs. A broad conductivity anomaly peaks along eastern parts of the U-shaped deposit, but the main part of the response is ascribed to tailings and historical leaching of a gossan. Ground electromagnetic investigations in the 1950's indicate that the deposit produced a noticeable response. A coincident radiometric signature is not evident, though significantly higher values of the three radioelements are observed near the eastern extremity of the deposit.

CARIBOU

GEOLOGY



Modified from Cavelero (1991) and van Staal (1994e)

GEOLOGICAL LEGEND

TETAGOUCHE GROUP

Flat Landing Brook Formation

OFLfv — mainly rhyolite flows, domes & sills

Boucher Brook Formation

OBBs — grey to black, locally graphitic shale & siltstone; grey to black, red & maroon manganiferous siltstone & chert

OBBCB — Camel Back Member: massive to pillowed amygdaloidal basalt

CALIFORNIA LAKE GROUP

Spruce Lake Formation

OSLfv — felsic feldspar-phyric crystal tuff & ash tuff

massive sulphide (Pb + Zn rich)

OSLs — laminated to thinly bedded shale interbedded with feldspathic sandstone & siltstone

Mount Brittain Formation

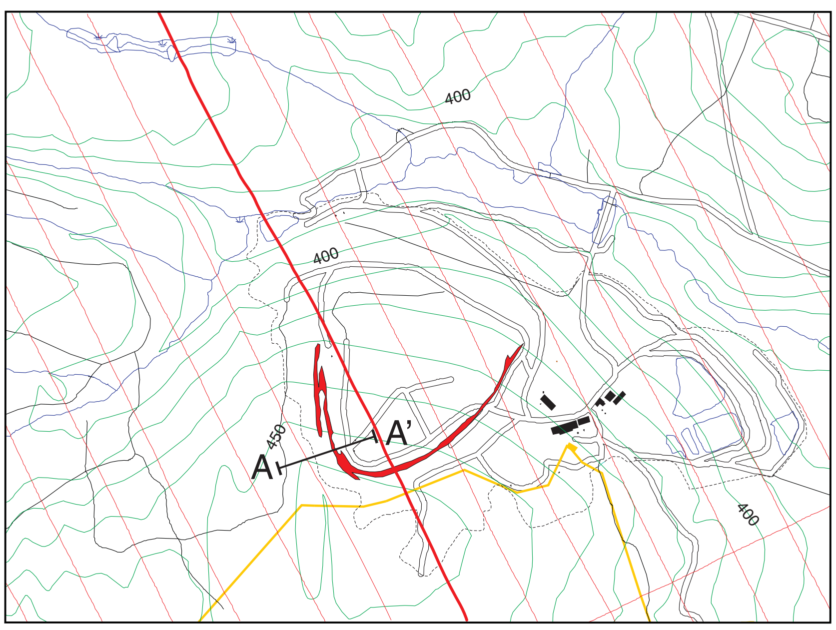
OMBfv — greenish grey to grey feldspar-crystal, lithic, lapilli tuff & related felsic flows

synform

normal fault

thrust fault

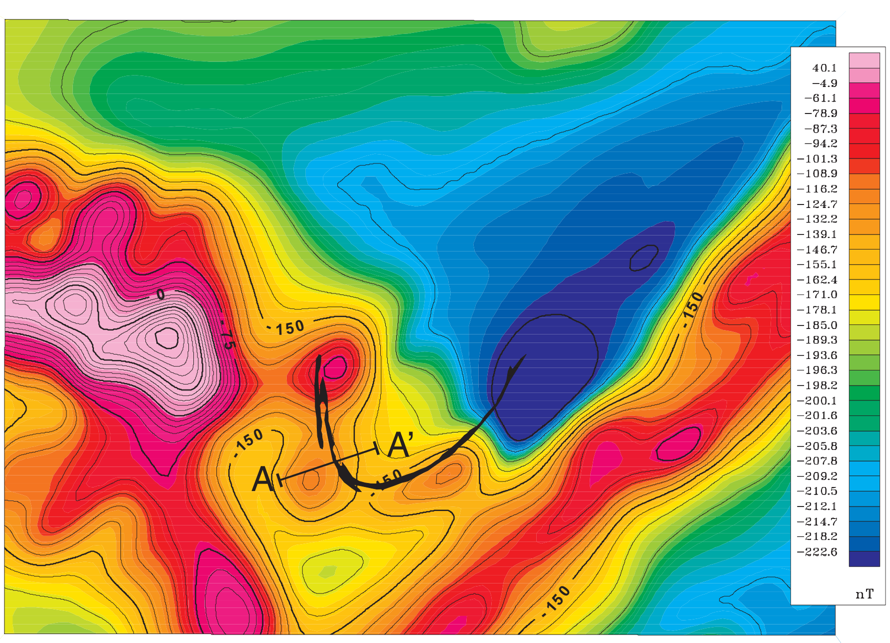
TOPOGRAPHY/FLIGHT LINES



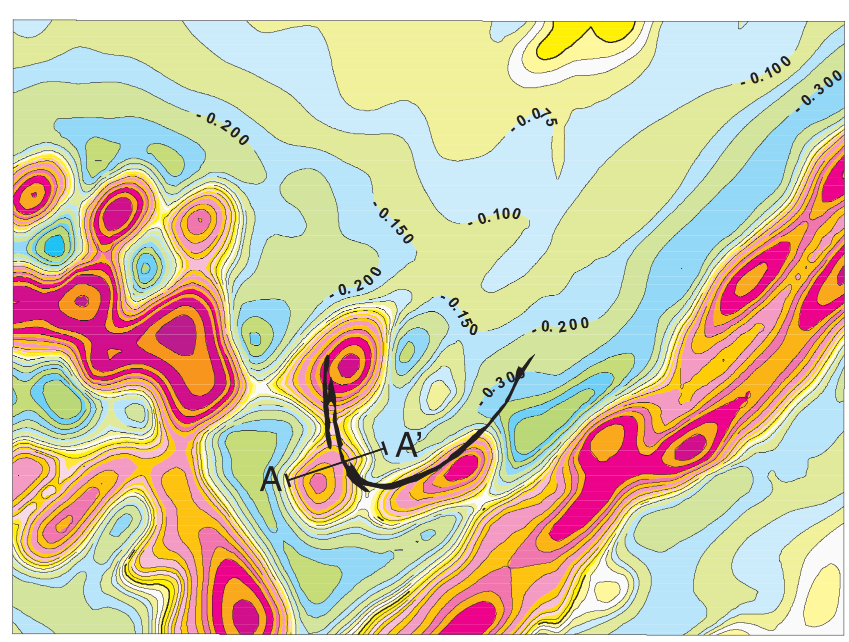
GRAVITY (mGal)

GRAVITY DATA UNAVAILABLE

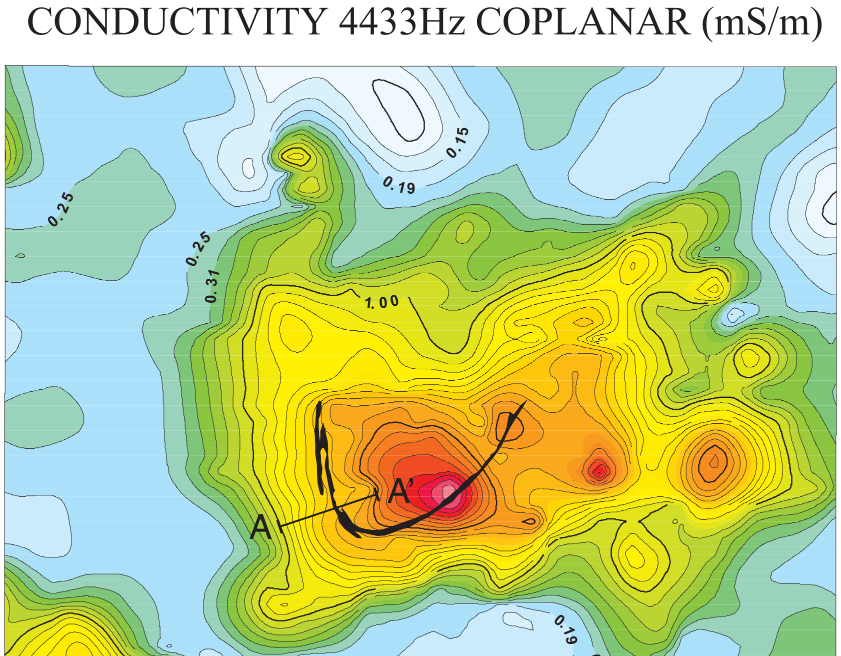
MAGNETICS (nT)



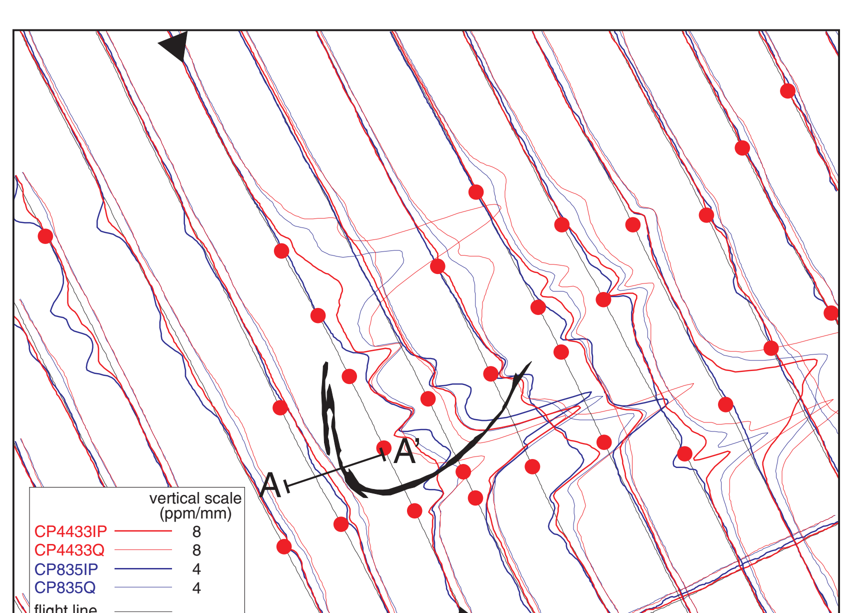
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



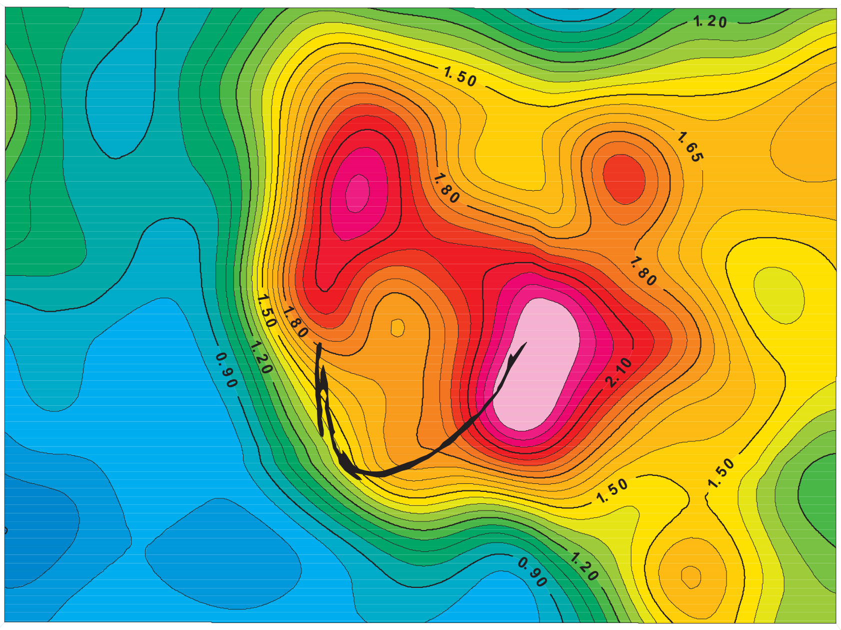
ELECTROMAGNETIC PROFILES/ANOMALIES



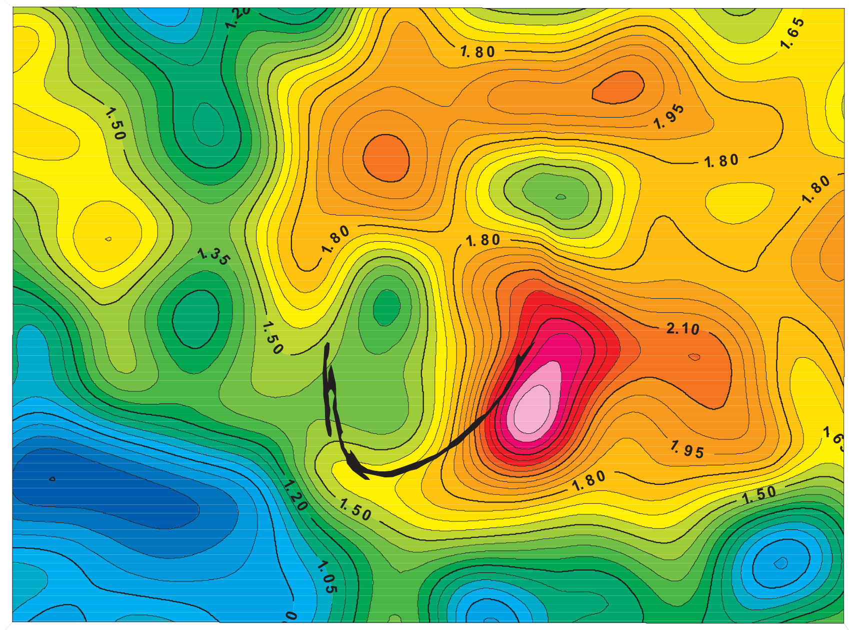
1000 m

CARIBOU

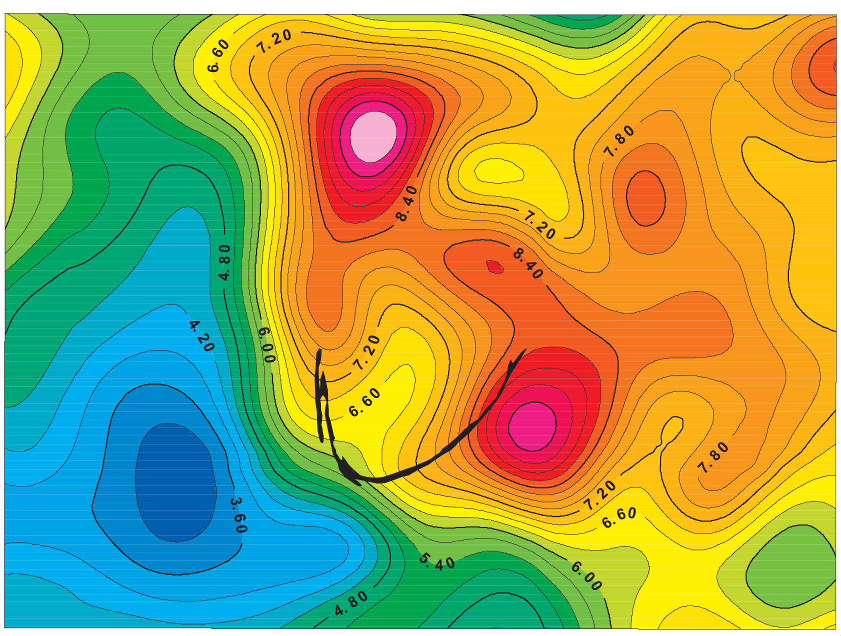
POTASSIUM (%)



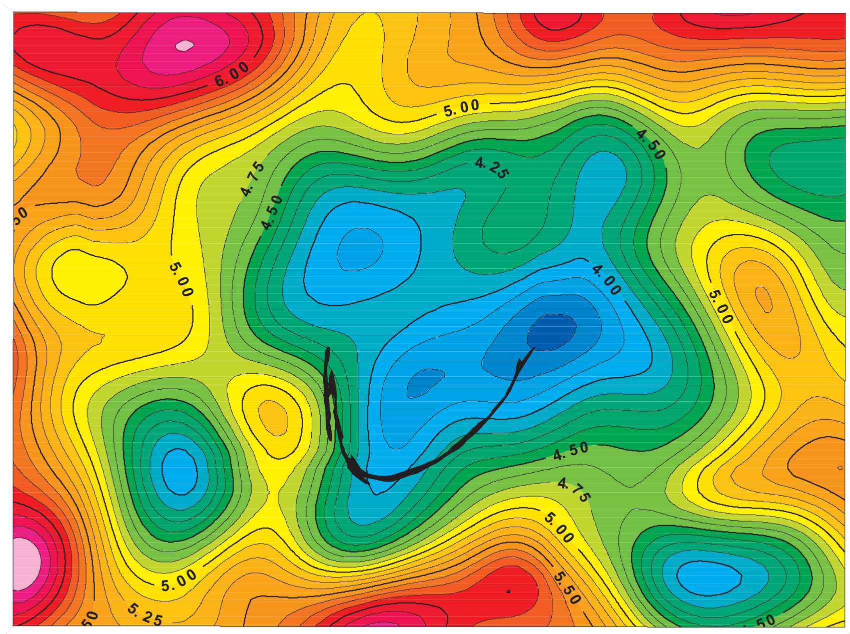
URANIUM (ppm)



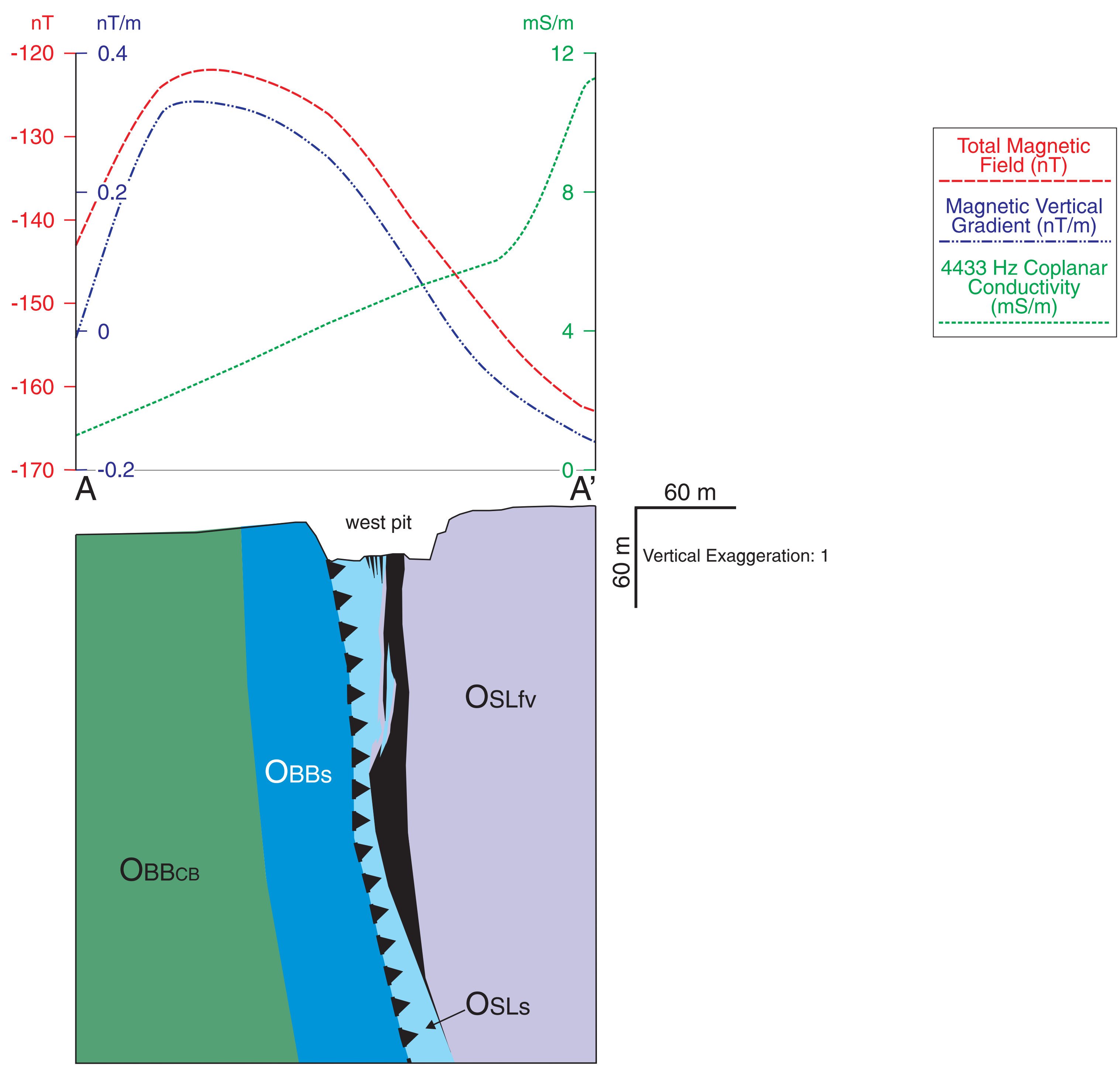
THORIUM (ppm)



THORIUM/POTASSIUM RATIO (x 10^{-4})

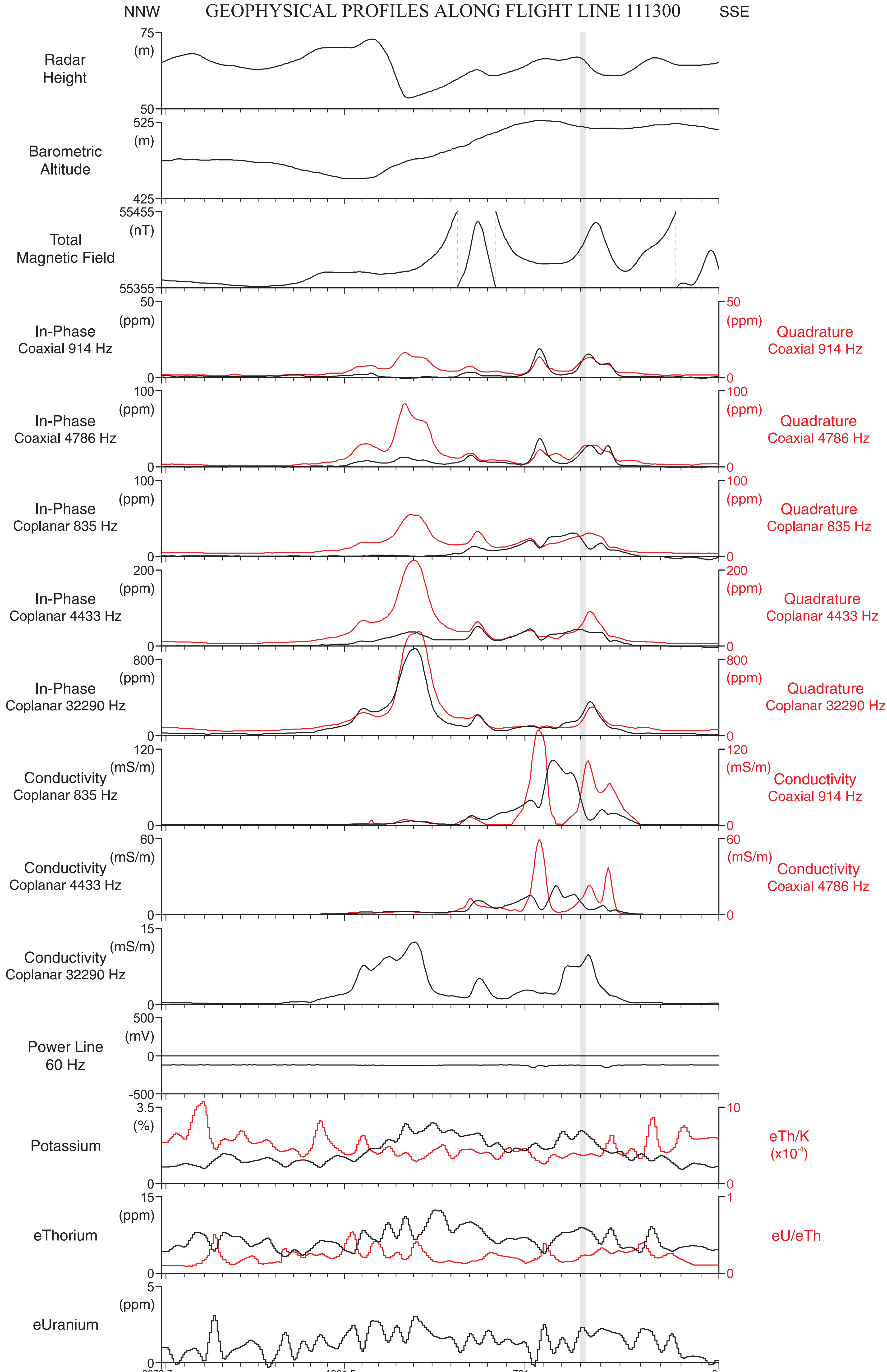


GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’



Modified from Cavelero (1991) and van Staal (1994e)

CARIBOU


NNW
GEOPHYSICAL PROFILES ALONG FLIGHT LINE 111300
SSE
Radar Height
75
(m)
50
Barometric Altitude
525
(m)
425
Total Magnetic Field
55455
(nT)
55355
In-Phase Coaxial 914 Hz
50
(ppm)
0
Quadrature Coaxial 914 Hz
In-Phase Coaxial 4786 Hz
100
Quadrature Coaxial 4786 Hz
In-Phase Coplanar 835 Hz
Quadrature Coplanar 835 Hz
In-Phase Coplanar 4433 Hz
200
Quadrature Coplanar 4433 Hz
In-Phase Coplanar 32290 Hz
800
Quadrature Coplanar 32290 Hz
Conductivity Coplanar 835 Hz
120
(mS/m)
Conductivity Coaxial 914 Hz
Conductivity Coplanar 4433 Hz
60
Conductivity Coaxial 4786 Hz
Conductivity Coplanar 32290 Hz
15
Power Line 60 Hz
500
(mV)
-500
Potassium
3.5
(%)
10
eTh/K
(x10⁻⁴)
eThorium
15
1
eU/eTh
eUranium
5
2072.7m
1391.5m
721m
0m

CHESTER DEPOSIT

GEOLOGY

The Chester deposit was discovered by Kennco in 1955 during follow-up work on an airborne EM anomaly (Black, 1957). The deposit comprises three sulphide zones that are hosted by feldspar-phyric crystal tuff of the Clearwater Stream Formation. Other than the stratiform sulphides, no chemical exhalative sedimentary rocks (iron formation) occur in the vicinity of the deposit. The East and Central zones crop out at surface, are overlain by as much as 15 m of overburden and gossan, and comprise flat to shallowly-west-dipping lenses of massive to disseminated sulphides that are 3 to 15 m in thickness. The East zone contains 450,000 tonnes grading 0.78% Cu, 0.36% Pb and 1.14% Zn, and the Central zone contains 1.1 million tonnes grading 0.47% Cu, 0.9% Pb and 2.22% Zn. The West zone contains 5 to 10% stringer and disseminated chalcopyrite and pyrrhotite that are restricted to a gently west-plunging (15-20°), 75 m thick zone of quartz-chlorite schist. The West zone is interpreted to be a feeder conduit to the East and Central zones and extends to a vertical depth of at least 600 m. It contains an estimated 15.2 million tonnes of 0.78% Cu. The dominant structural fabric in the area is axial-planar to southwest-plunging F_2 folds. The S_2 fabric is folded by tight, recumbent F_3 folds.

MAGNETIC DATA

The shallow Central and East zones of the Chester deposit both coincide with prominent circular peaks superposed on a gently arcuate and roughly east-northeast-trending positive magnetic anomaly. This anomaly stands out in a relatively subdued and gently varying background field that characterizes the plagioclase-phyric, dacitic tuffs of the hosting Clearwater Stream Formation. The Central and East zones consist of 70-80% (massive) and 50% (intermixed massive and disseminated) sulphides, respectively, mainly in the form of pyrite (Fyffe, 1995). Semi-discrete zones of Zn-Pb-Cu-rich massive sulphide and stringer chalcopyrite and pyrrhotite occur within the pyrite (Moore, 1995). It is concluded that pyrrhotite is the principal cause of the magnetic high. The West zone, which plunges westward from a shallow depth near the Central zone, consists of 5-10% stringer and disseminated sulphide, mainly in the form of chalcopyrite and pyrrhotite (Fyffe, 1995). This, apparently, has little or no influence on the magnetic field. The extremities of the arcuate positive high, contained within the boundaries of the Clearwater Stream Formation, suggest possible extensions of sulphide mineralization, both northeast of the East zone and along the north side of the West zone. Interestingly, small negative anomalies on the south side of the high may indicate the presence of remanent magnetization within the sulphide deposit. The Patrick Brook Formation, comprising mainly shale and siltstone, is associated with several conspicuous linear magnetic highs. Their sources are unknown, although disseminated sulphides, if present, could be an important influence.

ELECTROMAGNETIC DATA

The massive sulphide lenses of the Chester deposit generate a broad apparent conductivity anomaly on the mid-frequency coplanar coils. Its amplitude reaches a maximum of more than 5000 mS/m over the Central zone, and it attains more than 10 mS/m over the East zone. The anomaly extends westward from the Central zone, following the track of the buried stringer mineralization that defines the West zone. The amplitude of the anomaly diminishes in the same direction, reflecting the increasing depth of burial of the zone. EM responses are strong and complex over the Central zone. At low frequencies, on flight-line 440110, the in-phase and quadrature coplanar responses are 2000 ppm and 647 ppm, and the coaxial responses 640 ppm and 133 ppm, respectively. At mid frequencies, the in-phase and quadrature coplanar responses are 1753 ppm and 432 ppm, the coaxial responses are 624 ppm and 112 ppm. At high frequency, the in-phase and quadrature responses are 2976 ppm and 512 ppm. Stronger coplanar responses are due to the shallow dip of the sulphide body. In this case the coplanar coils are optimally coupled with the conductive massive sulphides, resulting in a response that is stronger than that on the coaxial coils. The very strong response is partly explained by the low altitude of the helicopter over the deposit. The radar altimeter indicates that the EM bird was 19 m above ground. The complex EM response is due to the fact that the top of the conductor is parallel to the flight-lines and dips to the west. This results in a weaker EM response on the adjacent flight-line to the west. The main EM anomaly can be modelled by a thin 200 m square plate that has a dip of 20° to the west. The interpreted conductivity-thickness is 50 S. Best and Shammas (1979) report that the Central zone consists of approximately 85% conductive massive sulphides.

Over the East zone EM responses are also strong and complex. At low frequencies, on flight-line 440130, the in-phase and quadrature coplanar responses are 104 ppm and 192 ppm, and the coaxial responses 24 ppm and 40 ppm. At mid frequencies the in-phase and quadrature coplanar responses are 312 ppm and 240 ppm, the coaxial responses are 80 ppm and 96 ppm. At high frequency, the in-phase and quadrature responses are 480 ppm and 112 ppm. The axis of the conductor is parallel to the flight-line orientation. As is the case for the Central zone, the adjacent flight-line to the west shows a similar but weaker EM response.

GRAVITY DATA

Gravity data for this deposit are unsuitable.

RADIOMETRIC DATA

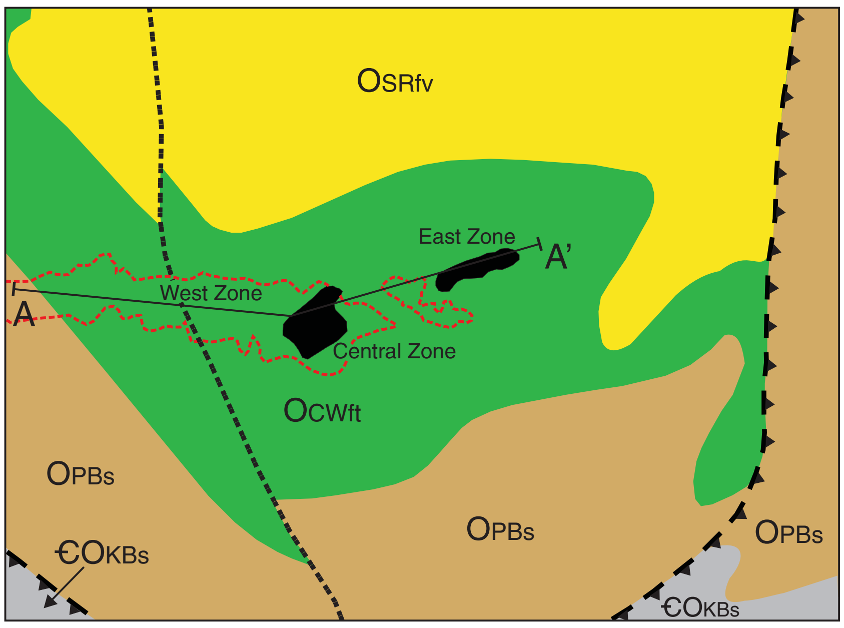
High K (1.8 - 2.6%) and eTh (9 - 11 ppm eTh) concentrations coincide with dacitic crystal tuff within the Clearwater Stream Formation and alkali feldspar-phyric and aphyric rhyolite assigned to the Sevogle River Formation. An exception to this occurs in the northeast corner of the map-area, where a thicker till blanket atop a broad plateau may be masking the felsic bedrock response. Maximum values are proximal to the sulphide zones, but are likely enhanced by increased exposure of bedrock due to exploration/development. The east-west trending eTh/K high provides a more sensitive indicator of probable K depletion within the pervasive quartz-chlorite alteration near the deposits, than does the corresponding, weak potassium low. Ground spectrometry (Shives and Ford, in press) was useful in delimiting the associated chloritization and silicification. In the case of the Chester deposit, where the sulphides and enclosing alteration zones are exposed, radioelement patterns can be useful in constraining geological contacts and alteration zones, thereby providing additional guides for exploration.

SUMMARY

Strong, coincident positive magnetic and conductivity anomalies embrace the Central and East zones of the Chester deposit, with local maxima positioned on both zones. These types of signatures would represent prime targets in an exploration program. Concentrations for all radioelements are high near the Central zone, but the most significant radiometric signature, from an exploration viewpoint, is an eTh/K high that covers most of the two zones. It is interpreted to signify potassium depletion associated with feldspar-destructive, quartz-chlorite alteration in the immediate footwall of the deposit.

CHESTER

GEOLOGY



Modified from Fyffe (1993)

GEOLOGICAL LEGEND

SHEEPHOUSE BROOK GROUP

Sevogle River Formation

OSRfv — schistose, alkali feldspar-phyric to aphyric rhyolite; silicified & pyrite-bearing near the sulphide deposit

Clearwater Stream Formation

OCWft — schistose, dacitic volcanics (crystal tuffs); pervasive quartz-chlorite alteration near sulphide deposit

massive sulphide at surface

stringer zone sulphide

surface projection of stringer sulphide body

MIRAMICHI GROUP

Patrick Brook Formation

OPBs — interlaminated shale & siltstone, grading locally into thin-bedded feldspathic wacke

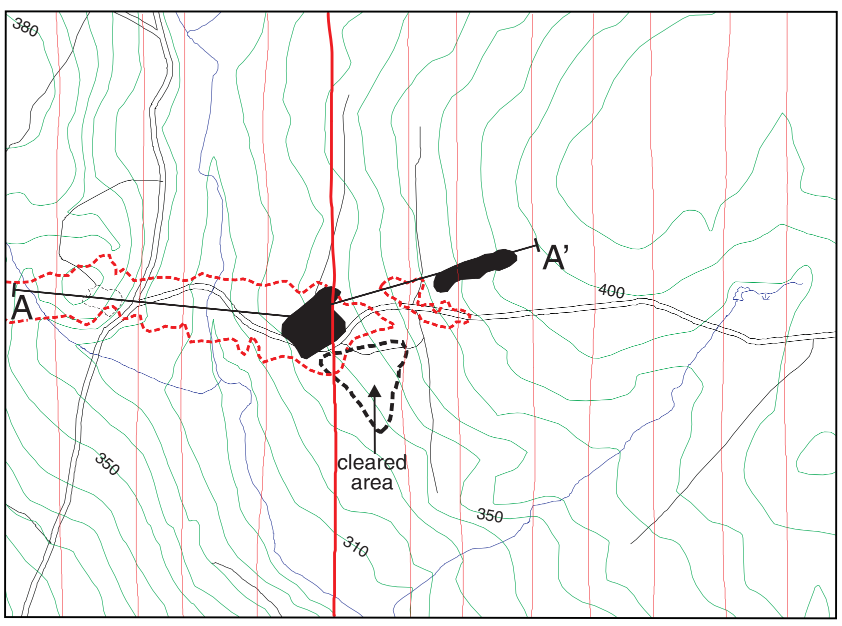
Knights Brook Formation

€OKBs — thin to medium-bedded quartzite interstratified with siltstone & shale

normal fault

thrust fault

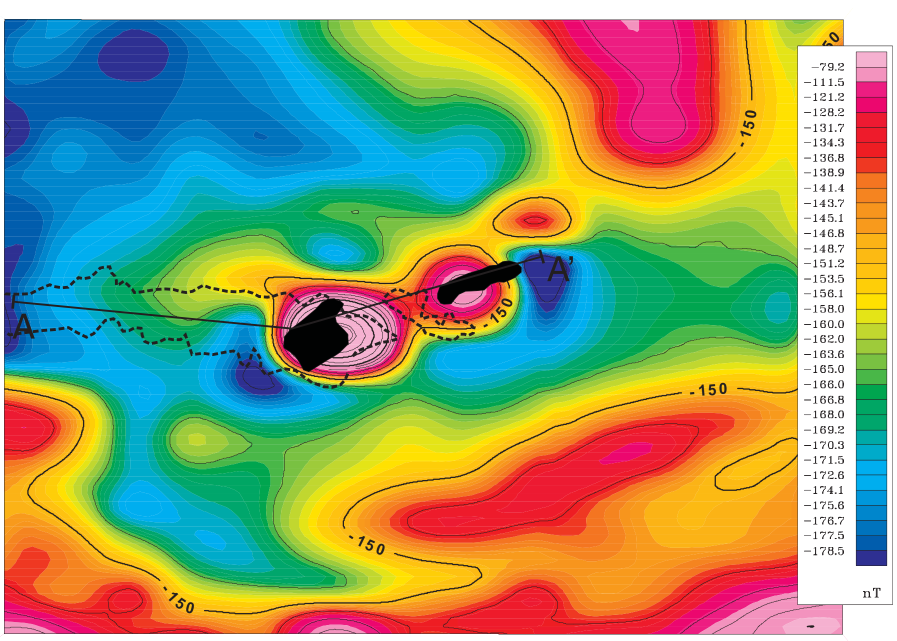
TOPOGRAPHY/FLIGHT LINES



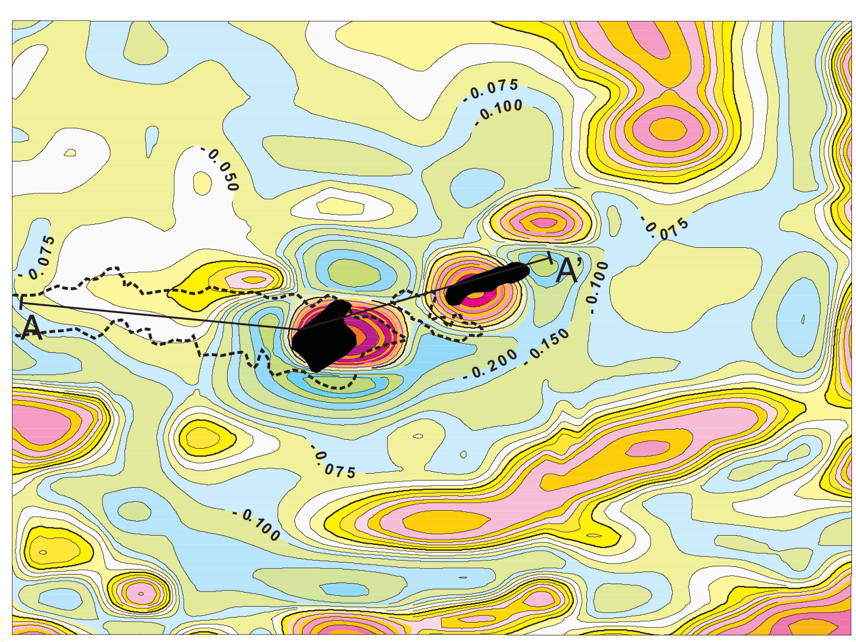
GRAVITY (mGal)

GRAVITY DATA UNSUITABLE

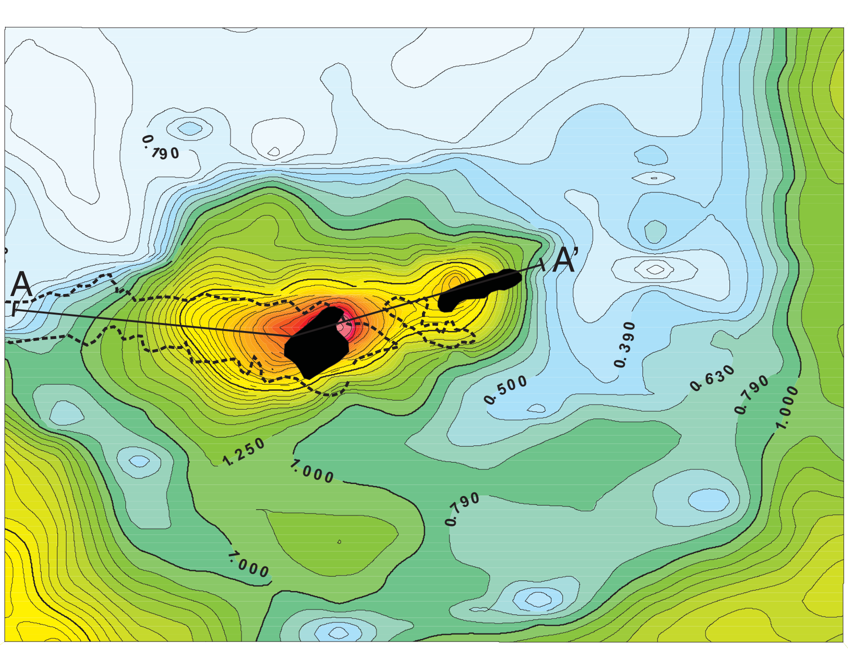
MAGNETICS (nT)



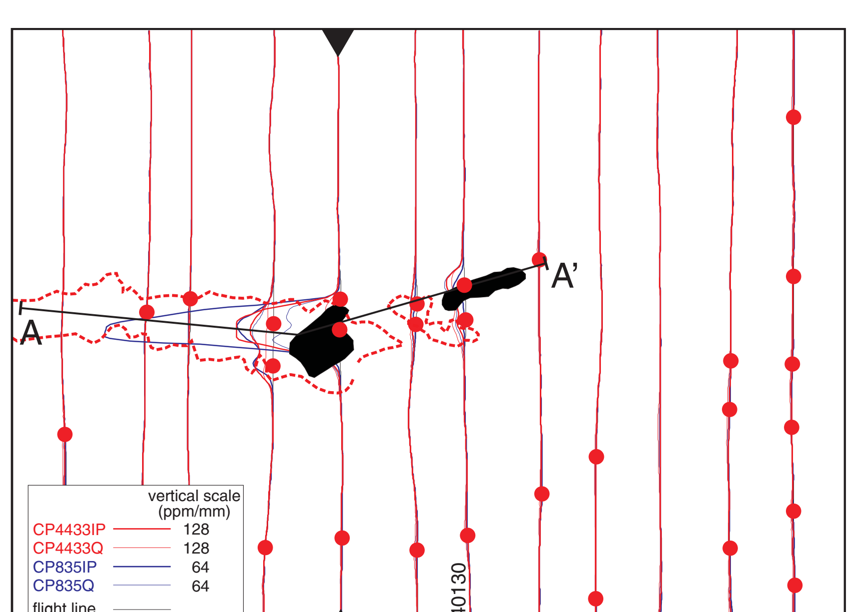
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



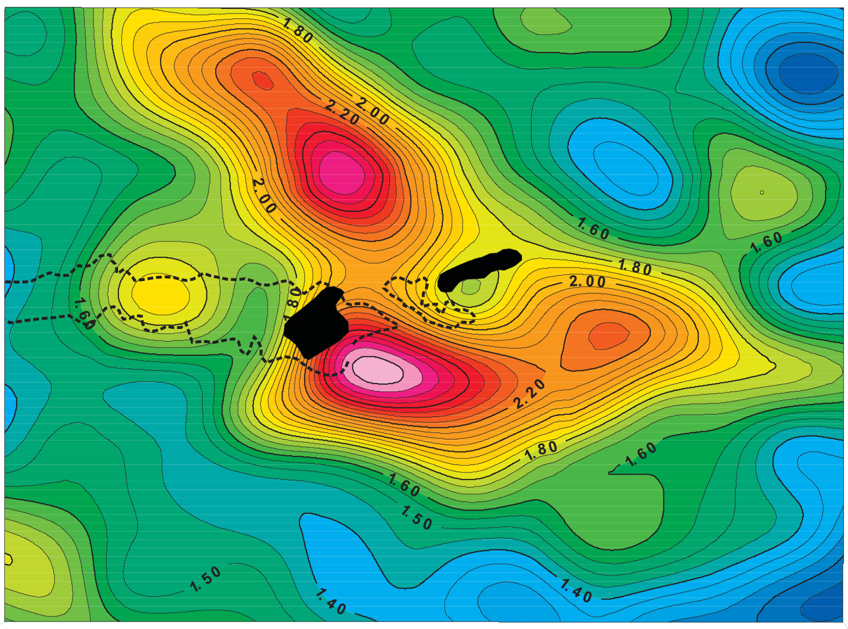
ELECTROMAGNETIC PROFILES/ANOMALIES



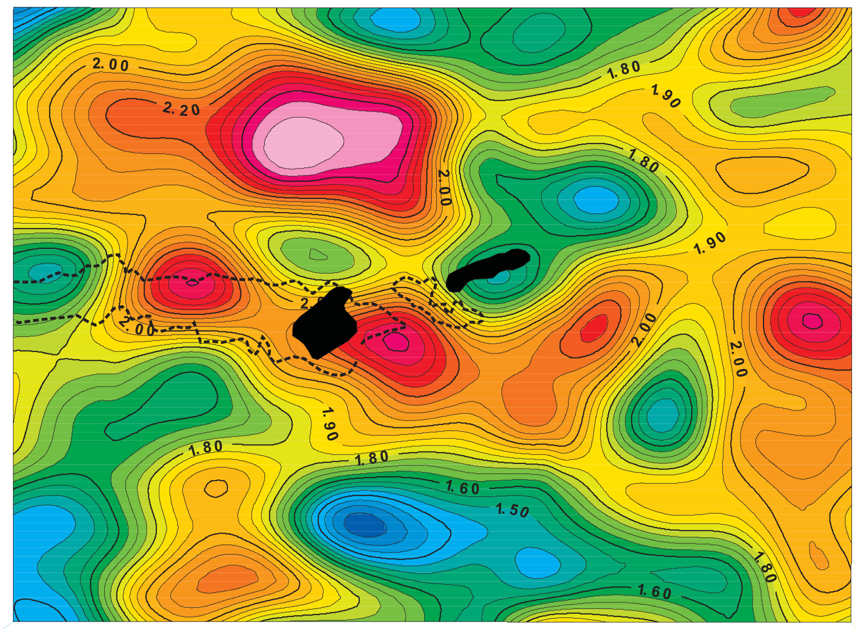
1000 m

CHESTER

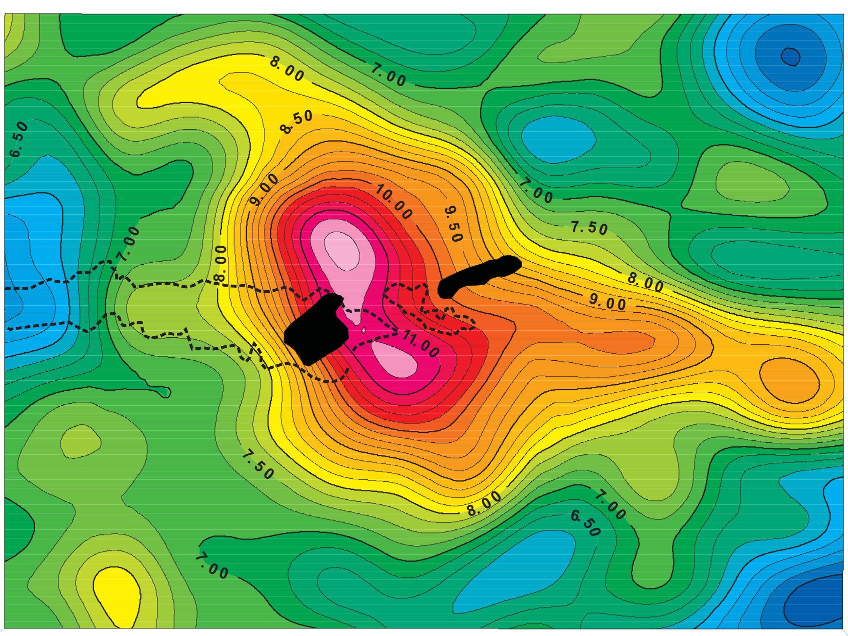
POTASSIUM (%)



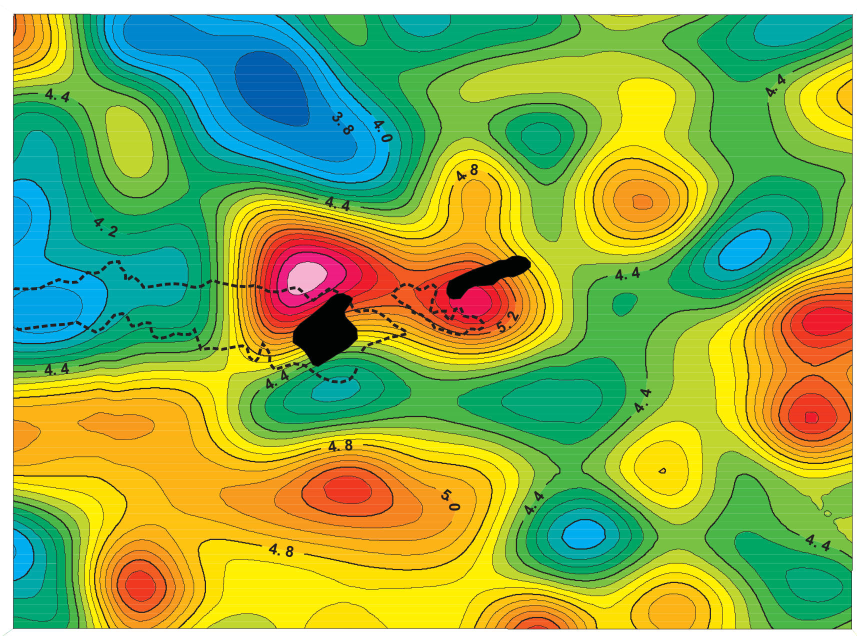
URANIUM (ppm)



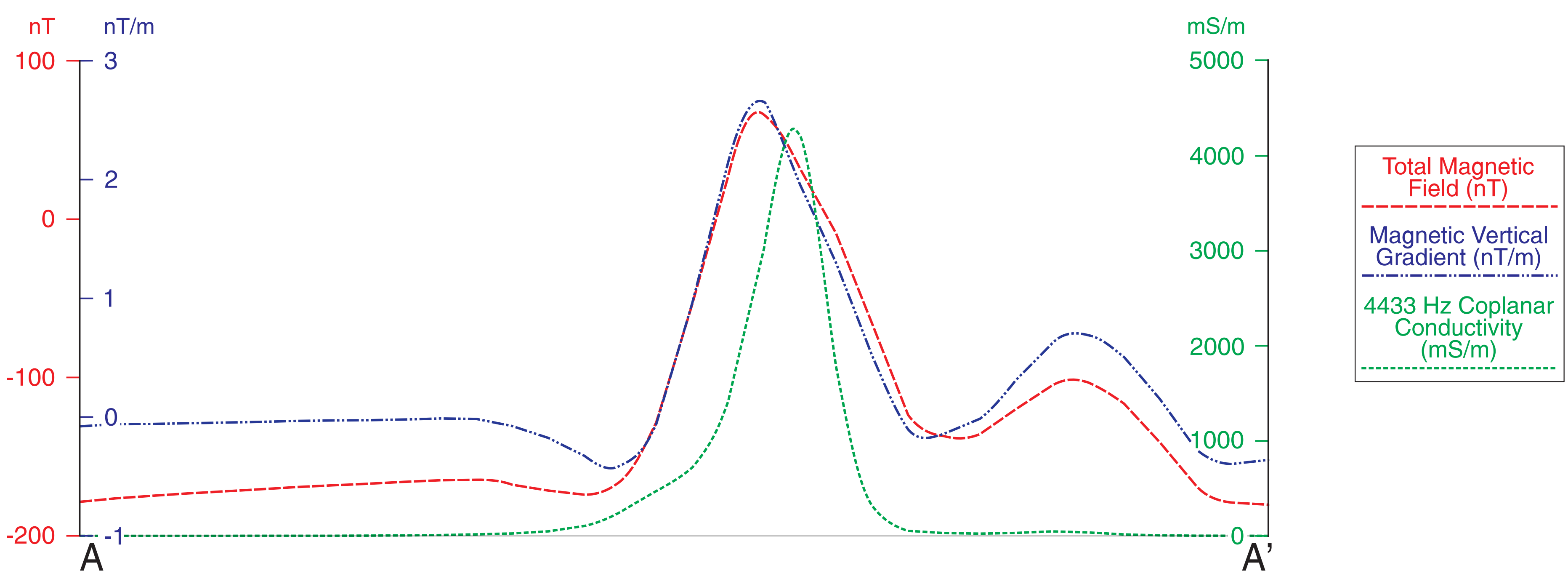
THORIUM (ppm)

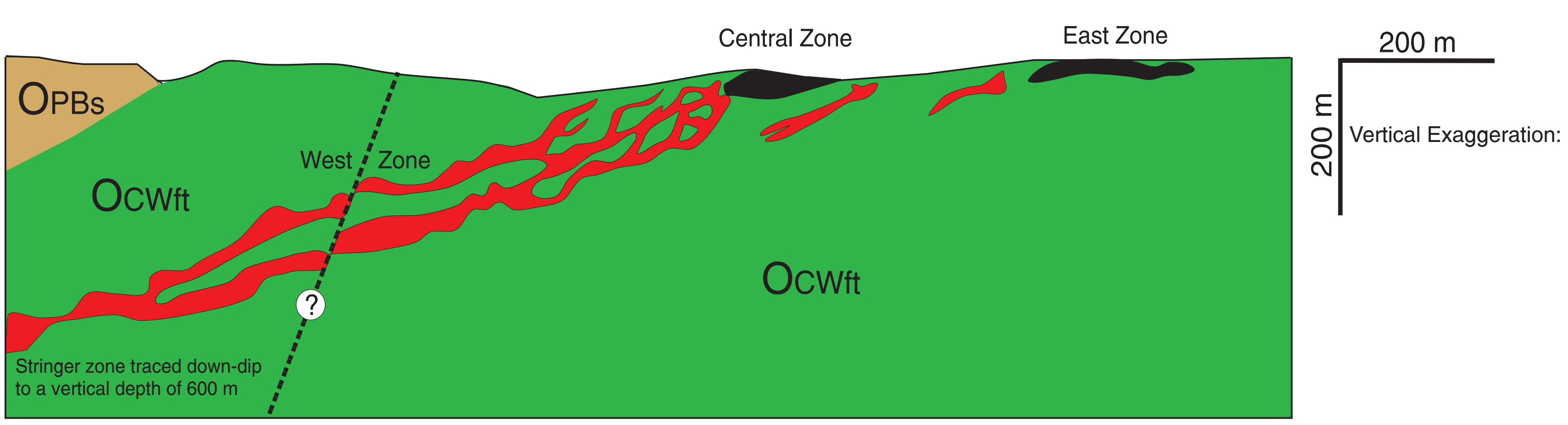


THORIUM/POTASSIUM RATIO (x 10^{-4})



GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'

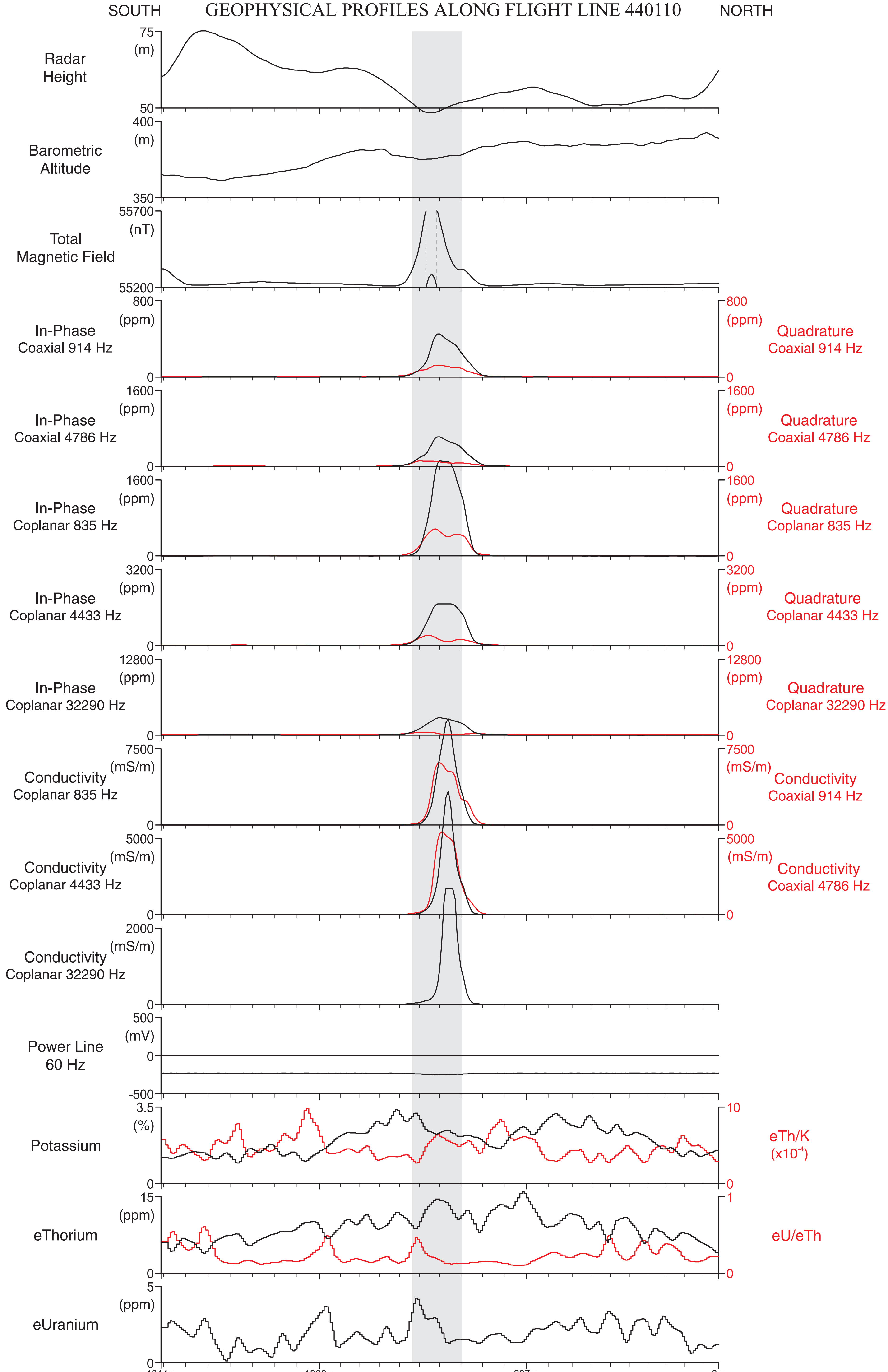




Modified from Fyffe (1994, 1995)

CHESTER

GEOPHYSICAL PROFILES ALONG FLIGHT LINE 440110



DEVILS ELBOW DEPOSIT

GEOLOGY

The Devils Elbow deposit was discovered by the American Metals Company Limited in 1956-57 during follow-up work on an airborne electromagnetic anomaly (Gledhill *et al.*, 1957). Devils Elbow contains a drill-indicated resource of 470,000 tonnes of massive and disseminated sulphides grading 1.08% Cu (Williams, 1974b), and occurs within the Nepisiguit Falls Formation near the contact with the conformably overlying Flat Landing Brook Formation (Caron and Gower, 1995; Gower, 1995a; Gower and McCutcheon, 1995). The structural footwall of the deposit comprises interlayered quartz-feldspar crystal tuff, ash tuff and related volcaniclastic rocks, whereas the structural hanging wall comprises quartz-feldspar crystal tuff, ash tuff, and volcaniclastic and epiclastic rocks interlayered with chloritic mudstone.

The mineralized zone trends north-northwest and appears to be discordant with local formational contacts that strike approximately east-west. Mineralization comprises an assemblage of fine- to coarse-grained, disseminated to semi-massive sulphides of pyrite > pyrrhotite >> chalcopyrite >> sphalerite + galena, hosted in fine-grained volcaniclastic rocks (Williams, 1974b; Walker, 1997). The mineralized zone is enveloped by an asymmetric alteration halo that comprises chloritic, sericitic, and siliceous alteration. The zone of alteration extends well into the structural hanging wall, but only a short distance into the structural footwall.

This deposit is interpreted as discordant to concordant stringer mineralization that was deposited from hydrothermal fluids focussed along a synvolcanic fault (Walker, 1997). The asymmetric alteration halo, coupled with a high Cu content, and large amount of sedimentary material in the structural hanging wall relative to the structural footwall is consistent with this interpretation.

MAGNETIC DATA

The Devils Elbow deposit is associated with a distinct, elongate magnetic anomaly, amplitude about 110 nT, which is attributed to its pyrrhotite content. The anomaly is superposed on a much broader, roughly oval-shaped magnetic high that extends away from the exposed sulphide horizon, mainly in a northeast direction, for well over 1000 m. The source of the broad high is uncertain, given that it overlies mainly felsic volcanic rocks of the Nepisiguit Falls Formation, which generally have weak magnetic susceptibilities (authors' data). Possibly, it is influenced to some extent by the sulphide deposit, since an extension of high magnetic field to the northeast is consistent with the prevailing northeast dips of the geology. Its broad lateral extent, which is considerably greater than the horizontal extent (about 150 m) of the underlying sulphide zones, may be explained by a northeast-dipping felsic tuff unit (horizontal extent of at least 350 m) that contains heavy concentrations of disseminated sulphide. Chloritic sedimentary layers within the sequence, in the structural hanging wall, may also contribute to the anomaly. On the vertical gradient map, the short wavelength anomaly directly over the sulphide deposit is separated from the broader anomaly, appearing as a more singular feature. The geological and geophysical environment in the area of the Devils Elbow deposit, with the strong contrast in magnetic properties of pyrrhotite-bearing sulphides and felsic volcanic rocks, is a favourable one for exploration using the magnetic method. In this respect, a magnetic high over felsic volcanic rocks due south-southwest of the deposit invites examination, although the absence of a concomitant conductivity anomaly makes it a less attractive target.

ELECTROMAGNETIC DATA

The Devils Elbow deposit is characterized by an approximately 600 m long apparent conductivity anomaly (from the 4433 Hz coplanar coils) centred over the deposit. This strong conductivity anomaly has a maximum amplitude of about 90 mS/m, resulting in an obvious exploration target. It is superposed on a broader, discrete area of elevated conductivity extending over a distance of about 1400 m. The sulphide body is intersected by three flight-lines and generates EM responses at all five frequencies of the HEM system, which are well above the noise level. At low frequencies, the in-phase and quadrature responses are 54 and 18 ppm, respectively, on the coplanar coils, and 12 and 5 ppm on the coaxial coils. At mid frequencies the corresponding responses are 50 and 18 ppm on the coplanar coils, and 18 and 7 ppm on the coaxial coils. At high frequency the in-phase response is about 100 ppm, whereas the quadrature response is negative. Inspection of the profile data shows that the negative quadrature is likely due to system drift and/or levelling problems. Taking this into account, the quadrature response is about 40 ppm above the local background.

Pyrite and pyrrhotite, which have typical conductivities of 3300 mS/m and 10^7 mS/m, respectively, are the major conductive minerals. The presence of small amounts of chalcopyrite (250,000 mS/m), sphalerite (10 mS/m) and galena (500,000 mS/m) also contribute to the conductivity anomaly. This deposit is located within felsic crystal tuff and ash tuff of the Nepisiguit Falls Formation, both of which have a very low conductivity. The eastward extension of the conductivity anomaly is likely due to the presence of chloritic sedimentary rocks, which can have a typical conductivity of ~10 mS/m. It should be noted that such rocks display a strong conductivity anisotropy; they are much more conductive along the foliation than across it (Connell *et al.*, 1999; Katsube *et al.,* 1998a). The small conductivity anomaly located west of the main anomaly is also associated with chloritic sedimentary rocks intersected by drill hole No. 119 (see cross section).

GRAVITY DATA

The gravity map of the area surrounding the Devils Elbow deposit is based on the digitization of a contour-line gravity map included in a report prepared for Brunswick Mining and Smelting Corporation (Babin, 1982). Data included in that map were collected at 100 ft (~30 m) intervals along property grid lines. The deposit is crossed by three lines spaced 800 ft (~245 m) apart, whereas line spacing elsewhere is generally 400 ft (~120 m). The gravity field in the map-area is characterized by a gradient across which values decrease from northwest to southeast. Superimposed on this gradient, and conspicuous by its north-northwest trend, is an elongate gravity high related to the Devils Elbow sulphide deposit. The amplitude of the high has been estimated from a gravity profile along a northeast-southwest line passing through the peak of the anomaly, following removal of a "regional" trend. Depending on whether a questionable gravity value defining the peak is included (0.4 mGal greater than adjacent values), the amplitude is 1.2 mGal or 0.9 mGal (preferred). The deposit lies along the western edge of the high, whereas the axis of the high coincides closely with a geological unit (ONFs) formed mainly of mudstone and fine-grained wacke, which have been subjected to chloritic alteration. A report on a gravity survey carried out for the American Metal Company Limited (Gledhill *et al.*, 1957) noted that "five samples of massive chlorite" had a mean density of 2.92 g/cm^3 compared to a value of 2.71 g/cm^3 for "all unmineralized rock types", and concluded that the anomaly might be explained by intense chloritic alteration. However, the geological section, compiled with significantly more knowledge than available at that early date, shows that sulphides extend further northeast than portrayed on the geological map. The section provides unequivocal evidence that the sulphide body is the primary source of the gravity high, and accounts for the apparent offset between the deposit and the peak of the anomaly, as implied by comparison of gravity and geology maps.

RADIOMETRIC DATA

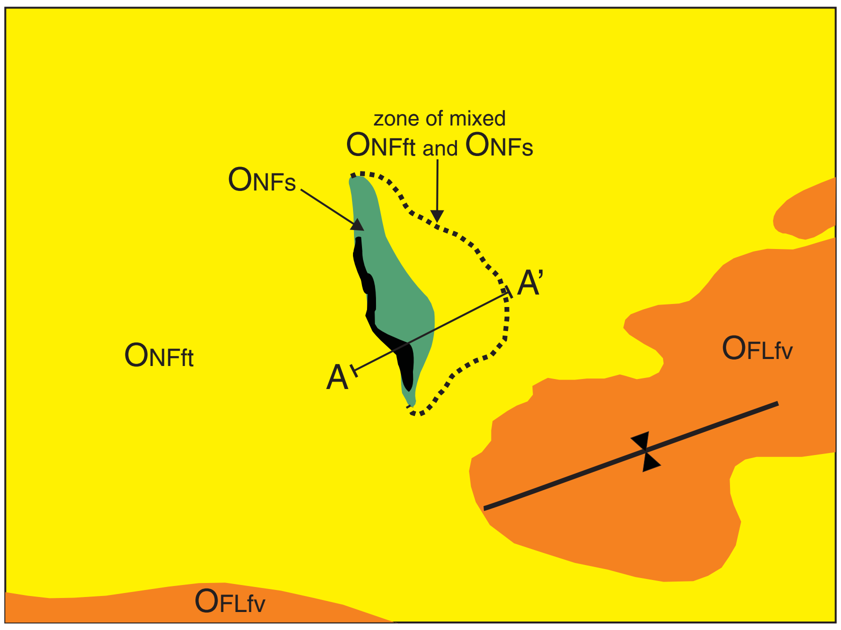
The deposit does not subcrop and therefore is not reflected in the airborne radioelement patterns. Although correlation with mapped geology is poor, ground investigations in the area indicate eTh/K patterns do reflect a general east-west lithological distinction. Higher K and lower eTh values (thus low eTh/K ratio) occur over felsic units of the Flat Landing Brook Formation. Conversely, lower K and higher eTh values (high eTh/K ratio) are apparent over units of the Nepisiguit Falls Formation. Thus, the K high in the northeast corner of the map-area probably represents an unmapped keel of Flat Landing Brook Formation, which is consistent with mapping conducted by Walker (1997). Variations within these overall patterns probably reflect local unmapped geological variations, such as the distinct low K, high eTh "bull's-eyes" along the west margin. Ground investigations showed these anomalies overlie Cambro-Ordovician quartzites of the Knights Brook Formation, which are not indicated on the geology map. Field checking over the central eU anomaly suggests it relates to increased exposure and geometric changes associated with the steep valley walls west of the deposit, with no obvious bedrock source.

SUMMARY

The Devils Elbow deposit is another example where strong "bull's-eye" magnetic and conductivity anomalies related to the deposit stand out in relatively featureless background fields over mainly felsic volcanic rocks. The deposit is also marked by a prominent gravity anomaly. No discriminating radiometric signatures are developed.

DEVILS ELBOW

GEOLOGY



Modified from Walker (1997) and Caron and Gower (1995)

GEOLOGICAL LEGEND

TETAGOUCHE GROUP

Flat Landing Brook Formation

OFLfv — aphyric to sparsely feldspar-phyric rhyolitic rocks & related hyaloclastite &/or pyroclastics

Nepisiguit Falls Formation

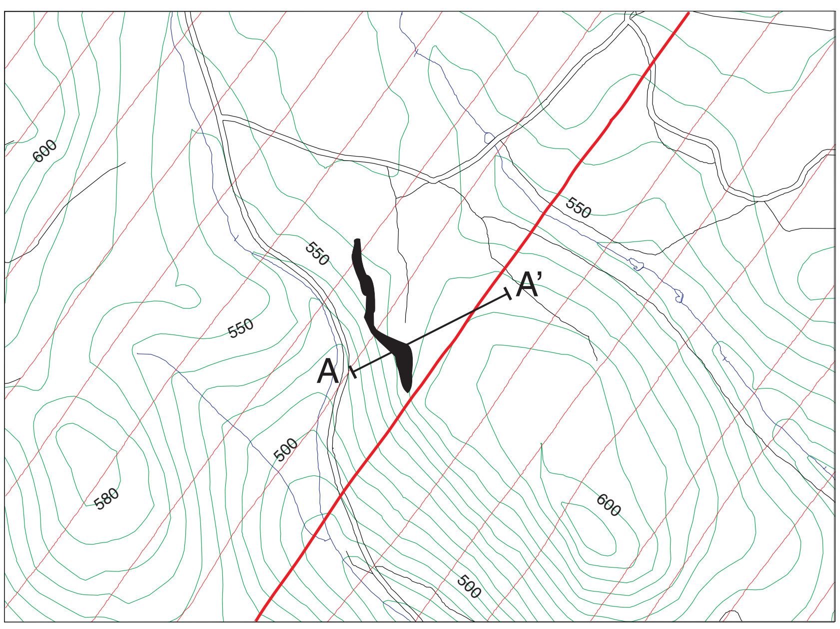
ONFt — quartz-phyric & quartz-feldspar-phyric crystal & ash tuff & related volcaniclastics; minor sediments

ONFs — mostly mudstone & fine-grained wacke interlayered with unit ONFt

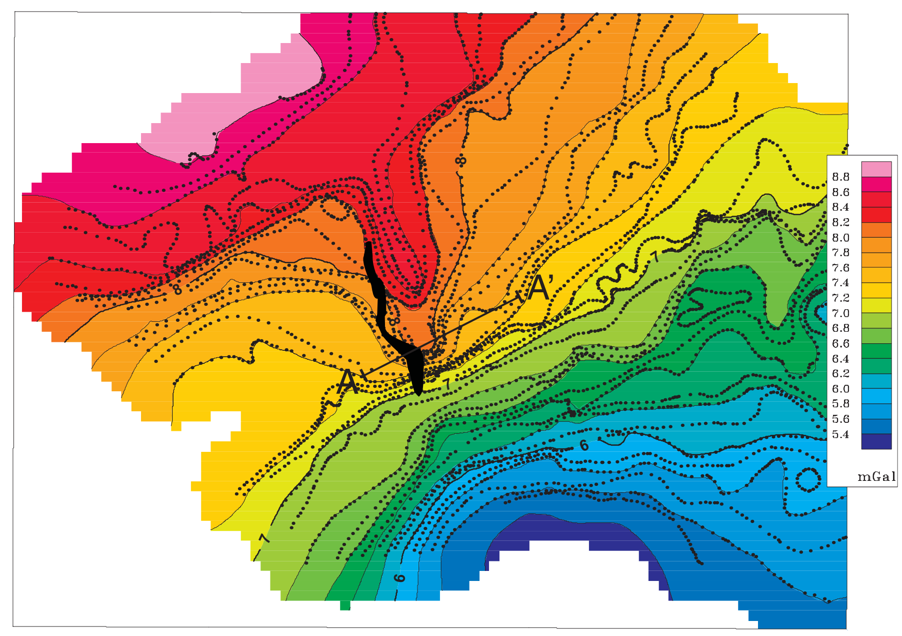
massive sulphide

synformal fold axis

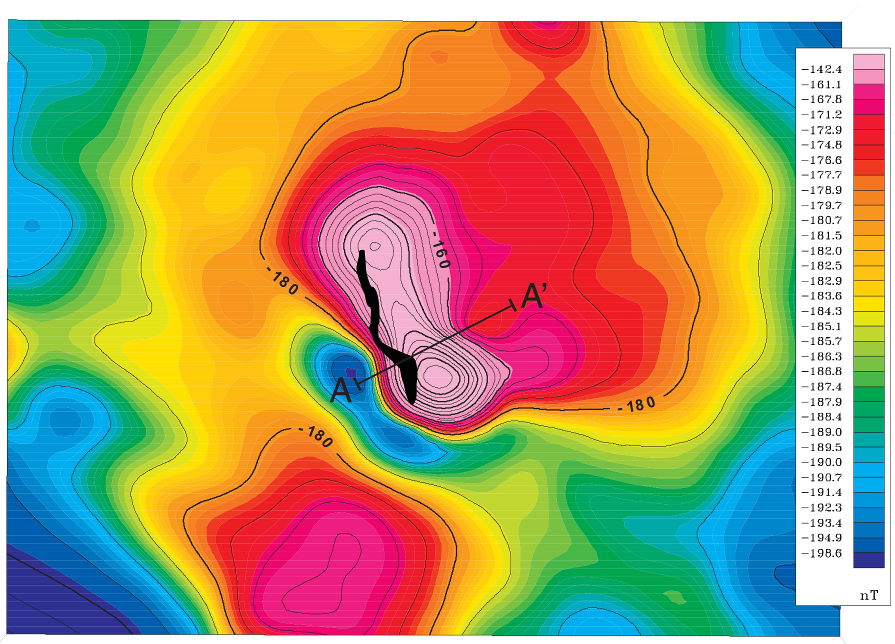
TOPOGRAPHY/FLIGHT LINES



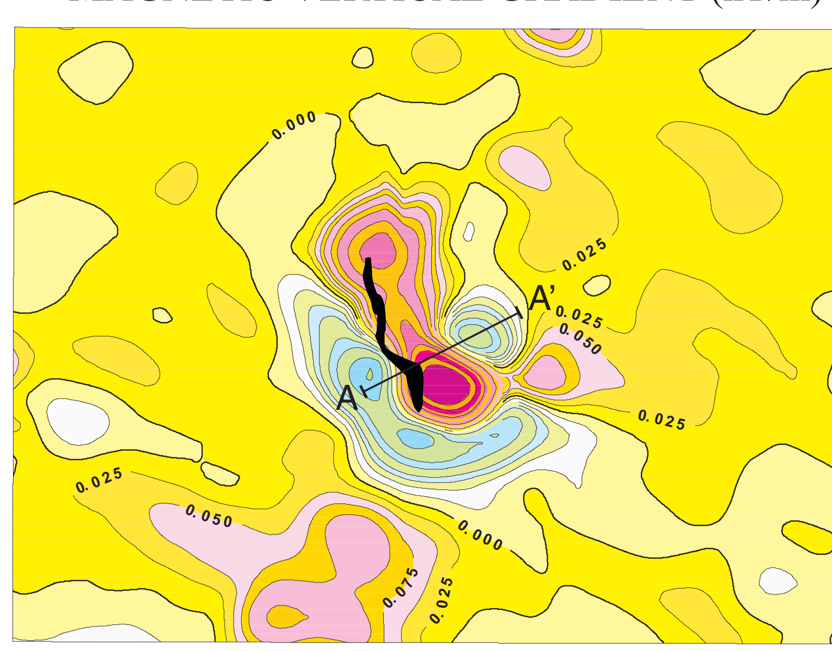
GRAVITY (mGal)



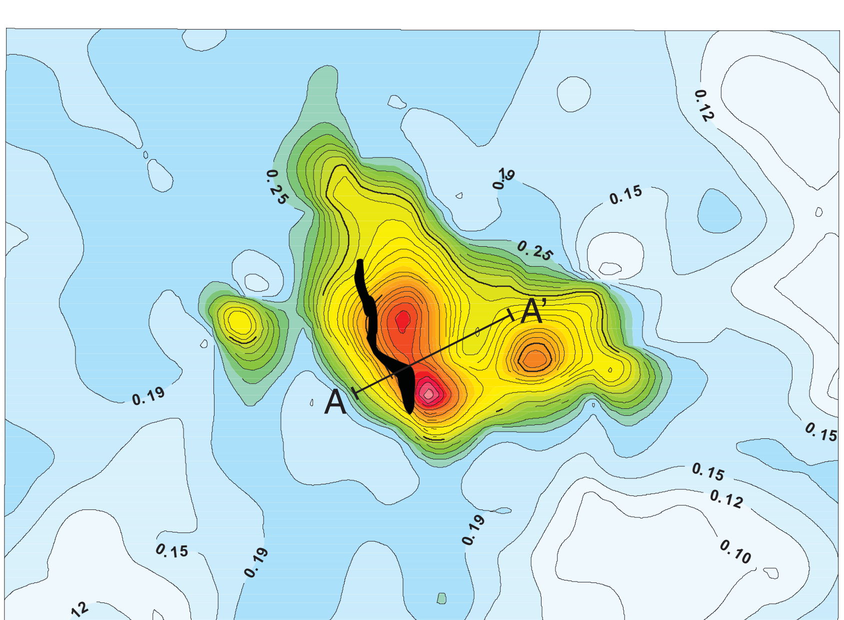
MAGNETICS (nT)



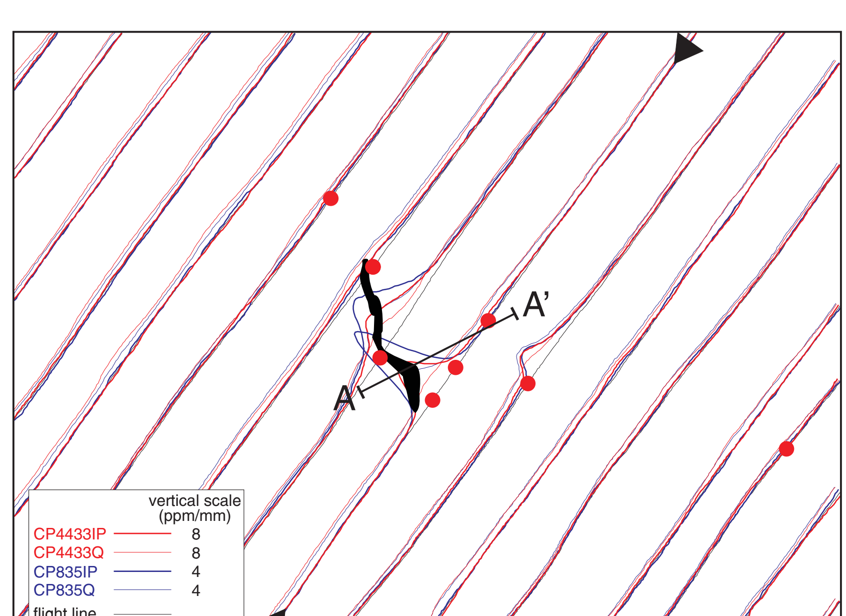
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



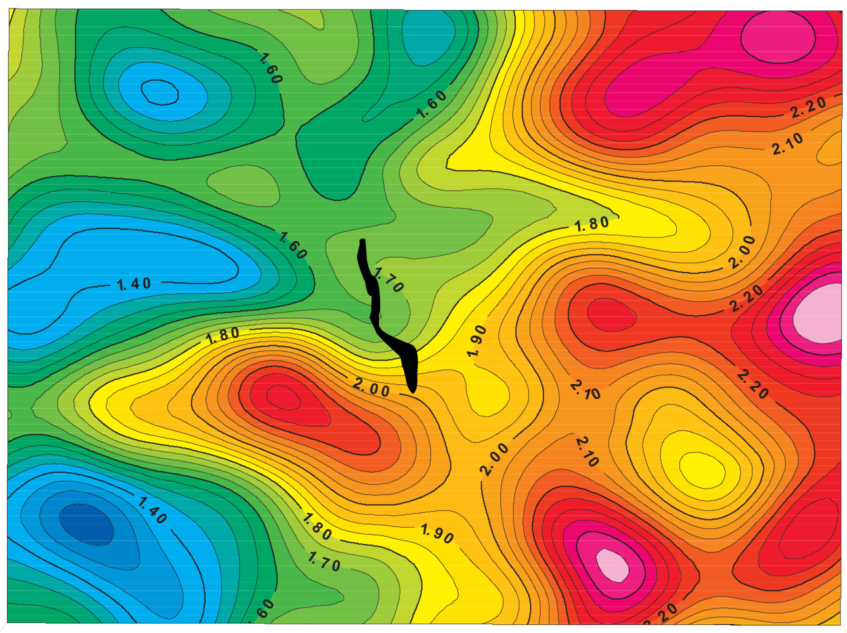
ELECTROMAGNETIC PROFILES/ANOMALIES



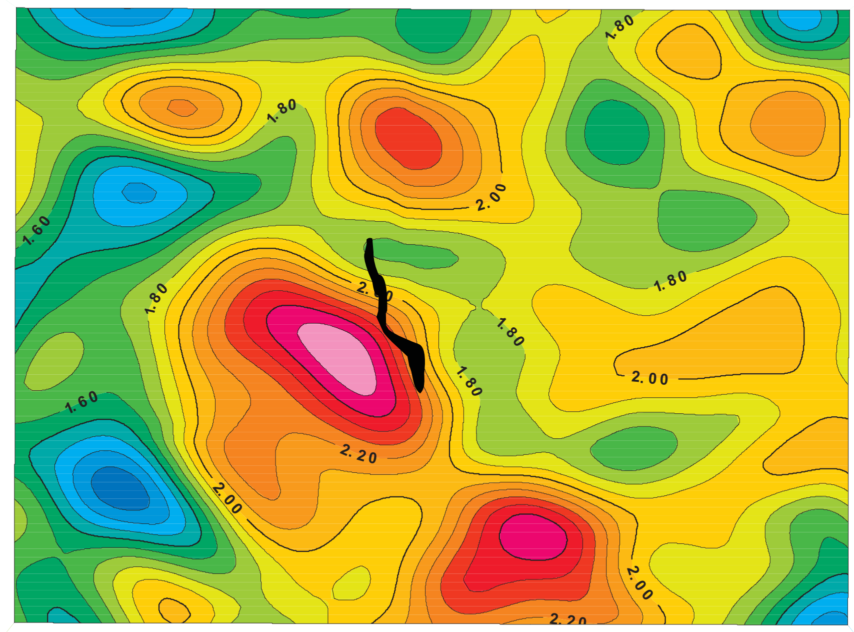
1000 m

DEVILS ELBOW

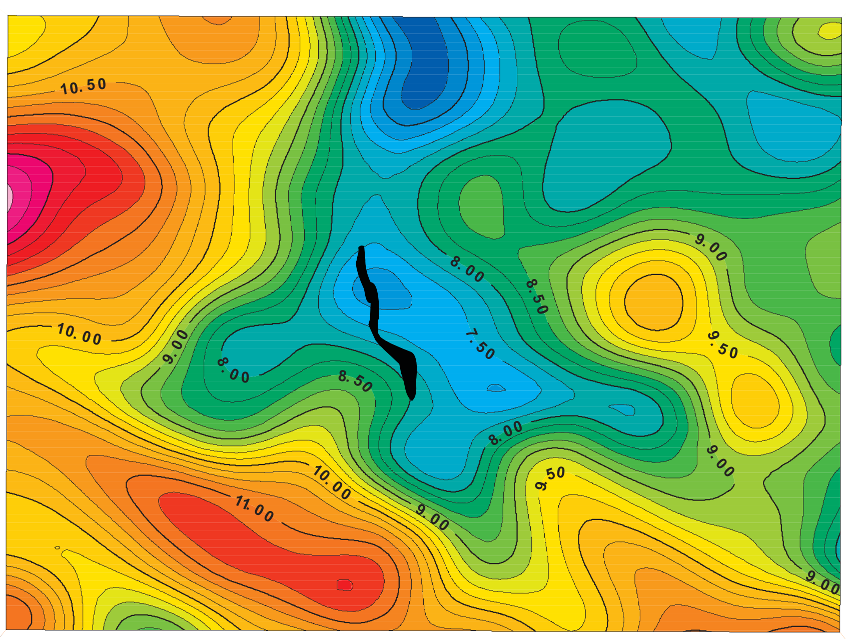
POTASSIUM (%)



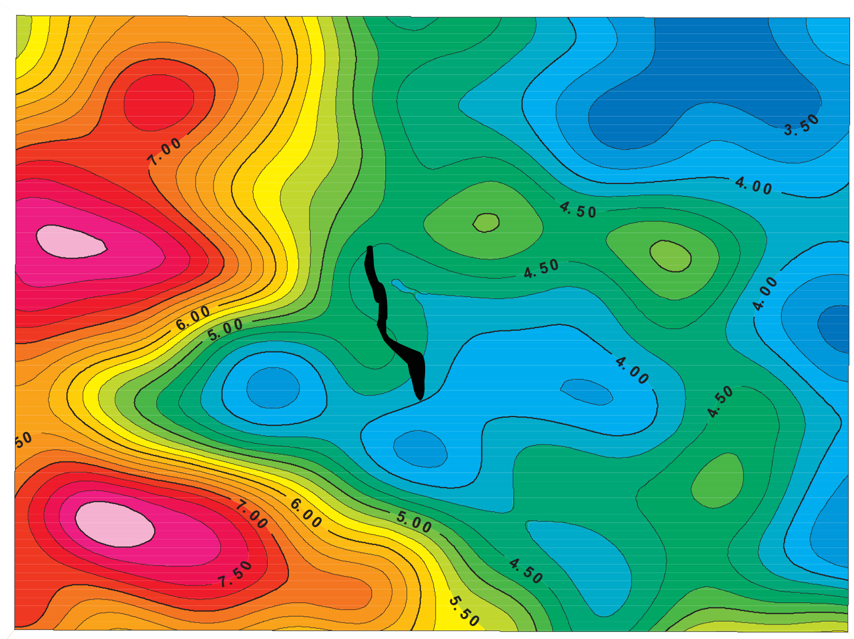
URANIUM (ppm)



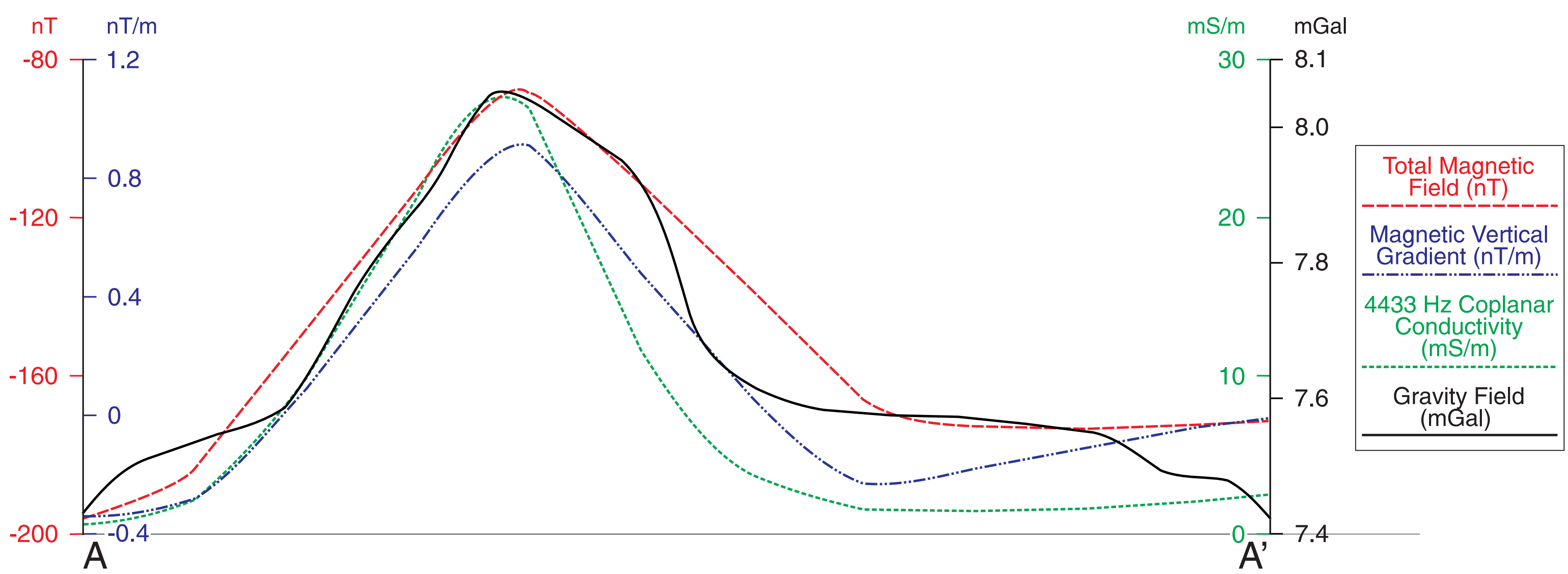
THORIUM (ppm)

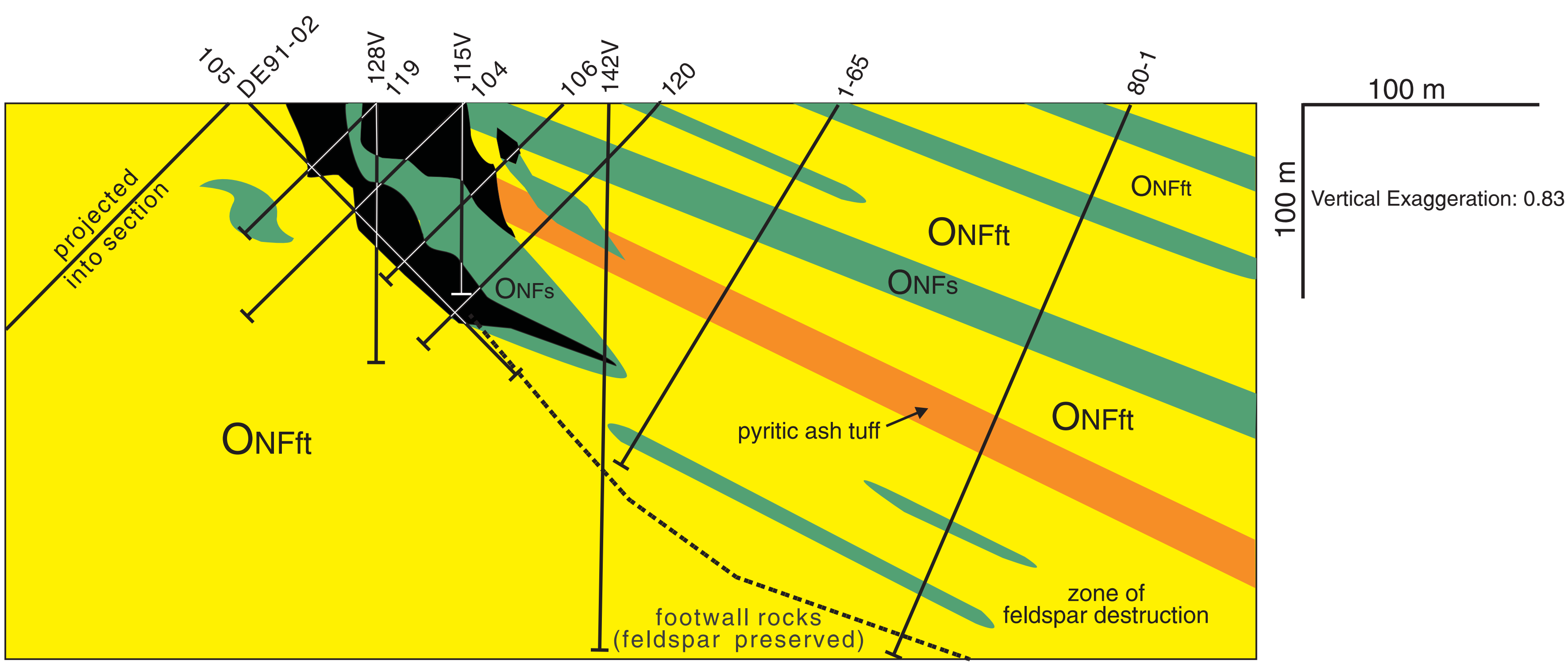


THORIUM/POTASSIUM RATIO (x 10^{-4})



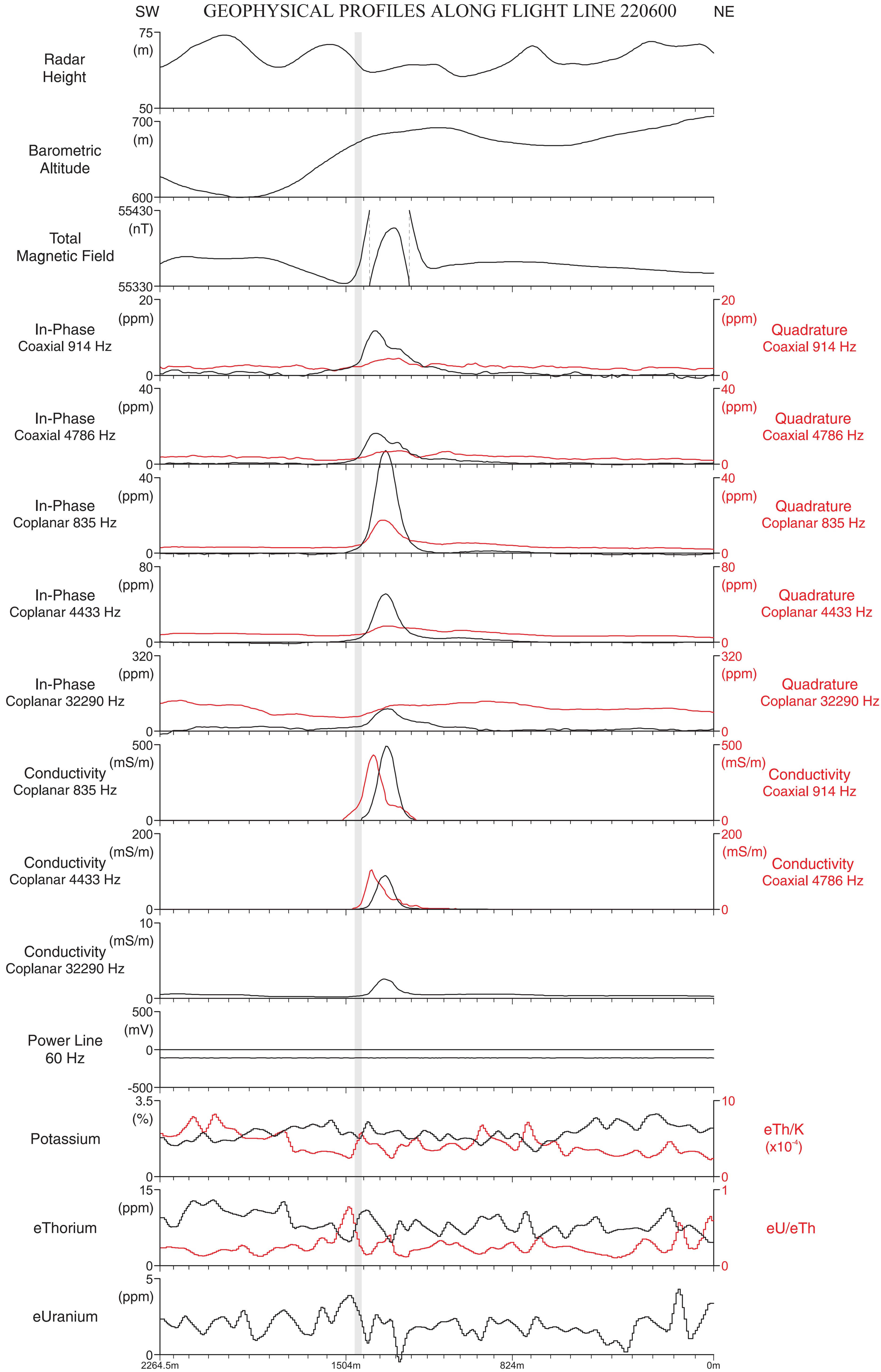
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’





Modified from Walker (1997)

DEVILS ELBOW



FLAT LANDING BROOK DEPOSIT

GEOLOGY

The Flat Landing Brook deposit was discovered by Sabina in 1975 after follow-up work on airborne electromagnetic anomalies. The deposit contains a drill-indicated resource of 1.4 million tonnes grading 4.9% Zn, 1.0% Pb and 0.03% Cu (Troop, 1984). Regional mapping by van Staal (1994c) shows the deposit is at the "Brunswick Horizon", *i.e.* at the top of the Nepisiguit Falls Formation. The deepest rocks in the footwall sequence are quartz-feldspar crystal tuffs that are overlain by fine-grained felsic (ash ?) tuffs of the Nepisiguit Falls Formation. The hanging wall rocks comprise aphyric- to feldspar-phyric rhyolite containing minor oxide facies iron formation and are assigned to the Flat Landing Brook Formation. Gabbro dykes and sills intrude the sequence (Troop, 1984).

The deposit occurs on the west limb of a north-trending anticline and dips approximately 70° to the west. For the most part it consists of one or two sulphide layers, although toward the south the deposit comprises several sulphide layers; this is probably related to repetition by isoclinal folds. Two types of sulphides are present: the first comprises euhedral to massive pyrite, pyrrhotite and chalcopyrite associated with intensely chloritized and silicified tuff, and is interpreted to represent feeder zone mineralization. The second comprises finely-banded pyrite, sphalerite, and galena ± marcasite, arsenopyrite, tetrahedrite-tennantite, and magnetite, and is interpreted to represent originally stratiform exhalative massive sulphides. A zone of siliceous, chloritic and/or pyritic alteration underlies and is in part interlayered with the sulphide lens. The alteration can be traced down into quartz-feldspar-phyric rocks. The deposit grades into siliceous and/or oxide iron formation along strike.

MAGNETIC DATA

A prominent, oval-shaped positive magnetic anomaly (~330 nT amplitude) coincides with the southern third of the Flat Landing Brook sulphide deposit (south of section A-A'), which contains pyrrhotite as a volumetrically significant sulphide and significant amounts of magnetite, particularly near oxide iron formation (Troop, 1984). The coincidence of anomaly and deposit, and the magnetic nature of the aforementioned minerals, suggest the anomaly to be principally a signature of the deposit, with some contribution from iron formation. Even so, this conclusion is tempered by the fact that the deposit is roughly 200 m below ground surface and quite narrow (~10 m), factors that should result in marked attenuation of its magnetic signal. To produce an anomaly of >300 nT amplitude, the deposit at depth would probably have to be very rich in pyrrhotite and/or magnetite, and/or larger than presently defined by drill-holes. Furthermore, a north-northeast extension of the anomaly, having a much diminished amplitude, diverges from the northern part of the deposit, which apparently has no expression in the magnetic field. These factors suggest that oxide facies iron formation associated with the sulphide body (Troop, 1984) may make an important contribution to the anomaly. The lack of expression in the north may signify a preponderance of the relatively non-magnetic sulphide minerals observed in the deposit (pyrite, sphalerite, galena, chalcopyrite; Troop, 1984) in this area. Although trace amounts of magnetite have been observed in the gabbro which intrudes the deposit, it has little influence on the magnetic field. The conspicuous magnetic highs near the western and eastern margins of the regions are tentatively attributed to iron formations, or possibly magnetite-rich gabbros, which have not been geologically mapped.

ELECTROMAGNETIC DATA

The Flat Landing Brook deposit has a good response on flight-line 331420 and a weaker one on the adjacent line to the north. The deposit generates a well defined, discrete apparent conductivity anomaly on the mid-frequency coplanar coils. Although its amplitude is only 17 mS/m, it stands above a non-conductive background. At low frequencies, on line 331420, the in-phase and quadrature responses are 10 ppm and 38 ppm, and the coaxial responses 2.5 ppm and 11 ppm. At mid frequencies the in-phase and quadrature responses are 50 ppm and 44 ppm, the coaxial responses are 17 ppm and 21 ppm. At high frequency, the in-phase and quadrature responses are 176 ppm and 144 ppm. Negative in-phase responses in the northwest and along the eastern margin of the map-area, coincident with prominent magnetic highs, may be related to iron formation or magnetite-rich gabbro.

GRAVITY DATA

Gravity surveys within the area of the Flat Landing Brook deposit are described by Powers (1982, 1983) for Brunswick Mining and Smelting Corporation Limited. Over the central part of the survey area, line spacing was generally 200 ft (~60 m); elsewhere it was 400 ft (~120 m). Station spacing was 100 ft (~30 m), except over the deposit where it was 50 ft (~15 m). The gravity data displayed here were digitized from a gravity anomaly map contained in the report by Powers (1983, Fig. 4). The sulphide deposit sits on the eastern margin of a plateau of relatively positive Bouguer anomaly values, ranging from about 5.2 to 6.5 mGal, which extends to the western boundary of the map-area. This is separated from lower values to the east (minimum ~3.5 mGal) by a roughly north-south belt of steep gradients. The higher gravity field to the west is attributed to gabbroic intrusions, which surface in the central part of the area, and likely continue at depth to the west. A unit of gabbro north of the deposit associated with low gravity values is probably very thin. Powers (1982) describes the gravity map as having a complex pattern due to superposition of effects from the deposit, diorite (gabbro as defined here) and iron formation, noting that the effect of diorite may mask those of sulphides and iron formation. Nevertheless, he states that the Flat Landing Brook deposit is well defined as an anomalous sharp peak on four lines that cross the deposit. Gravity profiles for these lines reveal amplitudes ranging from about 0.45 to 0.65 mGal for three of the peaks, and one exceptionally large one of about 1.1 mGal. Iron formation is mapped near to the peak in all cases. One of the peaks is discernible on the gravity map shown here, near the south end of the deposit.

RADIOMETRIC DATA

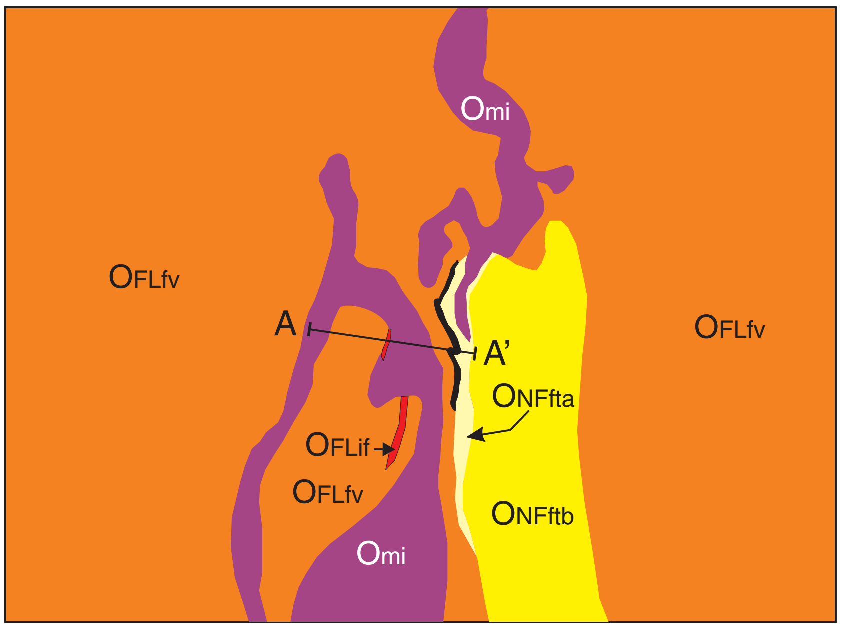
There is no obvious correlation between gamma-ray spectrometry patterns and geology. Low K, eU and eTh concentrations coincide with gabbroic dykes and sills, but generally occur over swampy areas. Beyond the central radiometric low, aphyric and feldspar-phyric rhyolitic flows of the Flat Landing Brook Formation yield airborne values of 1.2 - 2.7% K, 1.5 - 2.4 ppm eU and 5.25 - 9.8 ppm eTh. Felsic volcaniclastic rocks and quartz-feldspar porphyry of the Nepisiguit Falls Formation, which host the deposit, have no recognizable radioelement signature.

SUMMARY

Distinct "bull's-eye" magnetic and conductivity anomalies correlate with the southern half of the Flat Landing Brook deposit, whereas the northern half lies on the western flanks of the respective anomalies, and has low geophysical relief. The lack of signature in this area may relate to an enrichment of galena and sphalerite in the deposit relative to more magnetic and conductive sulphide minerals and/or magnetite. A distinct gravity anomaly of moderate amplitude, ~1.1 mGal, also peaks on the southern part of the deposit. The deposit does not have any associated radiometric signatures.

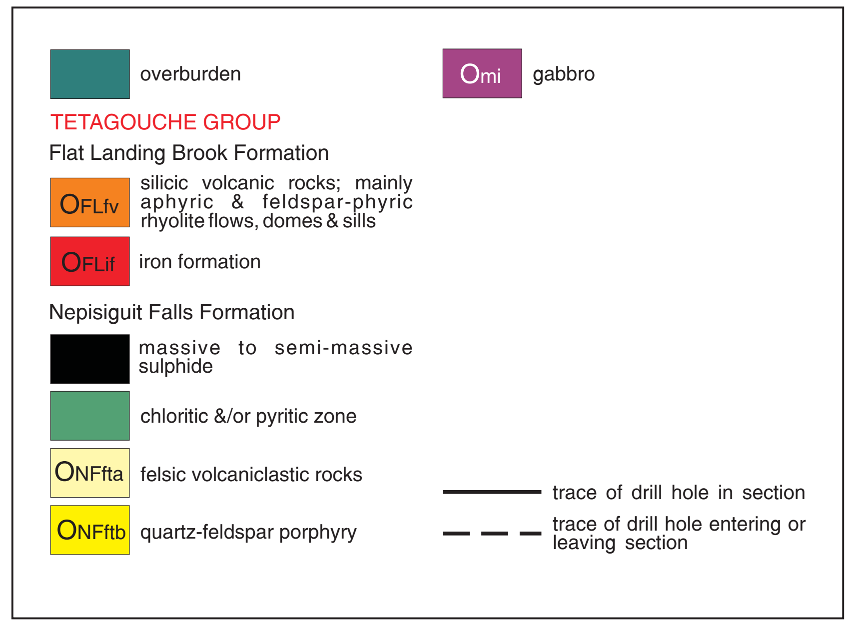
FLAT LANDING BROOK

GEOLOGY

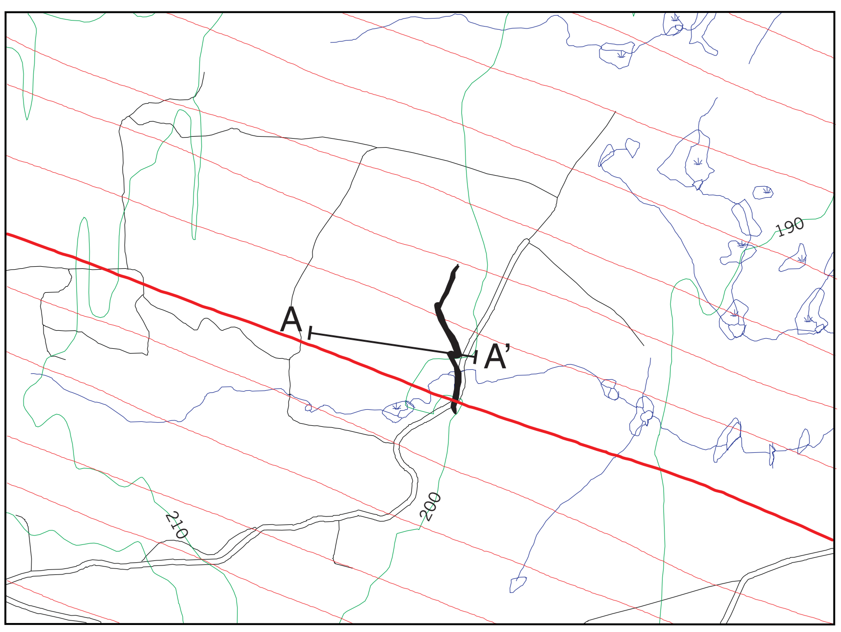


Modified from van Staal (1994c)

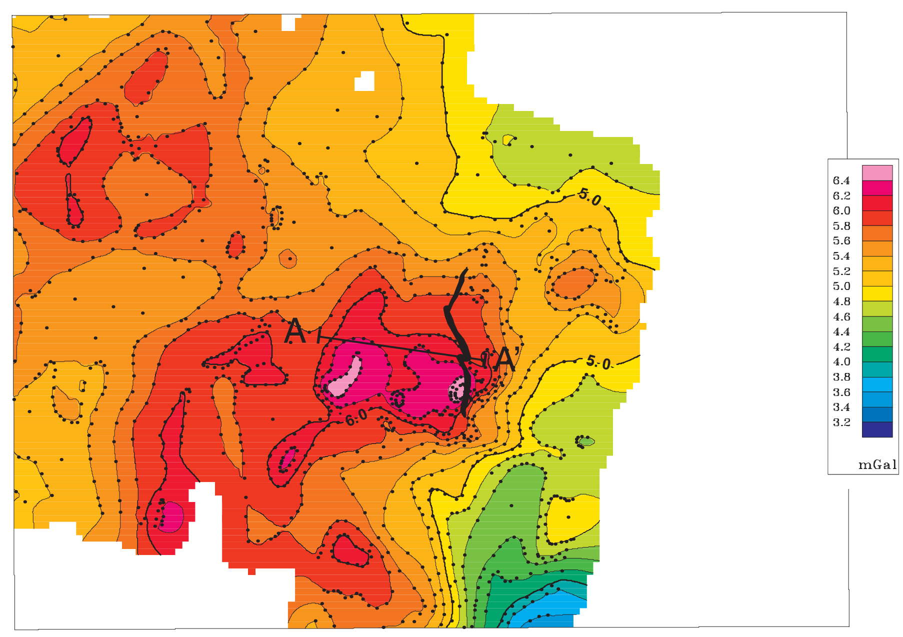
GEOLOGICAL LEGEND



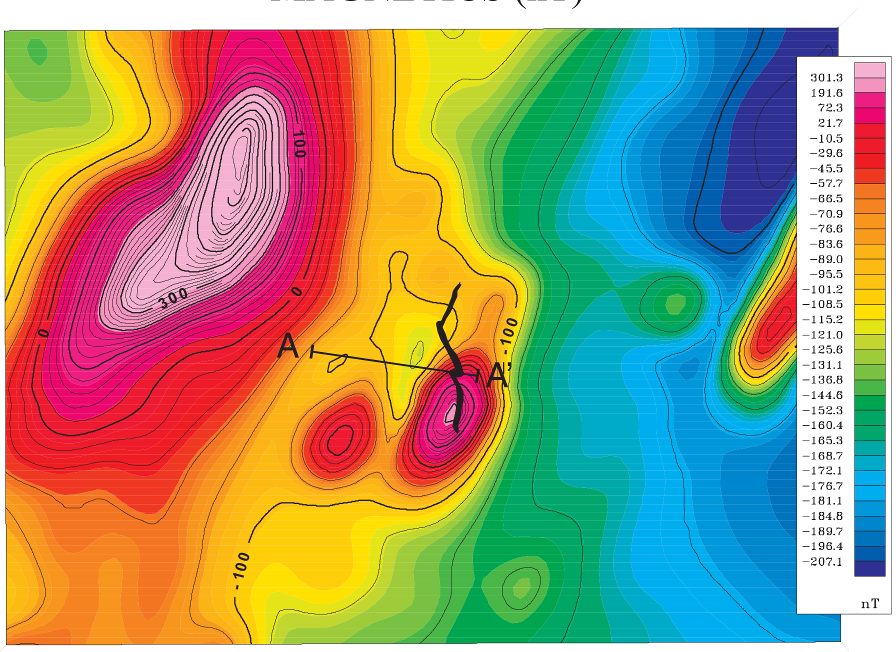
TOPOGRAPHY/FLIGHT LINES



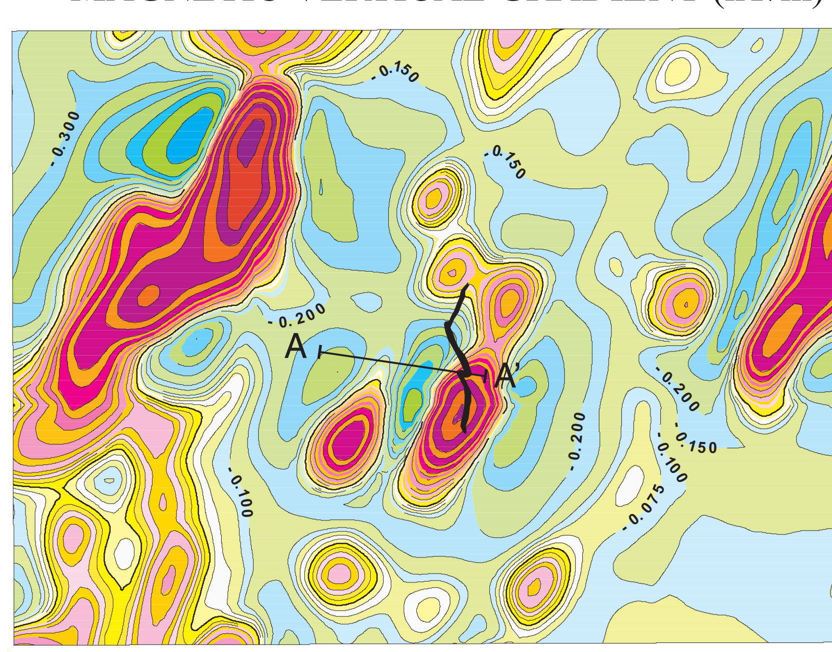
GRAVITY (mGal)



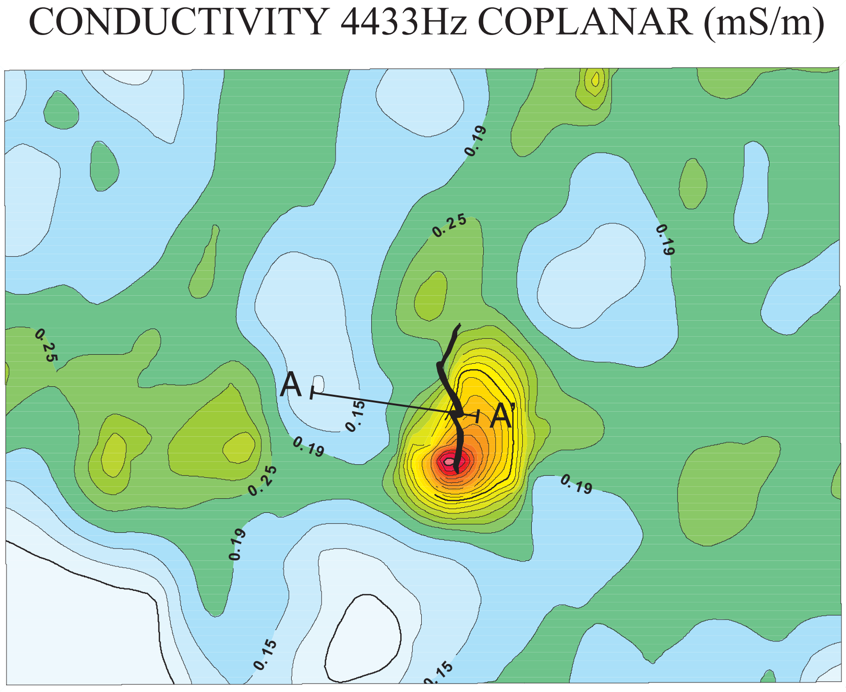
MAGNETICS (nT)



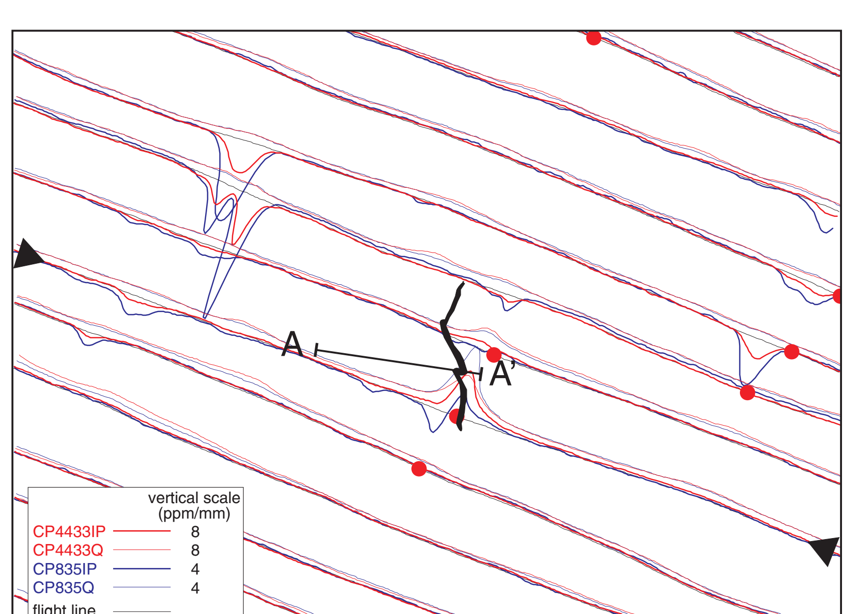
MAGNETIC VERTICAL GRADIENT (nT/m)

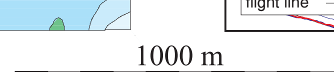


CONDUCTIVITY 4433Hz COPLANAR (mS/m)



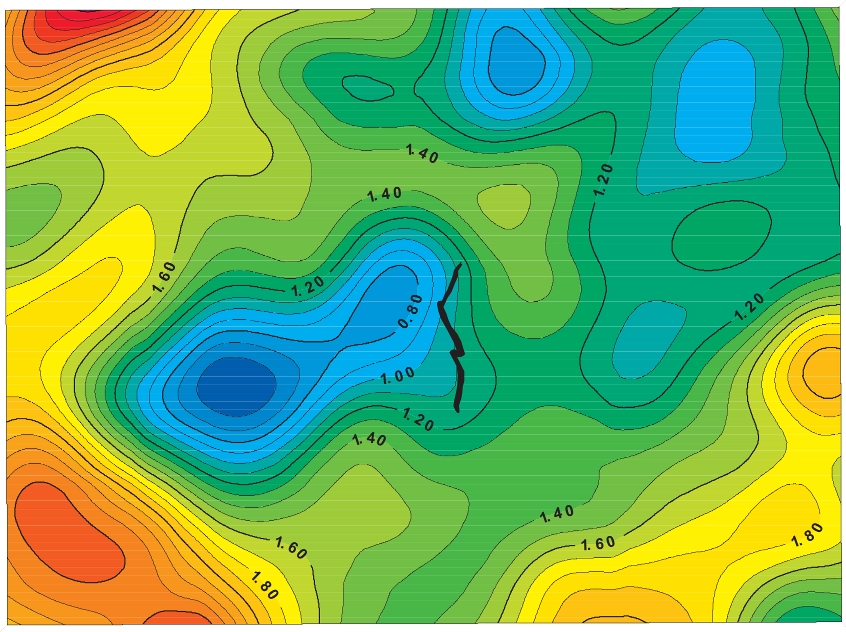
ELECTROMAGNETIC PROFILES/ANOMALIES



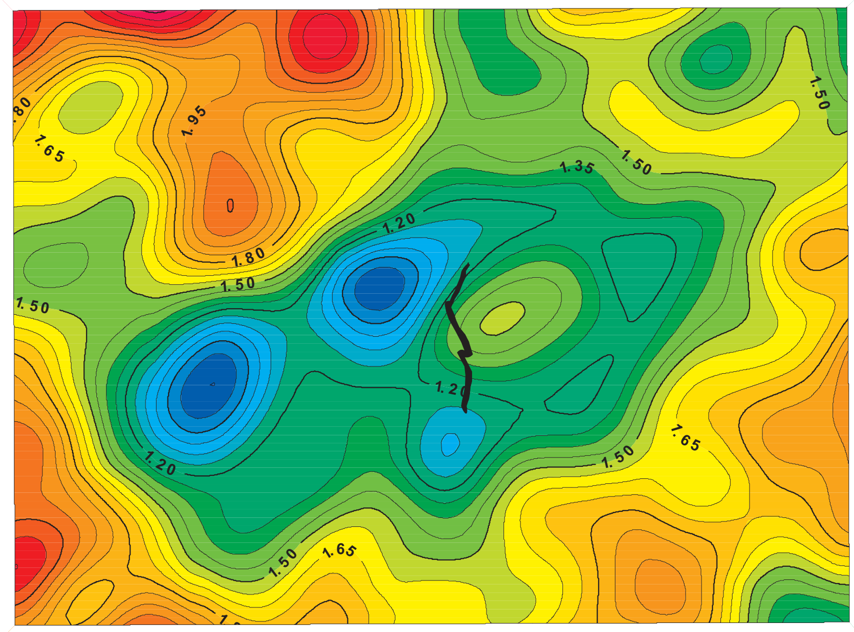


FLAT LANDING BROOK

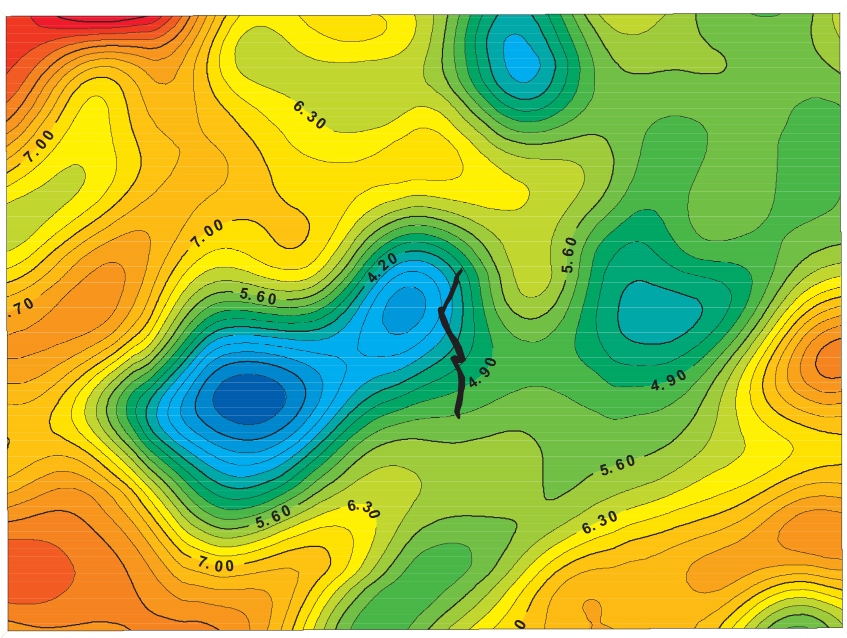
POTASSIUM (%)



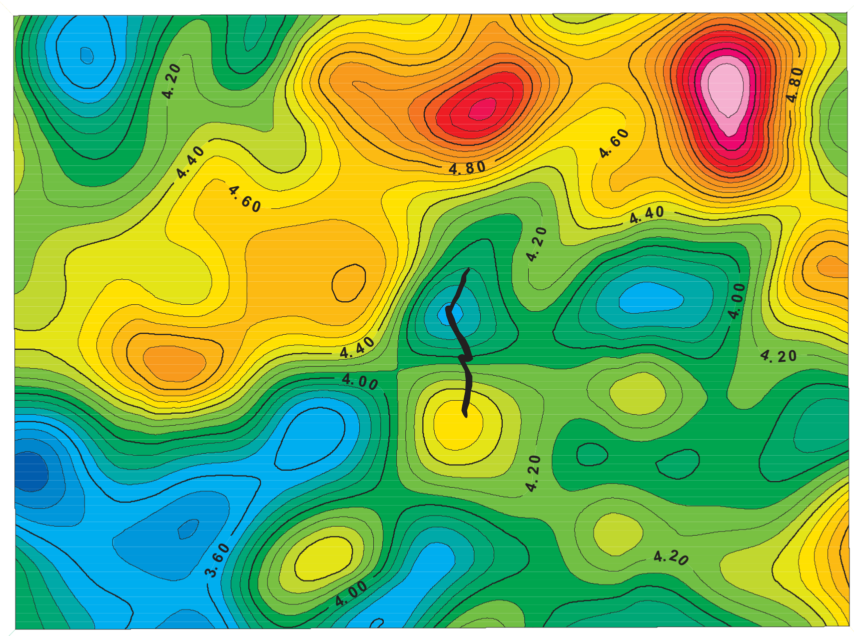
URANIUM (ppm)



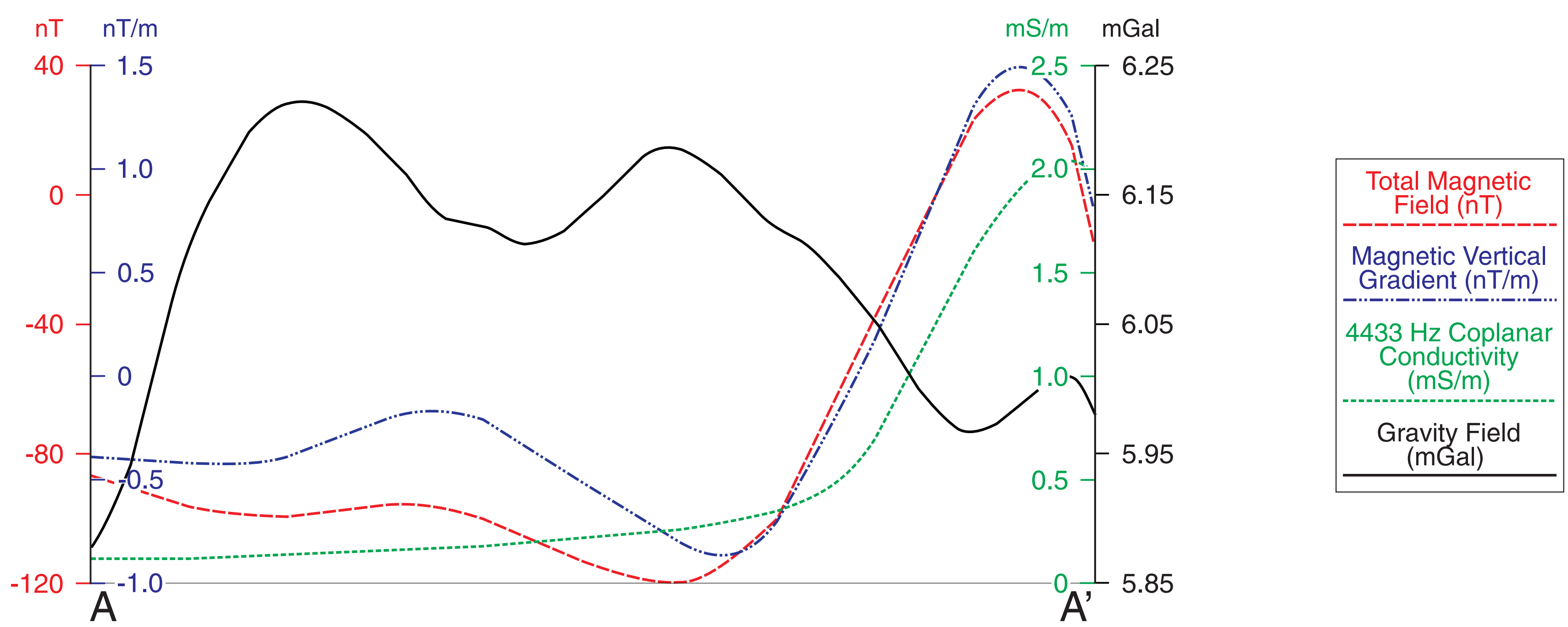
THORIUM (ppm)

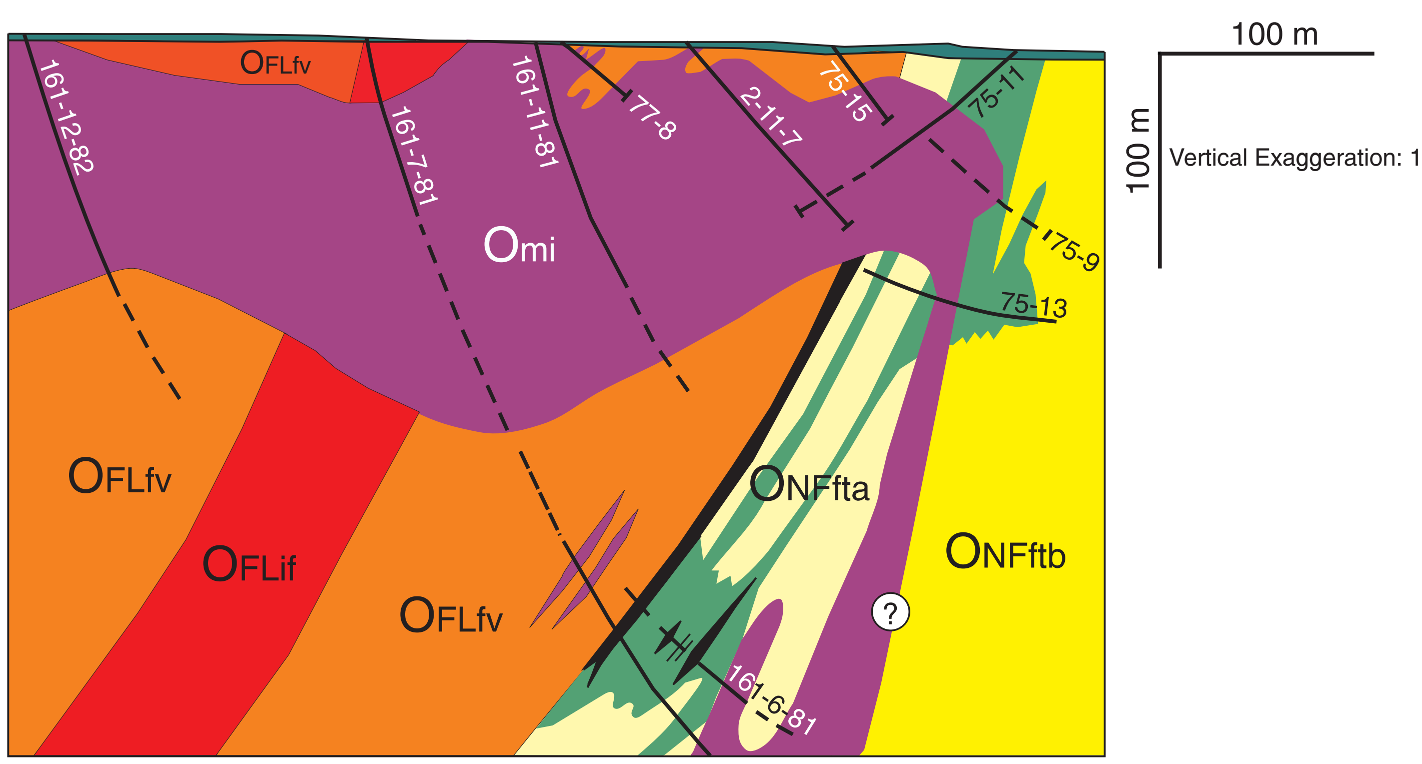


THORIUM/POTASSIUM RATIO (x 10^{-4})



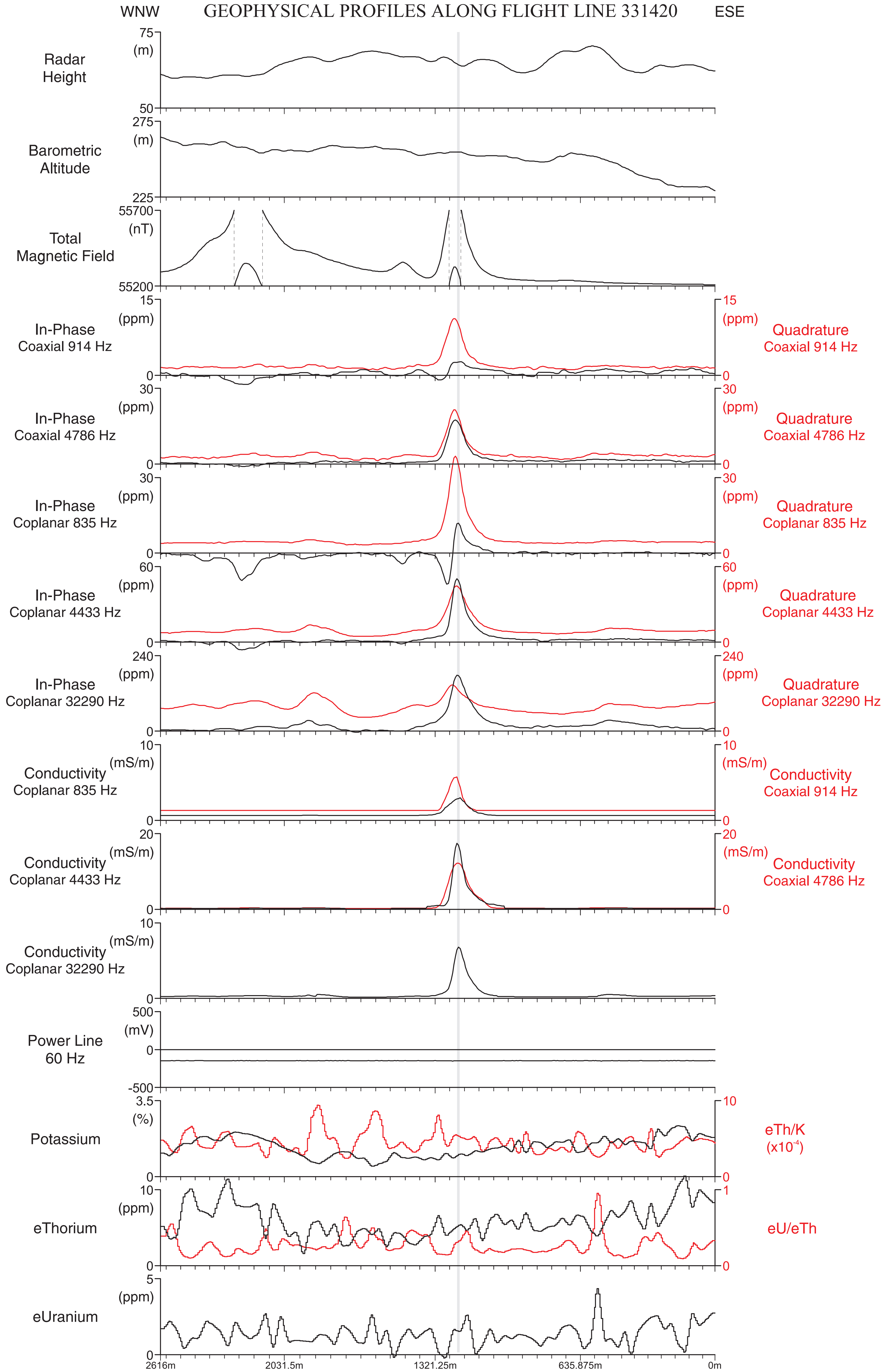
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’





Modified from Troop (1984)

FLAT LANDING BROOK



HALFMILE LAKE DEPOSIT

GEOLOGY

The Halfmile Lake deposit was discovered by Middle River Mining Co. (Texas Gulf Sulphur Co.) in 1955 as a result of follow-up work on coincident airborne EM and soil geochemical anomalies. The deposit is hosted by the Nepisiguit Falls Formation, and has been divided into 4 zones: C, North, Lower AB and Upper AB that together contain 26 million tonnes of sulphides. The Lower AB zone is the largest with probable reserves of 7,900,000 tonnes grading 0.1% Cu, 2.43% Pb, 7.45% Zn and 22 g/t Ag (McCutcheon, 1992 and references therein). The deposit occurs within a sequence of felsic ash- and lapilli-tuff and related epiclastic rocks overlying coarse-grained, quartz-feldspar crystal tuff deeper in the footwall; all are assigned to the Nepisiguit Falls Formation. The Nepisiguit Falls Formation is thrust over mafic and felsic volcanic rocks of the Flat Landing Brook Formation to the southeast. Unlike many deposits hosted by the Nepisiguit Falls Formation, no iron formation is associated with this deposit.

Mineralized rocks are divided into stringer-type and exhalite-type. The exhalite unit is further divided into: (1) breccia-matrix sulphides, (2) layered sulphides, (3) black shale and chert. The stringer zone varies from 3 to 150 m in thickness and contains between 5 and 60% pyrrhotite and chalcopyrite. The strike of the sulphide lens varies moderately along its length, but overall is approximately east-west. The massive sulphide zone has been intersected along a strike length of 950 m and to a depth of 1000 m; it has an average thickness of 2 to 4 m, but locally may reach a maximum thickness of 75 m (Adair, 1992). The position of stringer zone mineralization on the north side of the deposit (stratigraphic footwall) indicates that the deposit is overturned to the southwest.

MAGNETIC DATA

The widest part of the surface trace of the Halfmile Lake sulphide deposit, which is crossed by section A-A', coincides with the peak of an oval-shaped magnetic high, roughly 90 nT amplitude. In section A-A' the combined surface width of the massive sulphide and the structurally overlying zone of stringer mineralization is about 60 m (Adair, 1992). Both units are pyrrhotite-rich and are undoubtedly the principal contributors to the anomaly. The massive sulphide facies comprises mainly pyrrhotite-rich, breccia-matrix sulphides containing chloritic schist fragments (10 - 50% of the volume), and lesser amounts of pyrite-rich layered sulphides containing subsidiary amounts of pyrrhotite. The stringer zone is characterized by pyrrhotite-chalcopyrite stringers that form 5 to 60% of the rock, and have pyrrhotite/chalcopyrite ratios as high as 5:1. Layered oxide or carbonate iron formations are not developed, hence magnetite is not expected to have a significant influence on the magnetic field. Even though there is convincing evidence that the anomaly is linked to the orebody, the northwest trend of the axis of the anomaly, virtually perpendicular to the strike of the body, suggests a possible additional source. The anomaly is apparently limited by two thrusts, suggesting that the rocks between them are sufficiently enriched in magnetic minerals to impact on the magnetic field. Susceptibility measurements on drill-core from the Halfmile Lake property have yielded mean values for most lithological units (logged by Noranda) that range from about 0.1 to 0.5 x 10^{-3} SI, some sections with more enriched sulphide dissemination attain values >1 x 10^{-3} SI. The highest individual value obtained for the massive sulphides was >60 x 10^{-3} SI. The package between the thrusts may thus have the potential to produce the observed anomaly. Alternatively, the limited extent of the anomaly along geological strike, and its apparent continuity from a northwest-trending anomaly lying south of the southern thrust, hint at a contribution from a deeper source possibly located within intermediate to mafic volcanics of the Moody Brook Member, which itself has a relatively low magnetic susceptibility (~0.5 x 10^{-3} SI).

ELECTROMAGNETIC DATA

The Halfmile Lake deposit dips at about 45° northward, is oriented at about 55° to the flight-lines, and gives strong responses on all five frequencies of the HEM system on flight-line 221252 and the two adjacent lines to the west. The next line west, however, gives weak responses. On the middle line, at low frequencies, the coplanar in-phase and quadrature responses are 52 ppm and 40 ppm, respectively. The coaxial responses are 20 ppm and 11 ppm. At mid frequencies, the coplanar responses are 84 ppm and 64 ppm, and the coaxial responses are 25 ppm and 20 ppm. At high frequency the responses are 256 ppm and 160 ppm. Stronger responses are observed on the coplanar coils because the HEM system is sub-parallel to the conductor. The conductivity response is due to the presence of massive sulphides, and to black shale also, which is normally conductive. The weak responses observed on the third line west from flight-line 221252, at low and mid frequencies, result from the conductor (deposit) being significantly deeper and located about 500 m under the EM system. At low frequencies, apparent conductivity is 234 mS/m on the coplanar coils and 200 mS/m on the coaxial coils. Corresponding values at mid frequencies are 228 mS/m and 72 mS/m. At high frequency the apparent conductivity is 18 mS/m.

Responses of this deposit to the Hunting and Newmont-Aero EM systems obtained during test surveys in 1956 are described by Brant *et al.* (1966). For both systems the anomalies are sharp and stand out against a non-conductive background. The EM response obtained by an Input system is more complex, since it includes two adjacent anomalies (Best, 1985); however, the response is strong and observed on five of the six channels of this system.

GRAVITY DATA

The gravity map for the Halfmile Lake deposit is derived from data provided by Noranda. These were obtained by a survey along grid lines spaced ~120 m apart; observations were made at intervals of ~30 m. Variations in gravity in the area are confined to a relatively small range of ~1.3 mGal. The principal feature of the gravity field is a broad high that strikes about north 60° east, lying for the most part north of the trace of the Halfmile Lake sulphide deposit and its attendant stringer zone. The high coincides mainly with two units (ONFfta, ONFLFc) of the Nepisiguit Falls Formation, comprising variously volcaniclastic, fine-grained sedimentary and tuffaceous sedimentary rocks, and crystal tuff. A narrow belt of steep gradients separates this high from a lower level of the field to the southeast that coincides mainly with intermediate to mafic volcanics of the Flat Landing Brook Formation. In the eastern part of the map-area the foot of the gradient coincides closely with a major northwest-dipping thrust, indicating that here the gradient could be attributed to hanging wall rocks that are more dense than footwall rocks. However, this possibility seemingly is not supported by available density measurements on drill core. Mean densities for sedimentary rocks and intermediate-mafic volcanics are practically identical, being 2.80 and 2.79 g/cm^3, respectively; the density of tuffs is 2.75 g/cm^3. The trace of the principal sulphide horizon in the east, in part, also coincides with the foot of the gradient, but traced west it migrates progressively up the gradient. A noticeable thickening of the horizon, induced by folding, occurs near the centre of the map-area, and coincides with a prominent, narrow, southward-directed bulge of gravity contours. This local gravity high, apparently, is the only discernible gravity signature produced by the Halfmile Lake deposit, which is picked up on just one of the survey lines. The gravity profile along this line, passing through the widest part of the sulphide horizon, indicates that the amplitude of the high is just 0.2 mGal. A high pass filter applied to the map produced an oval-shaped residual anomaly having a slightly larger amplitude of about 0.3 mGal.

RADIOMETRIC DATA

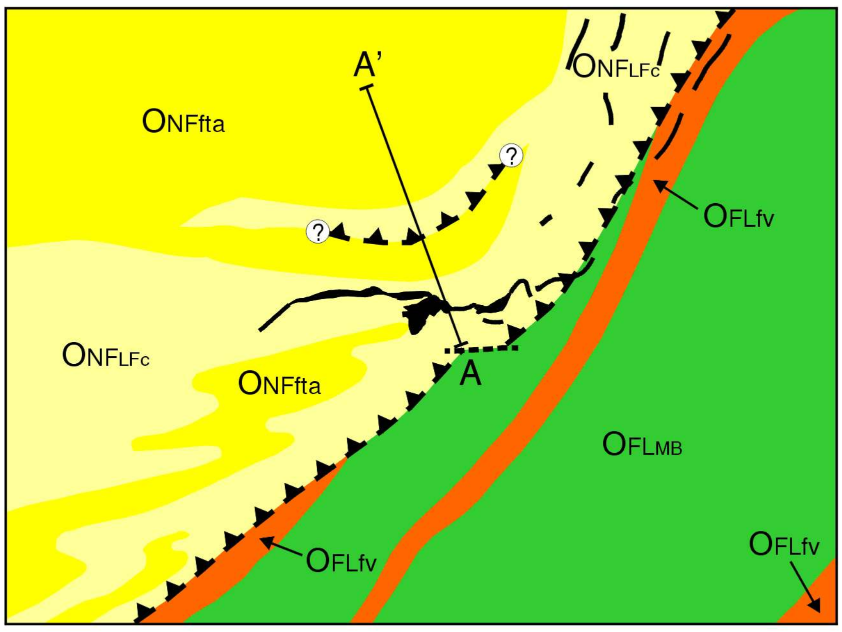
The airborne gamma-ray spectrometry patterns clearly reflect the mapped geological units. Radioelement highs (1.7 - 2.7% K, 1.8 - 2.2 ppm eU, 8 - 11 ppm eTh) are associated with felsic tuff and volcaniclastic rocks within the Nepisiguit Falls Formation. Intermediate values overlie the sediment-dominated Little Falls Member. A sharp northeast-trending break in K and eTh patterns (and eU to a lesser degree) coincides with a thrust which separates felsic units in the Nepisiguit Falls Formation from mafic volcanic rocks within the Moody Brook Member of the Flat Landing Brook Formation. These mafic rocks yield consistently low radioelement values (<1.4% K, generally <1.55 ppm eU, <6.5 ppm eTh). These relationships are influenced slightly by variations in drainage and topographic relief, but provide useful local and regional bedrock mapping guides.

SUMMARY

The central, and widest, part of the Halfmile Lake deposit coincides with a pronounced oval-shaped magnetic high, that is probably generated by pyrrhotite-rich sulphides in the massive and stringer facies. The same segment of the deposit and also a large area of the adjacent hanging wall is characterized by an extensive conductivity high. From the pattern of its distribution, in addition to its link to the deposit and stringer zone, much of it must be related to sedimentary and tuffaceous rocks in the structural hanging wall. A local gravity high, just 0.2 mGal amplitude, and manifested as a distinct bulging of contours is also present where the surface trace of the deposit/stringer zone is thickest. Distinctive radiometric signatures for the sulphide facies are not apparent.

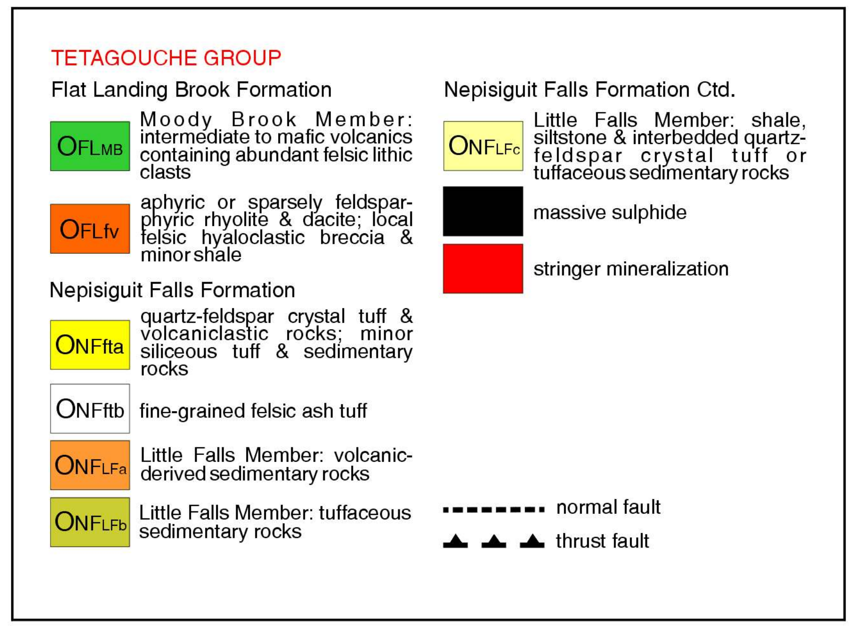
HALFMILE LAKE

GEOLOGY

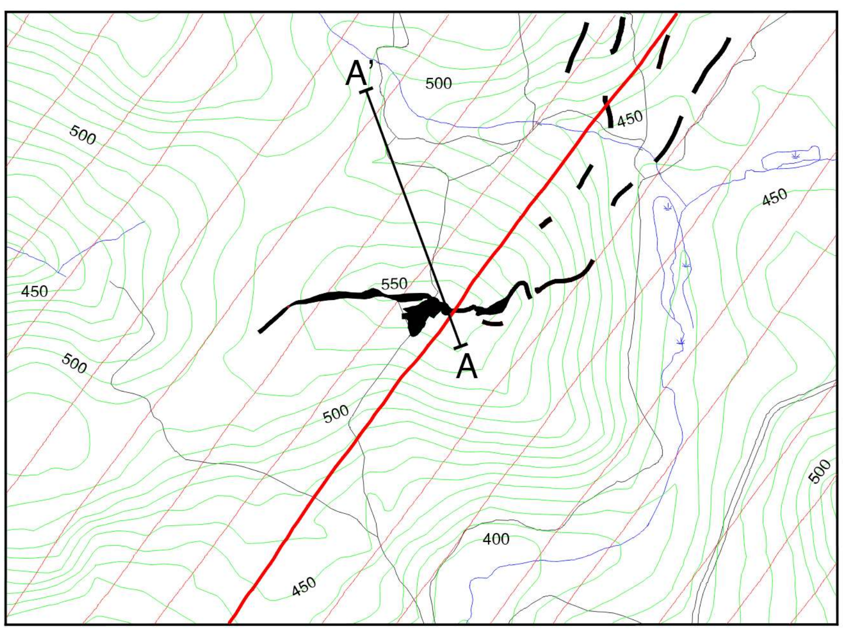


Modified from Adair (1992) and Wilson (1993b)

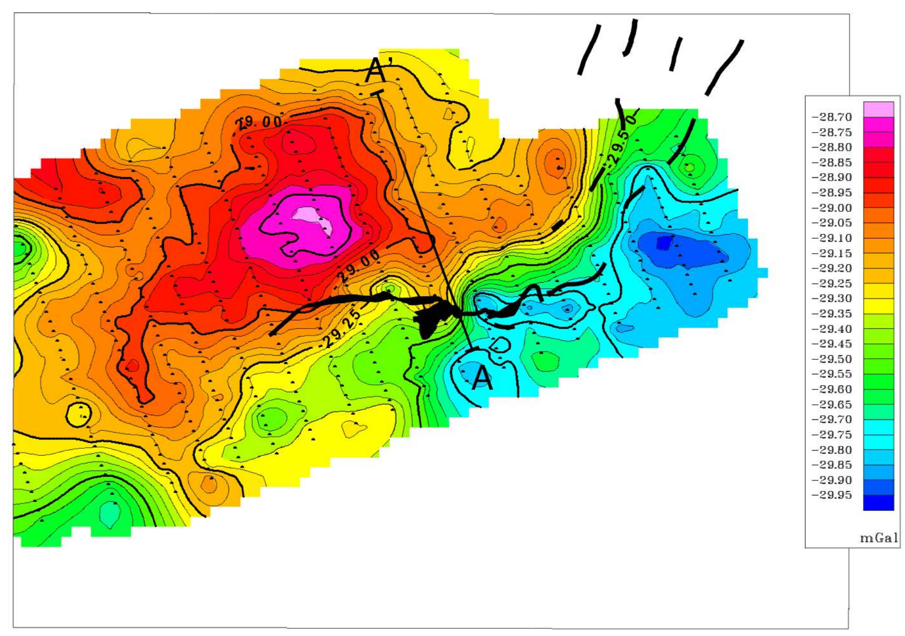
GEOLOGICAL LEGEND



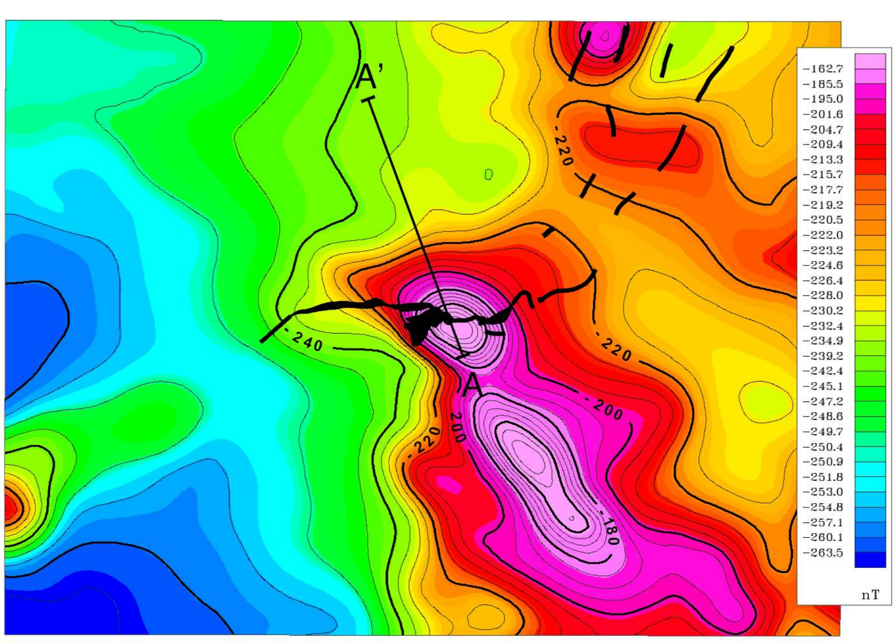
TOPOGRAPHY/FLIGHT LINES



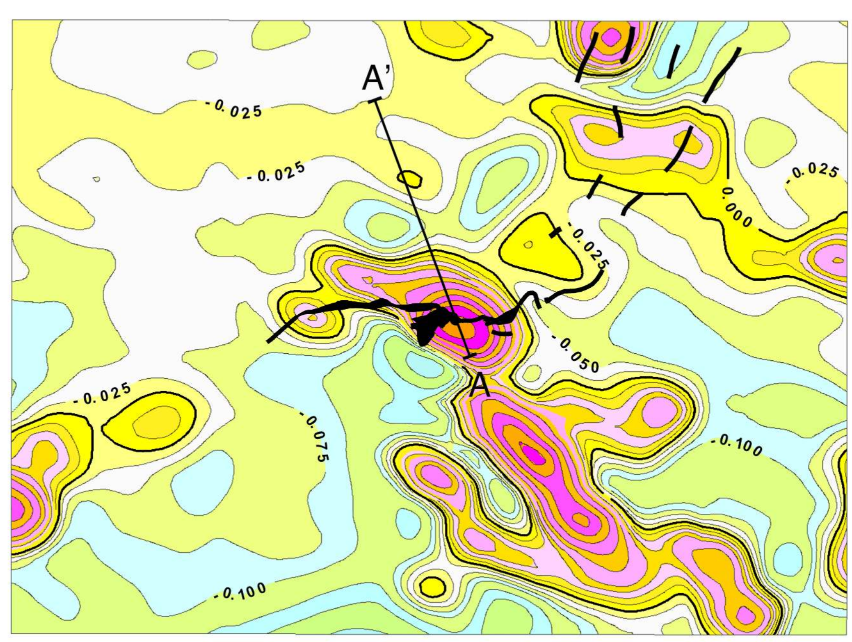
GRAVITY FIELD (mGal)



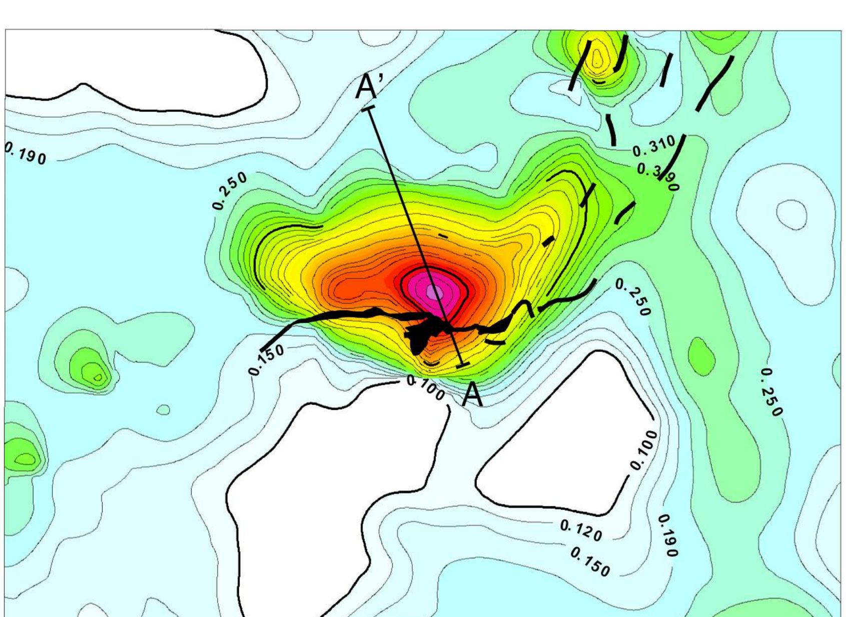
MAGNETIC FIELD (nT)



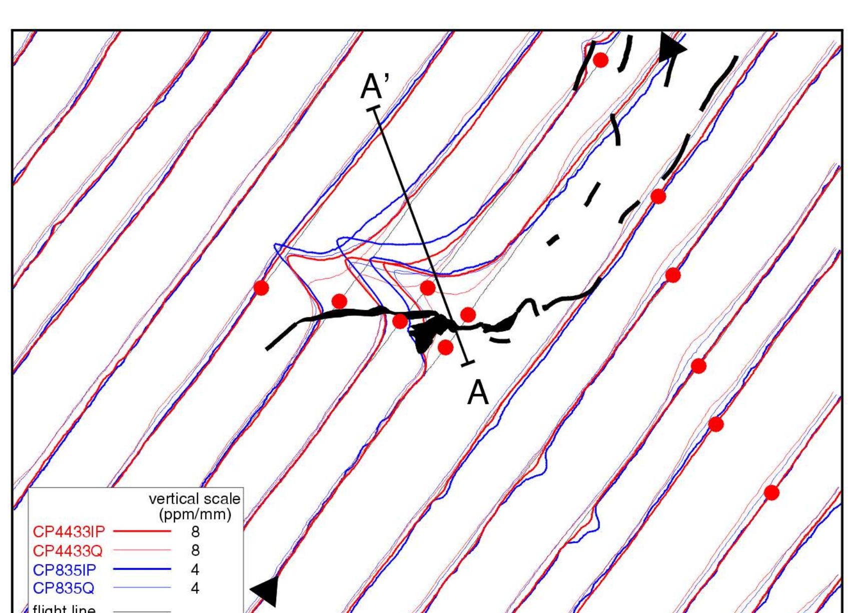
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



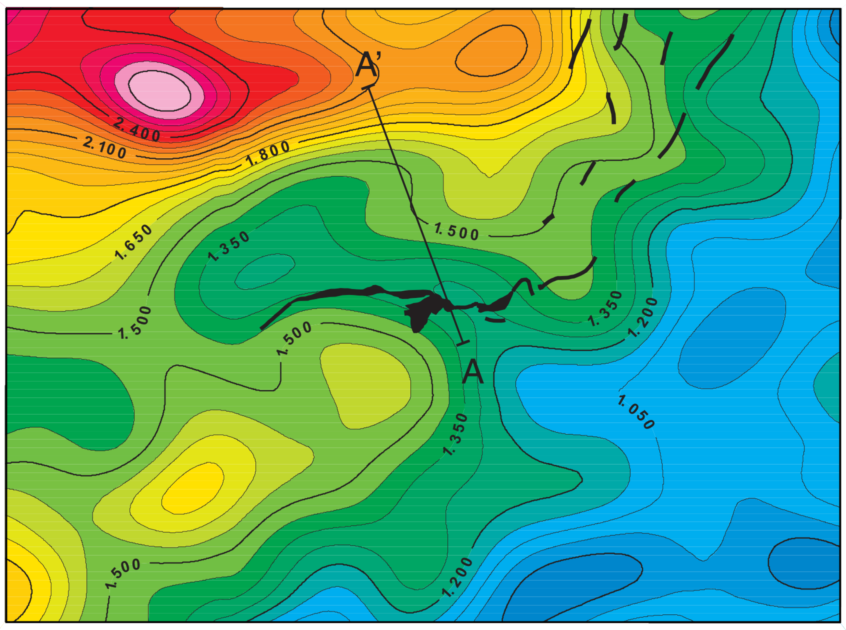
ELECTROMAGNETIC PROFILES/ANOMALIES



1000 m

HALFMILE LAKE

POTASSIUM (%)



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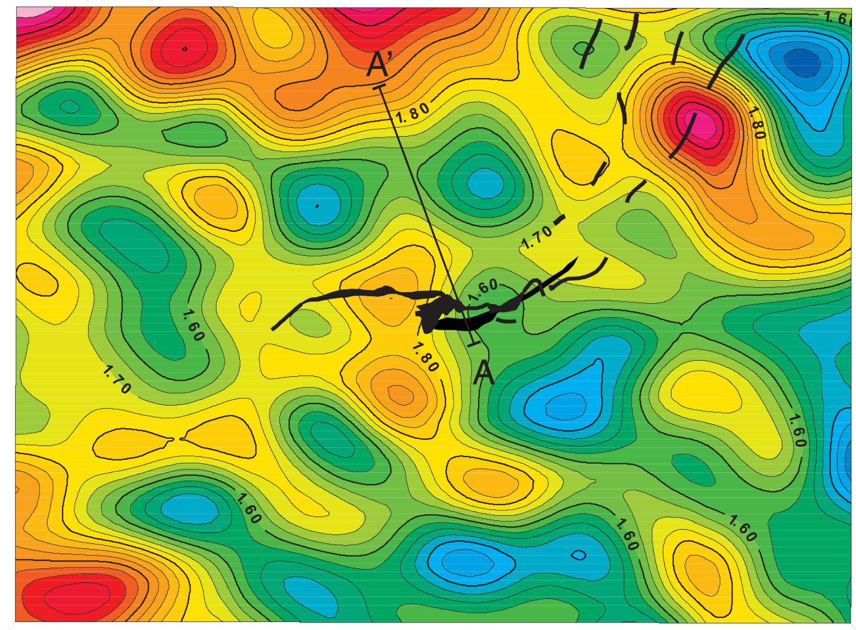
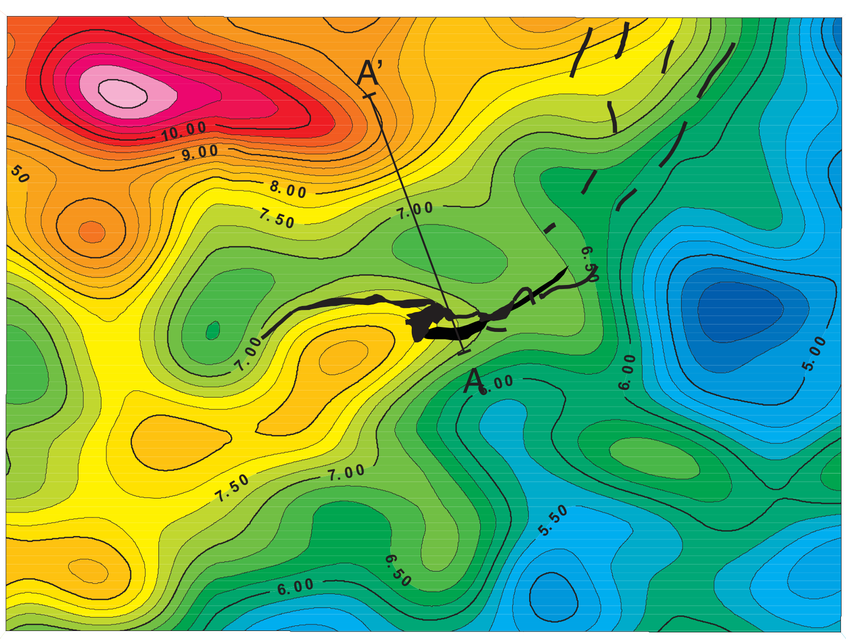
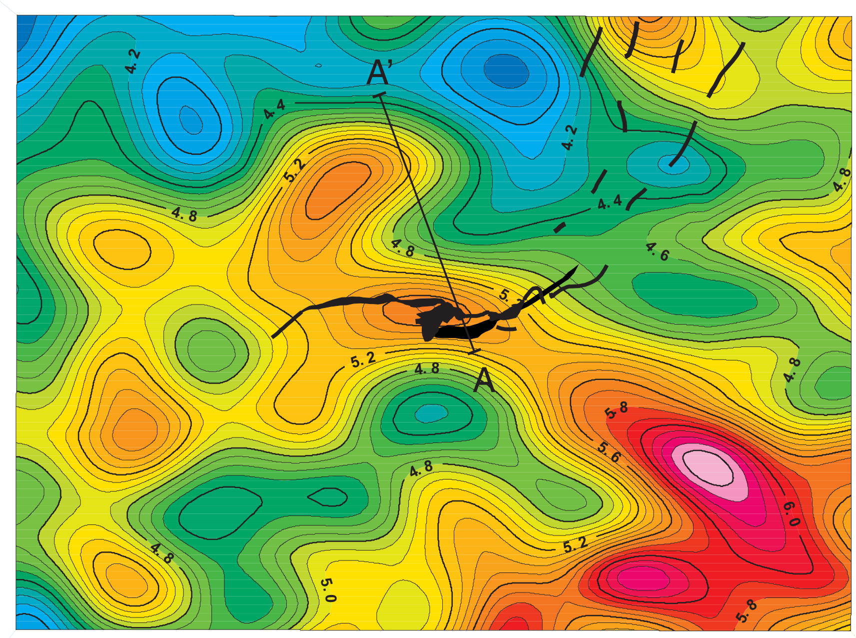


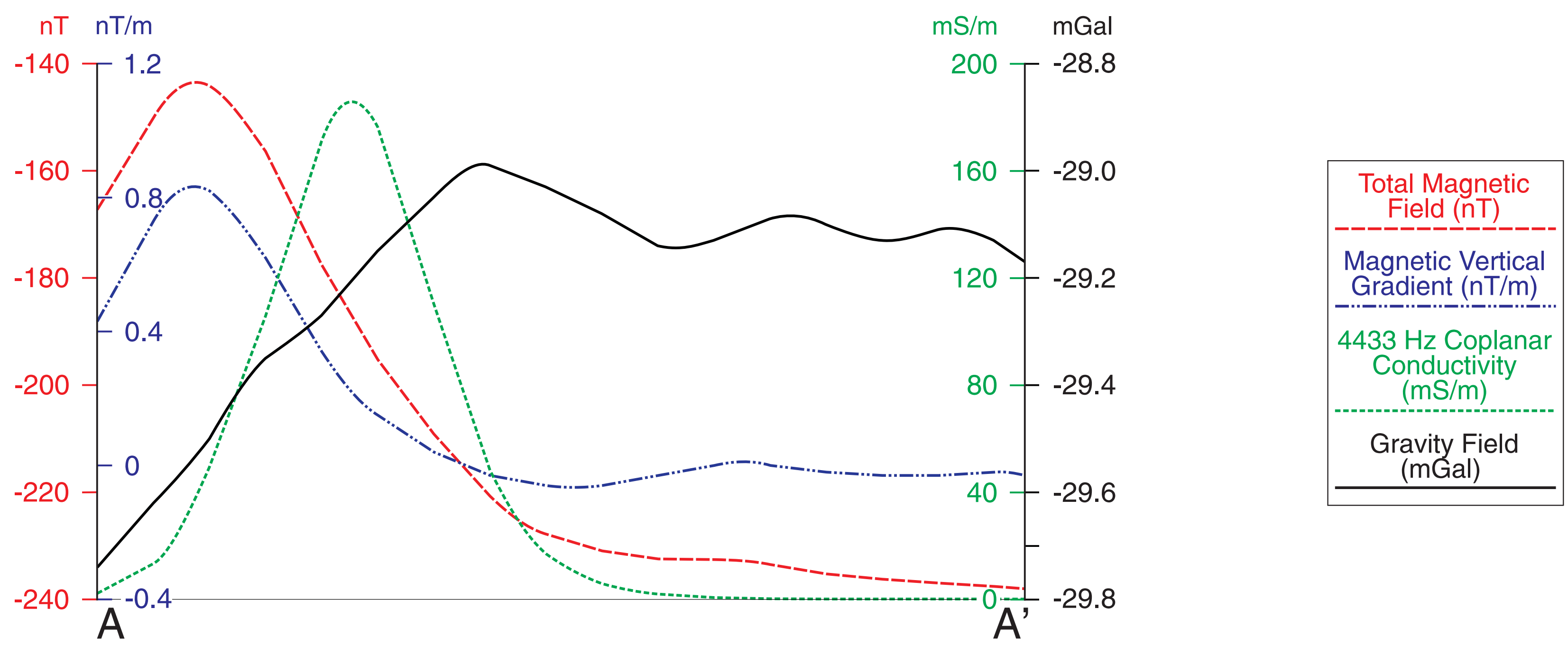
THORIUM (ppm)

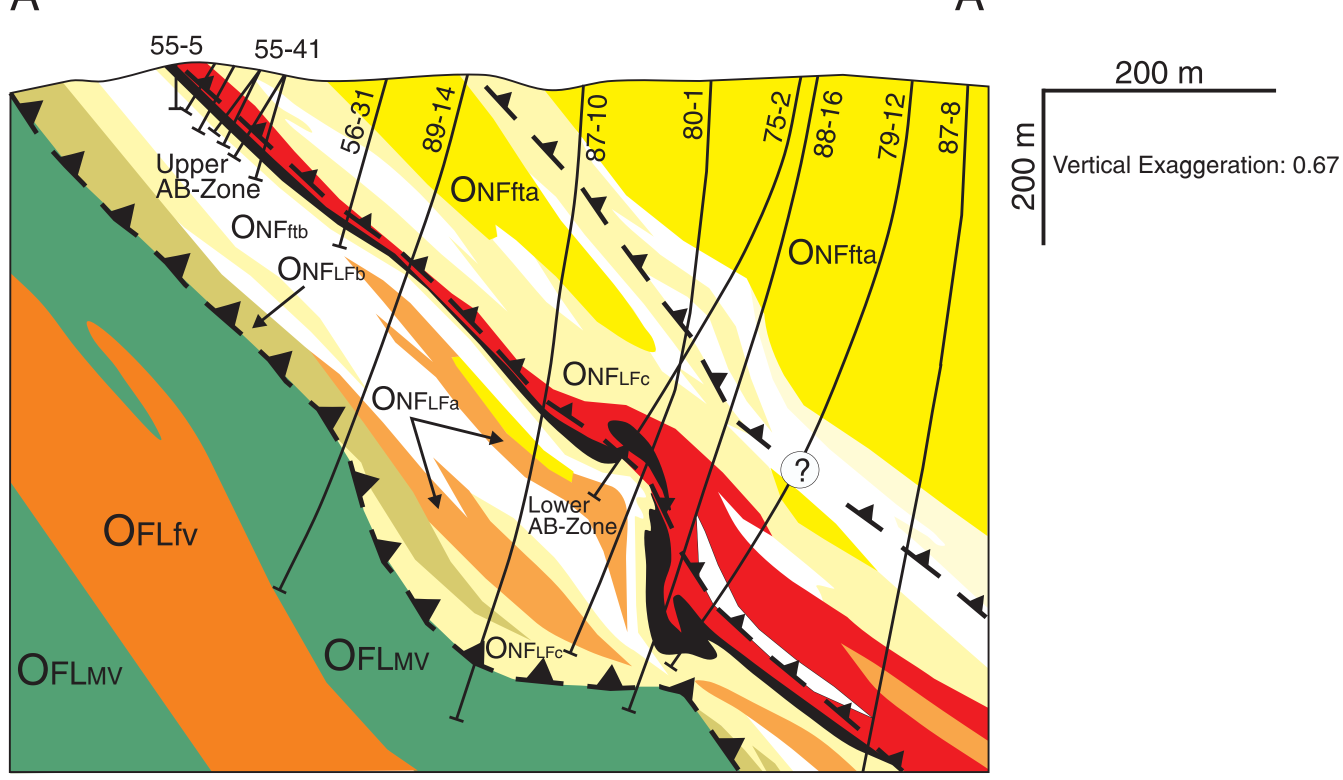


THORIUM/POTASSIUM RATIO (x 10^{-4})



GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'

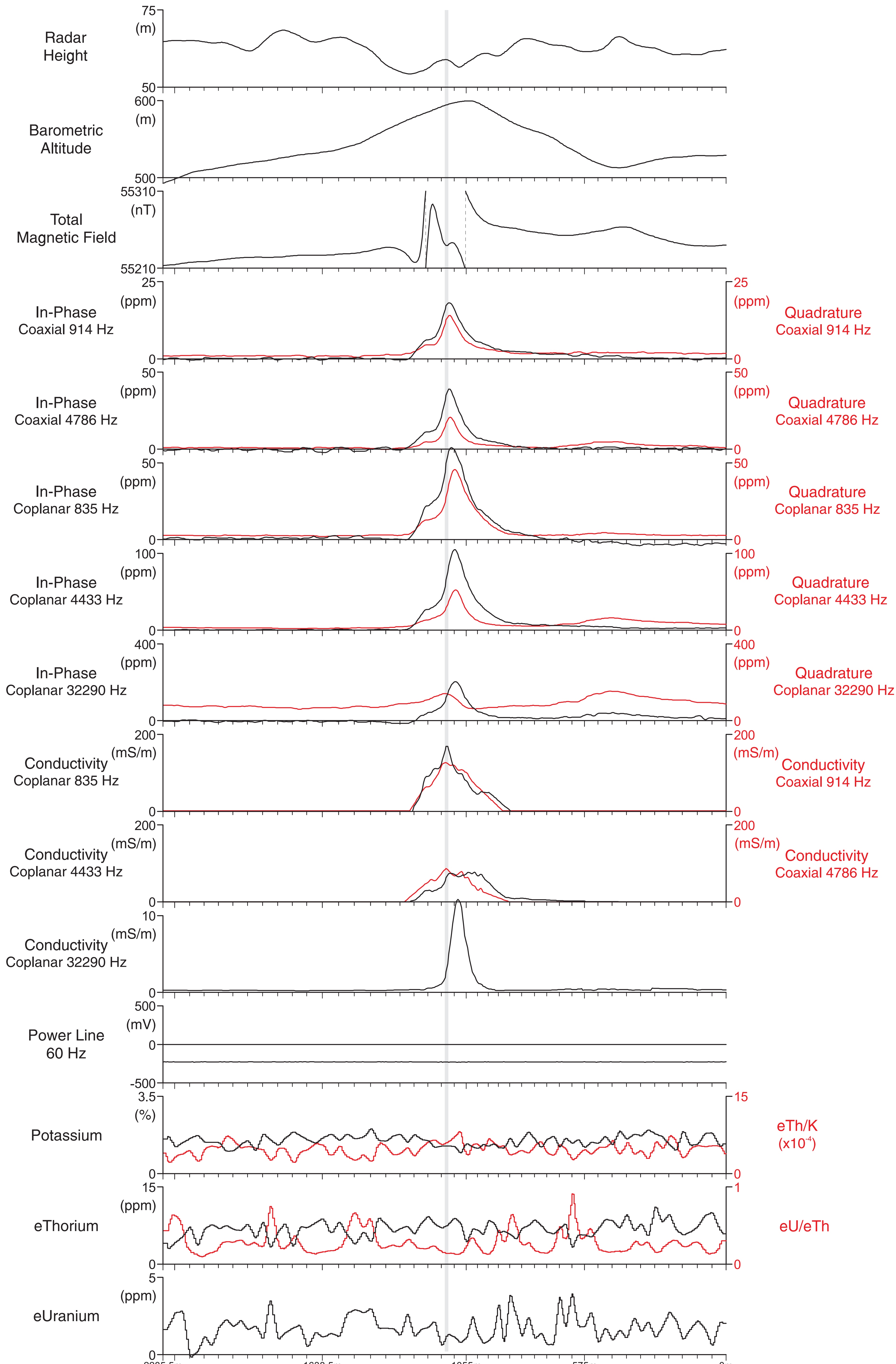




Modified from Adair (1992)

HALFMILE LAKE

SW GEOPHYSICAL PROFILES ALONG FLIGHT LINE 221252 NE



HEATH STEELE B ZONE DEPOSIT

GEOLOGY

The Heath Steele B Zone was discovered in 1953 following an airborne EM survey by INCO and American Metal Co. According to Hamilton and Wilson (1997) to August 31, 1996 the deposit produced 19,649,600 tonnes grading 1.75% Pb, 4.76% Zn, 0.98% Cu and 65 g/t Ag. The deposit occurs within the Nepisiguit Falls Formation and is hosted by siltstone and ash tuffs. The sulphide lens is capped by, and gradational into, silicate, carbonate, and oxide iron formations (Wilson, 1993c). Quartz-feldspar crystal tuffs in the hanging wall, to the north of the deposit, are also assigned to the Nepisiguit Falls Formation (Wilson, 1993c).

The B zone is a continuous to locally discontinuous sulphide sheet that has a strike-length of 1500 m, extends down dip 800 m and reaches a maximum thickness of 60 m. The ore textures vary from massive pyrite through massive banded pyrite-galena-sphalerite and pyrrhotite-chalcopyrite breccia ore. Sulphide mineralogy in order of decreasing abundance is: pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, arsenopyrite, tetrahedrite and Ag-Pb-Bi-Sb sulfosalts. The sulphides are divisible into three types; (1) pyrrhotite-chalcopyrite fragmental ore which commonly occurs along the footwall, but transgresses the sulphide body locally and consists of pyrite and lithic clasts in a chalcopyrite-pyrrhotite matrix, (2) massive pyrite, and (3) banded pyrite-sphalerite-galena. These sulphide types have been interpreted to represent primary metal zoning, although they have been affected by remobilization during deformation and metamorphism.

The deposit is on the north limb of a tight east- to northeast-trending F_1 anticline and is refolded by tight to isoclinal, northward-overturned, west-plunging F_2 folds. The F_1 anticline is cored by shale, siltstone, tuffaceous sedimentary rocks and crystal tuffite assigned to the Little Falls Member of the Nepisiguit Falls Formation and/or Patrick Brook Formation. These are overlain by dominantly quartz-feldspar crystal tuff, ash tuff and minor fine-grained sedimentary rocks of the Nepisiguit Falls Formation (Lentz, 1997: Lentz and Wilson, 1997). To the south, the Nepisiguit Falls Formation is juxtaposed against aphyric to feldspar-phyric felsic volcanic rocks of the Flat Landing Brook Formation along an interpreted thrust.

MAGNETIC DATA

The horizon of the Heath Steele B Zone deposit is accompanied by a prominent (~860 nT amplitude) magnetic high, that is one of the most extensive sulphide-related anomalies in the Bathurst Mining Camp. Its axis, trending east-northeast, lies immediately south of the ore horizon in the east, but diverges from it in the west, the horizon taking a more westward direction. In this area, the anomaly may be controlled by a band of iron formation, about 300 m long. Mineralogical descriptions (McBride, 1976; Moreton, 1989; Hamilton, 1992) of the deposit and host rocks indicate that the high is an expression of the sulphide mineralization and the iron formation, which includes an oxide facies. Pyrrhotite is the principal magnetic mineral in the deposit. The iron formation ranges in thickness from about 0 to 20 m, and contains 15 to 40% magnetite (McBride, 1976). Pyrite occurs in hanging wall and footwall rocks, and is abundant in one rock unit (Moreton, 1989). Minor amounts of pyrrhotite, chalcopyrite and magnetite are present in various units (McBride, 1976, Moreton, 1989). These host rocks probably have little effect on the magnetic field. Magnetic susceptibilities determined on drill core from the immediate hanging wall rocks, mainly quartz-feldspar and quartz porphyries, rhyolites and grey tuffs (Brunswick Mining and Smelting Corporation Limited log), range from 0.1 to 0.5 x 10^{-3} SI, whereas sericite and chlorite tuffs in the footwall have a mean value of about 2.8 x 10^{-3} SI. Units of massive and sub-massive sulphides have mean values ranging from 50 to 140 x 10^{-3} SI, with individual values attaining about 400 x 10^{-3} SI.

ELECTROMAGNETIC DATA

The Heath Steele deposit was the first airborne EM discovery in the world. The EM system consisted of orthogonal coils in the transmitter and in the towed receiver. The EM response of the Heath Steele deposit from a 1956 EM survey is illustrated by Pemberton (1989). Three strong EM anomalies are observed on both the in-phase and quadrature responses. The Heath Steele B Zone deposit is associated with a 1500 m long conductivity anomaly. Although it is located nearby a road, no 60 Hz interference is observed on the EM traces. This deposit generates strong in-phase and quadrature anomalies on all five frequencies of the HEM system. The response of flight-line 440810 that intersects the deposit is typical. At low frequency, the coaxial in-phase and quadrature responses are 27 ppm and 20 ppm, respectively; the coplanar responses are 97 ppm and 51 ppm. For the flight-lines intersecting the conductor, both coaxial and coplanar configurations show complex responses over the conductor. A double peak response is observed on the coaxial coil and a single peak on the coplanar coil. This single peak anomaly has a shoulder on some profiles, suggesting the presence of a thick conductor (about 100 m). The maximum thickness of the massive sulphide sheet is 60 m, although it is much thinner near the surface. The sheet and the adjacent mixed tuffaceous sedimentary rocks of the Nepisiguit Falls Formation are the source of the EM anomaly. There is an excellent correlation between the EM and magnetic anomalies, indicating a common source.

GRAVITY DATA

The gravity map of the Heath Steele B Zone is based on a gridded data set (30 m spacing) provided by Noranda. The prevailing trend of gravity contours is east-northeast, which is generally similar to strikes of geological units. Over the eastern two-thirds of its course, the B Zone horizon runs more or less parallel to the gravity contours, but diverges from them at its western end, suggesting that deeper geology also influences the gravity field. The sulphide horizon, itself, lies on the northern flank of a broad gravity high that extends over much of the southern part of the map-area. This flank is represented by a broad gradient across which the gravity field decreases from south to north.

Contrary to expectations, the two exposures of sulphide mineralization do not produce discernible perturbations on this gradient. Along section A-A' the deposit is subvertical and about 10 m thick over the first 70 m below surface, and would be expected to produce a small anomaly, of at least a few tenths of a milligal in amplitude. A lack of signature could indicate that where lines of gravity survey cross the sulphide horizon, sulphide sections are much thinner. Alternatively, the absence of a signal may be an apparent absence, if for some unseen circumstance geology and gravity maps have been incorrectly co-registered. If this were the case, an elongate gravity high about 200 m south of the sulphide horizon represents a potential candidate for the missing signature. As it stands, this high coincides partially with sedimentary and tuffaceous rocks belonging to the Patrick Brook Formation and Little Falls Member of the Nepisiguit Falls Formation. These may be more dense than adjacent felsic volcanics of the Nepisiguit Falls and Flat Landing Brook formations. The source of the broad gravity high south of the sulphide horizon is not evident in the surface geology.

RADIOMETRIC DATA

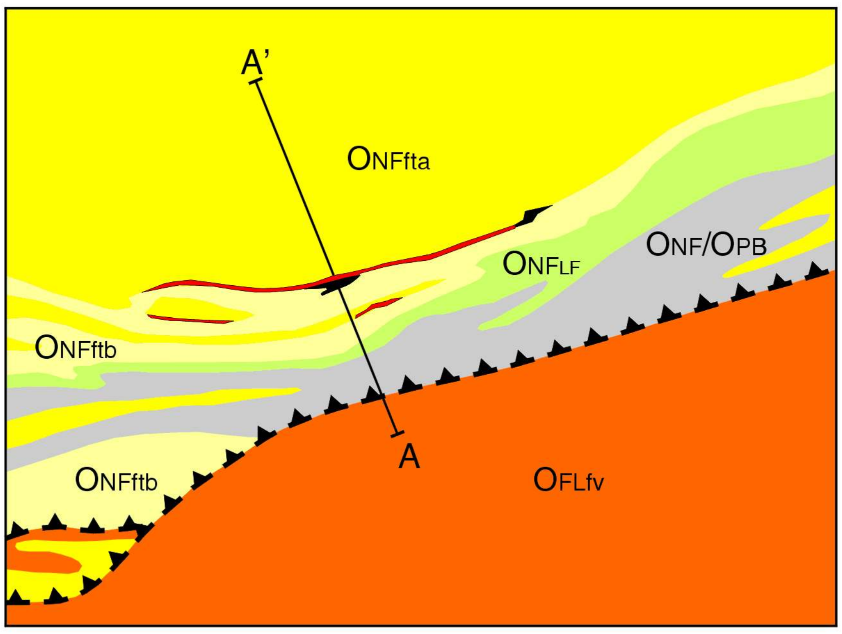
The airborne radioelement patterns reflect the west-southwest to east-northeast geological trends. Potassium is highest over hanging wall crystal tuffs (2.15 - 2.45% K) and mixed tuffaceous sedimentary rocks (1.4 - 2.45% K) of the Nepisiguit Falls Formation, and aphyric to feldspar-phyric rhyolitic flows and related volcaniclastic rocks (1.5 - 2.35% K) of the Flat Landing Brook Formation. Footwall crystal tuffs and sedimentary rocks of the Little Falls Member (Nepisiguit Falls Formation) and Patrick Brook Formation yield moderate K concentrations (1.35 - 2.00%). Maximum K, eTh and elevated eU concentrations are apparently enhanced by increased bedrock exposure over an open pit south of the B Zone deposit. Elevated eU concentrations overlie the B Zone deposit and extend to the northeast along the contact between mixed tuffaceous sedimentary rocks and crystal tuffs of the Nepisiguit Falls Formation. Maximum eU concentrations (2.7 - 2.85 ppm) are not associated with K or eTh highs, and thus reflect changes in bedrock geology, rather than variations in the amount of bedrock exposure. Elsewhere, low eU concentrations (1.35 - 2.25 ppm) show little correlation with bedrock geology. The eTh concentrations are lowest (5.2 - 8.0 ppm) over footwall crystal tuffs and sedimentary rocks of the Nepisiguit Falls and Patrick Brook formations. Higher values (6.5 - 9.0 ppm eTh) occur in hanging wall crystal tuffs. The association of higher K and eTh values with hanging wall crystal tuffs, and lower K and eTh concentrations with hydrothermally-altered footwall crystal tuffs, has been confirmed by ground gamma-ray spectrometry (Rickard, 1998). Lentz (1994) described a similar relationship between hydrothermal alteration and lower concentrations at Brunswick No. 6 deposit. The ability to radiometrically distinguish hanging wall and footwall units has important exploration implications.

SUMMARY

The Heath Steele B deposit, together with an associated magnetite-rich iron formation and adjacent tuffaceous sedimentary rocks, produces strong, co-extensive magnetic and conductivity anomalies along the mineralized horizon. A gravity signature of the deposit is not recognized, possibly because of uncertainty in georeferencing the gravity data set. If the data set is misplaced, then an elongate gravity high about 200 m south of, and co-extensive with, the sulphide horizon could represent the missing signature. A potential radiometric signature is the change from higher K and eTh values in the hanging wall to lower ones associated with altered crystal tuffs in the footwall.

HEATH STEELE B ZONE

GEOLOGY



Modified from Lentz and Wilson (1997) and Wilson (1993c)

GEOLOGICAL LEGEND

TETAGOUCHE GROUP

Flat Landing Brook Formation

- OFLfv — aphyric to feldspar-phyric rhyolite flows, domes & related volcaniclastic rocks

Nepisiguit Falls Formation

- ONFfta — crystal tuff & sedimentary rocks
- ONFftb — mixed tuffaceous sedimentary rocks
- massive sulphide
- iron formation & exhalite
- ONFLF — Little Falls Member: footwall crystal tuff & sedimentary rocks

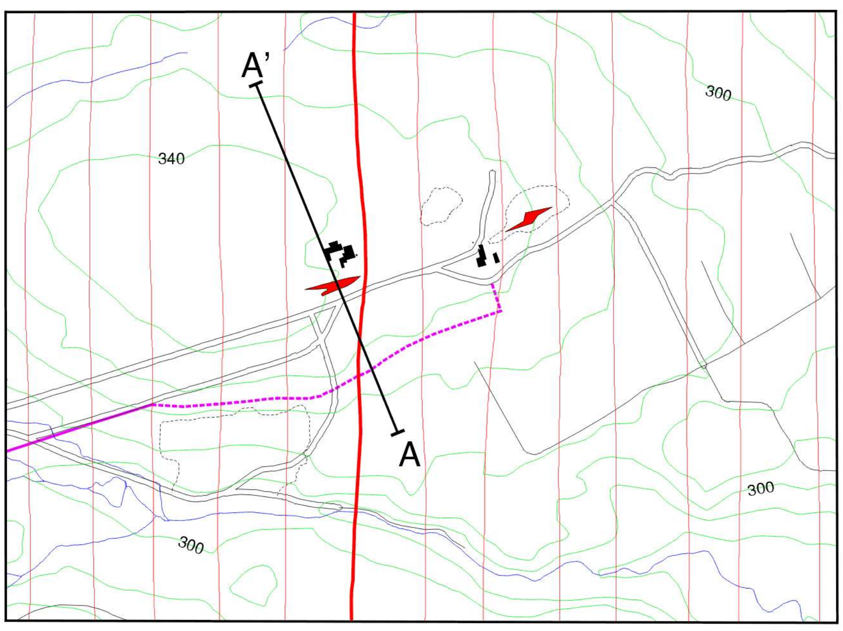
TETAGOUCHE GROUP and/or MIRAMICHI GROUP

Nepisiguit Falls Formation and/or Patrick Brook Formation

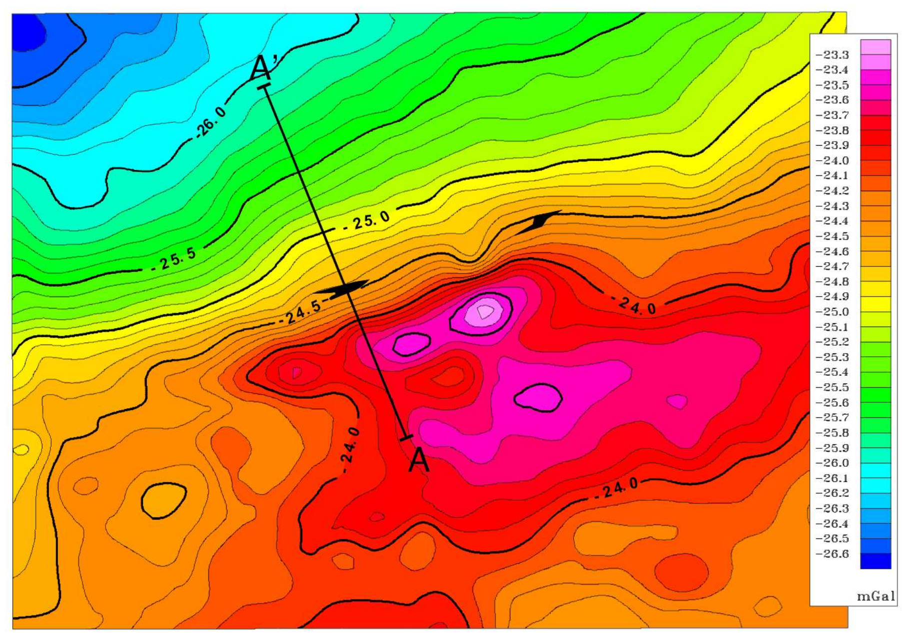
- ONF OPB — siltstone, shale, quartzite & mixed tuffaceous sedimentary rocks

- thrust fault
- antiformal fold axis

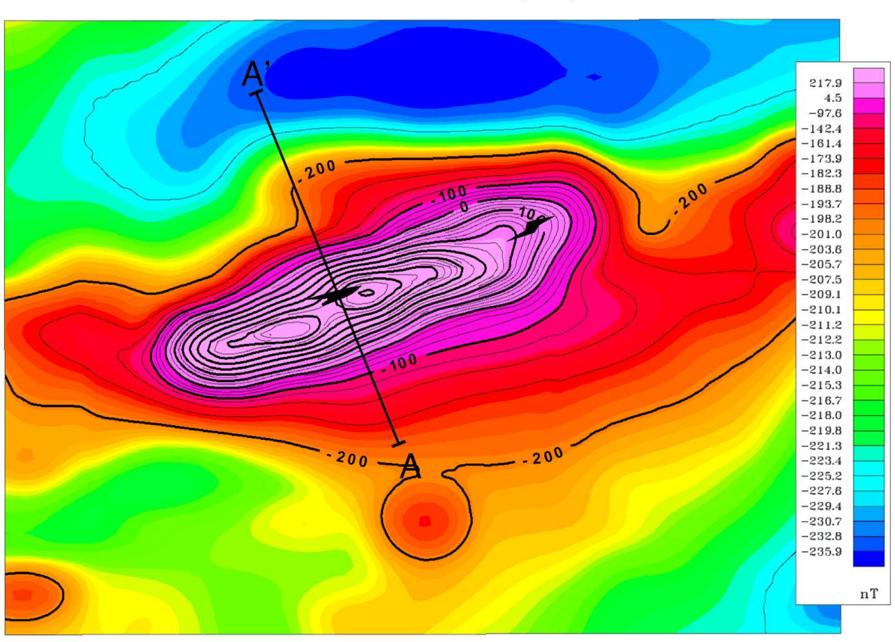
TOPOGRAPHY/FLIGHT LINES



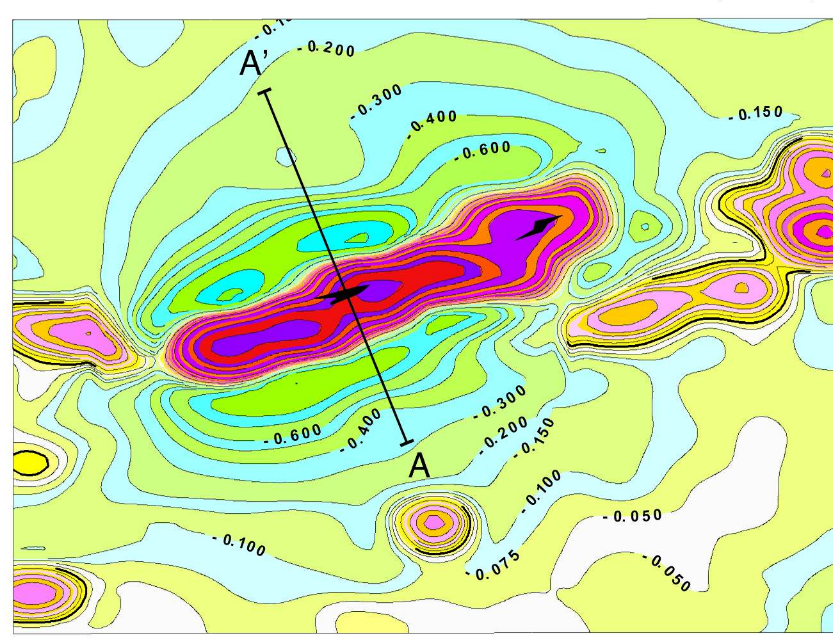
GRAVITY (mGal)



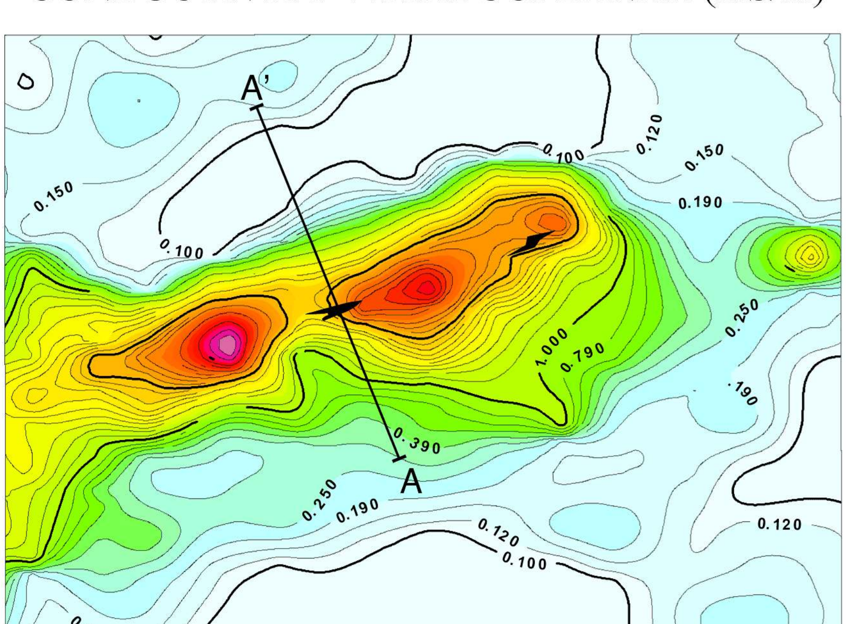
MAGNETICS (nT)



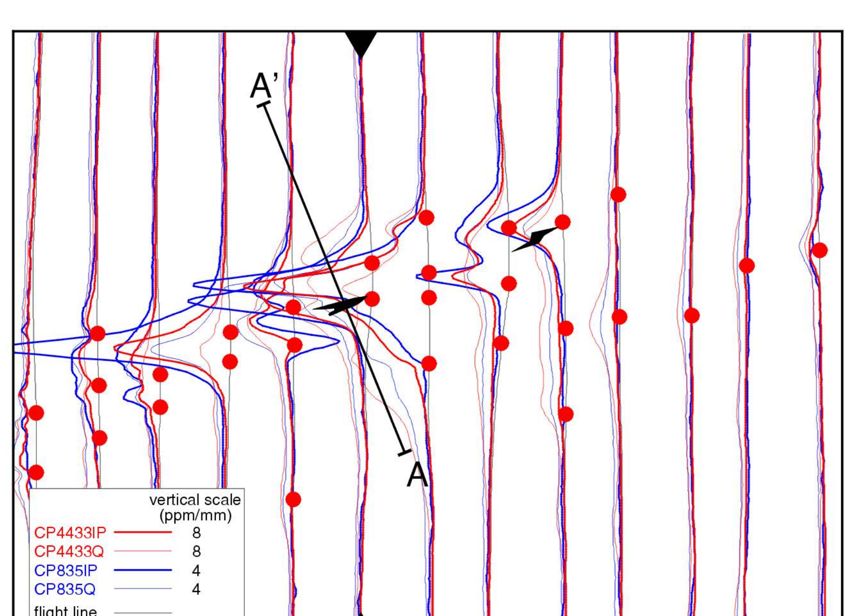
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



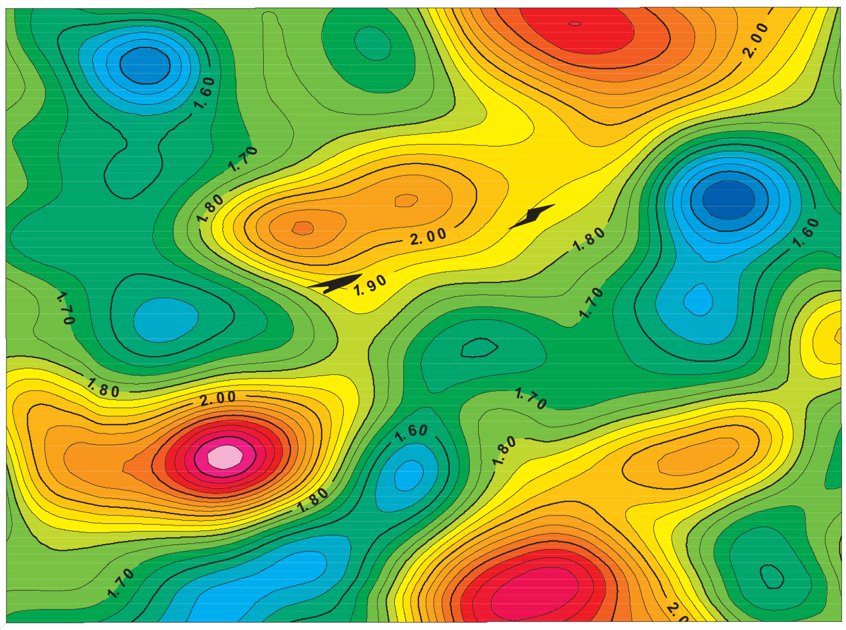
ELECTROMAGNETIC PROFILES/ANOMALIES



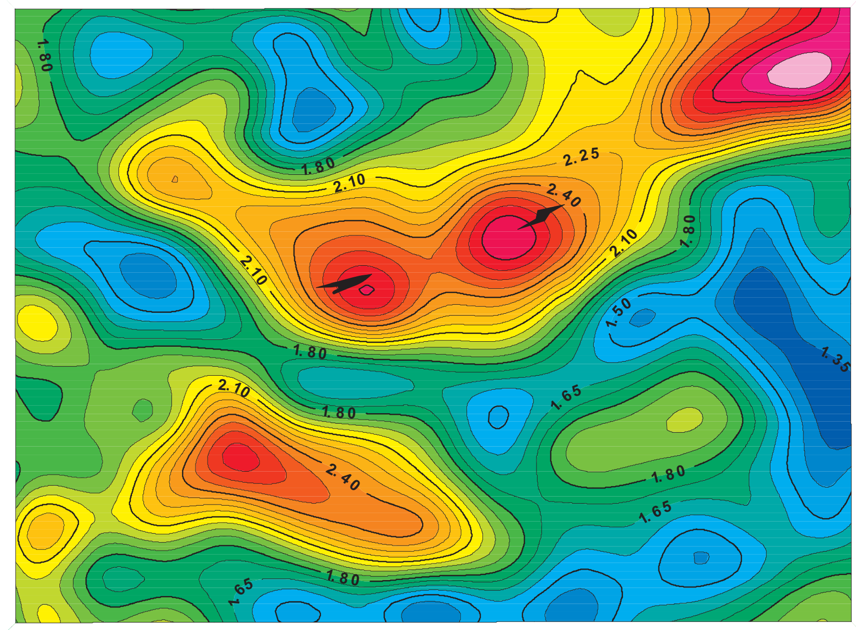
1000 m

HEATH STEELE B ZONE

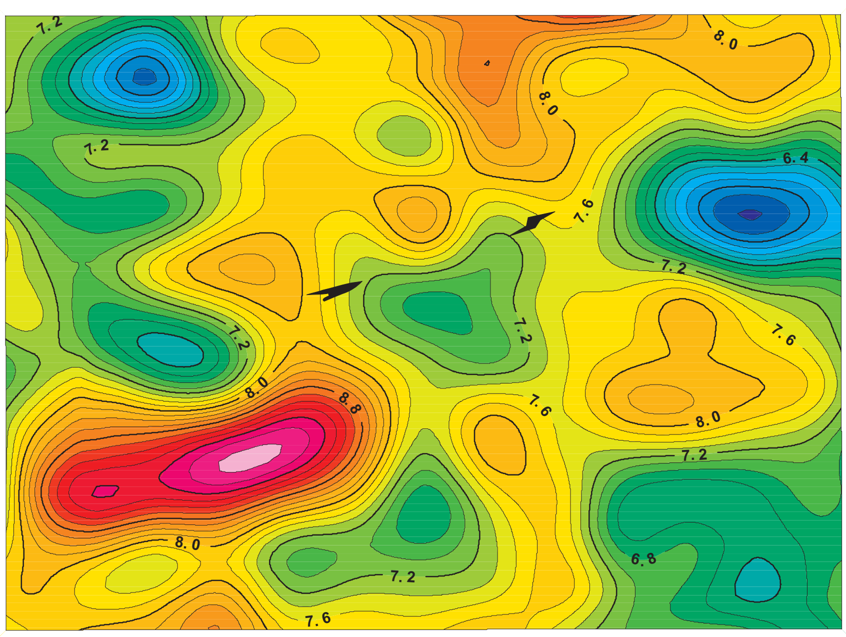
POTASSIUM (%)



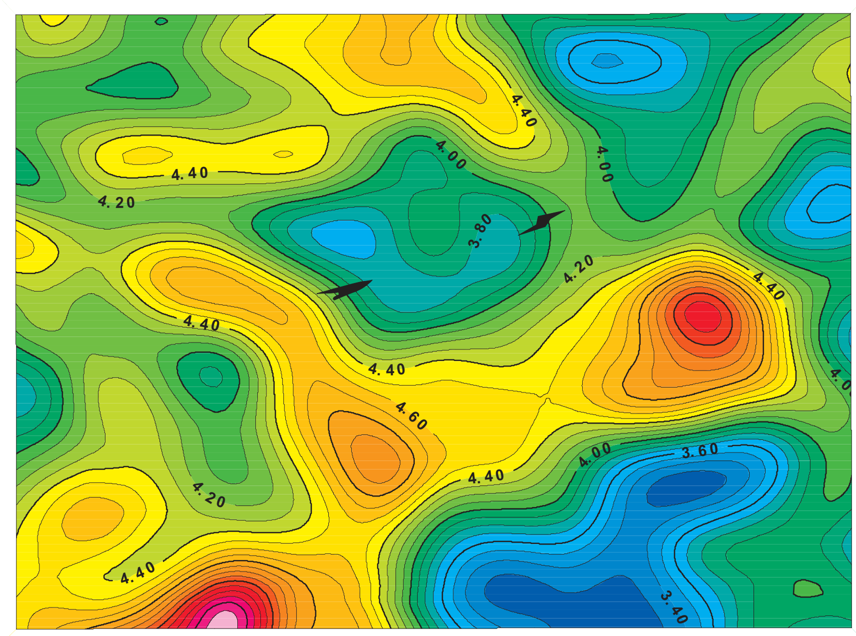
URANIUM (ppm)



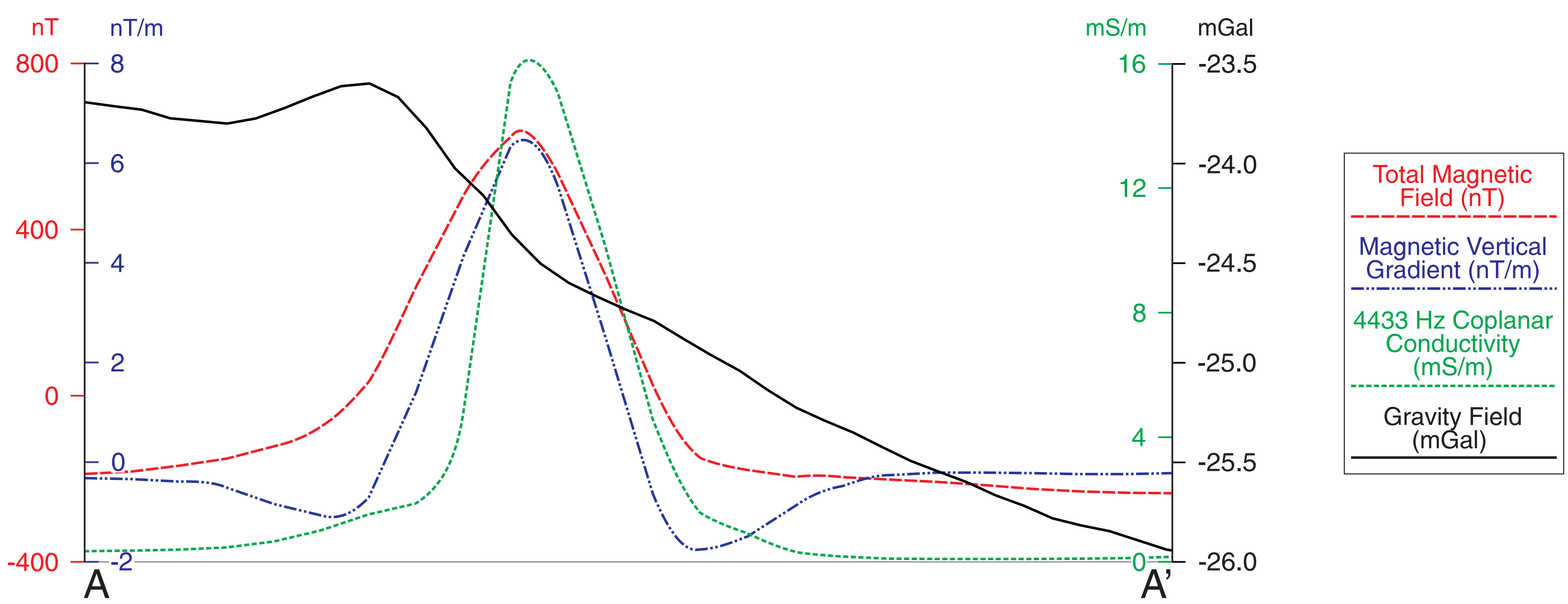
THORIUM (ppm)

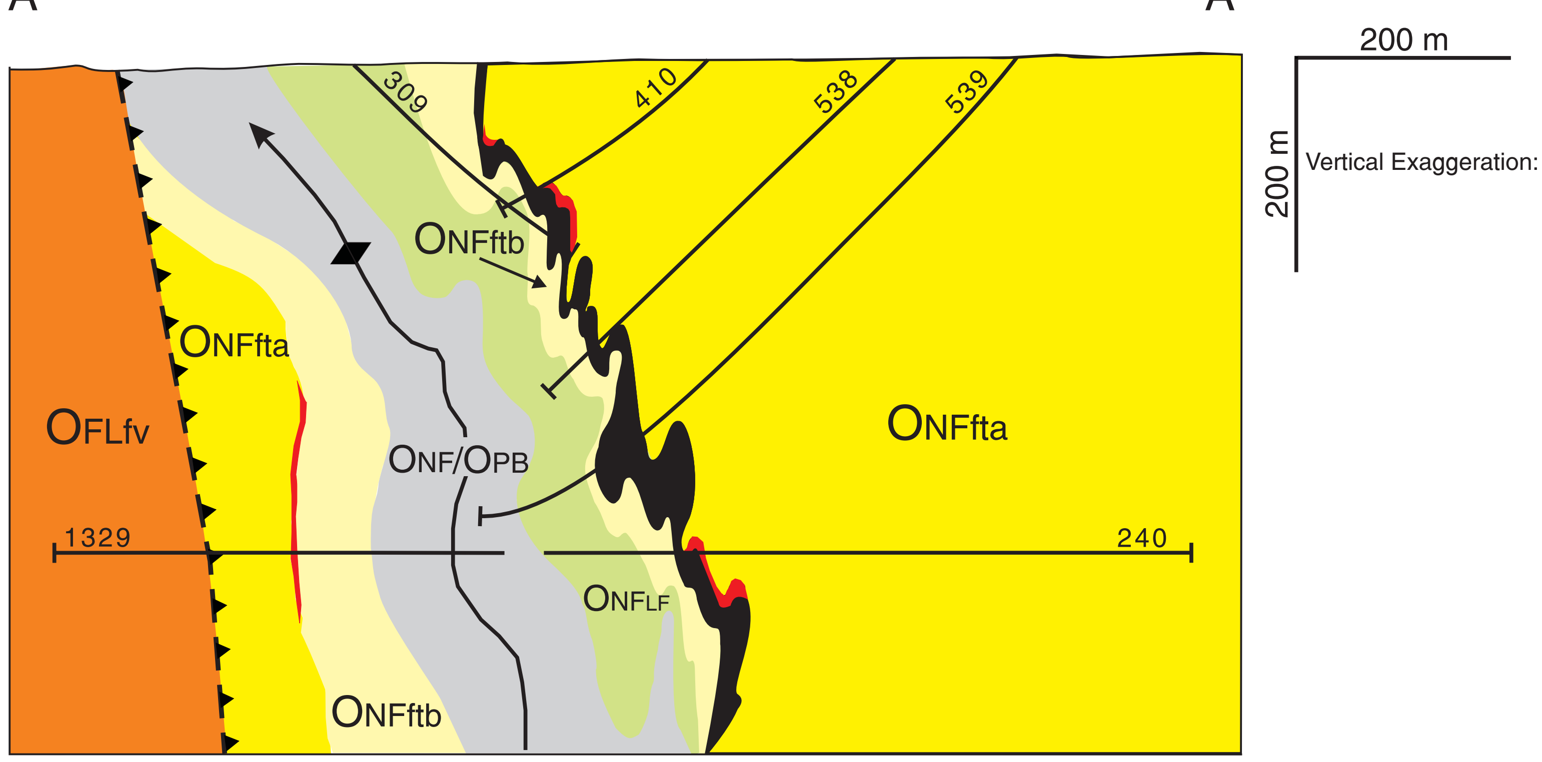


THORIUM/POTASSIUM RATIO (x 10^{-4})



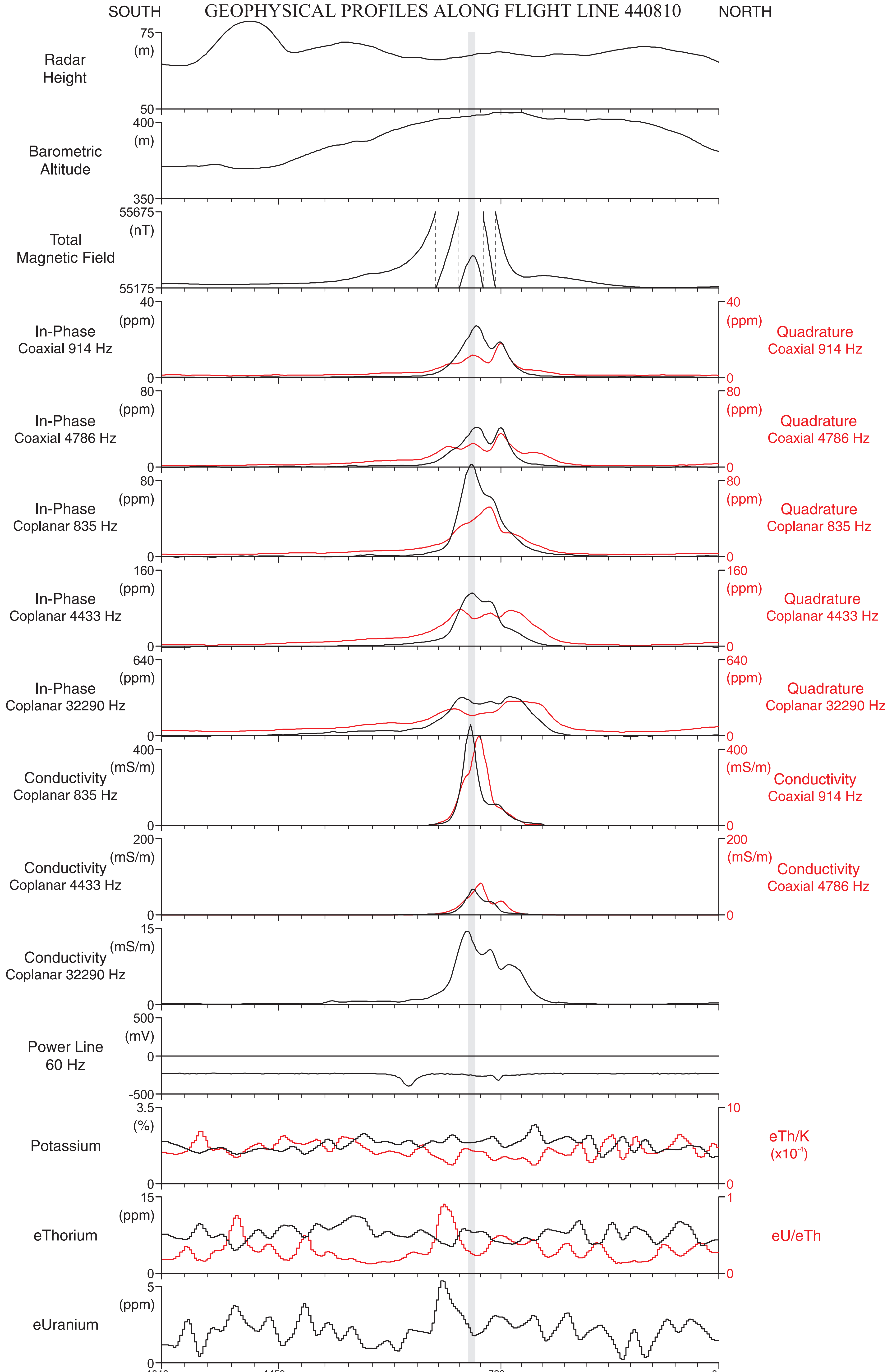
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'





Modified from Lentz (1997)

HEATH STEELE B ZONE



KEY ANACON DEPOSIT

GEOLOGY

Vein-copper mineralization was first discovered at Middle Landing on the banks of the Nepisiguit River in 1930 (Irrinki, 1992 and references therein). However, the actual massive sulphide deposit was discovered by New Larder "U" Island Mines Ltd. in 1953-54 during follow-up drilling on airborne EM anomalies. Between 1955 and 1957 a 457 m shaft was sunk. The deposit occurs at the contact between the Nepisiguit Falls Formation and overlying Little River Formation. Footwall rocks are assigned to the Nepisiguit Falls Formation and comprise felsic ash and crystal tuffs and related volcaniclastic rocks. Hanging wall rocks of the Little River Formation comprise mafic volcanic flows that are interbedded with volcaniclastic siltstone, sandstone and shale. The deposit lies within the thermal aureole of the Pabineau Granite which accounts for the presence of biotite and garnet in chemically favourable beds.

The deposit comprises three en-echelon stratiform (?) zones of disseminated to massive sulphides, and two stringer copper lenses. The economically most significant sulphide lens (Zone 2) is open below 427 m and has proven reserves of 1.11 million tonnes grading 0.22% Cu, 3.47% Pb, 8.41% Zn and 96 g/t Ag (Irrinki, 1992). Along strike and at depth, the sulphide lenses grade into calcareous siltstone and rocks interpreted to represent a mixture of mafic volcanic detritus and chemical exhalite, *i.e.* iron formation. It is possible that this "iron formation" represents post-mineralizing hydrothermal alteration of the hanging wall rocks, rather than precipitation of a chemical exhalite (Lentz, 1995). A well developed Cu-rich pyrrhotite, pyrite stockwork (Middle Landing Cu) in a chlorite-sericite alteration zone occurs at the northwest end of the deposit, and is interpreted to represent a transposed feeder zone to the massive sulphide lenses.

The deposit sits on the northeast limb of a north-northwest-striking F_2 syncline that has a strong, steeply-dipping axial-planar fabric. Mineralization occurs in tight to isoclinal parasitic folds on the northeast limb of this structure. The folds are steeply south-plunging with steeply-dipping to vertical limbs. In 1992, Rio Algom (Weidner, 1992) intersected (diamond drill hole KA-93-32) significant mineralization on the west limb of the Key Anacon Syncline at much greater depths (750 m below surface) than previously known and discovered the Key Anacon East Zone, 1.5 km northeast of the main zone and beneath the Carboniferous cover (Lentz, 1995).

MAGNETIC DATA

A narrow zone embracing the surface projections of the buried Key Anacon sulphide lenses falls along or close to the axis of a broad magnetic high extending northwest across the map-area. The anomaly changes character significantly near the shaft of the Key Anacon No. 2 Zone (Irrinki, 1992). To the northwest, it has a peak amplitude of about 350 nT, whereas to the southeast the amplitude attains over 1500 nT. The vertical gradient image suggests a dextral offset of the magnetic high near the No. 2 Zone shaft, if it is indeed a singular feature. The sulphide lenses lie close to the axis of the magnetic high in the northwest, but are displaced to the northeast flank of the high in the southeast. This displacement and the coincidence of peak areas of both the northwest and southeast segments of the anomaly with mafic volcanic and volcaniclastic rocks of the Little River Formation, indicate that these rocks are the principal control on the anomaly. Magnetic susceptibility measurements on drill core demonstrate that the mafic volcanic and volcaniclastic rocks have susceptibilities that rival those of the sulphides. A sample of three sulphide intersections yielded mean values of 5.7, 38 and 50 x 10^{-3} SI and three sections of mafic rocks produced mean values of 1.2, 30 and 80 x 10^{-3} SI. Given that mafic rocks are exposed at surface (the sulphides are buried), and cover significantly larger areas, it is speculated that any magnetic signal related to the sulphide lenses is masked by that of the mafic rocks. In the sulphide lenses, pyrrhotite, the mineral with most potential to generate magnetic anomalies, occurs in a pyrrhotite-sphalerite-galena assemblage (Irrinki, 1992) that occurs mainly at depth in the No. 2 Zone. This is further evidence in support of a dominantly mafic volcanic origin for the magnetic high. Pyrrhotite, pyrite and chalcopyrite are predominant sulphides in zones at the northwest end of the belt, but they occur in thin fracture zones (Irrinki, 1992), and are expected to have little influence on the magnetic field. An interesting aspect of the northwest end of the magnetic high is its continuance, for some distance, into the weakly magnetic (susceptibility ~1 x 10^{-3} SI) sedimentary rocks of the Patrick Brook Formation, suggesting that the synformal structure plunges to the northwest.

ELECTROMAGNETIC DATA

The Key Anacon massive sulphide deposit strikes sub-parallel to the flight-line orientation. The deposit was bulk-sampled underground and the HEM response is contaminated by cultural effects and waste piles related to this activity. A power line crosses the west of the area and is detected at low and mid frequencies. At low frequency, the coplanar and coaxial responses are complex and noisy. The source of the EM response is unlikely to be the deposit. There is less noise on the mid frequency responses, but the source of the anomalies remains uncertain. The complex response is partly due to the fact that the flight-lines are sub-parallel to the strike of the deposit.

GRAVITY DATA

The gravity map is based on a detailed survey carried out for Rio Algom Exploration Incorporated. Most readings were made at 50 m intervals along a series of parallel lines spaced approximately 300 m apart, and a few lines crossing the main series at right angles. A density of 2.67 g/cm^3 was used to derive the Bouguer anomalies. The northwest-trending series of lenses that make up the Key Anacon deposit sits on the southwestern shoulder of a broad gravity high, whose axis runs northeast-southwest. West of the Nepisiguit River, the gravity field falls off to the southwest and northwest. Apparently, a principal control on the high is a sequence of mafic volcanic flows and interbedded volcaniclastic sedimentary rocks of the Little River Formation. Measurements of their densities made by the authors on drill core from two holes yielded mean densities of 2.88 and 2.90 g/cm^3. These compare with values of 2.72 and 2.74 g/cm^3 for sedimentary rocks of the Patrick Brook Formation, which cover most of the area. The influence of mafic rocks is reflected in their coincidence with small local culminations in the axial area of the gravity high.

The sulphide lenses are not associated with perceptible signatures on the gravity map, because they are thin and buried. A figure in Irrinki (1992) indicates that the No. 2 sulphide zone, potentially the richest, is buried about 50 m below surface; more specific information on depth of burial is not given. A sulphide-related signal is not obvious on the gravity map, but a small gravity high is identified on a gravity profile crossing the No. 2 zone. This is superposed on a "regional" gradient. Although an inflection marks the eastern limit of the high, its western flank merges gradually with the gradient. This makes separation of the high from the regional trend an uncertain exercise. Subtraction of an estimated regional trend yielded a residual anomaly having an amplitude of ~0.25 mGal. Computation of the gravity effect of a section of the sulphide deposit presented by Irrinki (1992) produced an anomaly of approximately the same amplitude and shape.

RADIOMETRIC DATA

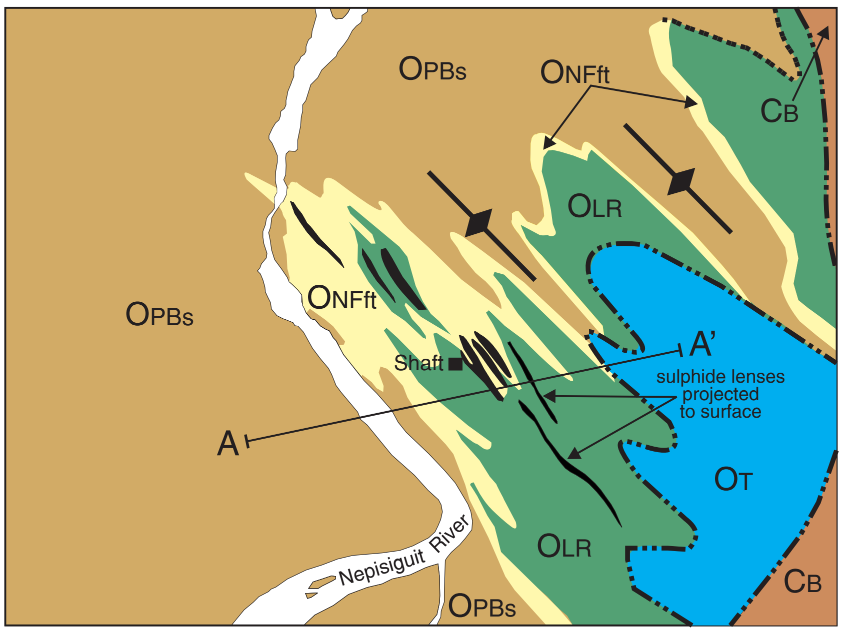
Relationships between the airborne spectrometry patterns and mapped bedrock geology are not well defined. There is no expression of the sulphides, which lie well below the surface, or of the associated hydrothermal alteration. In general, sedimentary rocks within the Patrick Brook Formation yield moderate radioelement values (1.2 - 1.6% K, 1.5 - 1.9 ppm eU, 5.4 - 6.6 ppm eTh). Potassium and eTh highs in the northwest corner of the map-area could reflect increased bedrock exposure related to roads/mine development. Spotty eU highs occur throughout the Patrick Brook Formation and may indicate areas where (uraniferous) shaley units predominate, offering potential mapping guides. A prominent, linear high eTh anomaly, located in the southeastern corner of the area, may relate to thorium-bearing minerals within quartz-lithic wackes of the Tomogonops Formation.

SUMMARY

The zone of narrow sulphide lenses that comprise the Key Anacon deposit extends along a moderately narrow conductivity high, and a much broader coincident magnetic high. However, these signatures cannot be attributed specifically to the sulphide deposit, which is buried at depths of some tens of metres. The magnetic signature is likely caused mainly by mafic volcanic rocks, and the conductivity anomaly by felsic ash and tuff and related volcaniclastic rocks together with sedimentary sources. Two culminations of the conductivity high that coincide with sulphide lenses, one near the shaft and the other just to the northwest, are probably related to material extracted from the shaft and/or represent signals of the buried lenses. An obvious gravity signature is not observed, because of the masking effect of a gravity high related to mafic volcanics. A small high, estimated amplitude ~0.25 mGal, is present on a single profile crossing the No. 2 zone. There are no radiometric signatures related to either the ore deposit or hydrothermal alteration.

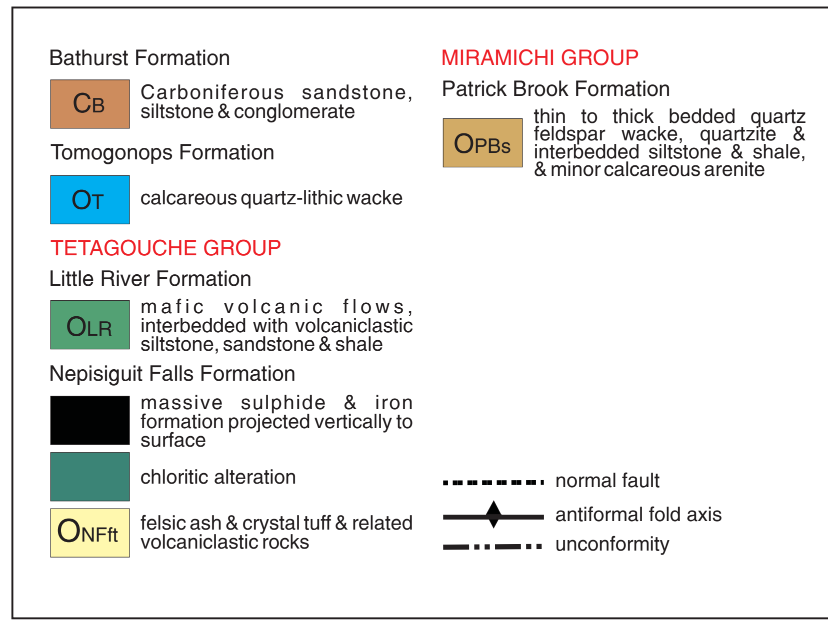
KEY ANACON

GEOLOGY

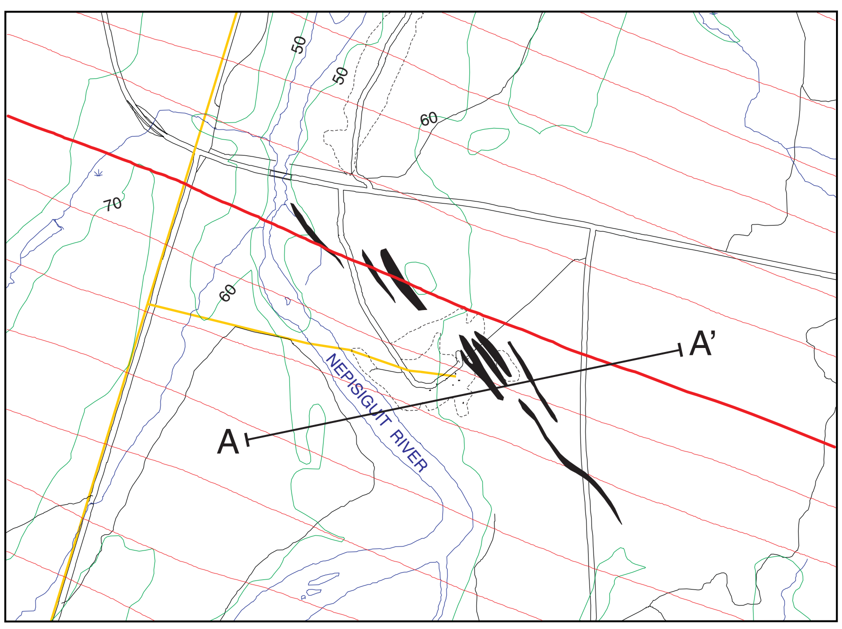


Modified from Irrinki (1992) and Lentz (1995)

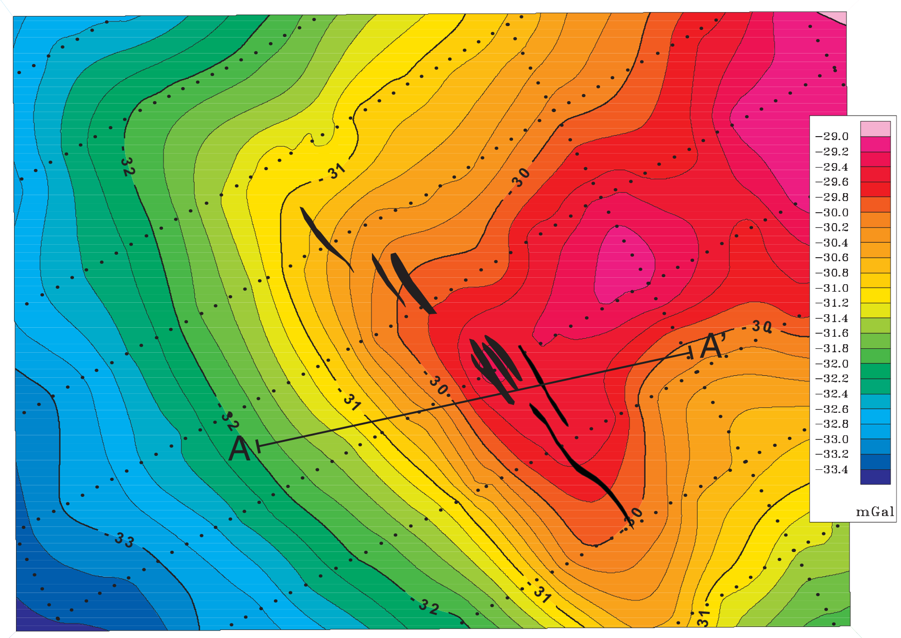
GEOLOGICAL LEGEND



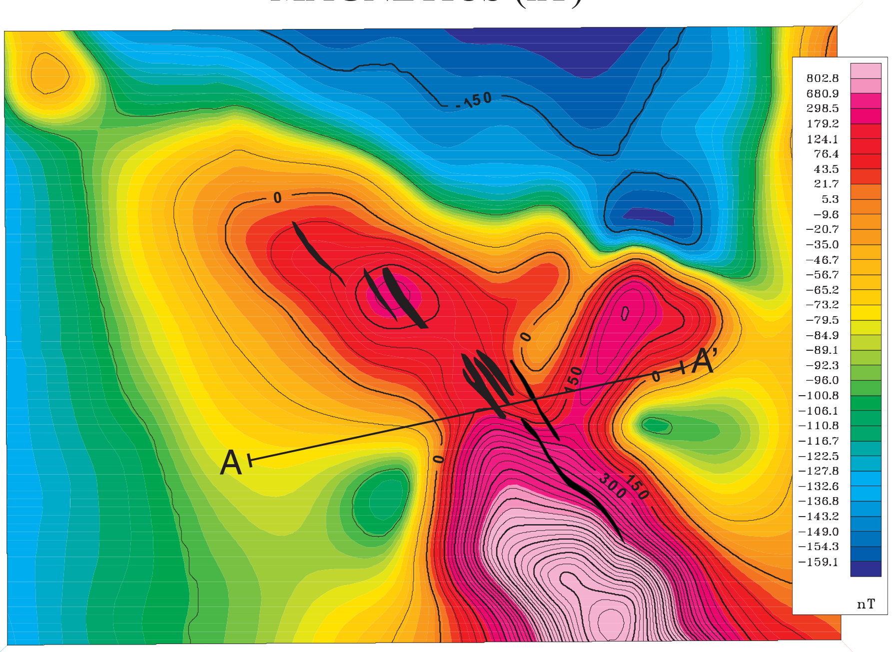
TOPOGRAPHY/FLIGHT LINES



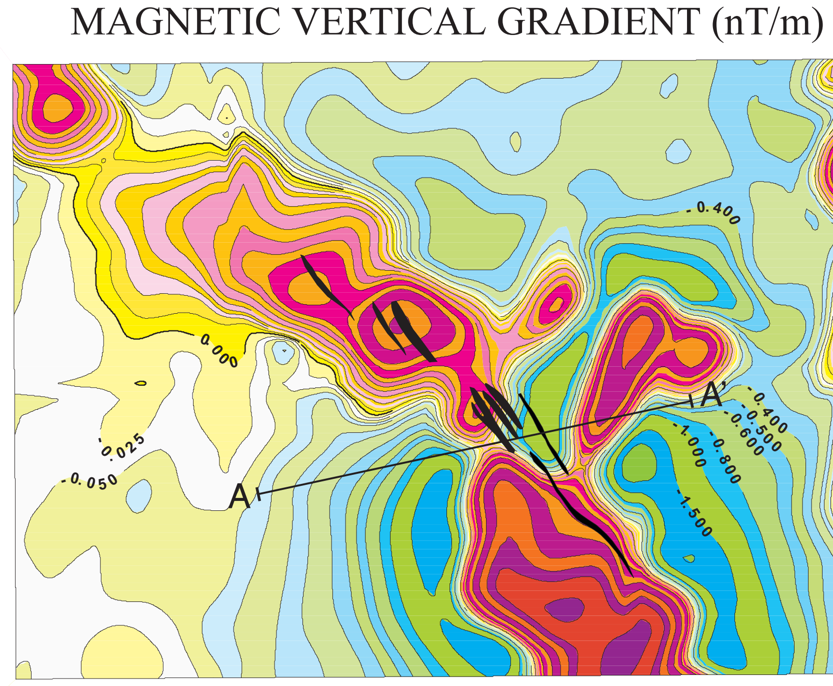
GRAVITY (mGal)



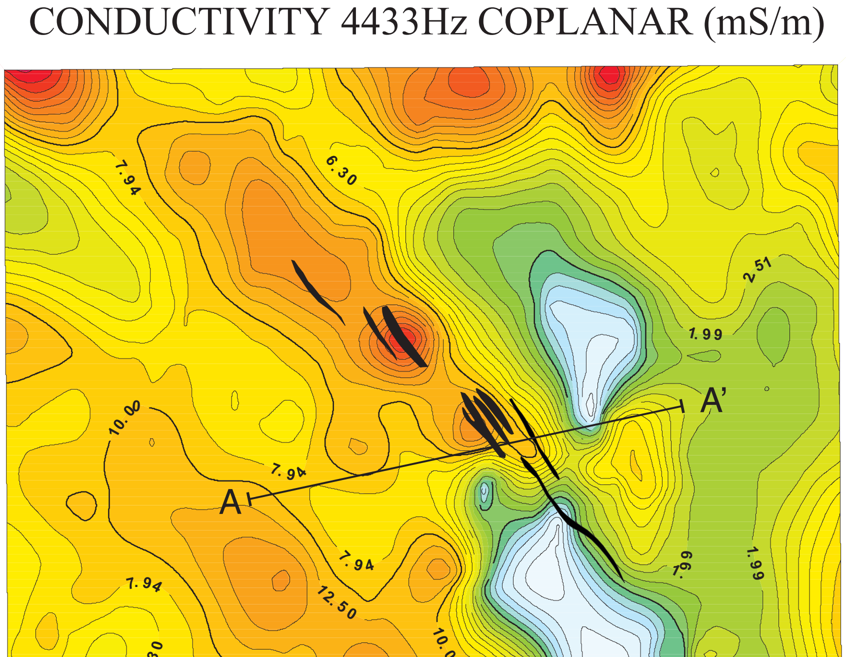
MAGNETICS (nT)



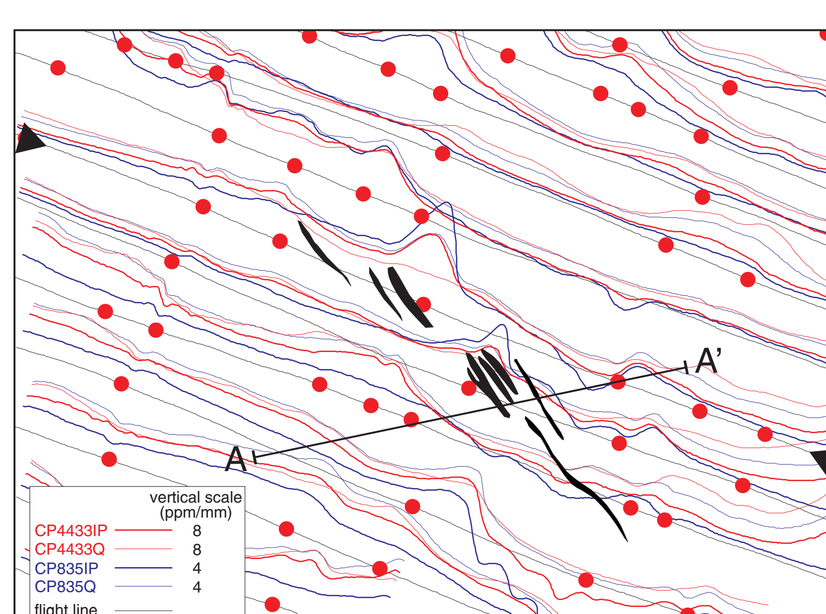
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



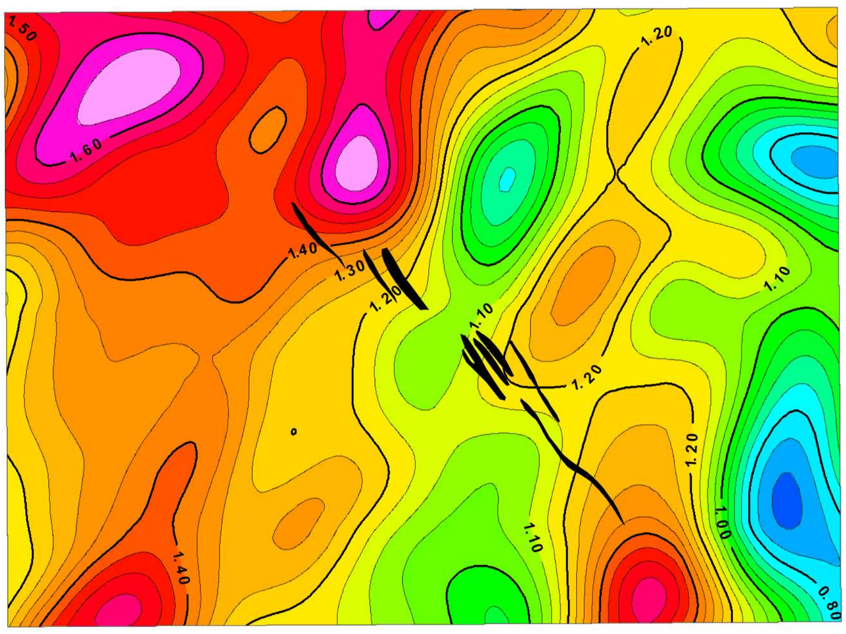
ELECTROMAGNETIC PROFILES/ANOMALIES



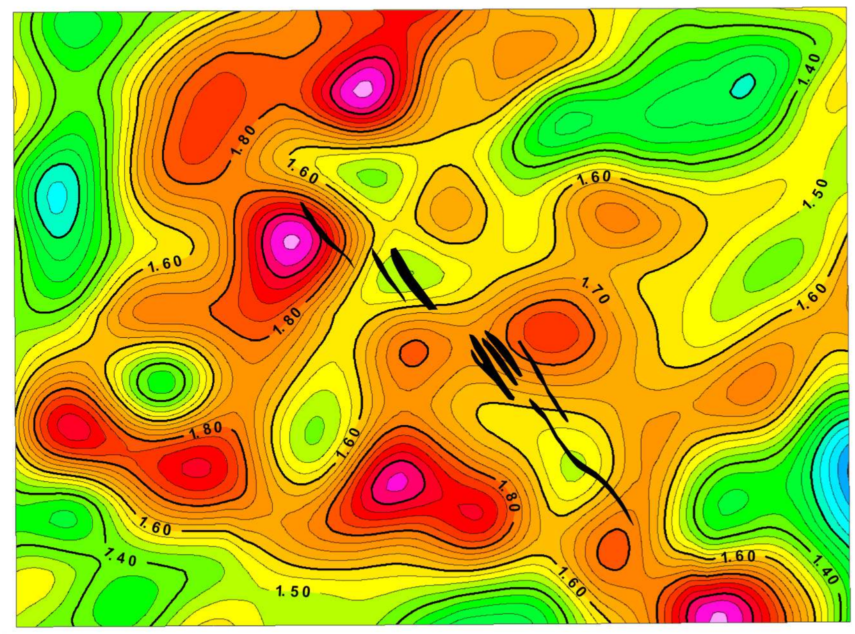
1000 m

KEY ANACON

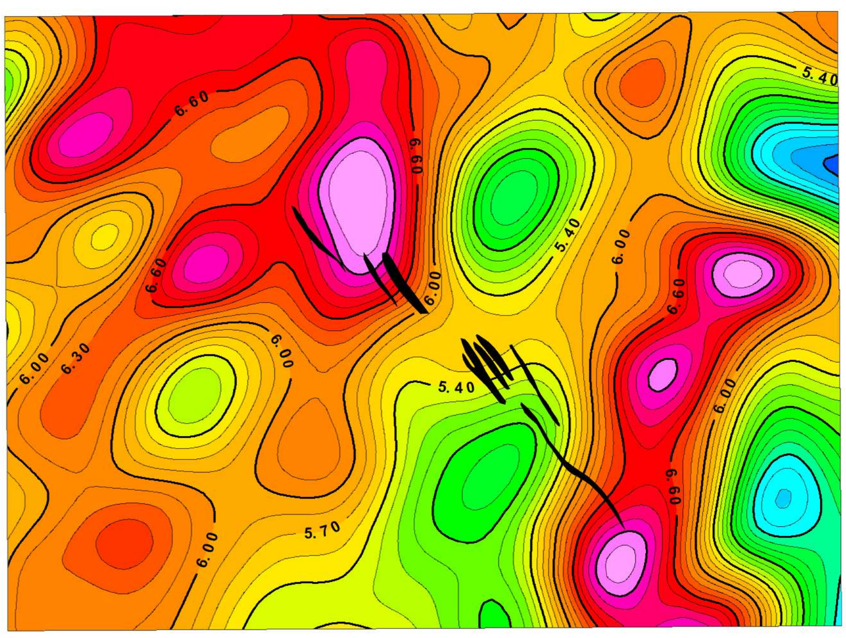
POTASSIUM (%)



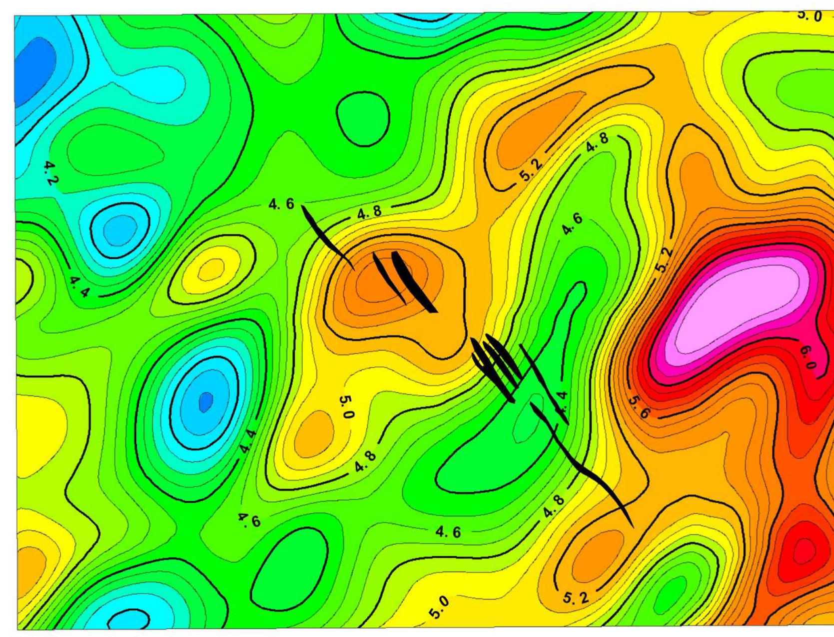
URANIUM (ppm)



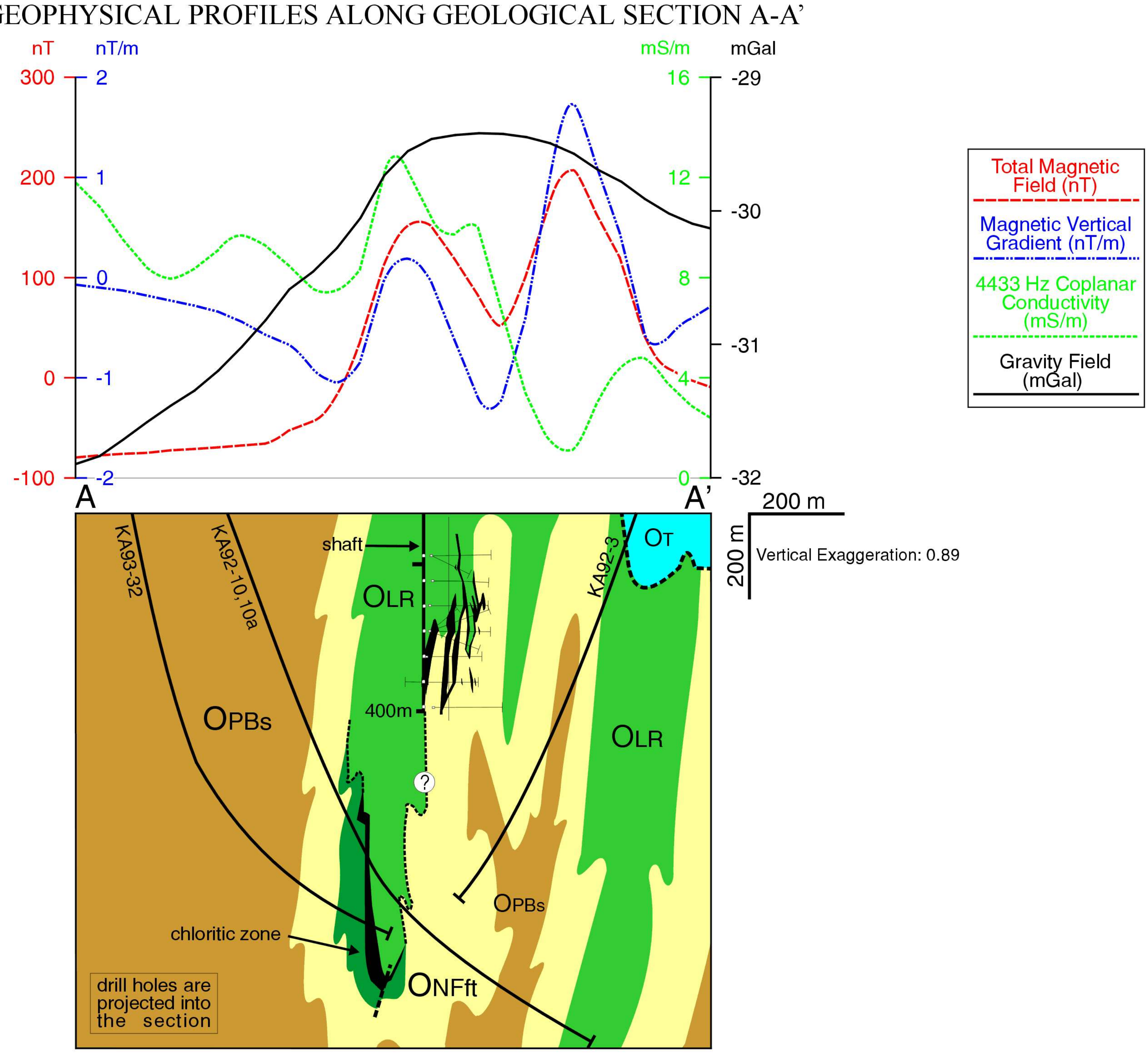
THORIUM (ppm)



THORIUM/POTASSIUM RATIO (x 10^{-4})

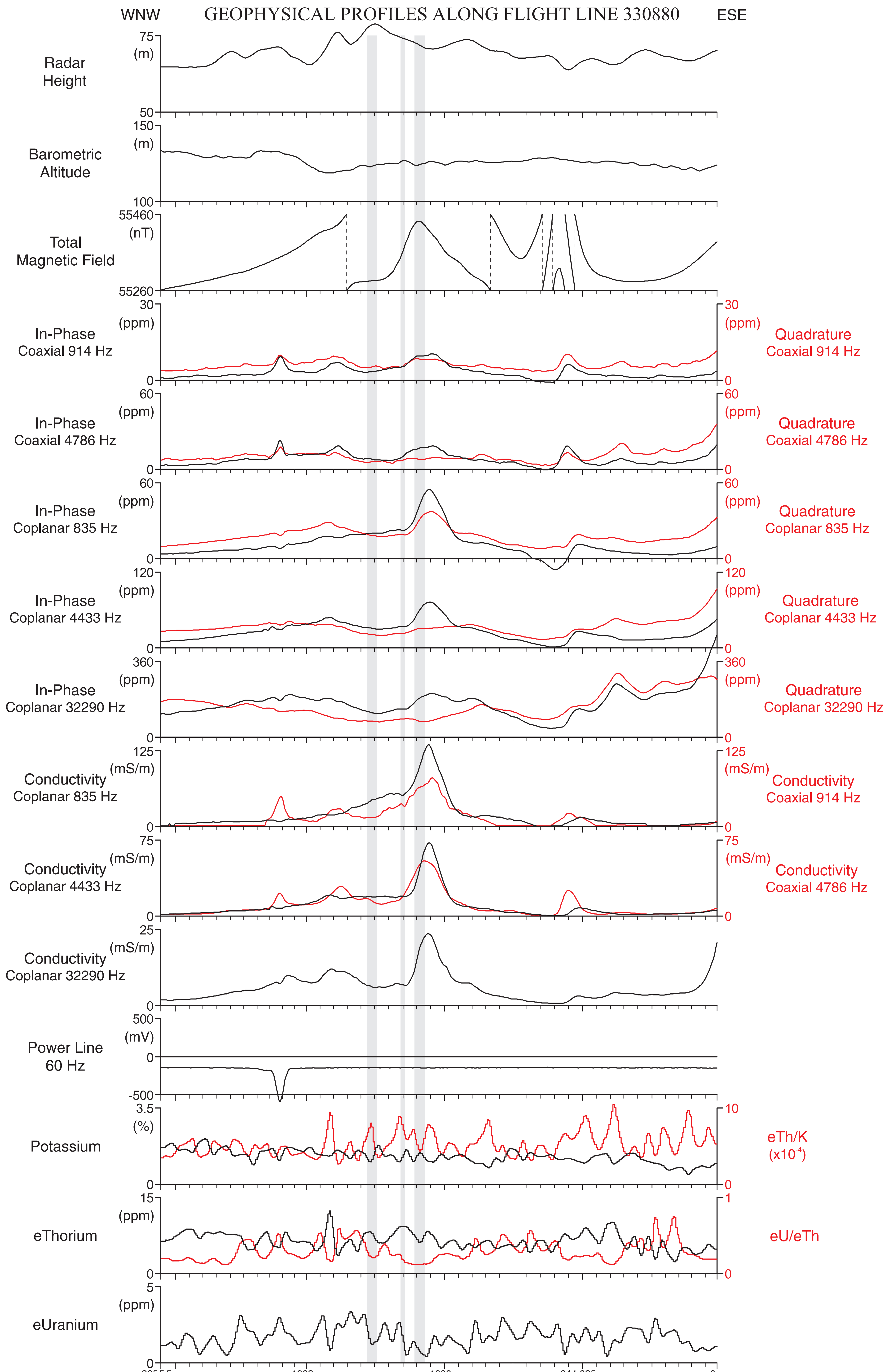


GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'



Compiled from Irrinki (1992) and Weidner (1992)

KEY ANACON


WNW
GEOPHYSICAL PROFILES ALONG FLIGHT LINE 330880
ESE
Radar Height
Barometric Altitude
Total Magnetic Field
In-Phase Coaxial 914 Hz
Quadrature Coaxial 914 Hz
In-Phase Coaxial 4786 Hz
Quadrature Coaxial 4786 Hz
In-Phase Coplanar 835 Hz
Quadrature Coplanar 835 Hz
In-Phase Coplanar 4433 Hz
Quadrature Coplanar 4433 Hz
In-Phase Coplanar 32290 Hz
Quadrature Coplanar 32290 Hz
Conductivity Coplanar 835 Hz
Conductivity Coaxial 914 Hz
Conductivity Coplanar 4433 Hz
Conductivity Coaxial 4786 Hz
Conductivity Coplanar 32290 Hz
Power Line 60 Hz
Potassium
eTh/K (x10-4)
eThorium
eU/eTh
eUranium
2655.5m
1962m
1303m
644.625m
0m

MURRAY BROOK DEPOSIT

GEOLOGY

The Murray Brook deposit was discovered by Kennco in 1956 during follow-up work on a stream geochemical anomaly. This is the fifth largest deposit in the Bathurst Camp with an indicated resource of 21.5 million tonnes of 0.48% Cu, 0.66% Pb, 1.95% Zn and 31.4 g/t Ag (Perusse, 1958). In the period 1989-1992 NovaGold Resources mined the gossan overlying the deposit and processed 1.25 million tonnes of 61.38 g/t Ag and 1.79 g/t Au.

The deposit is hosted by an interlayered sequence of shale, siltstone and lithic tuff all assigned to the Mount Brittain Formation (Charlotte Brook Member). The sedimentary host rocks are gradational into a sequence of feldspar crystal-lithic lapilli tuffs and flows that are also assigned to the Mount Brittain Formation. The host sequence is in tectonic contact to the north with mafic volcanic rocks assigned to the Camel Back Member of the Boucher Brook Formation.

The sulphide lens strikes east-west, dips to the north and plunges northeast. The deposit comprises pyrite-rich, semi-massive to massive sulphides that are locally layered and tightly to isoclinally folded. Metal zoning is evident with a Cu-rich, chloritic zone occurring around the periphery of the lens. Pb-Zn-rich sulphides occur near the core of the deposit and are separated from the Cu-zone by low-grade, pyrite-rich sulphides.

MAGNETIC DATA

The Murray Brook deposit is not associated with a discernible signature in the total magnetic field, although a very weak positive feature is apparent in the vertical gradient map, near the northern limit of the open pit. The lack of response can be attributed to the mineralogy of the deposit, which is dominated by pyrite (Burton, 1993), that has a very low magnetic susceptibility (5.3×10^{-3} SI). Pyrrhotite, the sulphide mineral having the highest susceptibility (3200×10^{-3} SI) and most potential to produce a magnetic signal, is common as inclusions in pyrite, but is estimated to form <1% of the sulphides (Burton, 1993). Also contributing to the lack of magnetic expression is the fact that the deposit was buried beneath a gossan, now removed by mining, that had a maximum thickness of 45 m (Rennick and Burton, 1992), later revised to 70 m (Burton, 1993). The additional distance to the airborne magnetometer would result in significant attenuation of any potential signal. Strong positive anomalies characterize basaltic rocks of the Camel Back Member. Weaker magnetic highs, that stand out in the vertical gradient map, occur in the southwest over sedimentary and volcanoclastic rocks. An isolated oval-shaped magnetic high near the northeastern edge of the open pit is probably produced by mining-related facilities and structures.

ELECTROMAGNETIC DATA

A prominent mid-frequency, oval-shaped conductivity anomaly calculated from the co-planar coils is centered near the northern margin of the open pit. EM responses are observed at all frequencies and are likely caused by massive sulphides cropping out in the pit. The deposit is intersected by three flight-lines, 11075 and two adjacent lines to the east. Responses are well above background except for the high frequency coplanar response, which is difficult to distinguish from the background EM response. Responses are broad, which is typical of a thick massive sulphide body. An elongated northwest-trending conductivity anomaly located east of the orebody is associated with shale and siltstone of the Boucher Brook Formation. These rocks contain graphite locally, which is interpreted to be the source of the conductivity anomaly.

GRAVITY DATA

The gravity map of the region around the Murray Brook deposit is based on a survey described by Prendergast (1961). Observations were made on grid lines spaced 400 ft (~120 m) apart at intervals of 100 ft (~30 m). Bouguer anomalies were derived using a density of 2.67 g/cm^3 and an arbitrary elevation datum. Surprisingly, no correction was made for latitudinal position, the effect of which translates into a fairly significant north-south gradient of about 0.08 mGal per 100 m (values increase northward). This effect contributes to the prevailing pattern (a gradient) of the gravity field, which increases by about 7.5 mGal from south to north. The gradient is most likely explained by the change from mainly sedimentary rocks south of the principal thrust to dominantly basaltic rocks north of it. Superposed on the gradient, and located within the boundary of the surface projection of the Murray Brook deposit, is a distinct southward bulging of the gravity contours. This is transformed into an oval-shaped residual gravity high, amplitude about 1.8 mGal, when a best-fitting planar surface is subtracted from the observed gravity field. This anomaly is undoubtedly generated by the deposit, yet its western flank extends beyond the projected limit of the deposit, and its centre lies somewhat further north than the expected position based on qualitative assessment. The latter conclusion needs to be confirmed by modelling. If the anomaly is indeed displaced, it is probably a result of poor positional control afforded by the assessment report gravity maps. In spite of the masking effect of the north-south gradient, the anomaly over the deposit presents an attractive target for exploration.

RADIOMETRIC DATA

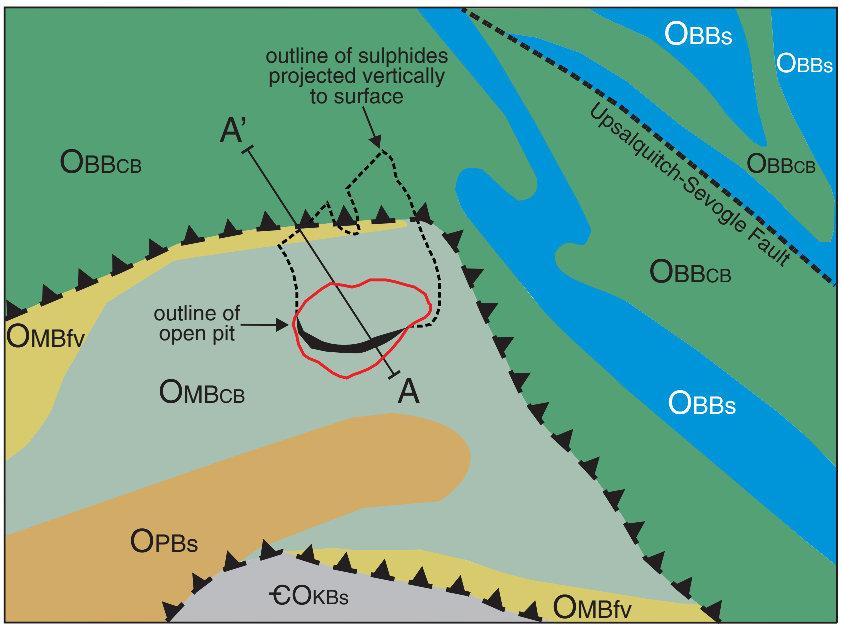
No airborne radioelement patterns can be related to the sulphides, the gossan, open pit or other mine development. Uniformly low K and eTh values over the northeast half of the map-area reflect the low radioelement content of mafic volcanic and sedimentary rocks within the Boucher Brook Formation. Weak eU highs in the same area may correlate with local exposures of graphitic shale. In the southwest part of the map-area, intermediate radioelement concentrations correlate well with shale, siltstone, wacke and lithic tuff within the Patrick Brook and Mount Brittain formations. Along the extreme western and southern margins, high K (>1.6%) and eTh (>7.5 ppm) values overlie felsic volcanic units within the Mount Brittain Formation.

SUMMARY

The Murray Brook deposit is marked by a distinct, elongate conductivity high that extends east-northeast across the open pit, and a sizable (1.8 mGal amplitude), oval-shaped gravity high centred just north of it. The discrepancy in positions of these anomalies may be a consequence of the northward dip of the deposit, and/or possibly poor positional control for the gravity data. A coincident magnetic high is not present, primarily because the sulphide contains less than 1% pyrrhotite. Radiometric signatures are not associated with the deposit, or its alteration envelope.

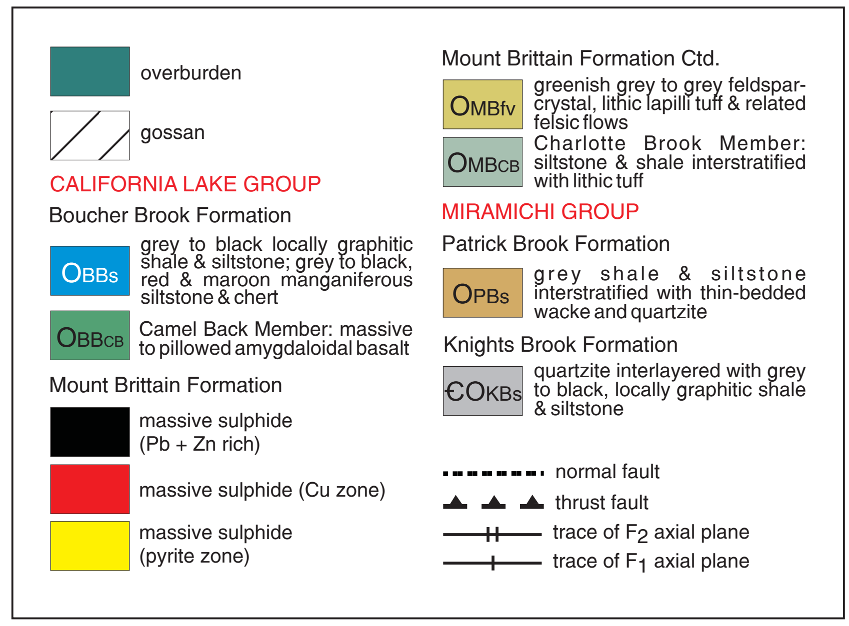
MURRAY BROOK

GEOLOGY

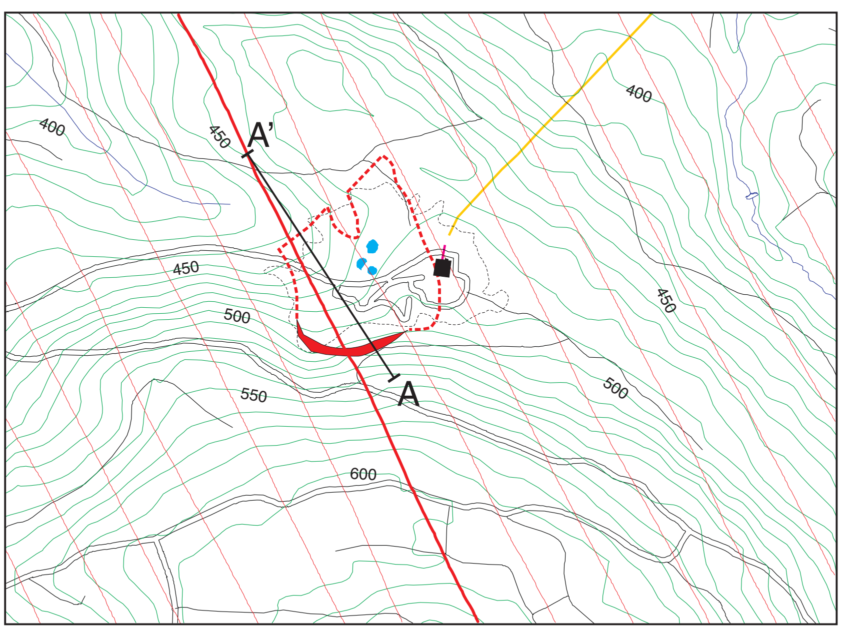


Modified from Gower (1997)

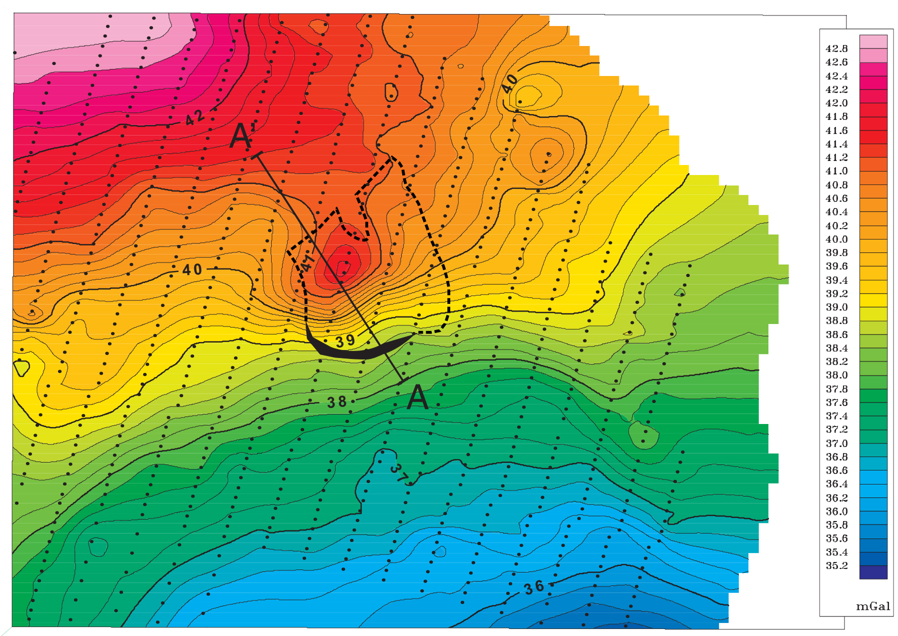
GEOLOGICAL LEGEND



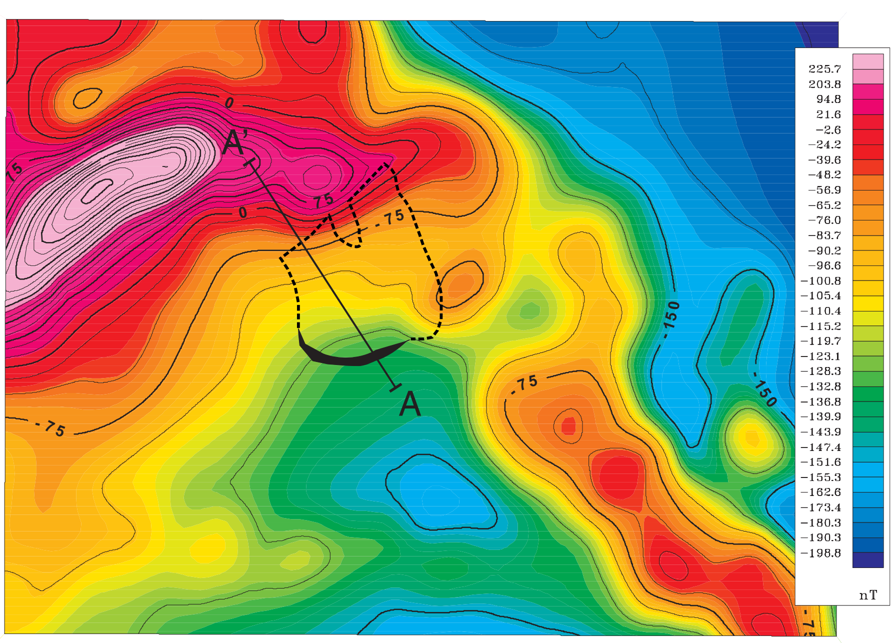
TOPOGRAPHY/FLIGHT LINES



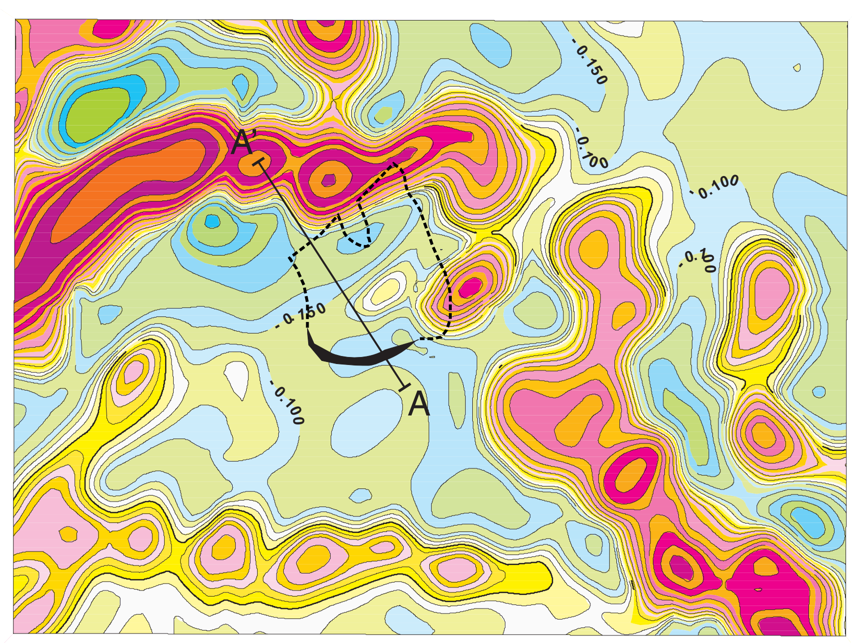
GRAVITY (mGal)



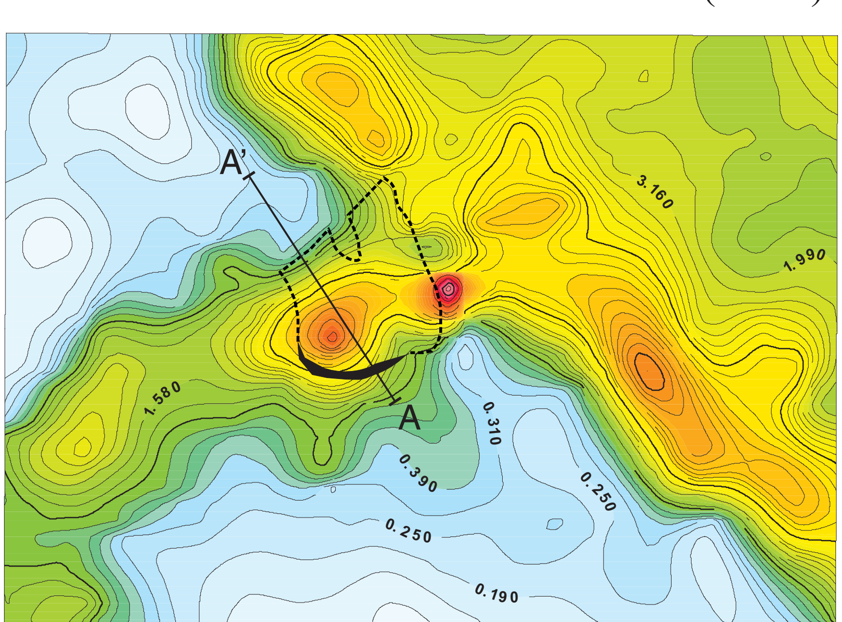
MAGNETICS (nT)



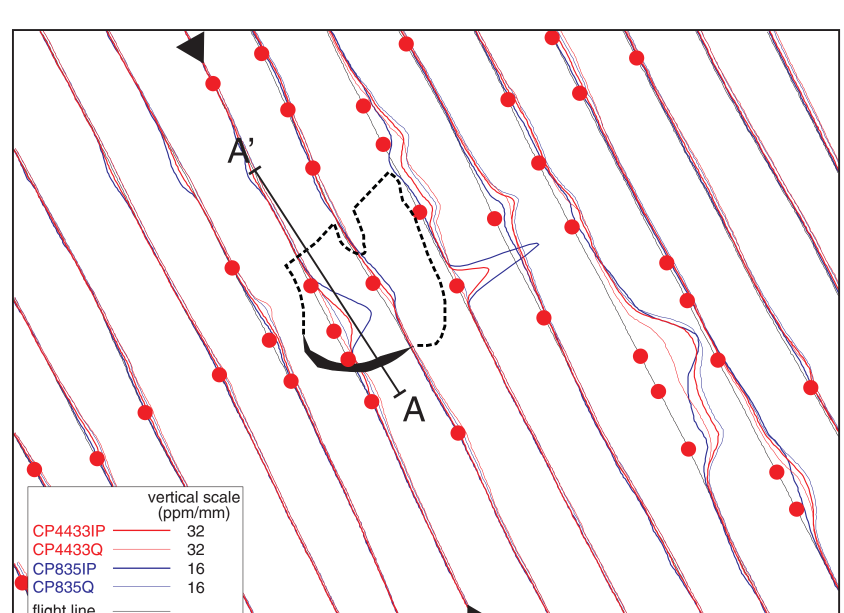
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)

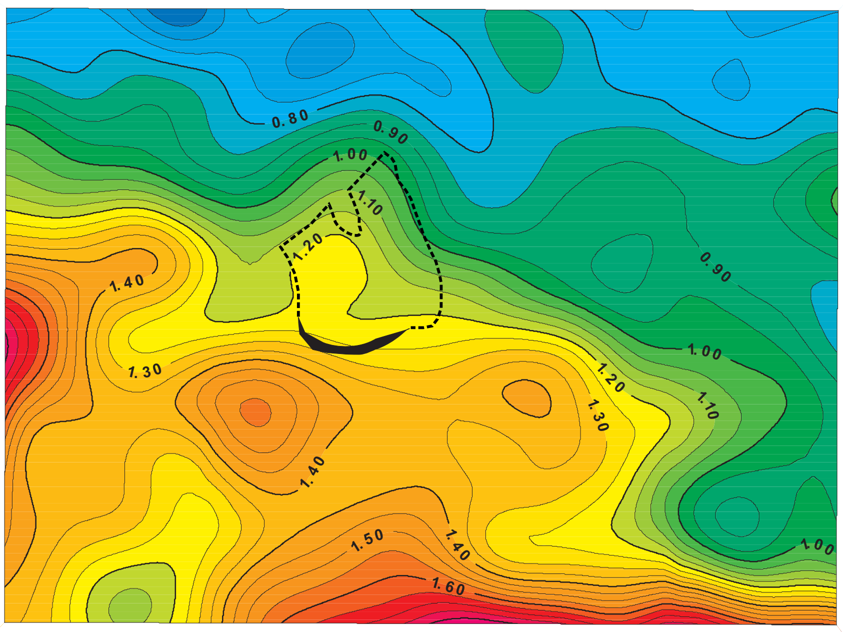


ELECTROMAGNETIC PROFILES/ANOMALIES

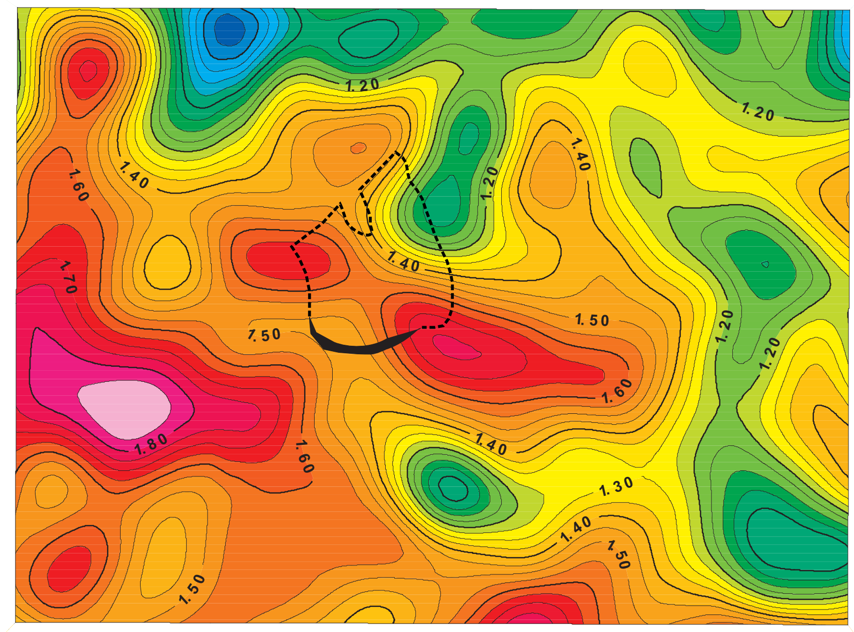


MURRAY BROOK

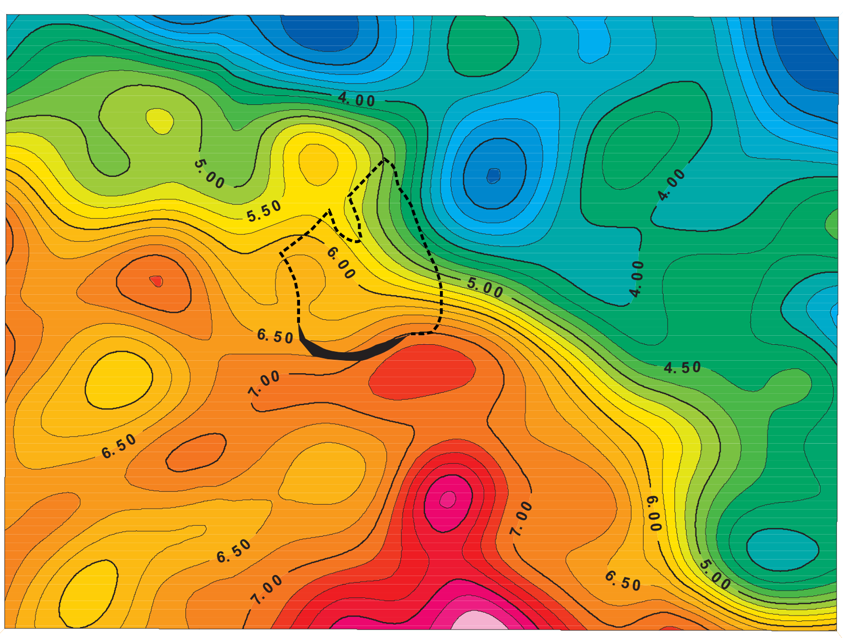
POTASSIUM (%)



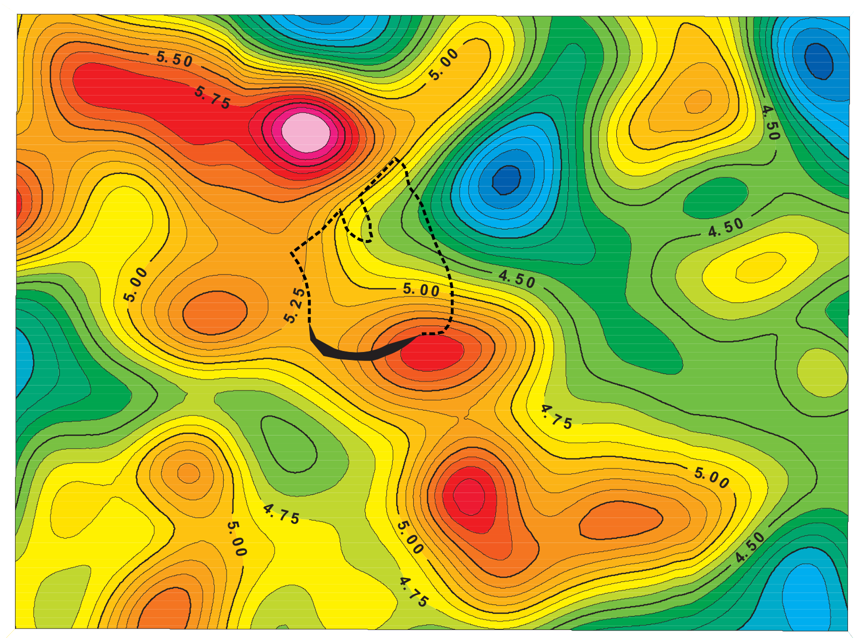
URANIUM (ppm)



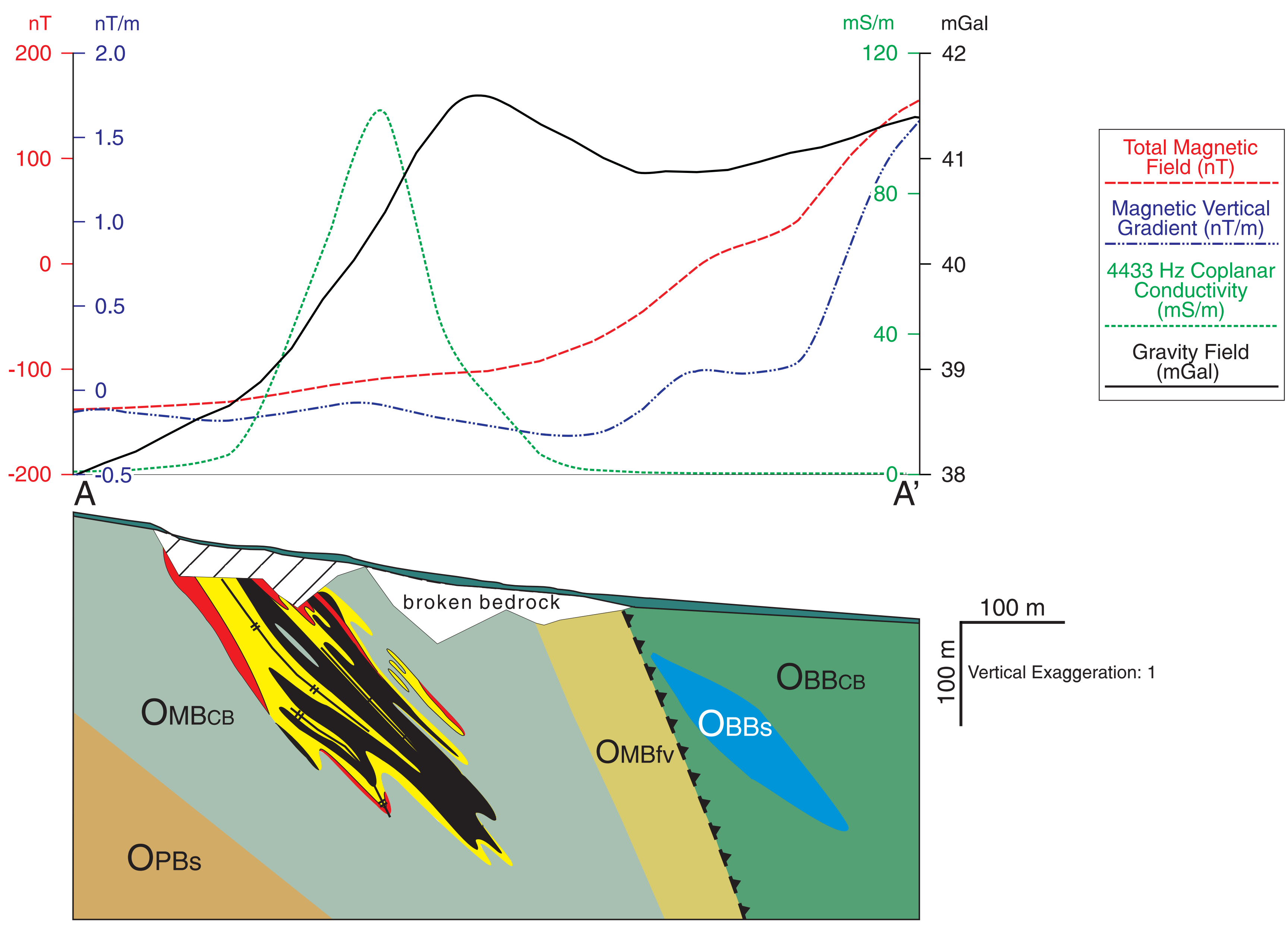
THORIUM (ppm)



THORIUM/POTASSIUM RATIO (x 10^{-4})

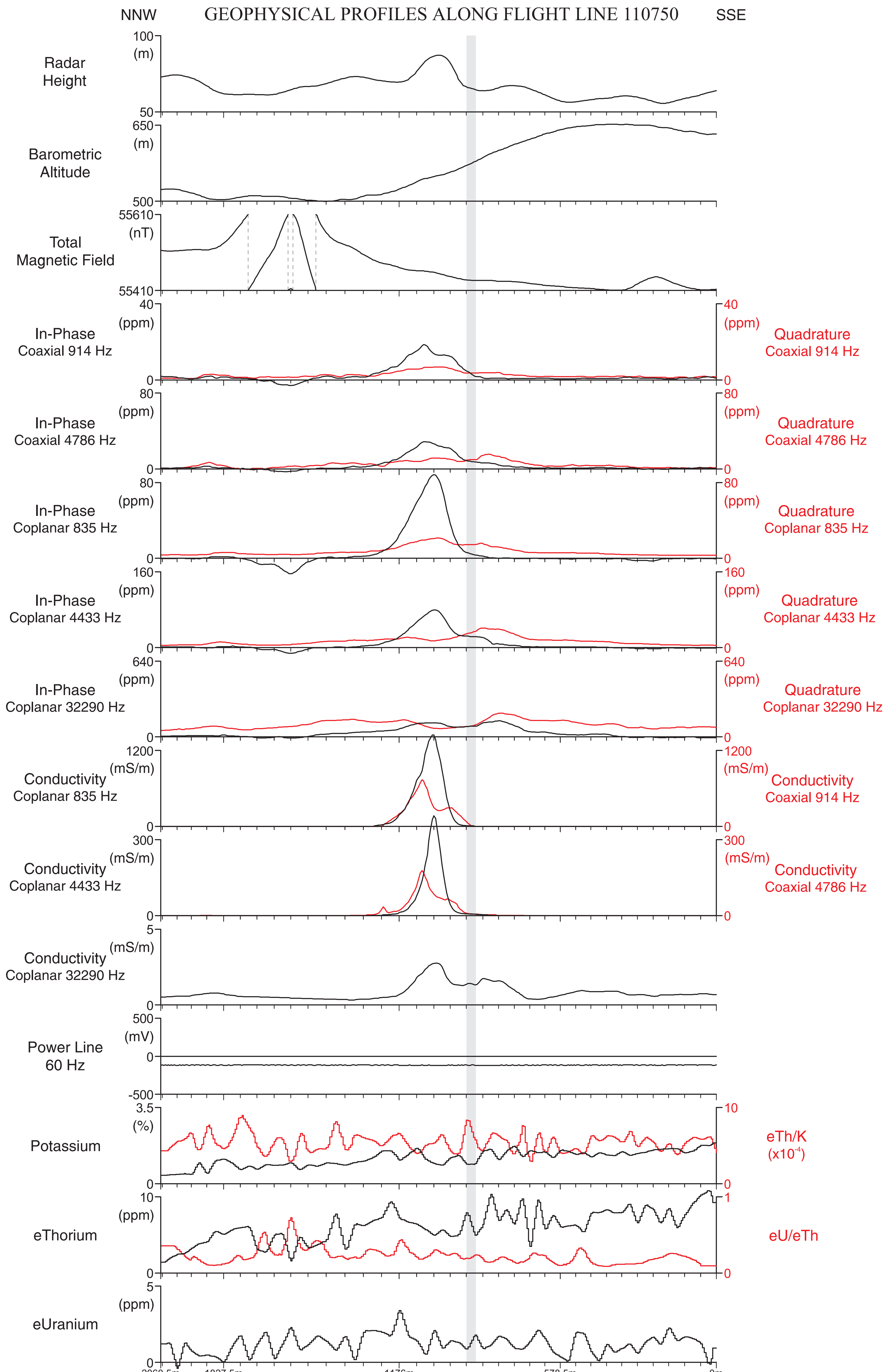


GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'



Modified from Rennick and Burton (1992) and Gower (1997)

MURRAY BROOK



NEPISIGUIT A DEPOSIT

GEOLOGY

The Nepisiguit A deposit is one of three spatially- and genetically-related deposits (Nepisiguit A, B and C) that were discovered by Kennco in 1955-56 during follow-up work on an electromagnetic anomaly (Brooks and Stevenson, 1956). The deposit occurs within the Spruce Lake Formation and is hosted by dark shale and fine-grained wacke. These sedimentary units are part of an interlayered sequence that contains mafic volcanic rocks, quartz-feldspar crystal tuff, and feldspar-phyric to aphyric rhyolite. The rocks of the Spruce Lake Formation are thrust over clastic sedimentary rocks of the Little River Formation to the south and north.

The Nepisiguit A deposit comprises two sulphide lenses, that at surface, strike east-northeast and dip approximately 65° to the northwest. The deposit contains an inferred resource of 1.54 million tonnes grading 0.4% Cu, 0.60% Pb and 2.80% Zn (Rose and Johnson, 1990 and references therein). Sulphide mineralogy comprises pyrite, pyrrhotite, sphalerite, galena and chalcopyrite. Unlike deposits of the Brunswick horizon, there is no exhalative sedimentary iron formation associated with this deposit. Review of diamond drill logs suggests that the northernmost lens youngs to the south and is overturned. This interpretation is based on Cu enrichment and sulphide stringers in mafic volcanic rocks in the stratigraphic footwall. Work by Noranda (Mitton, 1994) and regional mapping by Wilson (1993c) suggest that the Nepisiguit A, B and C deposits all lie on the same horizon, repeated by tight to isoclinal folding.

MAGNETIC DATA

The Nepisiguit A deposit coincides with a prominent elongate magnetic high having an amplitude of 70 nT. The Nepisiguit B and C deposits, which also occur in the map-area, are positioned on similar magnetic highs of approximately the same amplitude. There are several other highs in the area having similar geometries, but their amplitudes are much smaller, ranging from about 30 to 45 nT. The anomalies over the deposits are attributed to pyrrhotite, which is present in all of the deposits, though not a major component in any of them. Iron formation is not developed locally. Jones (1960) describes the Nepisiguit A and B ore bodies as massive, fine- to medium-grained sulphides comprising approximately 70 - 80% pyrite, up to 10% pyrrhotite and about 15% combined sphalerite, galena, chalcopyrite, quartz and carbonates. The relatively narrow and elongate geometry of the Nepisguit A anomaly is consistent with the steep dip of the deposit. Other oval anomalies in the map-area, particularly those along strike from the Nepisiguit B deposit, may have exploration potential. Their lower amplitudes may signify the presence of buried and/or thinner sheets of sulphide, or possibly a change in sulphide mineralogy.

ELECTROMAGNETIC DATA

The Nepisiguit A deposit produces a well defined anomaly on all five frequencies of the HEM system. Apparent conductivity calculated from the mid-frequency coplanar coils attains 200 mS/m over the deposit. Although the deposit includes two separate lenses, only one broad anomaly is observed (flight-line 440860). However, the presence of a shoulder suggests the presence of a second conductor. The two sub-parallel lenses forming the deposit are about 75 m apart and their EM responses combine as one broad response. At low frequencies, the in-phase and quadrature coplanar responses are 136 ppm and 116 ppm, respectively, and corresponding coaxial responses are 34 ppm and 24 ppm. At mid frequencies the responses are 232 ppm and 120 ppm on the coplanar coils, and 64 and 36 ppm on the coaxial coils. At high frequency the in-phase and quadrature responses are 432 ppm and 240 ppm. The coaxial responses are smaller than the coplanar responses due to the fact that the conductor is striking at about 70° from the flight direction, thereby reducing the EM coupling between the coaxial coils and the conductors.

The Nepisiguit C deposit, comprising short sulphide lenses, produces an EM response on just one flight-line, but the longer lenses of the Nepisiguit B deposit generate HEM responses on three lines.

GRAVITY DATA

The gravity coverage of the map-area containing the Nepisiguit A, B and C deposits is based on a grid of values provided by Noranda. The gravity field is characterized by contours that trend essentially east-west, slightly at variance with the east-northeast trend of geological units, and decreases from north to south.

All three deposits are associated with distinct gravity highs. The registration of geology with gravity seems to be precise for the Nepisiguit A deposit. A local, oval gravity high, 0.9 mGal amplitude, falls on the eastern extremity of the northern lens of the deposit. A westward bulging of contours indicates a positive response, also, for the remainder of it, albeit slightly offset. The southern lens does not produce a discernible response. The Nepisiguit B and C deposits are each offset from what are obviously related gravity highs by about 70 m. This is attributed to an unidentified problem with one or both of the base maps used for the geological mapping and gravity survey, which has resulted in mis-registration. The amplitudes of anomalies over the B and C deposits are about 0.6 and 0.4 mGal, respectively.

RADIOMETRIC DATA

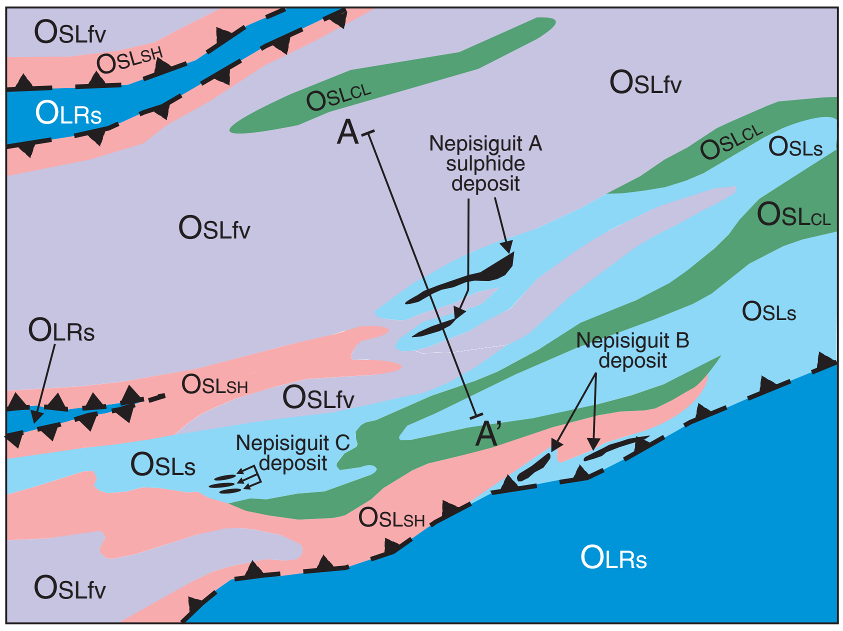
Airborne gamma-ray spectrometry patterns reflect the east-northeast geological trends. In general, felsic volcanic rocks of the Spruce Lake Formation yield elevated K, eU and eTh concentrations. Unmapped internal variations within the formation are suggested by high K (maximum 1.84%) and eTh (maximum 11 ppm) anomalies west and north of the Nepisiguit A deposit, associated with the southern half of the broadest geological unit, which comprises feldspar-phyric to aphyric rhyolite. Lower K concentrations (1.68 - 1.72%) immediately north of the deposit may reflect K-feldspar-destructive footwall alteration, or the influence of unmapped mafic volcanic units. The eTh anomaly extends further north than the K trend, resulting in areas of high eTh/K values that may reflect primary chemostratigraphic variations within the Spruce Lake Formation. The lowest K and eTh concentrations occur in the southeast along the Nepisiguit River valley.

SUMMARY

Pronounced oval-shaped conductivity, magnetic and gravity anomalies coincide with the Nepisguit A deposit (and with the nearby B and C deposits). The conductivity anomaly over the A deposit has two peaks, one at the eastern extremity, where the gravity anomaly also peaks, and another near the satellite lens at the western extremity, where the magnetic anomaly culminates. Diagnostic radiometric signatures that can be directly attributed to the Nepisiguit A deposit are not observed, though lower K concentrations north of the deposit may reflect destruction of K-feldspar in the footwall.

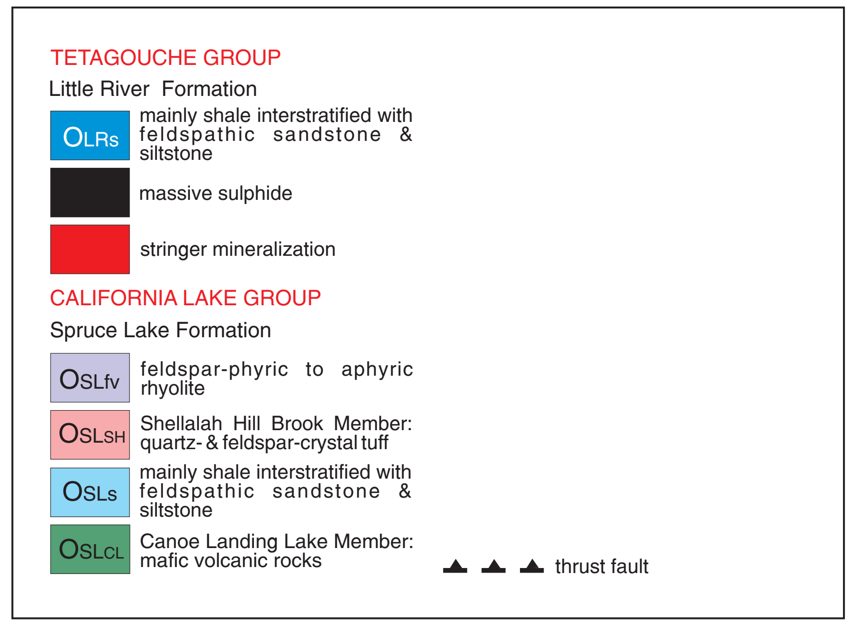
NEPISIGUIT A

GEOLOGY

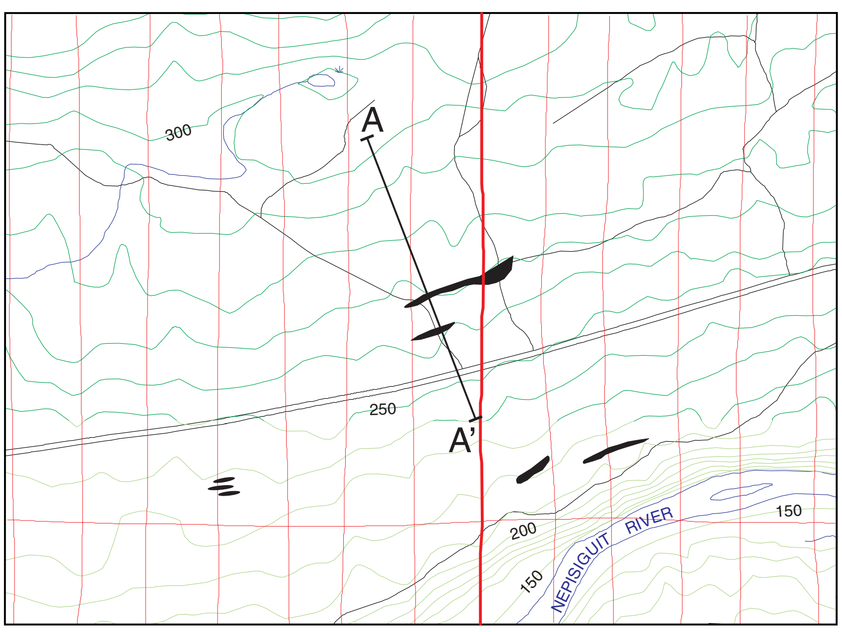


Modified from Wilson (1993c)

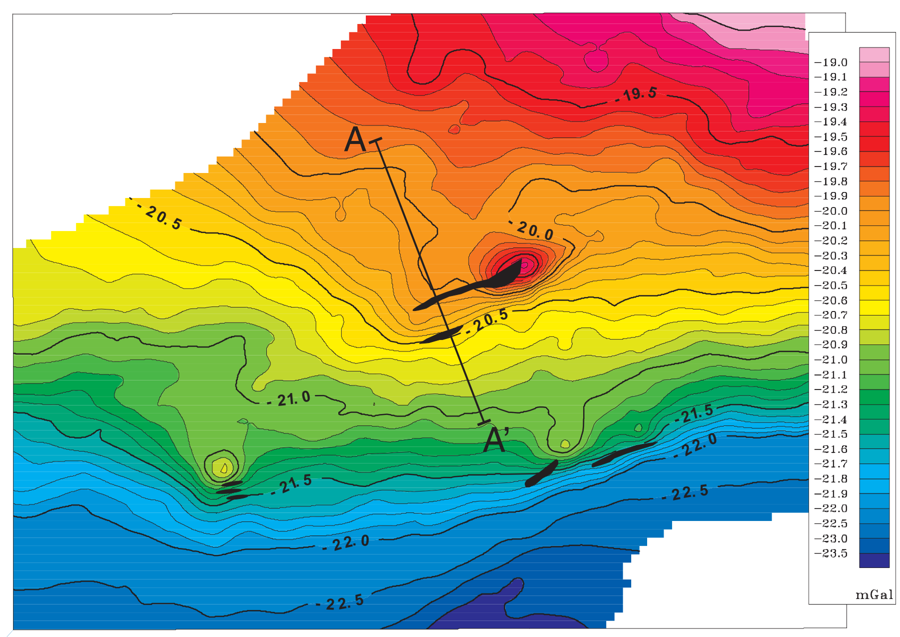
GEOLOGICAL LEGEND



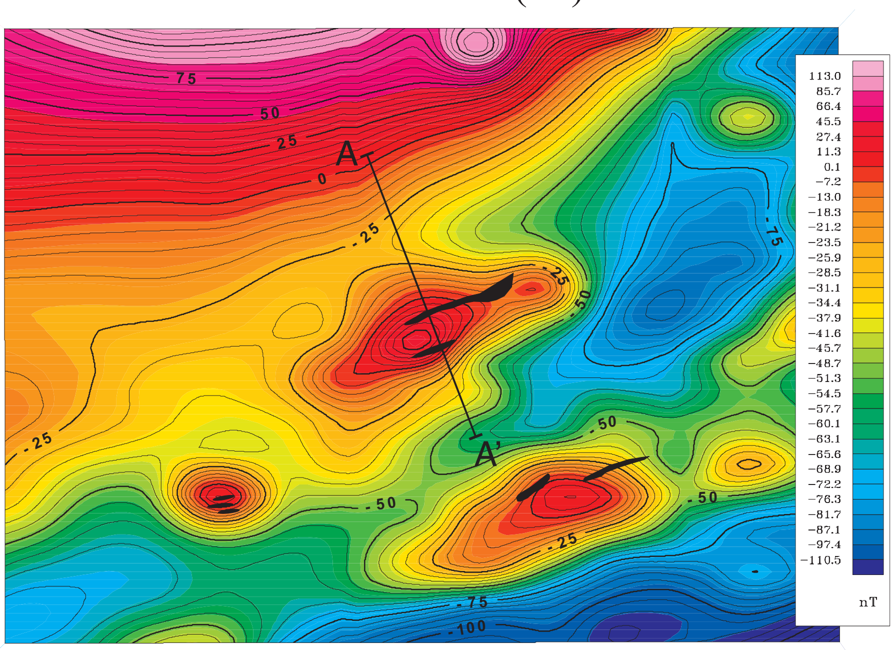
TOPOGRAPHY/FLIGHT LINES



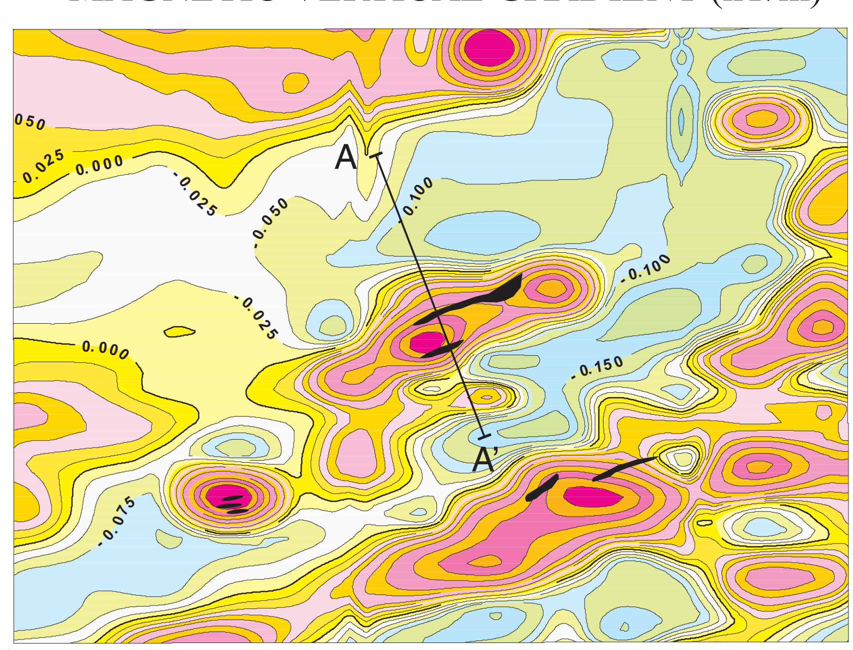
GRAVITY (mGal)



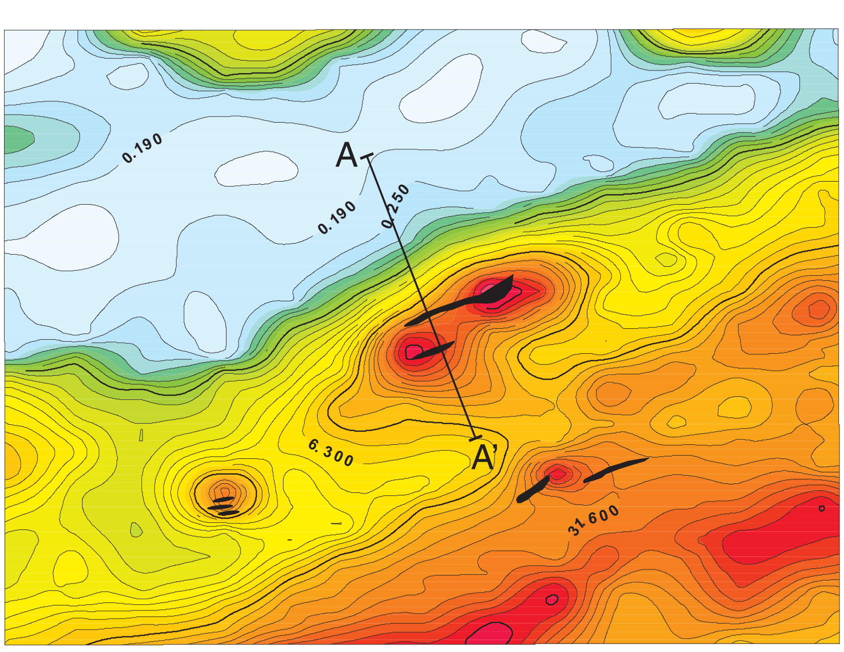
MAGNETICS (nT)



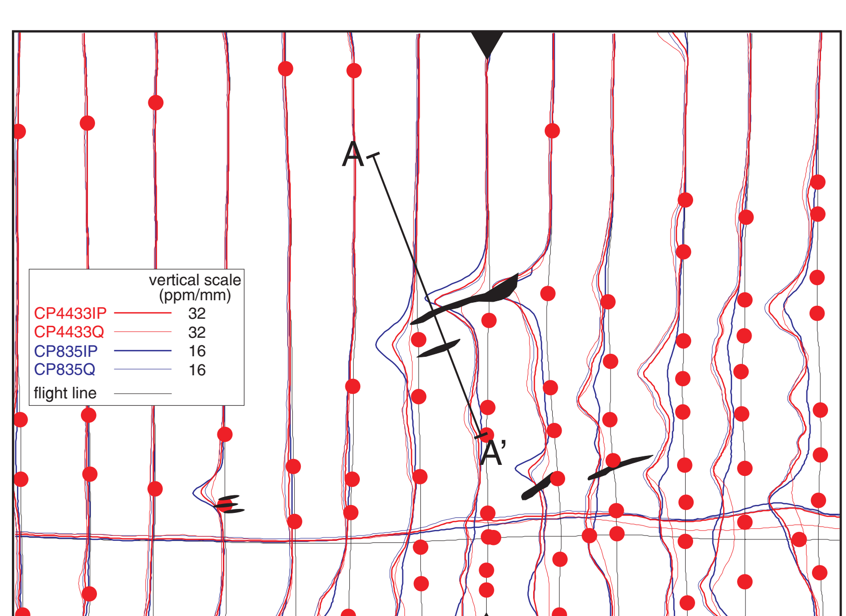
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



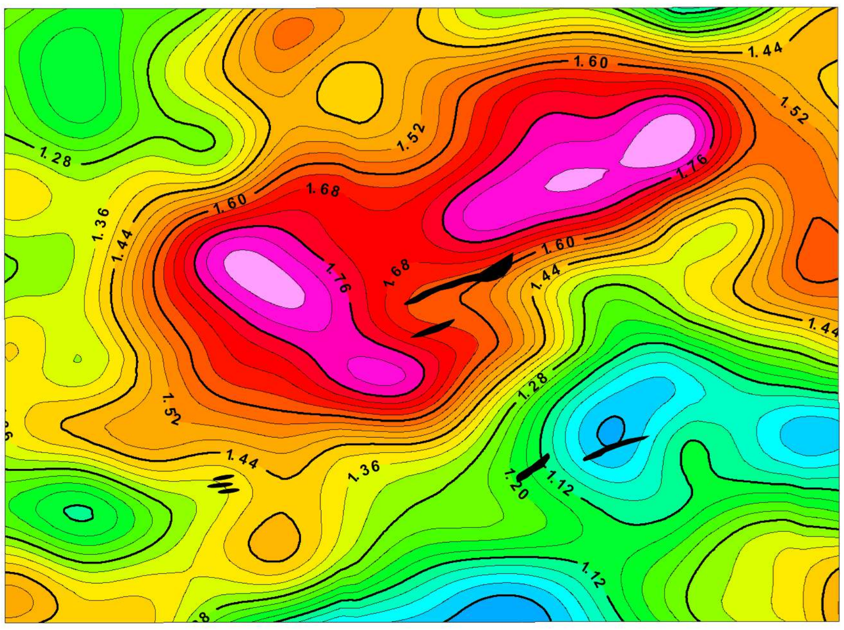
ELECTROMAGNETIC PROFILES/ANOMALIES



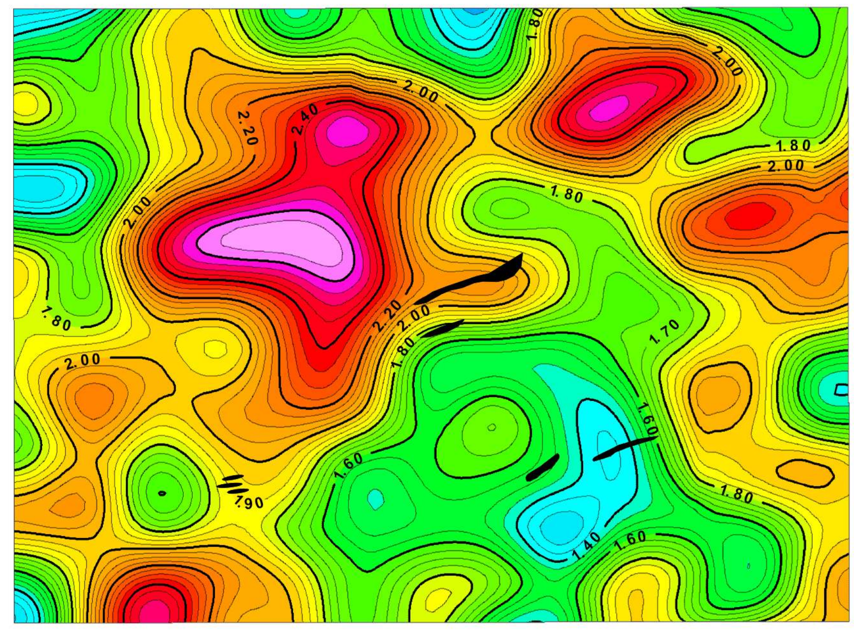
1000 m

NEPISIGUIT A

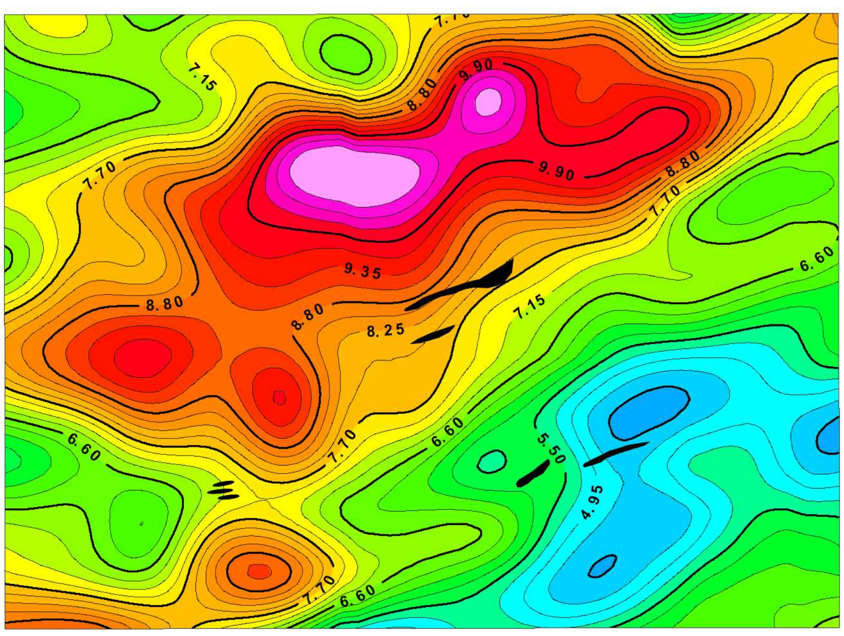
POTASSIUM (%)



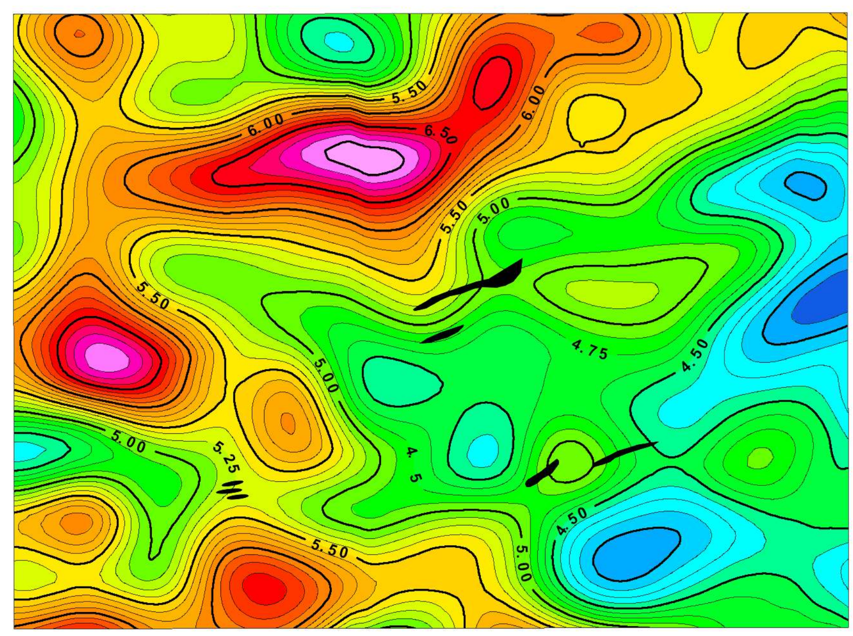
URANIUM (ppm)



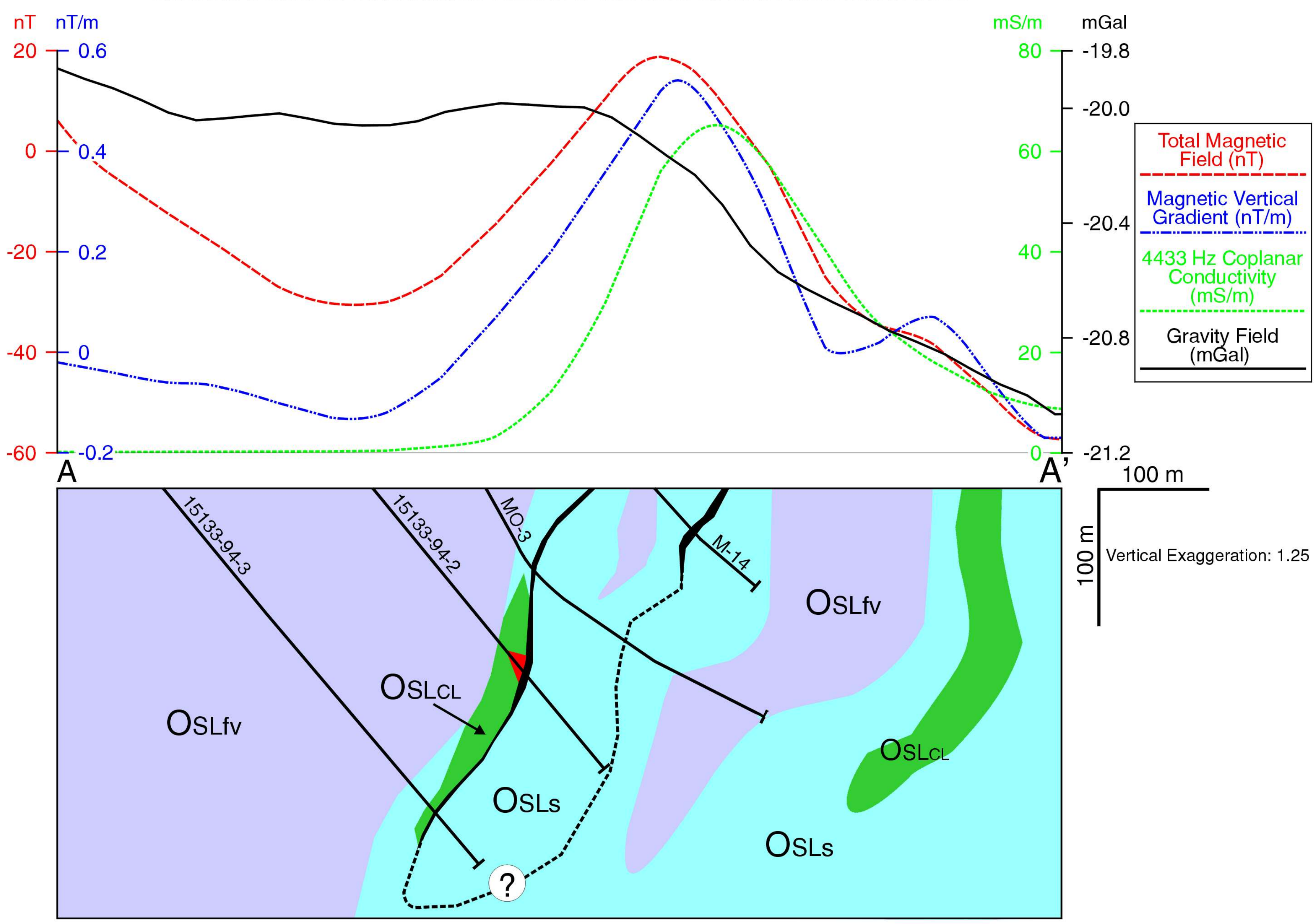
THORIUM (ppm)



THORIUM/POTASSIUM RATIO (x 10^{-4})

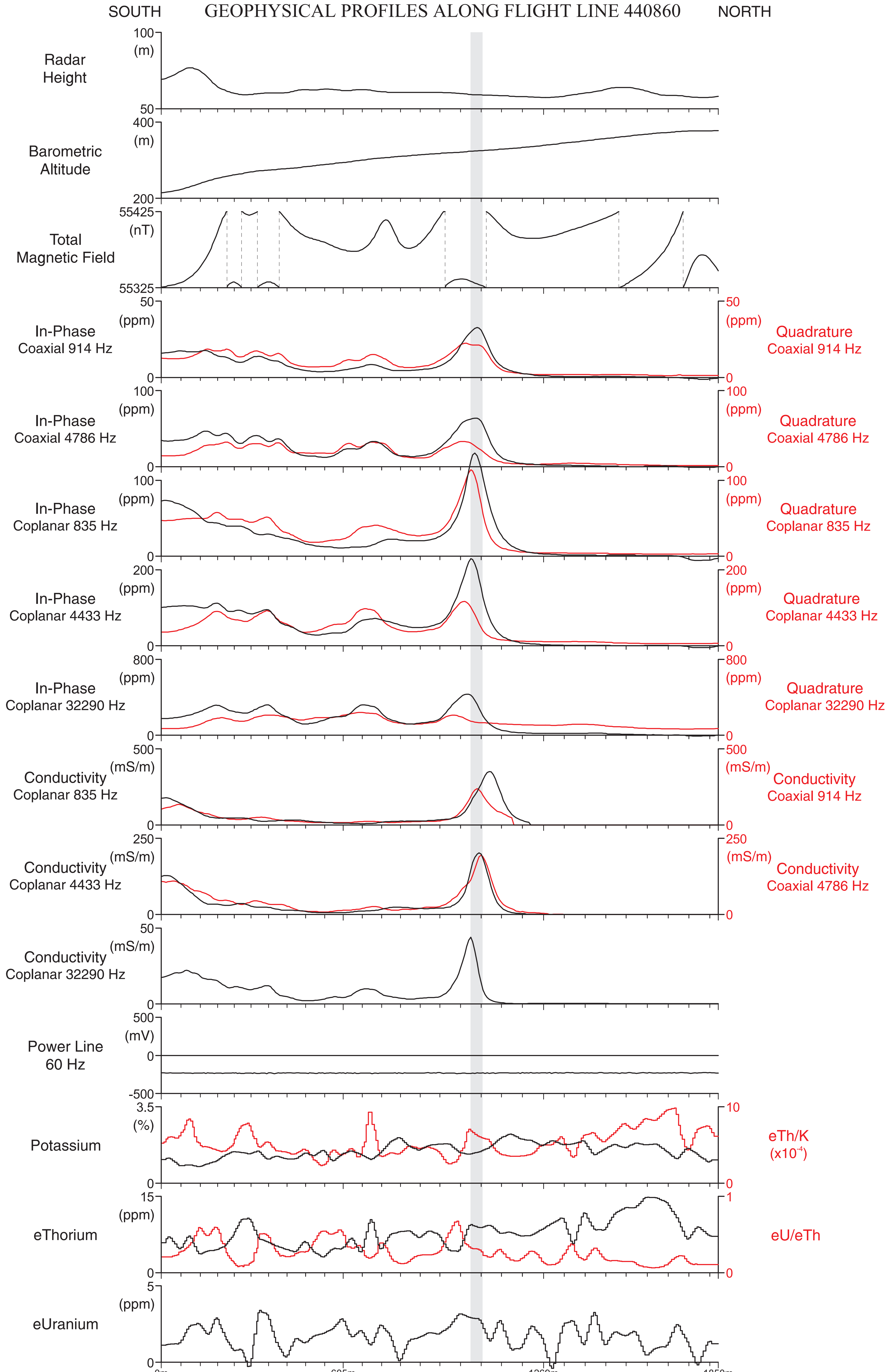


GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’



Compiled from Mitton (1994) and Wilson (1993c)

NEPISIGUIT A



ORVAN BROOK DEPOSIT

GEOLOGY

The Orvan Brook deposit was discovered in outcrop in the bed of Orvan Brook, by the Tetagouche Mining Company in 1938. The discovery came about as a result of up-ice tracing of massive sulphide erratics that had been known since 1860 (Tupper, 1969).

The Orvan Brook deposit has a strike-length in excess of 2400 m with a maximum thickness of 5 m and is open below 200 m. The deposit comprises several thin, sub-parallel lenses of fine-grained, disseminated to massive banded sulphides. According to Williams (1974c) the deposit contains an inferred resource of 100,000 tonnes grading 0.4% Cu, 0.7% Pb, 2.1% Zn and 20.57 g/t Ag.

The sulphide mineralogy of the deposit, according to Tupper (1969), consists of 80% pyrite with lesser sphalerite, galena, chalcopyrite, arsenopyrite, and tetrahedrite. Pyrrhotite is notable by its absence. Gangue mineralogy comprises quartz, sericite, calcite and minor chlorite. No mappable footwall stringer zone has been identified, but it is possible that the intense deformation has transposed any cross-cutting stringer zone into parallelism with the stratiform lens.

The deposit is hosted by feldspar-phyric to aphyric micaceous sericite tuff and dark grey, locally graphitic shale of the Spruce Lake Formation. Tupper (1969) identified a chlorite-magnetite-hematite-chert iron formation conformable with the sulphide body on the south side of the deposit, suggesting a south-younging sequence. The identification of an iron formation at Orvan Brook is significant in that none of the other deposits hosted by the Spruce Lake Formation in the Tetagouche Antiform, *i.e.* Armstrong B, Caribou, *etc.,* have an associated iron formation.

MAGNETIC DATA

The Orvan Brook sulphide deposit sits on the south flank of a prominent linear belt of positive magnetic anomalies that extends across three main geological units trending west-southwest across the map-area. The units are the Camel Back Member and Orvan Brook Member, both comprising basalts, and an assemblage of sedimentary rocks (OSLs), belonging to the Spruce Lake Formation, that host the deposit. The deposit itself does not appear to be reflected in the total magnetic field pattern. However, on the vertical gradient map, the linear positive belt of the total magnetic field map is transformed into two parallel positive features, the southern one of which corresponds closely with western third or so of the deposit. It is difficult to ascertain whether this is an expression of the deposit or fortuitous coincidence. Possibly, it is related mainly to the hosting sedimentary unit (OSLs), with a significant contribution being made by iron formation. If the signature of the deposit is lacking or weak, it may be explained by the narrowness of the deposit, and the absence of pyrrhotite; approximately 80% of the sulphide deposit is pyrite (Tupper, 1969). The iron formation attains widths ranging from 9 to 46 m (Tupper, 1969), and is described as a crudely banded quartz-chlorite schist containing some disseminated magnetite. This schist unit also contains scattered bands of quartz-hematite and jasper-hematite-magnetite iron formation, which are discontinuous along strike and are up to 9 m thick. To dispel any confusion regarding reference to iron formation, note that Tupper (1969) uses the term to describe the entire unit, but also refers to included scattered bands of iron formation of the aforementioned types.

ELECTROMAGNETIC DATA

The Orvan Brook deposit produces an anomaly on all five frequencies of the HEM system. It is characterized by a low amplitude conductivity anomaly of about 10 mS/m on the mid-frequency coplanar coils, and an anomaly of about 18 mS/m amplitude on the mid-frequency coaxial coils. However, the high-frequency response is complex, because the response of the deposit overlaps conductivity responses from other sources, such as the Siluro-Devonian rocks. The EM response of this deposit was previously studied by Best (1985), who noted the presence of other conductive rocks: quartz-graphite schist, chloritic argillite and greywacke and quartz-chlorite-hematite schist. These units were mapped by Tupper (1969). Two conductors are identified on the HEM profiles, which occur as double peak anomalies on the coaxial coil responses, about 100 m apart. On the coplanar coils the response is either a broad anomaly or a double peak anomaly, that result from the superposition of the signals from the two conductors.

These conductors were also detected on a previous HEM Dighem survey and a ground horizontal loop EM survey (Best, 1985). Resistivity soundings indicated that south of the deposit the bedrock has a conductivity of about 0.33 mS/m, whereas north of it, bedrock conductivity is about 1 mS/m. Overburden thickness is less than 10 m, and its conductivity is around 15 mS/m. This agrees with the apparent conductivity calculated from the mid-frequency coplanar coils. Apparent conductivity north of the deposit is in excess of 1 mS/m, whereas south of it, the conductivity is less than 1 mS/m. A perfect match between the ground and airborne values cannot be expected as the conductivities were measured by DC resistivity soundings in one case, and calculated from 4433 Hz HEM data in the other. Best (1985) calculated a conductivity of 100 mS/m for the inferred conductor, which is lower than expected for massive sulphides, as typical massive sulphides have conductivities higher than 1000 mS/m (Palacky, 1989). However, the estimated conductivity matches that of graphite which varies between 100 mS/m and 10000 mS/m (Palacky, 1989). The conductor is embedded within the black shales of the Spruce Lake Formation and the EM anomaly is interpreted to reflect the combined influences of graphitic sedimentary rocks and interbedded massive sulphides.

GRAVITY DATA

A large part of the Orvan Brook map-area is covered by a gravity survey carried out for Noranda. The survey extends along most of the length of the deposit and is based on measurements made at 25 m station spacing along ten lines spaced 200 m apart. A much smaller area near the southwest corner of the map-area, about 300 m due south of the west end of the deposit, was surveyed on behalf of Anaconda Canada Exploration Limited. In this survey, gravity observations were made at intervals of 25 ft (~7.6 m) along six lines spaced about 60 m apart, and Bouguer anomalies were derived using a density of 2.67 g/cm^3 (Mersereau, 1986). Because the surveys have been reduced to different elevation datums, a constant value has been added to one of the surveys in an attempt to obtain a more homogeneous data set and image of the data.

The Orvan Brook deposit sits on the southern flank of an extensive, linear positive anomaly that peaks along the unit of basaltic rocks belonging to the Orvan Brook Member. The northern and southern flanks of the anomaly extend, respectively, over adjacent basaltic rocks of the Camel Back Member and sedimentary rocks (OSLs) of the Spruce Lake Formation. The deposit is not associated with a discernible gravity signature, which is attributed to it being no more than about 5 m thick (Tupper, 1969). The small gravity survey in the southwest corner of the map-area defines a small east-west positive anomaly coinciding with sedimentary rocks (OSLs) of the Spruce Lake Formation.

RADIOMETRIC DATA

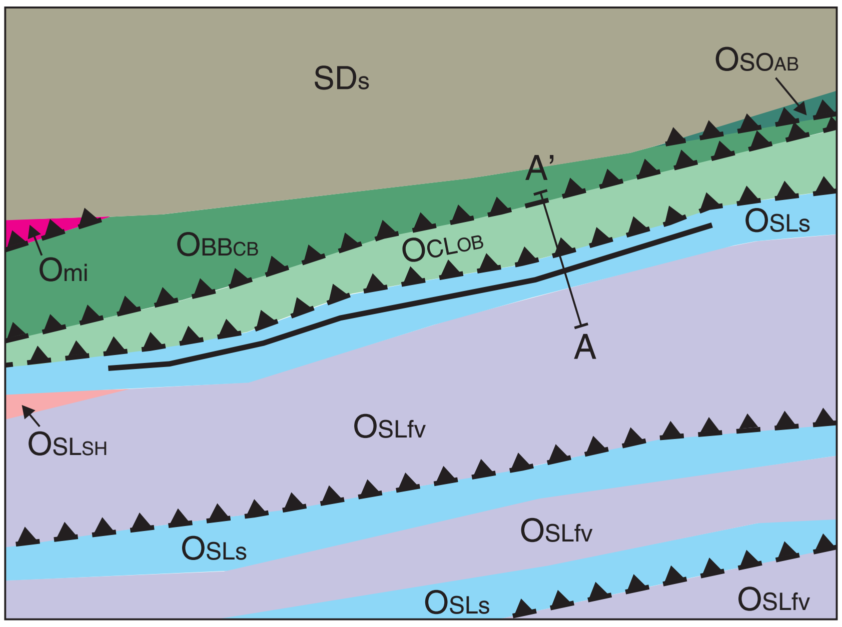
Airborne radioelement patterns in the map-area reflect the local, east-northeast trends of geological units very well. Three geological domains can be distinguished radiometrically. Low values (<0.9% K, <1 ppm eU, <4.25 ppm eTh) define a linear belt that is coincident with mafic basalts within the Boucher Brook and Canoe Landing Lake formations. North of the mafic units, Siluro-Devonian sedimentary rocks yield intermediate values (0.9 - 1.15% K, 1.13 - 1.42 ppm eU, 4.5 - 5.25 ppm eTh). Felsic feldspar-phyric tuff, ash tuff, shale, feldspathic sandstone and siltstone within the Spruce Lake Formation produce elevated airborne concentrations (0.9 - 1.5% K, 1.2 - 2.17 ppm eU, 4.5 - 7.5 ppm eTh). These patterns are disrupted by lower values along drainage systems, such as the low observed for each element along the extreme northeastern edge of the map-area. Equivalent thorium/potassium ratio values are indistinct. No correlation is apparent between the airborne patterns and the narrow mineralized zone.

SUMMARY

The Orvan Brook deposit runs along the southern flanks of magnetic, gravity and conductivity highs that are all very much broader than the 5 m thick (maximum) deposit, and have a primary source other than the deposit. The magnetic and gravity anomalies are attributed to basaltic rocks. A local gravity signature is not observed over the deposit, but the magnetic vertical gradient map suggests that a distinct local magnetic response is associated with the western third of the deposit. The broad conductivity anomaly peaks locally within the western third of the ore trace, indicating a sulphide response, but much of the anomaly extends over sedimentary and basaltic rocks north of the deposit, where other sources such as a graphitic zone in sedimentary rocks make contributions. No radiometric signatures are developed over the deposit.

ORVAN BROOK

GEOLOGY



Modified from van Staal (1994d)

GEOLOGICAL LEGEND

- SDs — undivided Siluro-Devonian sedimentary rocks
- Omi — mafic intrusion

FOURNIER GROUP

Sormany Formation

- OSOAB — Armstrong Brook Member: tholeiitic basalt

CALIFORNIA LAKE GROUP

Boucher Brook Formation

- OBBCB — Camel Back Member: massive to amygdaloidal basalt

Canoe Landing Lake Formation

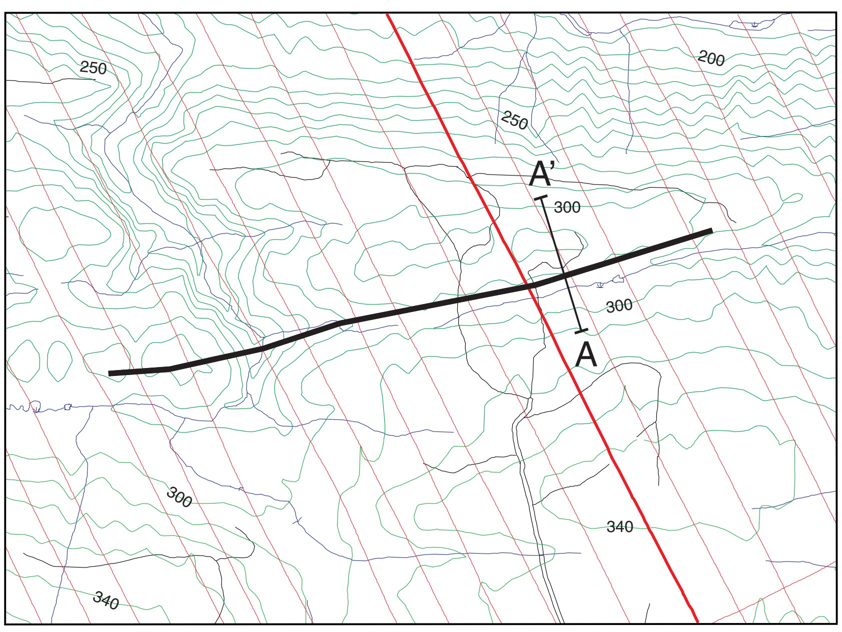
- OCLOB — Orvan Brook Member: tholeiitic to transitional basalt

Spruce Lake Formation

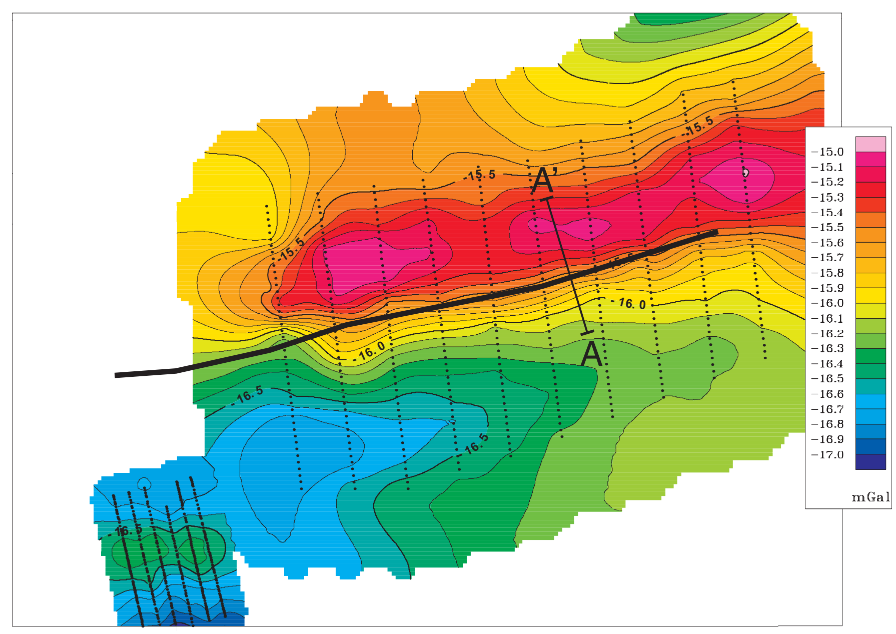
- OSLfv — felsic feldspar-phyric crystal tuff & ash tuff
- massive to semi-massive sulphide
- OSLs — laminated to thinly bedded shale interbedded with feldspathic sandstone & siltstone
- OSLSH — Shellalah Hill Brook Member: quartz-, feldspar-crystal tuff

thrust fault

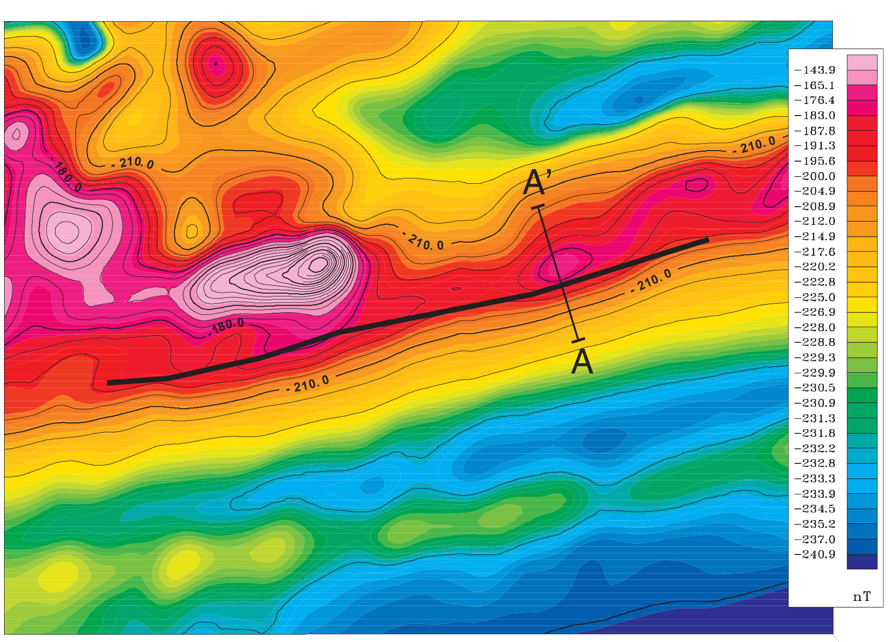
TOPOGRAPHY/FLIGHT LINES



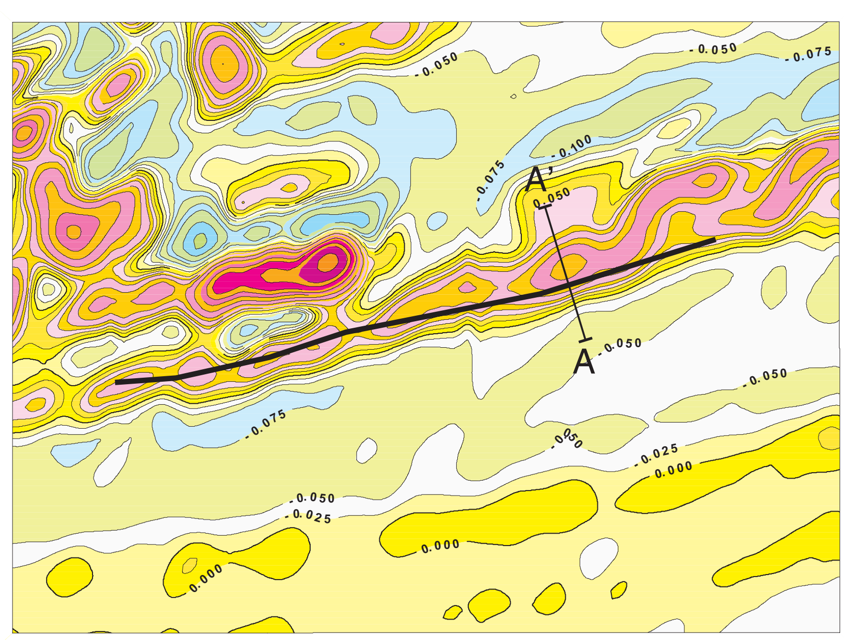
GRAVITY (mGal)



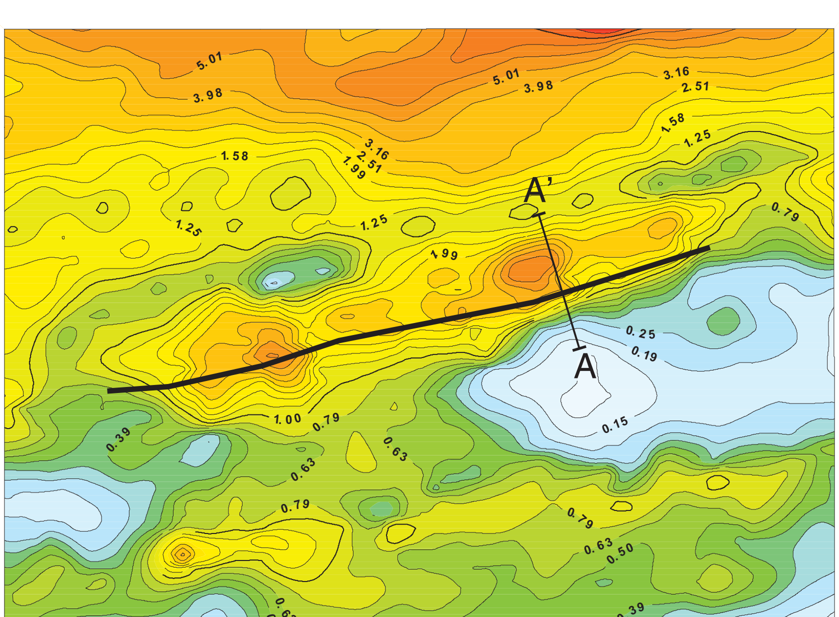
MAGNETICS (nT)



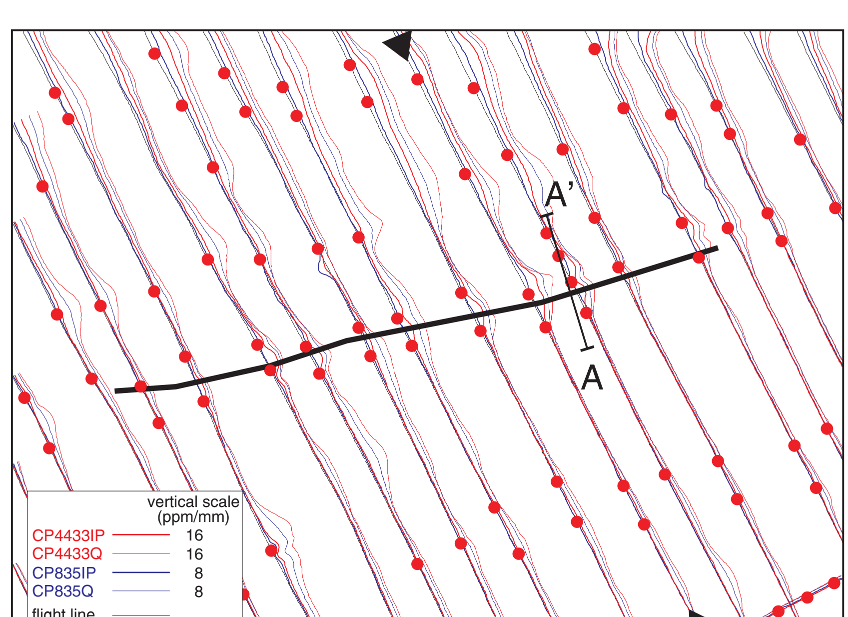
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



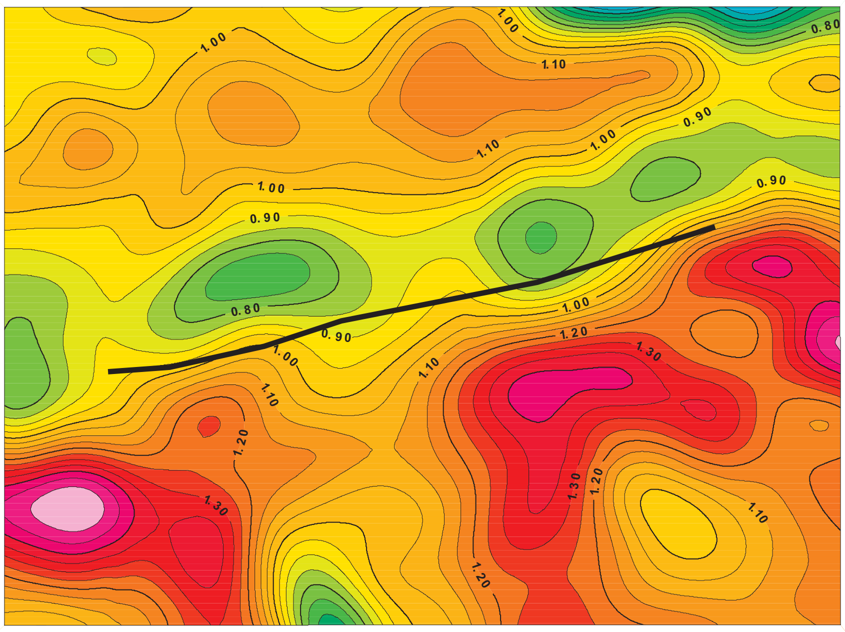
ELECTROMAGNETIC PROFILES/ANOMALIES



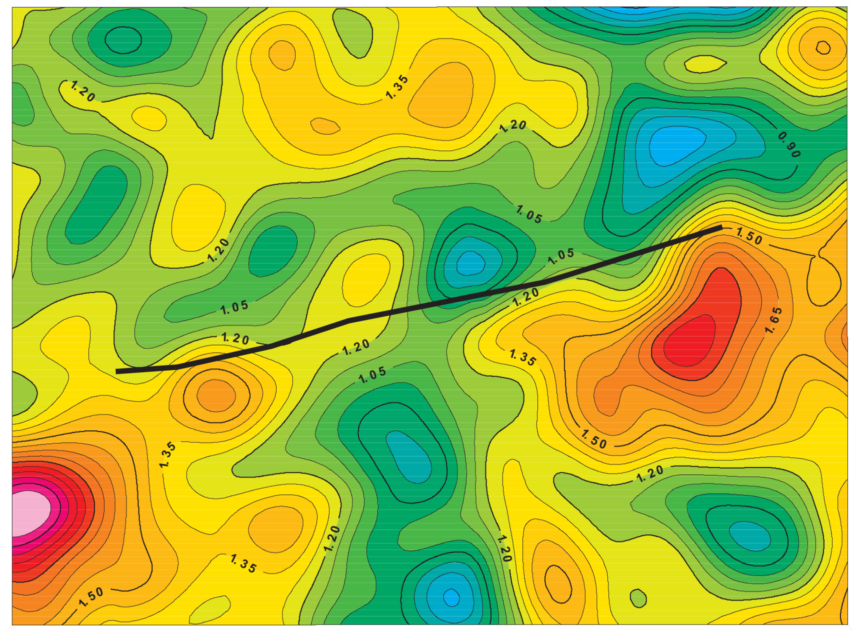
1000 m

ORVAN BROOK

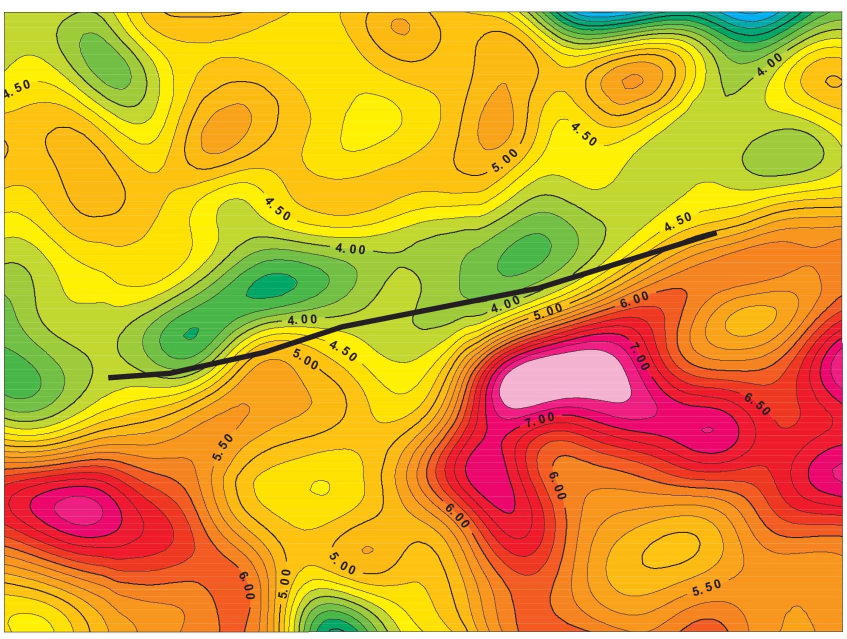
POTASSIUM (%)



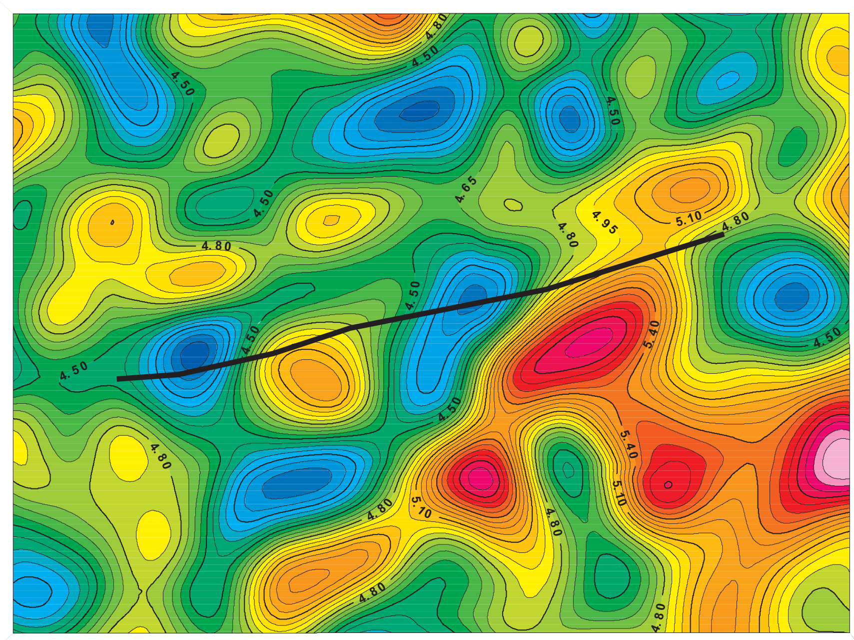
URANIUM (ppm)



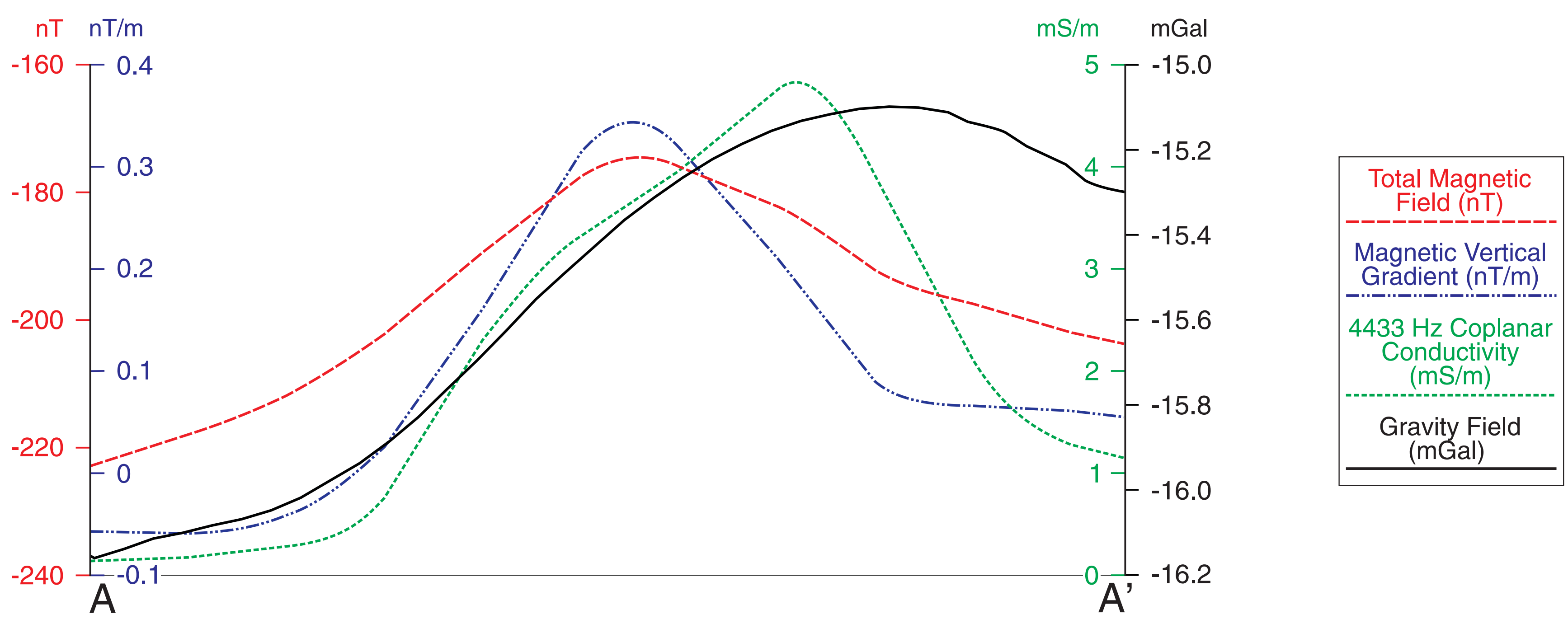
THORIUM (ppm)

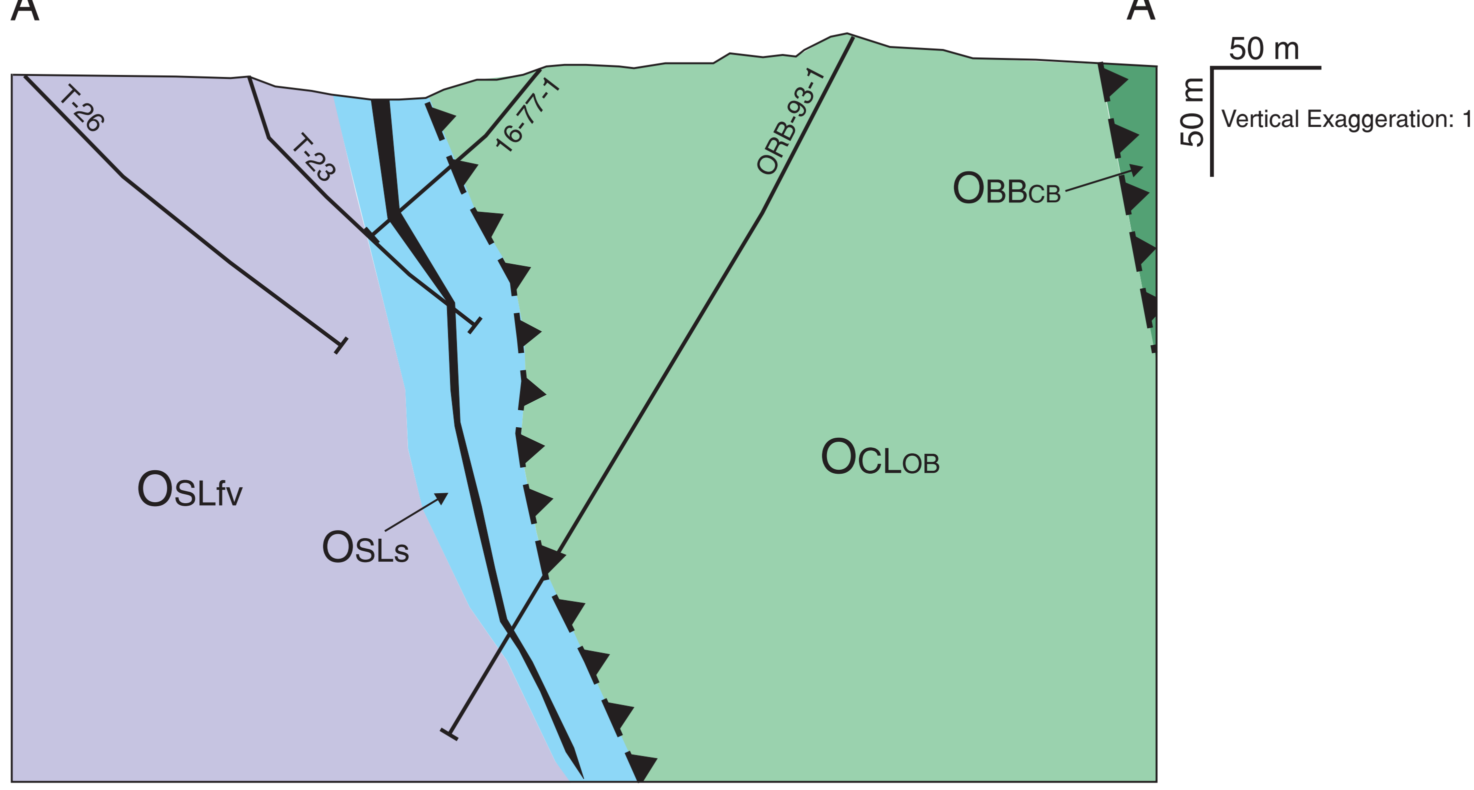


THORIUM/POTASSIUM RATIO (x 10^{-4})



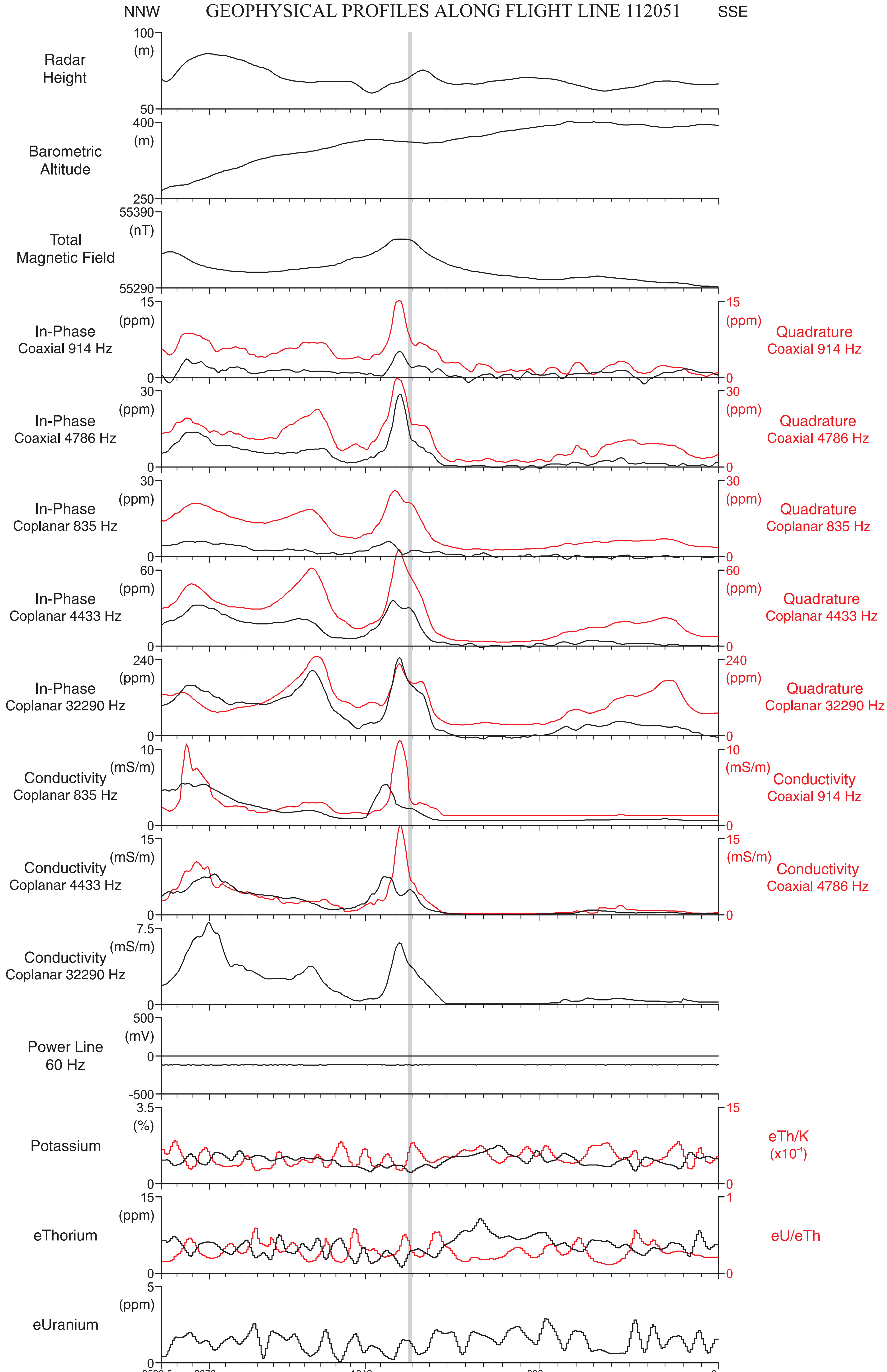
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A’





Modified from Tupper (1969) and Deveaux and Kempster (1993)

ORVAN BROOK


NNW
GEOPHYSICAL PROFILES ALONG FLIGHT LINE 112051
SSE
Radar Height
100 (m) 50
Barometric Altitude
400 (m) 250
Total Magnetic Field
55390 (nT) 55290
In-Phase Coaxial 914 Hz
15 (ppm) 0
Quadrature Coaxial 914 Hz
In-Phase Coaxial 4786 Hz
30 (ppm) 0
Quadrature Coaxial 4786 Hz
In-Phase Coplanar 835 Hz
Quadrature Coplanar 835 Hz
In-Phase Coplanar 4433 Hz
60 (ppm) 0
Quadrature Coplanar 4433 Hz
In-Phase Coplanar 32290 Hz
240 (ppm) 0
Quadrature Coplanar 32290 Hz
Conductivity Coplanar 835 Hz
10 (mS/m) 0
Conductivity Coaxial 914 Hz
Conductivity Coplanar 4433 Hz
15 (mS/m) 0
Conductivity Coaxial 4786 Hz
Conductivity Coplanar 32290 Hz
7.5 (mS/m) 0
Power Line 60 Hz
500 (mV) 0 -500
Potassium
3.5 (%) 0
eTh/K (x10-4)
15 0
eThorium
15 (ppm) 0
eU/eTh
1 0
eUranium
5 (ppm) 0
2593.5m 2370m 1642m 833m 0m

RESTIGOUCHE DEPOSIT

GEOLOGY

The Restigouche deposit was discovered by New Jersey Zinc in 1958 during follow-up work on a soil geochemical anomaly. The deposit has drill-proven reserves of 1.59 million tonnes grading 6.81% Zn, 5.38% Pb, 108 g/t Ag and 1.1 g/t Au (Gower and McCutcheon, 1997a). The deposit is presently controlled by CanZinco Ltd., and to the end of June 1998 produced 198,000 tonnes grading 5.34% Pb, 6.60% Zn and 127 g/t Ag (Luff, pers. comm.). Operations have ceased temporarily, because of low metal prices.

The deposit occurs within the Mount Brittain Formation. Footwall rocks comprise silicified, chloritized, aphyric- to sparsely feldspar-phyric rhyolite, whereas the hanging wall comprises feldspar-crystal lithic tuff interlayered with rhyolitic ash tuff. Pods and lenses of chert that occur locally in the immediate hanging wall may represent disrupted siliceous exhalite or preferential silicification of horizons that originally had greater permeability.

The deposit strikes northwest-southeast, and dips 15-20° to the northeast. The mineralized zone crops out at surface, is 490 m in length, 90 m in width, 30 m thick and has been traced to a maximum depth of 183 m. The deposit comprises at least two lenses that coalesce in the central part of the orebody. A pyrite-chlorite stringer/alteration zone underlies the massive sulphides. Mineralogically, the deposit is simple; pyrite is dominant with subordinate sphalerite, galena and chalcopyrite. Metal zoning, *i.e.*, Cu-rich base and Pb+Zn-rich top, that is typical of most VMS deposits in the Bathurst Camp, is not apparent at the Restigouche deposit. However, there is an appreciable increase in the grade of Ag near the top of each sulphide lens (Westoll and Associates, 1989).

MAGNETIC DATA

The map-area containing the Restigouche deposit contains many circular and elongate oval positive magnetic anomalies; the deposit is located on the flank of one of these. Most of the anomalies are distributed along three roughly linear belts of positive magnetic anomalies, that trend approximately west to west-northwest. The belt along the northern margin of the area, in part, is coincident with alkali basalt of the Camel Back Member. Sources of the other two belts are not as evident, although the belt along the southern margin is probably linked to mainly fine-grained sedimentary rocks (OMBCB) in this area. The central belt passes through the Restigouche sulphide deposit and traverses a variety of felsic volcanic rocks, which are not expected to contain significant quantities of magnetic minerals. The surface exposure of the deposit falls on an elongate pear-shaped magnetic peak, specifically on the narrow part of the pear, which trends north-northeast, approximately at right-angles to the deposit. Notwithstanding this partial correlation of a magnetic high with the deposit, it is suspected that the deposit makes very little contribution to the anomaly, for two main reasons: (1) the anomaly extends far beyond the surface exposure of the deposit and its known subsurface configuration, and (2) pyrite is the most abundant sulphide mineral in the deposit, followed by sphalerite, galena and chalcopyrite; pyrrhotite is not listed as being present (Gower and McCutcheon, 1997a). Furthermore, the shallow dip of the deposit would result in a smaller magnetic signal than that generated if the deposit was steeper (this would apply if minerals with a sufficiently high magnetic susceptibility were present to produce a recognizable signal). Finally, it is noted that no iron formation is associated with the deposit (Gower and McCutcheon, 1997a), ruling out any signal from this type of source. Possibly, the anomaly may be related to small Siluro-Devonian mafic dykes that are exposed in the pit, and are shown on the geological section.

ELECTROMAGNETIC DATA

The Restigouche deposit, presently exposed in an open pit, generates a single, well defined, low-amplitude conductivity anomaly of about 6 mS/m amplitude on the mid-frequency coplanar coils. The coplanar EM responses are well defined at all frequencies. Although there are anomalous responses on the coaxial coils, the traces are noisy. At low frequencies the in-phase and quadrature responses of the coplanar coils are 6 ppm and 18 ppm, respectively, and the coaxial responses are 2 ppm and 9 ppm. For flight-line 110290, at mid-frequencies, the coplanar responses are 24 ppm and 42 ppm, and the coaxial responses are 9 ppm and 17 ppm. At high frequency the in-phase and quadrature coplanar responses are both 136 ppm. Calculated apparent conductivities at low frequencies are 6 mS/m for the coplanar coils and 3 mS/m for the coaxial coils. At mid frequencies, the respective conductivities are 6 mS/m and 12 mS/m. At high frequency the apparent conductivity is 4 mS/m.

GRAVITY DATA

Gravity data for this deposit are unusable.

RADIOMETRIC DATA

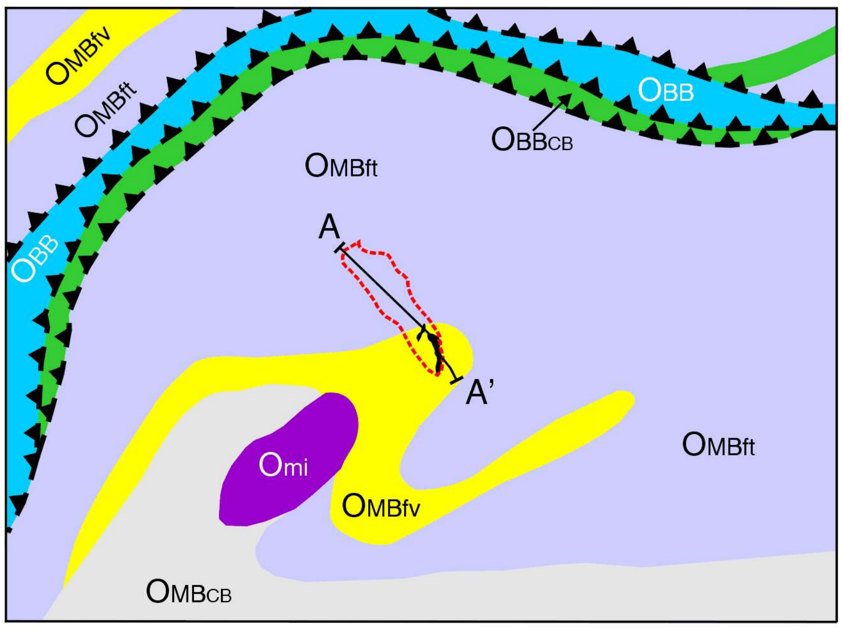
There is no airborne gamma-ray spectrometric signature associated with the deposit. The radioelement patterns reflect local geology, modified by topographic highs and drainage systems. Relative highs (1.4 - 2.2% K, 1.9 - 2.6 ppm eU, 6 - 11 ppm eTh) are associated with felsic tuff and feldspar-phyric rhyolite flows of the Mount Brittain Formation. These are cut by an arcuate belt of low values (<1.4% K, < 1.8 ppm eU, <6 ppm eTh) associated with alkali basalt, graphitic shale, siltstone and chert within the Boucher Brook Formation. Metasedimentary rocks within the Charlotte Brook Member (Mount Brittain Formation) also produce moderate lows along the southern edge of the map. Immediately southeast of the deposit, a deep low in all three radioelements coincides with, and extends beyond, coarse-grained gabbro, suggesting a more extensive distribution of the gabbro than indicated on the geological map.

SUMMARY

The principal geophysical signature of the Restigouche deposit is a circular conductivity high that is conspicuous in a generally featureless background field. The anomaly peaks just northwest of the sulphide body, half of it lying partly above the subsurface extension of the body, and half lying outside. The deposit sits on a prominent magnetic high, but the contribution from the deposit is concluded to be insignificant. Radiometric signatures are lacking over the deposit. Suitable gravity data were not available for comment.

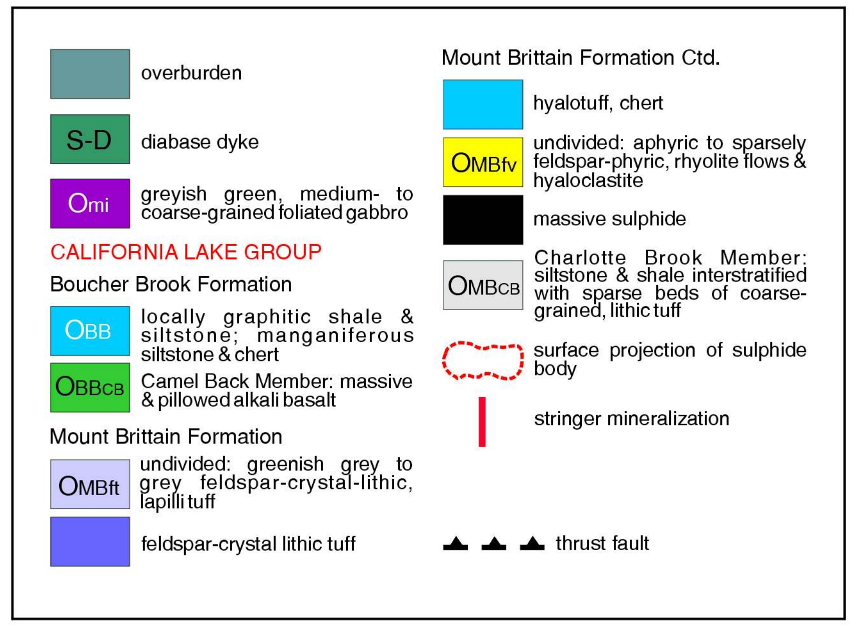
RESTIGOUCHE

GEOLOGY

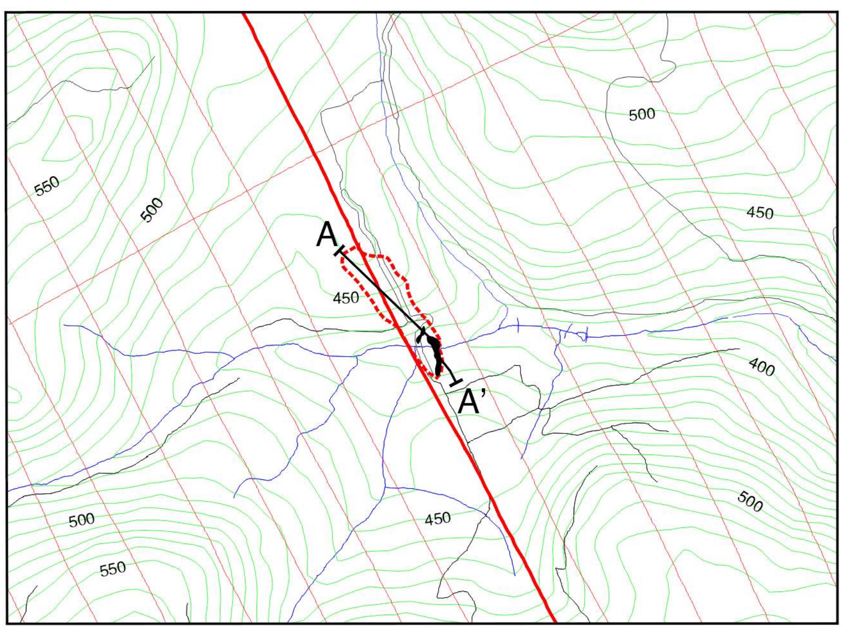


Modified from Gower (1995b)

GEOLOGICAL LEGEND



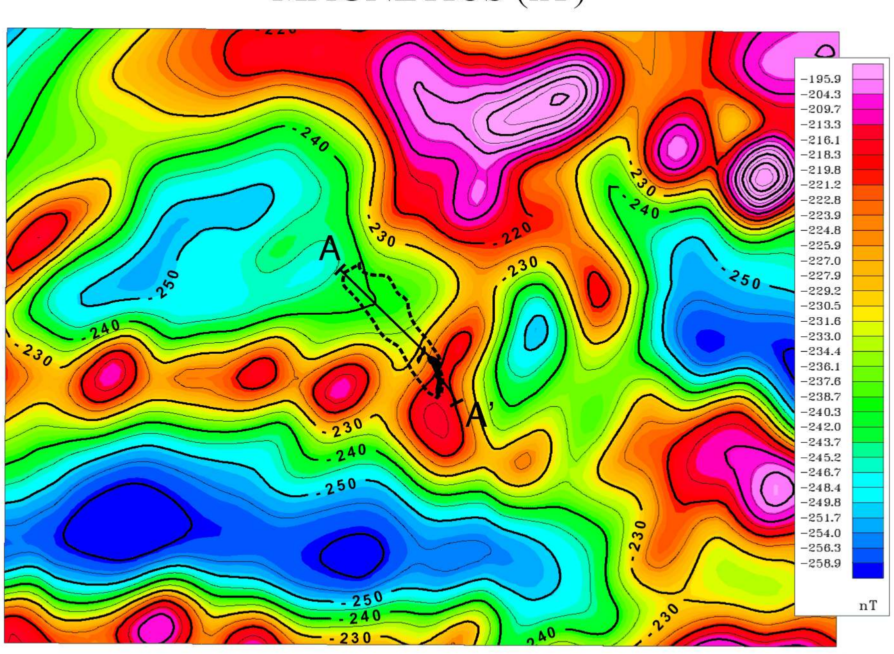
TOPOGRAPHY/FLIGHT LINES



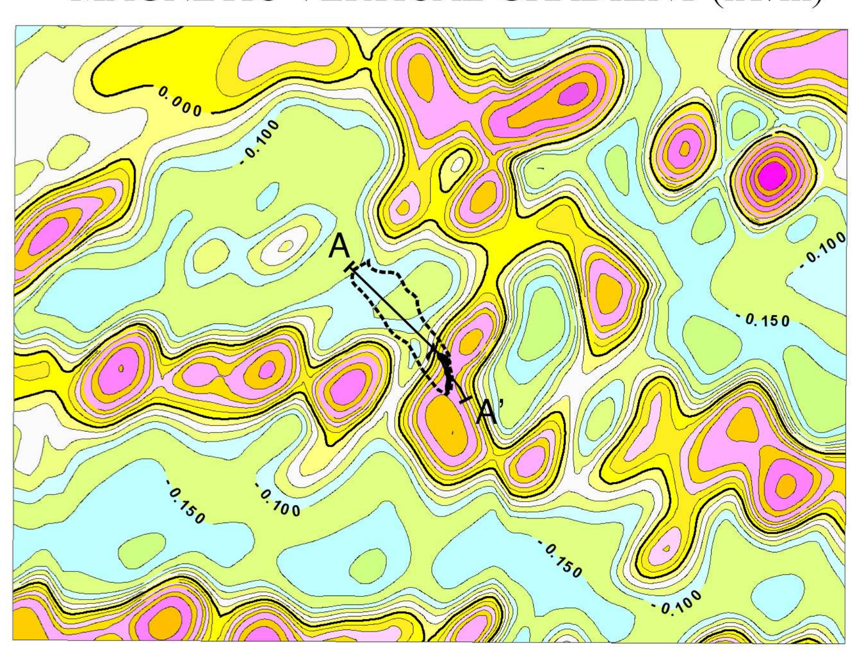
GRAVITY (mGal)

GRAVITY DATA ARE UNUSABLE

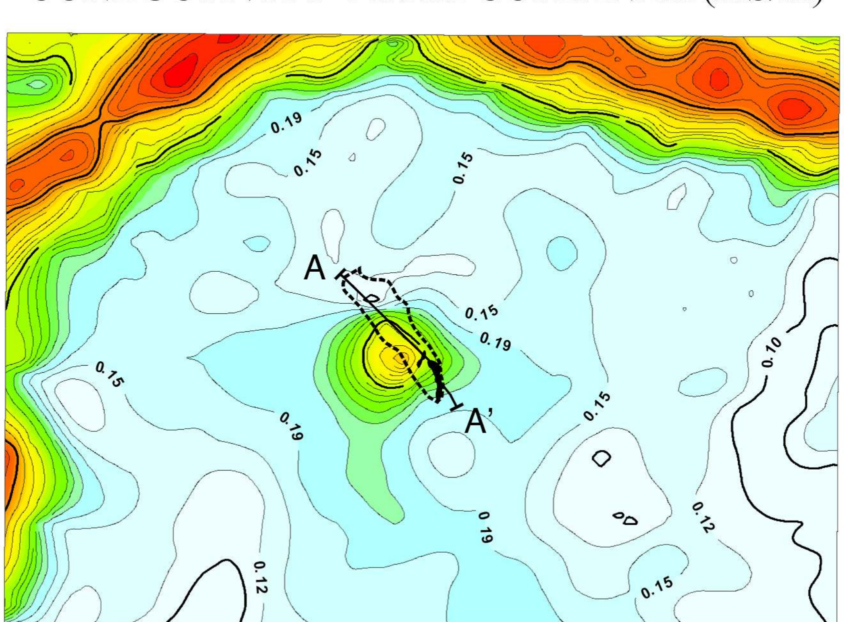
MAGNETICS (nT)



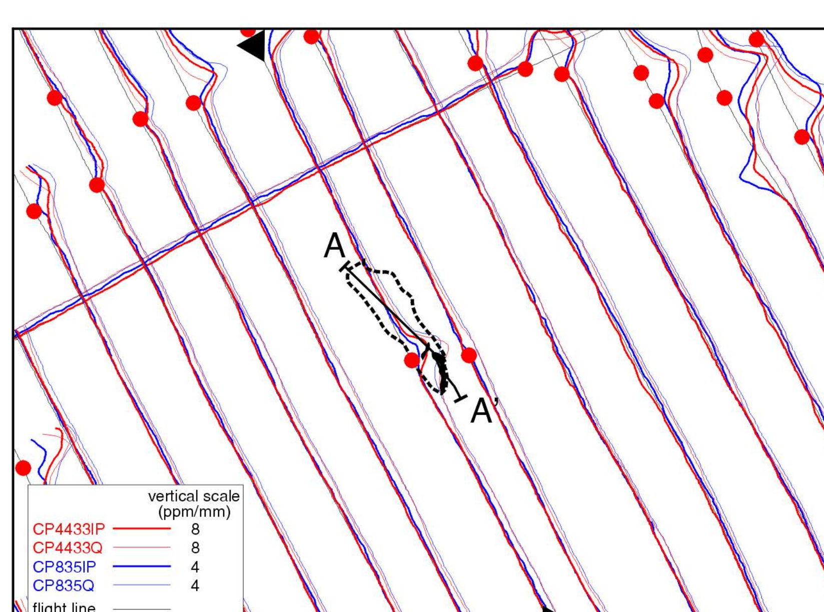
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)

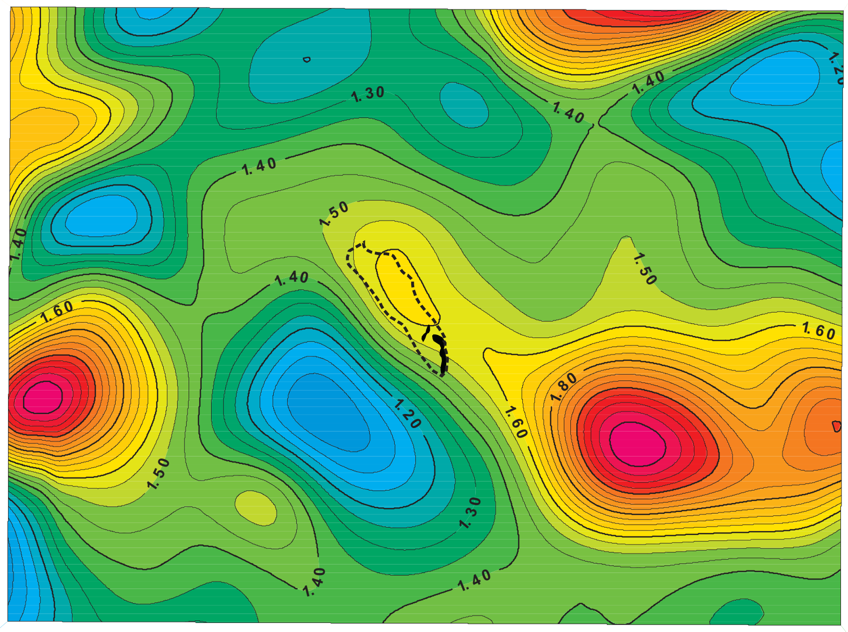


ELECTROMAGNETIC PROFILES/ANOMALIES

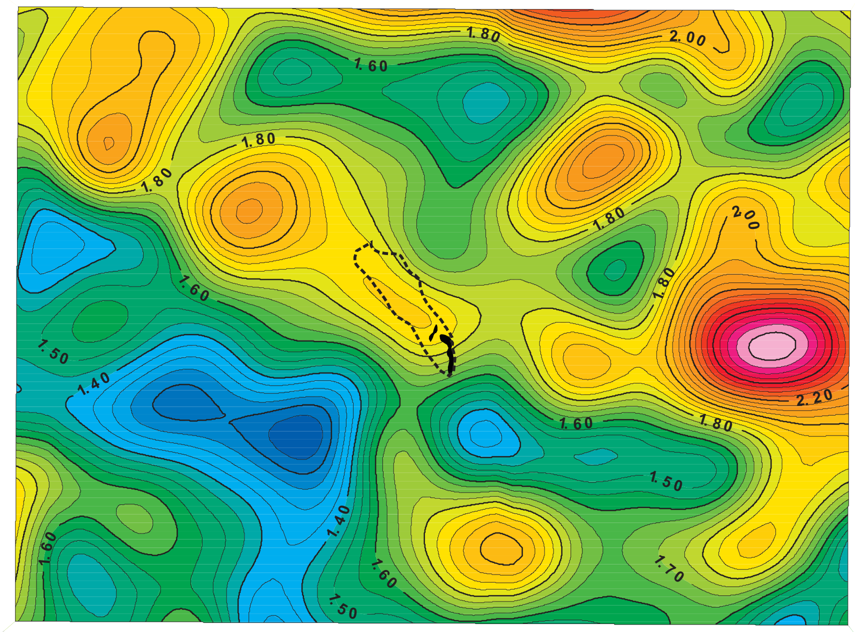


RESTIGOUCHE

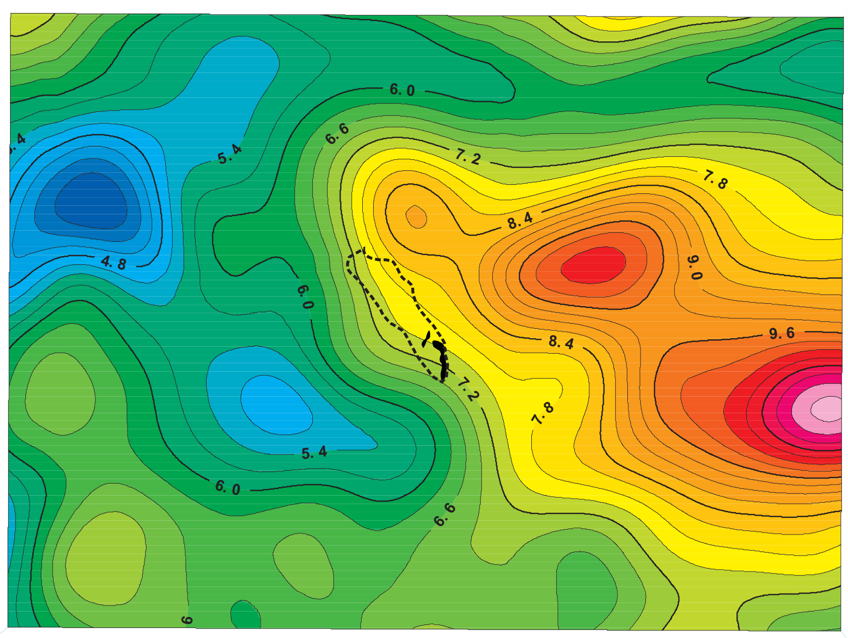
POTASSIUM (%)



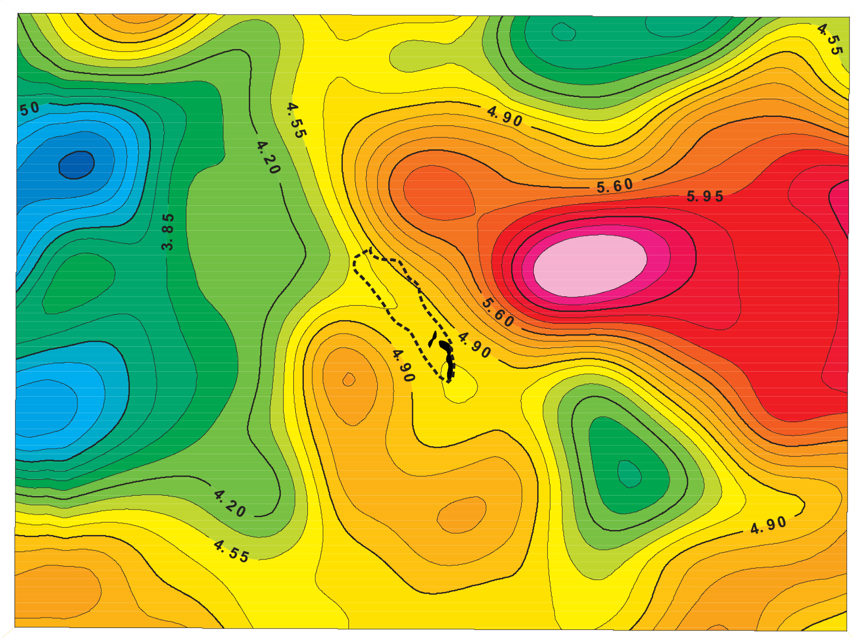
URANIUM (ppm)



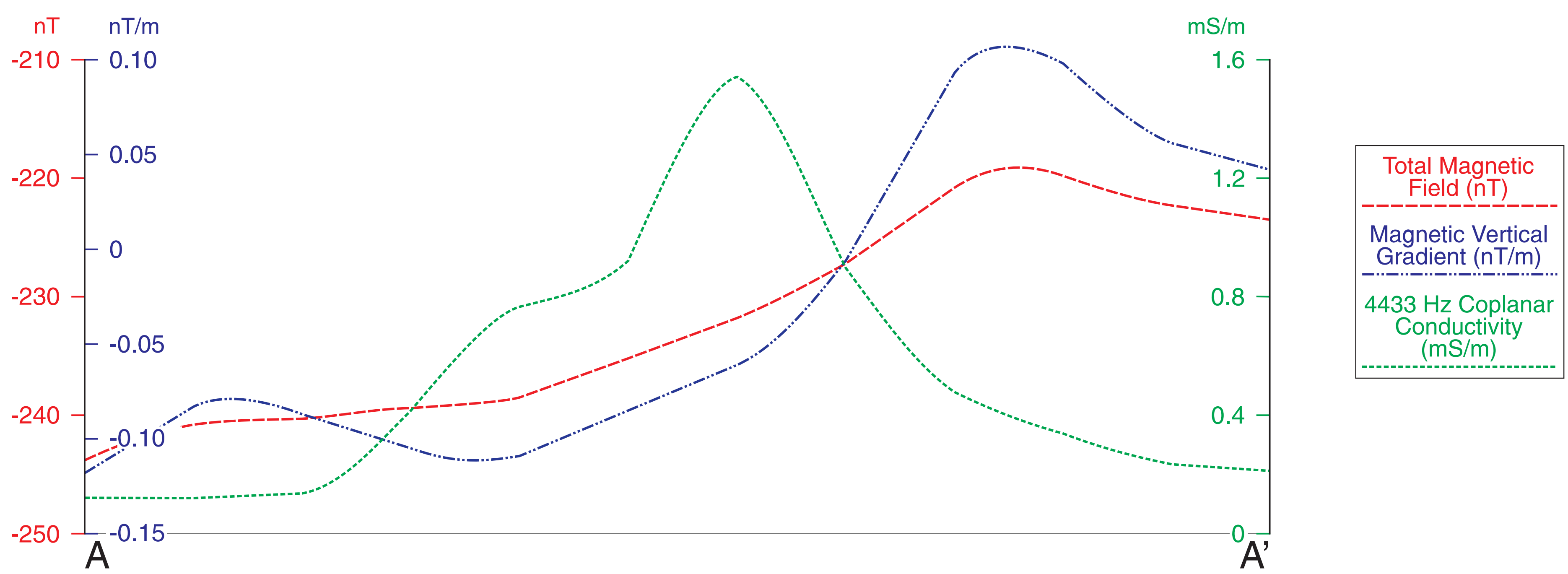
THORIUM (ppm)

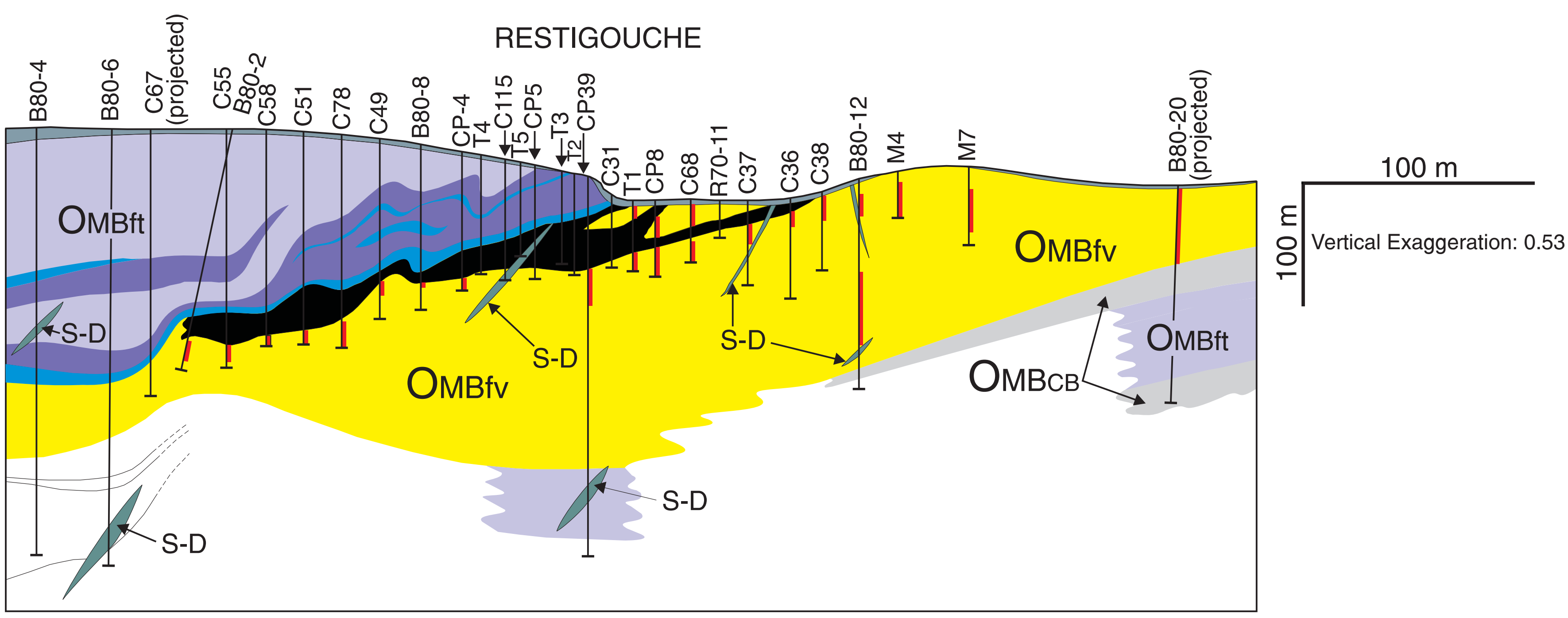


THORIUM/POTASSIUM RATIO (x 10^{-4})



GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'

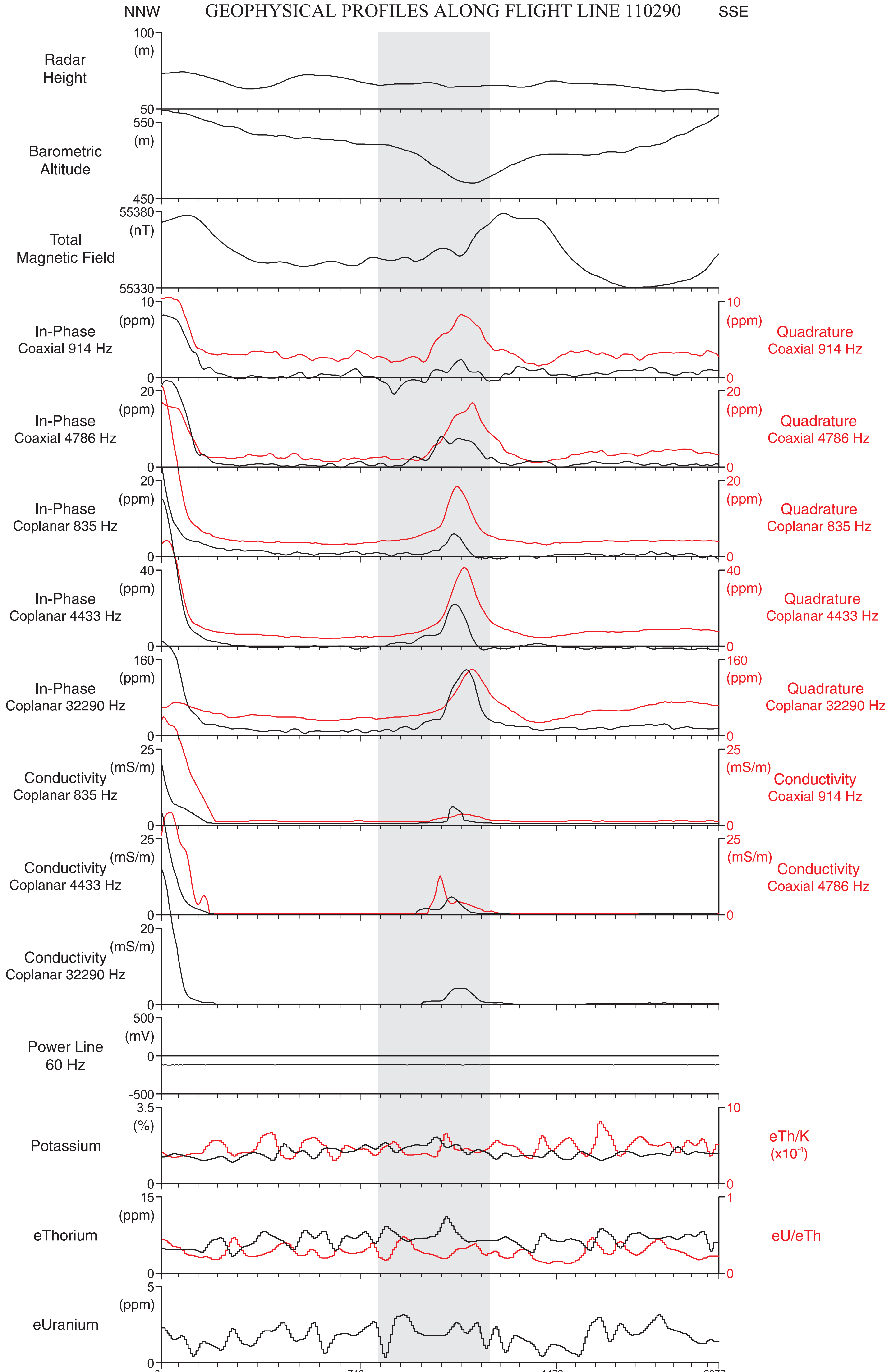




Modified from Barrie (1982), Gower (1996) and Westoll & Associates (1989)

RESTIGOUCHE

GEOPHYSICAL PROFILES ALONG FLIGHT LINE 110290



STRATMAT BOUNDARY DEPOSIT

GEOLOGY

A series of deposits occurs within the Stratmat Shear Zone, just north of the Heath Steele Mine licence. The Stratmat Boundary sulphide zone and its faulted offset, the N5 zone, are considered to be representative of these deposits. The Boundary zone was discovered by Cominco in 1961 during follow-up work on coincident electromagnetic and soil geochemical anomalies.

Regional mapping by Wilson (1993c, d) places this deposit within the Flat Landing Brook Formation. Felsic volcanic rocks in the structural footwall comprise white to pale-grey, fine-grained, siliceous hyaloclastic breccia and tuff. The ore horizon is within dark grey to green, tuffaceous siltstone. The hanging wall sequence comprises grey to greenish grey feldspar-phyric and aphyric rhyolite. According to Hamilton (1992) the deposit contained 891,000 tonnes grading 3.31% Pb, 7.96% Zn, 0.32% Cu and 44 g/t Ag and is unique relative to other deposits in the Bathurst Mining Camp, because of its low Fe content (15 - 20% pyrite). Massive to disseminated sulphides occur within highly strained argillaceous to cherty sedimentary rocks.

The ore consists of massive sphalerite, galena, pyrite and chalcopyrite and is coarser-grained than most of the deposits in the Bathurst Mining Camp. The coarse grain size is attributable to recrystallization caused by deformation. A pyrite-chalcopyrite layer, <1m thick and containing 1 - 2% Cu, occurs on the south side of the sulphide lens, probably indicating that the structural footwall is also the stratigraphic footwall. The Cu-rich layer grades northward into pyrite-poor massive galena and sphalerite that grades 5 - 15% Pb and 15 - 30% Zn. Gangue minerals include muscovite, talc, chlorite, quartz and carbonate.

The deformation in this area is polyphase and intense, and difficult to interpret. However, it seems that the overall trend of the mineralized zone is defined by F_1 folds that plunge approximately 30° to the east. These are refolded by upright, isoclinal F_2 folds (Park, 1996a, b).

MAGNETIC DATA

The Stratmat Boundary sulphide deposit sits on the western end of an east-west trending, elongate magnetic high (~13 nT maximum amplitude) that bears no relationship to mapped geology. It traverses mainly a variety of felsic volcanics, which predominate in the area, and locally cross-cuts a narrow band of tuffaceous sedimentary rocks at a high angle. This anomaly, and the dominant magnetic feature of the map-area, a northwest-southeast-trending linear high (~23 nT maximum amplitude) west of the deposit, that crosses the prevailing geological strike roughly at right-angles, are both attributed to mafic intrusions. The linearity and continuity of the latter anomaly suggest the presence of a dyke. The Stratmat Boundary deposit does not produce a signature in either the total magnetic field or vertical gradient maps. This is in accordance with the constituent sulphide mineralogy, which comprises disseminated and massive sphalerite-galena-pyrite and chalcopyrite (Hamilton, 1992), minerals all having low magnetic susceptibilities. The pyrite content is about 15 - 20%. The N5 sulphide zone is mineralogically similar, very narrow and also is without expression in either of the magnetic maps.

ELECTROMAGNETIC DATA

The Stratmat Boundary deposit is located within a weakly conductive zone outlined by the 0.3 mS/m contour, that generally follows the Stratmat Fault. The width of this conductive zone is between 500 and 600 m, and within it local peaks are associated with the Boundary and N5 zones, the open pit mine and waste piles. The deposit is locally associated with tuffaceous siltstone and wacke, but it is unlikely that these rocks contribute to the conductivity anomaly, as siltstone usually has a low conductivity. The principal conductivity anomaly is regional in scale and is most likely related to the Stratmat Fault. Maximum conductivity is observed over the deposit and the N5 Zone. Conductivity highs, of 5 to 8 mS/m, are observed for the low and mid frequencies. At high frequency, conductivity is more than 15 mS/m. The wide EM anomalies observed on flight-line 440480 and on the adjacent line to the west are located over the open pit, and these are caused by the remaining massive sulphides. These two wide EM anomalies are typical of a flat-lying conductor, which is in agreement with the geological cross-section. The low- and mid-frequency EM responses can be modelled by a thin horizontal plate in free space, with a strike length of 300 m, a width of 150 m and a conductance of 0.25 S. Although the deposit is known to extend to a depth of about 75 m (see cross-section), this vertical depth extension does not produce any discernible EM signature, since the response is dominated by the flat-lying massive sulphides.

GRAVITY DATA

Gravity coverage for the map-area including the Stratmat Boundary and N-5 deposits is based on data distributed on a 30 m grid, made available by Noranda. The main feature of the gravity field is a westward bulging of the contours, superposed on a gradient spanning the map-area, across which values decrease essentially from east to west. This salient in the contours, focussed approximately in the area between the northernmost and southernmost faults in the area, represents a gravity high. A likely cause for either this central high or the gradient is not readily evident in the surface geology, although it is noted that limited developments of tuffaceous siltstone and wacke are restricted to the region between the faults. If these are augmented by other developments, as yet unmapped or too small to portray at the scale of presentation, they might be sufficiently voluminous to influence the gravity field. Such an influence requires that they are more dense than surrounding felsic rocks. As such, the high might reflect a fault-bounded block enriched in enclaves of sedimentary rock.

The Stratmat Boundary deposit sits on the northern part of the central high and apparently is reflected in the gravity field by a small, superposed gravity high in the form of a tight arc-shaped, westward deflection of a single contour line. The contour interval is 0.2 mGal, so the amplitude is smaller than this value. The deflection coincides with the eastern half of the deposit. The series of lenses that make up the Stratmat N-5 deposit does not have an obvious effect on the gravity profile along line A-A'.

RADIOMETRIC DATA

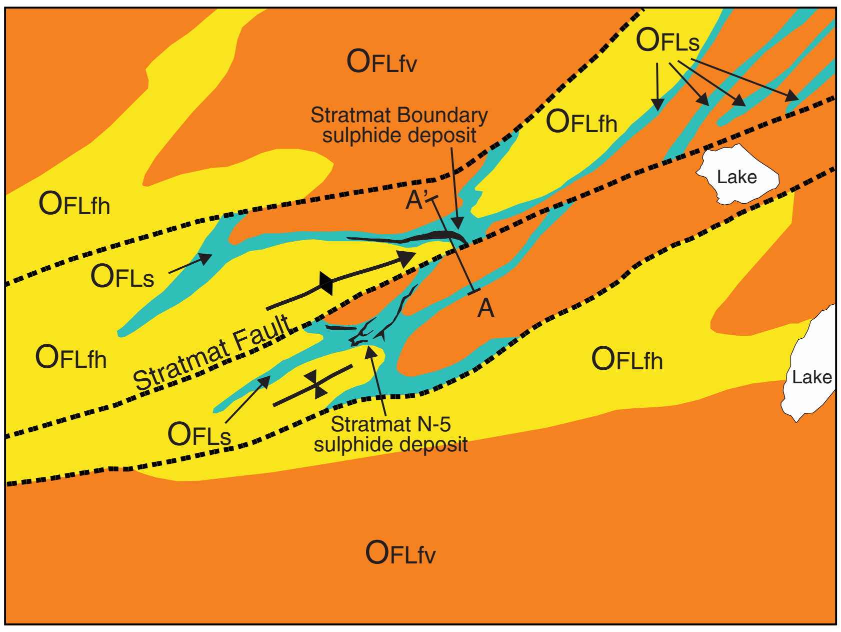
The deposit is associated with the highest airborne K, eU and eTh values within the map-area, reflecting increased exposure due to mining operations. Elsewhere, K and eTh concentrations are elevated over aphyric and feldspar-phyric rhyolite, hyaloclastite and tuff of the Flat Landing Brook Formation (2.0 - 2.5% K and 7.0 - 8.2 ppm eTh). Concentrations are low (1.7 - 2.0% K and 6.4 - 7.2 ppm eTh) over felsic hyaloclastic breccia, tuff and volcaniclastic sedimentary rocks of the Flat Landing Brook Formation, possibly reflecting increased abundance of sedimentary rocks. Equivalent uranium and eTh/K patterns show no correlation with mapped geology. A northwest-southeast zone of elevated eU concentrations cuts across known geological contacts, and may correspond to areas of increased bedrock exposure. Relative variations in K and eTh between footwall and hanging wall units are similar to those at the Heath Steele B Zone deposits (Lentz and Wilson, 1997; Rickard, 1998) and offer potential exploration guidance.

SUMMARY

The Stratmat Boundary deposit is located on the flank of an elongate magnetic high, attributed to an unmapped mafic dyke. The deposit, itself, has no magnetic expression. It does lie within an extensive conductivity anomaly attaining a minimum amplitude of about 0.3 mS/m attributed to the Stratmat Fault. In the region of the open pit and surrounding tailings, this anomaly attains a larger amplitude and culminates in several localized peaks. The thickened eastern extremity of the Stratmat Boundary deposit coincides with one of them. A small and inconspicuous gravity high is manifested as a tight bulge in a single contour, its amplitude being estimated to be less than 0.2 mGal. High K, eTh and eU concentrations over and around the deposit are attributed to mining operations.

STRATMAT BOUNDARY

GEOLOGY



Modified from Wilson (1993c, d)

GEOLOGICAL LEGEND

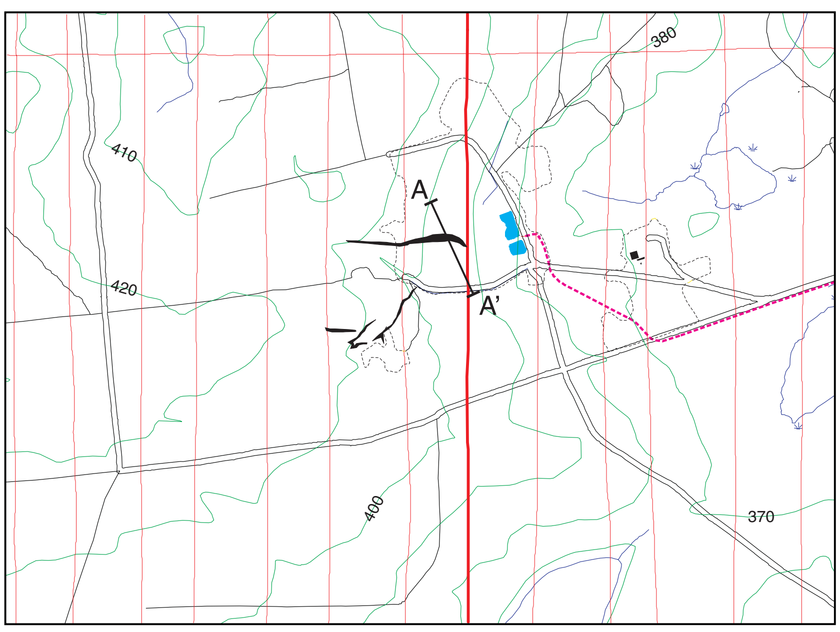
TETAGOUCHE GROUP

Flat Landing Brook Formation

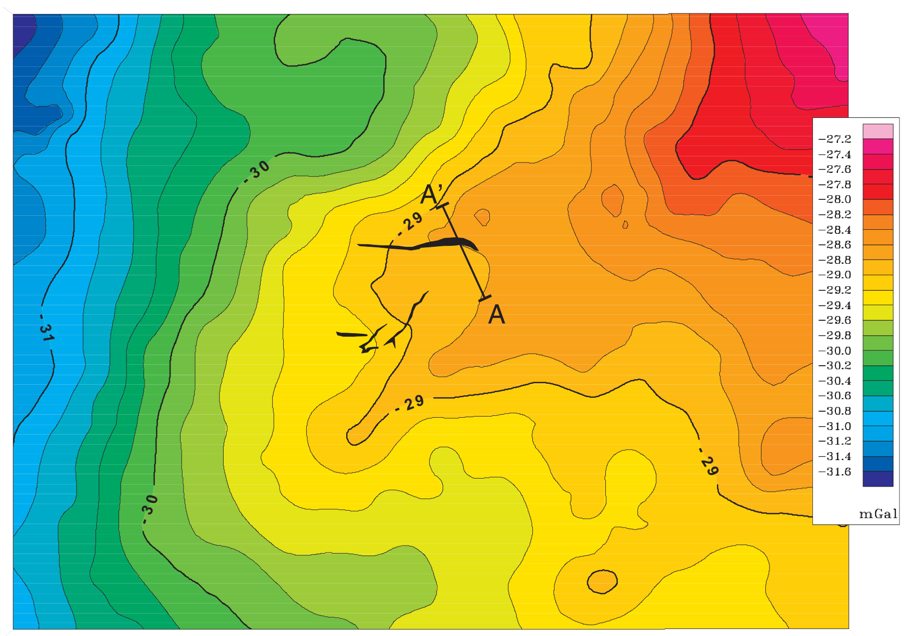
- OFLfv — grey to greenish grey aphyric rhyolite, feldspar-phyric rhyolite, hyaloclastite & tuff
- OFLs — dark grey to greyish green tuffaceous siltstone & wacke
- OFLfh — felsic hyaloclastic breccia & related tuffs & volcaniclastic sedimentary rocks; minor massive aphyric rhyolite
- massive sulphide

- normal fault
- antiformal fold axis with direction of plunge
- synformal fold axis

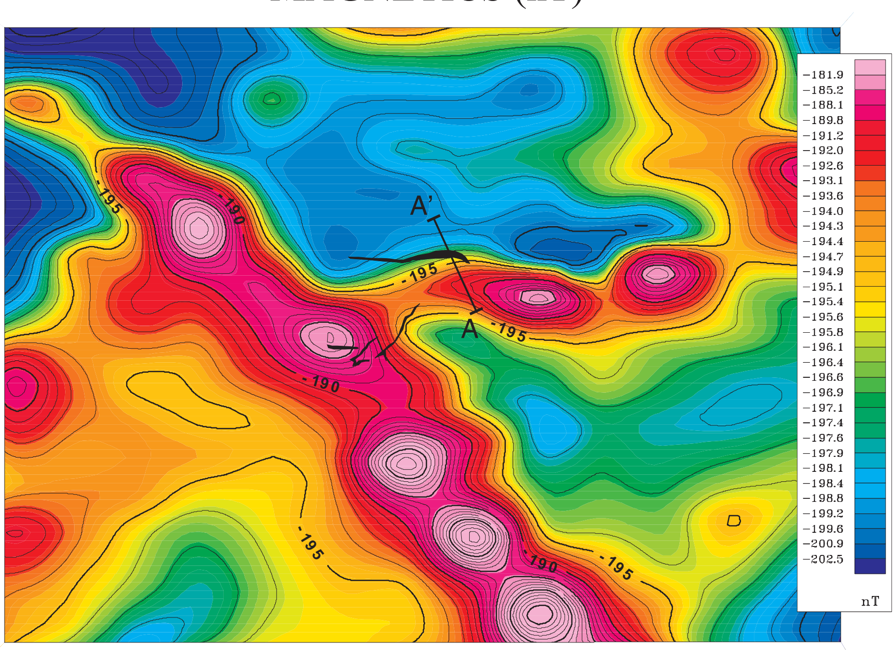
TOPOGRAPHY/FLIGHT LINES



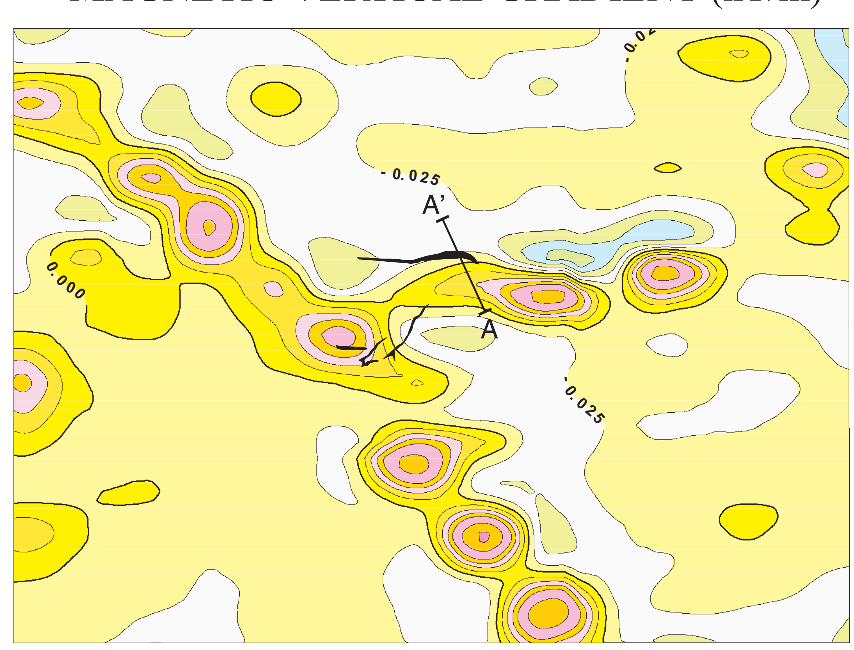
GRAVITY (mGal)



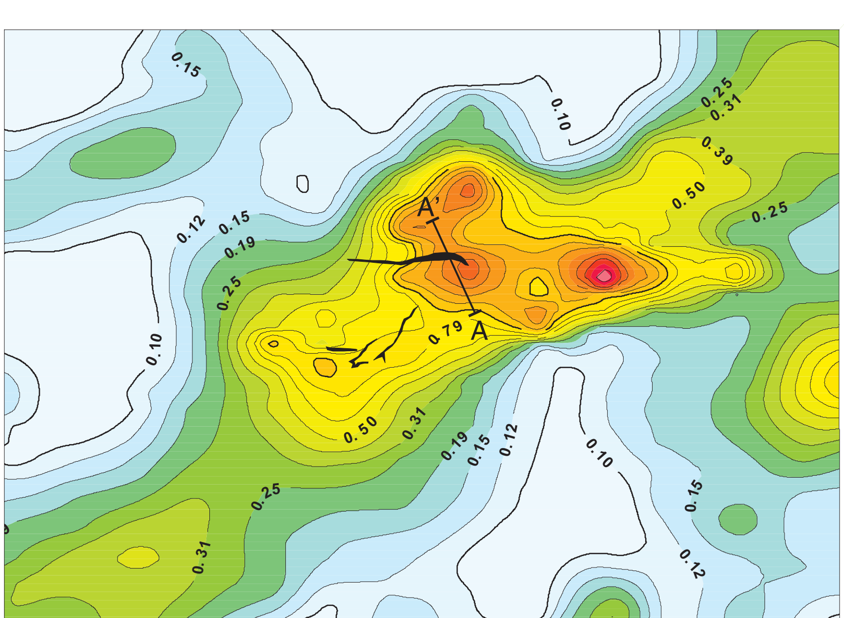
MAGNETICS (nT)



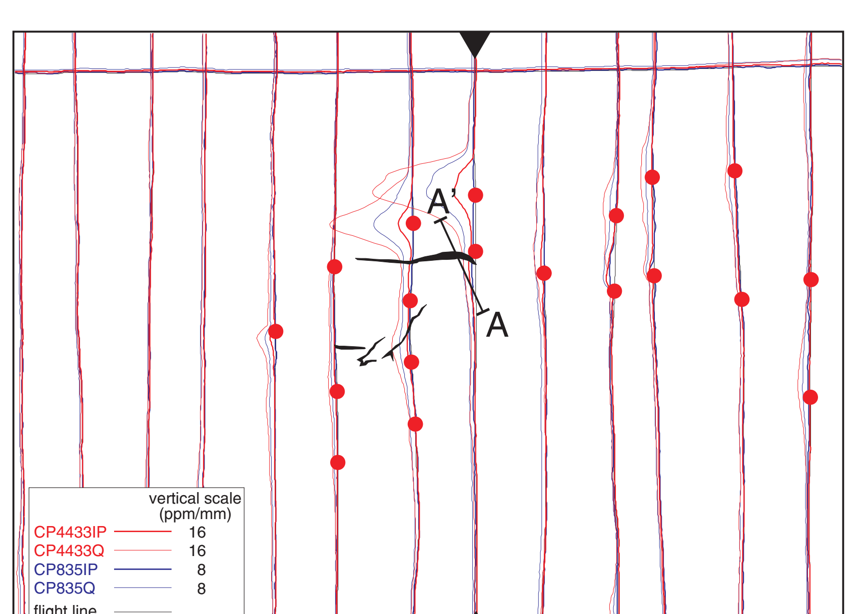
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



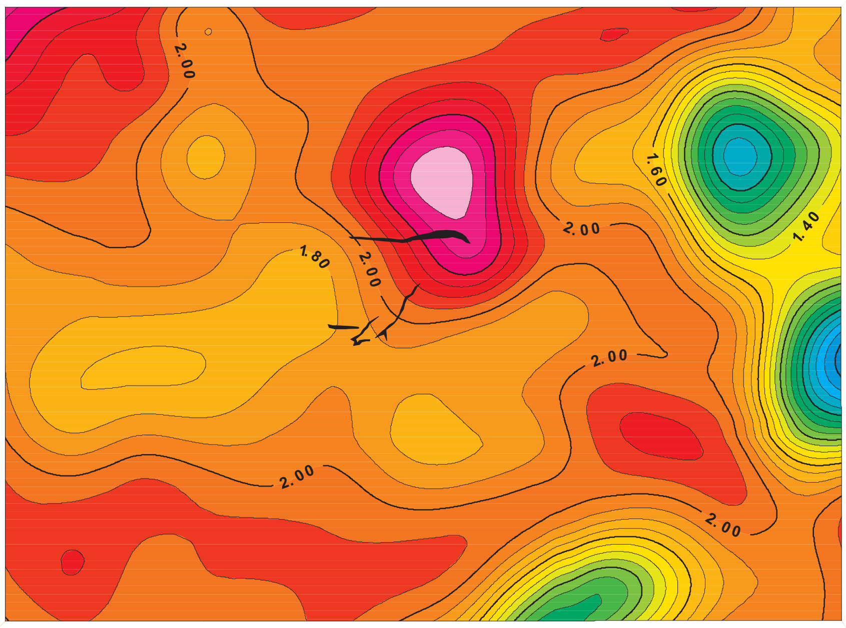
ELECTROMAGNETIC PROFILES/ANOMALIES



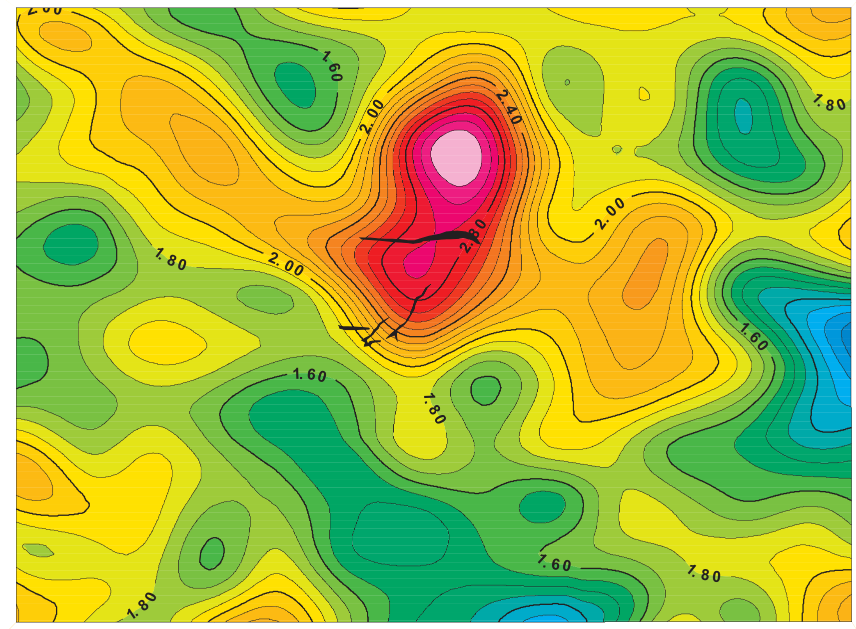
1000 m

STRATMAT BOUNDARY

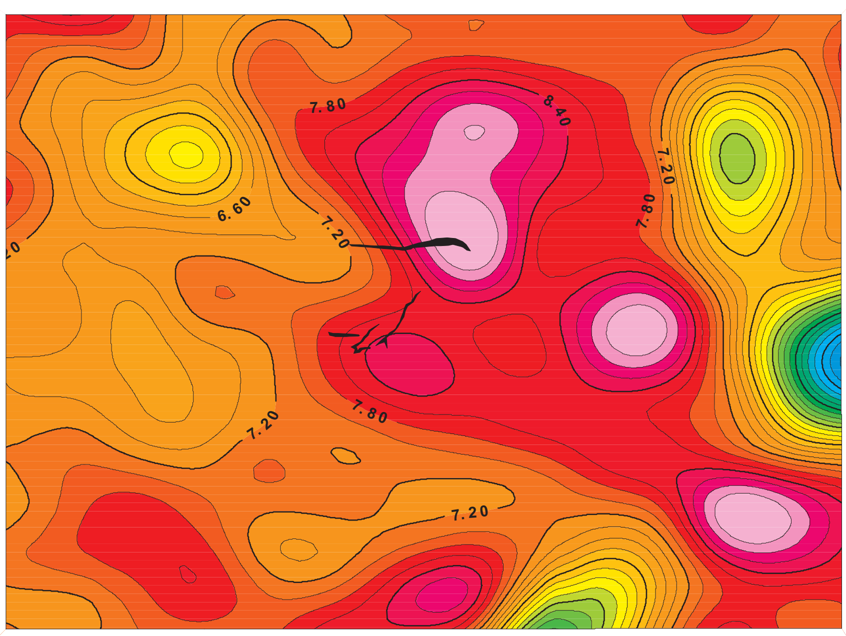
POTASSIUM (%)



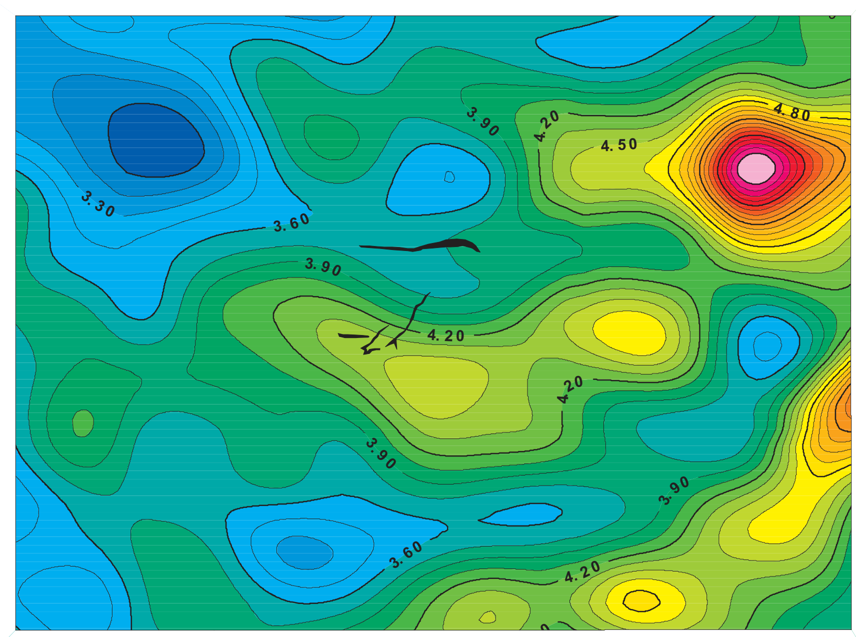
URANIUM (ppm)



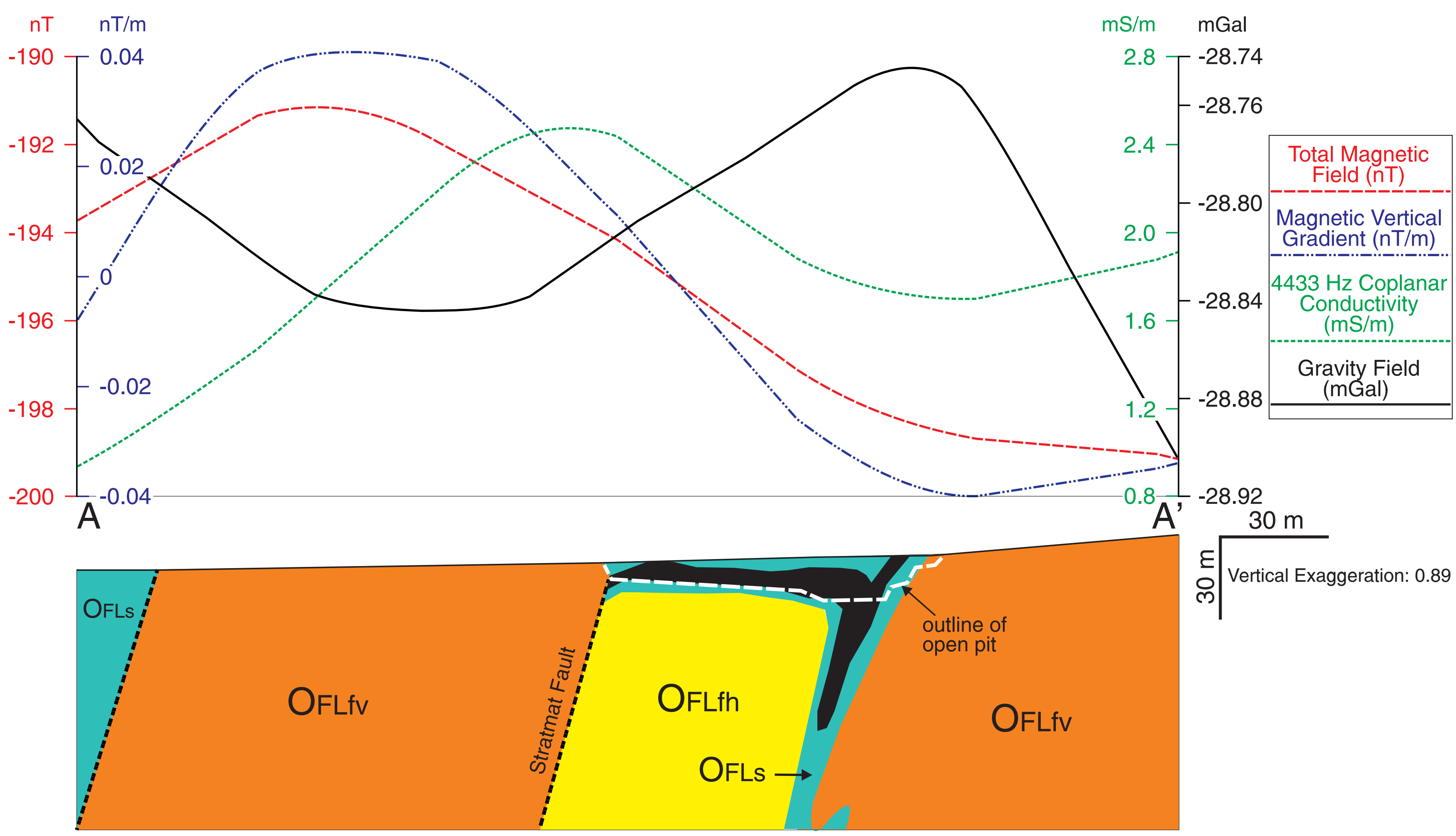
THORIUM (ppm)



THORIUM/POTASSIUM RATIO (x 10^{-4})



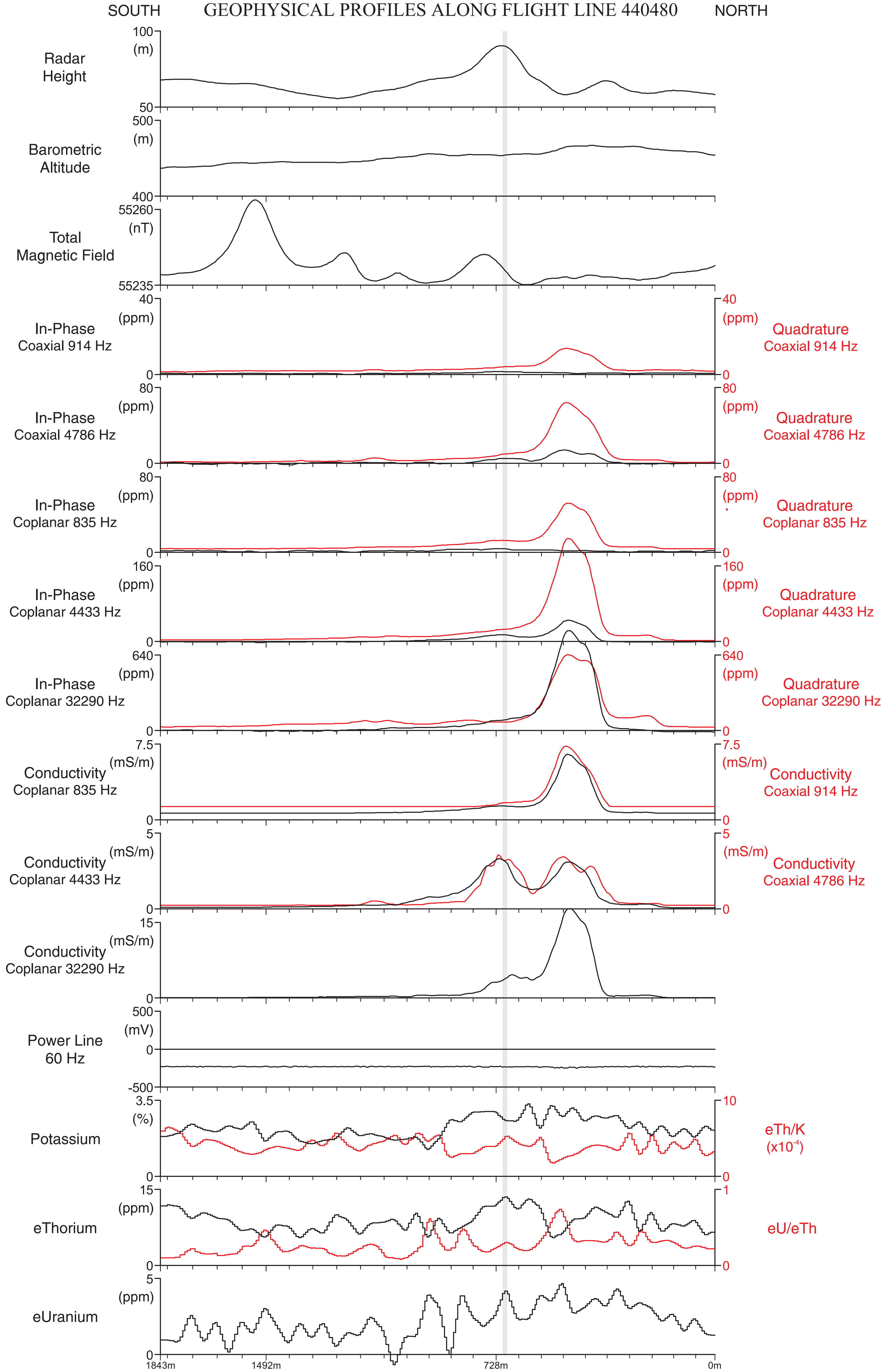
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'



Compiled from Hamilton (1992) and Wilson (1993c, d)

STRATMAT BOUNDARY

GEOPHYSICAL PROFILES ALONG FLIGHT LINE 440480



TAYLOR BROOK DEPOSIT

GEOLOGY

The Taylor Brook deposit was discovered by Consolidated Morrison in 1977 during follow-up work on a pulse EM anomaly (Burton, 1978; Gummer, 1978). Geologic reserves and grades have not been reported for this deposit. Recent mapping by Wilson (1993c) places this deposit within the Flat Landing Brook Formation, within a sequence of hyaloclastic breccias and related tuffs, sedimentary rocks and minor aphyric rhyolite flows.

The deposit is tadpole-shaped with a surface strike length of 650 m. The thickest accumulation of sulphides is in the northwest part of the deposit (strike 115°), where several sulphide layers coalesce. Here, the deposit extends down dip for at least 360 m. To the east, the deposit thins rapidly, its strike changes to 090° and it dips consistently to the south at 45°. The thickest single sulphide intersection is 23 m, and is near surface at the west end of the deposit. Mineralization comprises disseminated to massive sulphides interlayered with felsic hyaloclastites, hyalotuff and very minor fine-grained sedimentary rocks. Sulphide minerals in order of decreasing abundance are pyrite >> pyrrhotite, sphalerite, galena and chalcopyrite.

At the west end of the deposit and at depth (250 m vertical depth), a chloritically-altered chalcopyrite stringer zone was intersected. Elsewhere along strike, footwall and, to a lesser extent, hanging wall rocks are variably affected by sericitic and siliceous alteration. Unlike many of the deposits in the Bathurst Mining Camp, no Algoma-type iron formation has been identified at or along strike from this deposit.

MAGNETIC DATA

The Taylor Brook sulphide deposit lies on the southern flank of a broad positive total magnetic field anomaly that extends east-northeast across the entire area. The southern flank is a smoothly-varying, gentle gradient, with no discernible perturbations of the contours that might signify the presence of the deposit. Neither is there any sign of a positive feature on the vertical gradient map. Apparently, the Taylor Brook deposit does not produce a magnetic signature, even though pyrrhotite is present (quantitative details are not available). The deposit is crossed, virtually at right-angles, by three north-south flight lines, but inspection of the corresponding magnetic profiles reveals no distinct perturbations over the deposit. On one line there is a very broad anomaly of a few nT amplitude, but this cannot be assigned unequivocally to the sulphide body. The absence of magnetic expression may be explained by the narrowness of the body. The width attains a maximum of 23 m at the western end of the body, but elsewhere is less than half this value. The broad magnetic high that dominates the northern part of the map-area is resolved into a comparatively narrow feature on the vertical gradient map, which is closely associated with two narrow units of gabbro/diabase. Elsewhere, the magnetic field is relatively featureless, which is consistent with the ubiquitous distribution of felsic volcanic rocks that typically have low magnetic susceptibilities. Two small, yet noticeable, oval-shaped positive anomalies (~25 nT amplitude) occur within felsic volcanics near the southern margin of the map area, and several other small features are resolved on the vertical gradient map.

ELECTROMAGNETIC DATA

Although the Taylor Brook deposit has a strike length of about 650 m at the surface, it produces an EM response on only one flight-line 440940. This takes the form of a single peak anomaly which is located over the eastern part of the deposit. Since EM systems respond more strongly to massive sulphides, it suggests a possible local concentration of massive sulphides in this part of the deposit. At low frequencies the in-phase and quadrature coplanar EM responses are 15 ppm and 33 ppm, respectively. The coaxial responses are 6 ppm and 10 ppm. At mid frequencies the coplanar responses are both 56 ppm, and the coaxial responses are 23 ppm and 19 ppm. At high frequencies the responses are 176 ppm and 136 ppm. At low frequencies, calculated apparent conductivity is 15 mS/m on the coplanar coils and 20 mS/m on the coaxial coils. At mid frequencies the respective values are 21 mS/m and 25 mS/m. At high frequency the apparent conductivity is 6.5 mS/m. The observed EM anomaly can be modelled by a thin plate that has a strike length of 200 m and a depth-extent of 400 m. The plate has a dip of 45° and a strike angle of 55° relative to the flight-line. The interpreted conductivity-thickness product is 3S. Negative in-phase responses are observed over the thin band of gabbros located in the northern part of the map. The in-phase negative response observed on the flight-line west of line 440940 and of the conductivity anomaly corresponds to a small magnetic anomaly and could indicate a small lens of gabbro.

GRAVITY DATA

Gravity data for the map-area of the Taylor Brook deposit, distributed along four survey lines spaced 100 m apart, are provided courtesy of Stratabound Minerals Corporation. Measurements were made at intervals of 25 m. Coverage is restricted to the western end of the deposit. The gravity field is characterized mainly by a gradient across which the field decreases progressively from northeast to southwest. The gradient flattens out just north of the deposit, and gives way to a relatively broad gravity high that peaks in the area of a gabbro/diabase dyke. The relatively broad wavelength of the high suggests that a source other than the narrow dyke may be the principal cause of the high. The source of the gradient is not apparent in the surface geology, which is dominated by a variety of felsic and sedimentary rocks. The Taylor Brook deposit is reflected in the gravity map by an eastward deflection of contour lines, indicative of a local gravity high. Examination of gravity profiles along the survey lines reveals a distinct positive anomaly, 0.2 mGal amplitude, along the line closest to the geological section line A-A'. Along a line crossing near the western tip of the deposit, the amplitude is reduced to less than 0.1 mGal.

RADIOMETRIC DATA

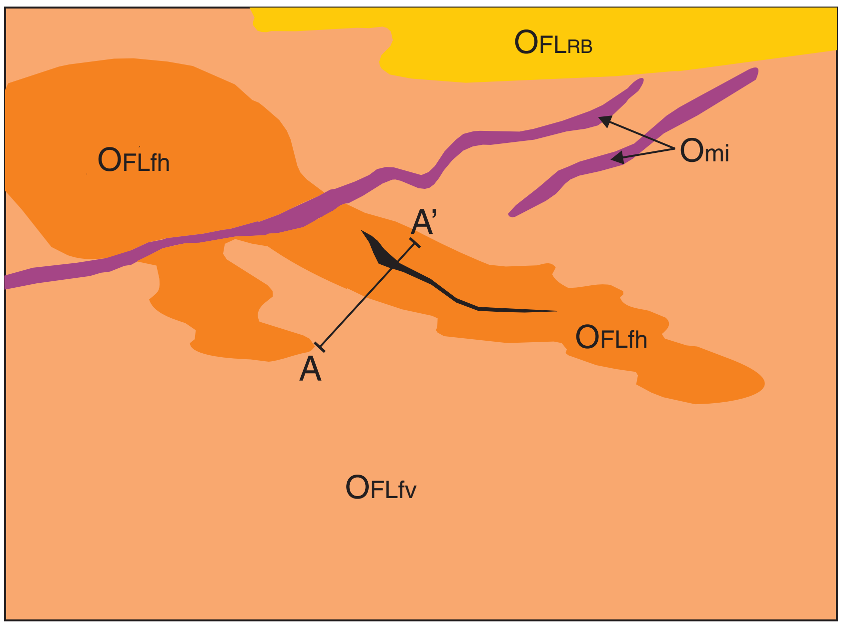
Elevated radioelement values in the area are associated with felsic volcanic units belonging to the Flat Landing Brook Formation. Areas characterized by low radioelement concentrations coincide with wet, swampy ground and water in the northeast and western portions of the map-area. Although not evident in the current geological mapping, subdivision of the more massive rhyolite units may be possible using the potassium and thorium patterns. No signatures are associated with the deposit or with the pyrite-sericite-chlorite footwall alteration.

SUMMARY

The best developed signature of the Taylor Brook deposit is the "bull's-eye" conductivity high that stands out in a relatively featureless background. Most of the anomaly covers ground to the south of the deposit, which is consistent with its moderate southward-directed dip. Positioning of the centre of the anomaly along the eastern part of the deposit indicates a concentration of massive sulphides in this area. A local gravity high provides a more subtle expression of the deposit in the form of a local bulging of contour lines over the western part of the deposit; this has an amplitude of about 0.2 mGal. No magnetic or radiometric signatures are observed.

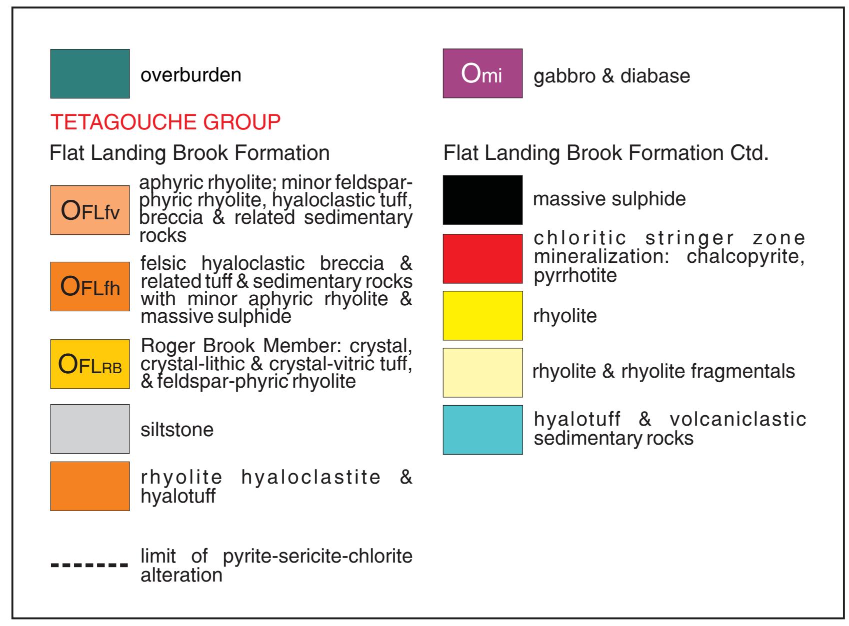
TAYLOR BROOK

GEOLOGY

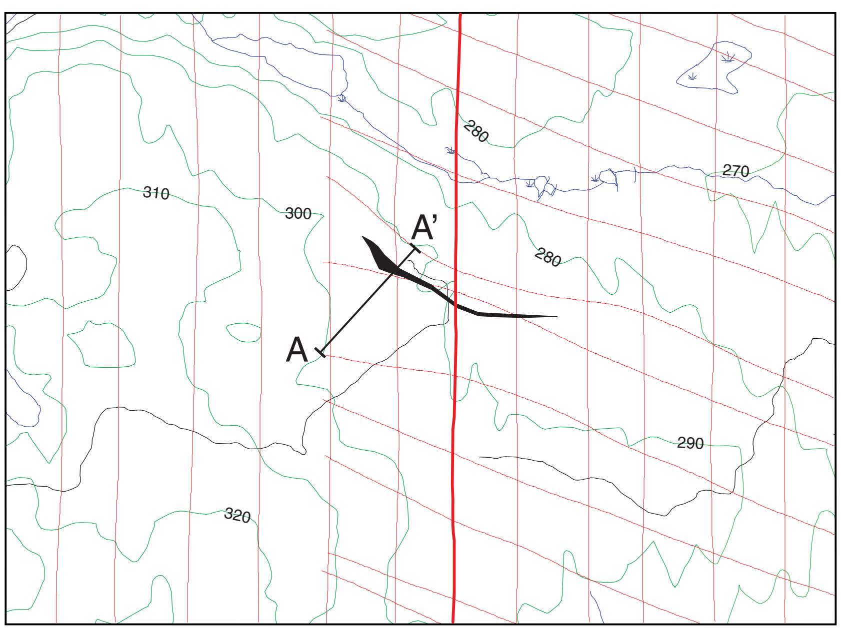


Modified from Wilson (1993c)

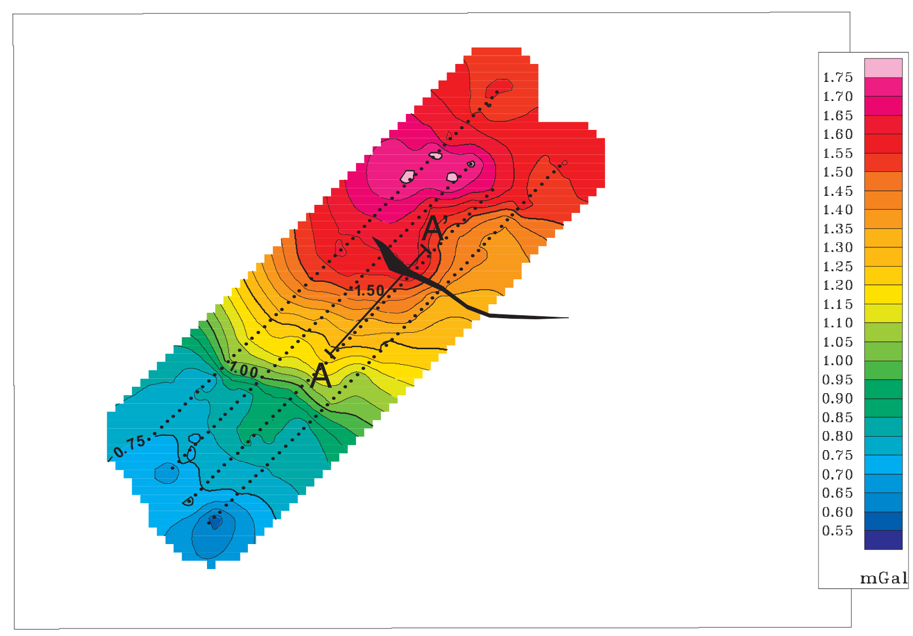
GEOLOGICAL LEGEND



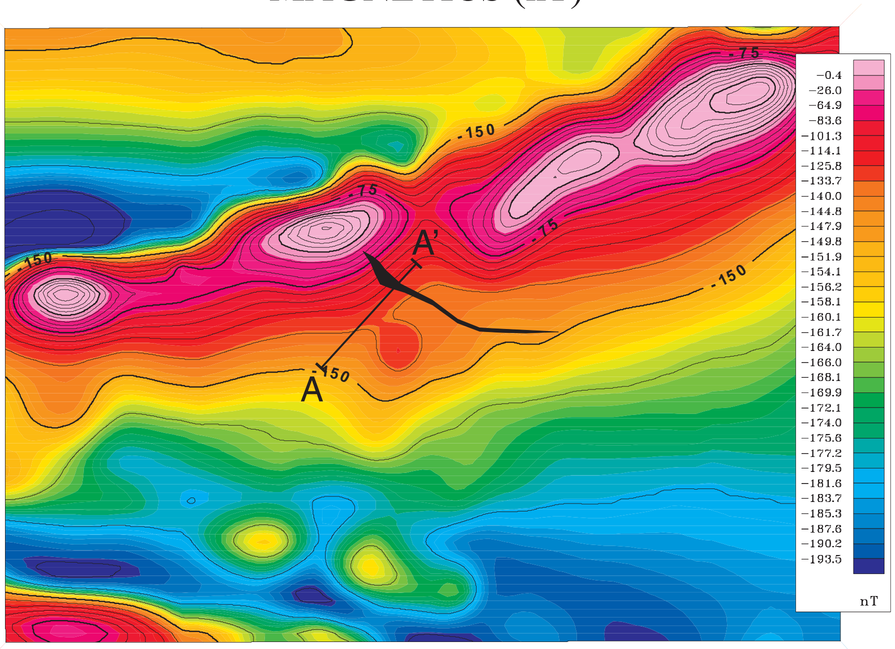
TOPOGRAPHY/FLIGHT LINES



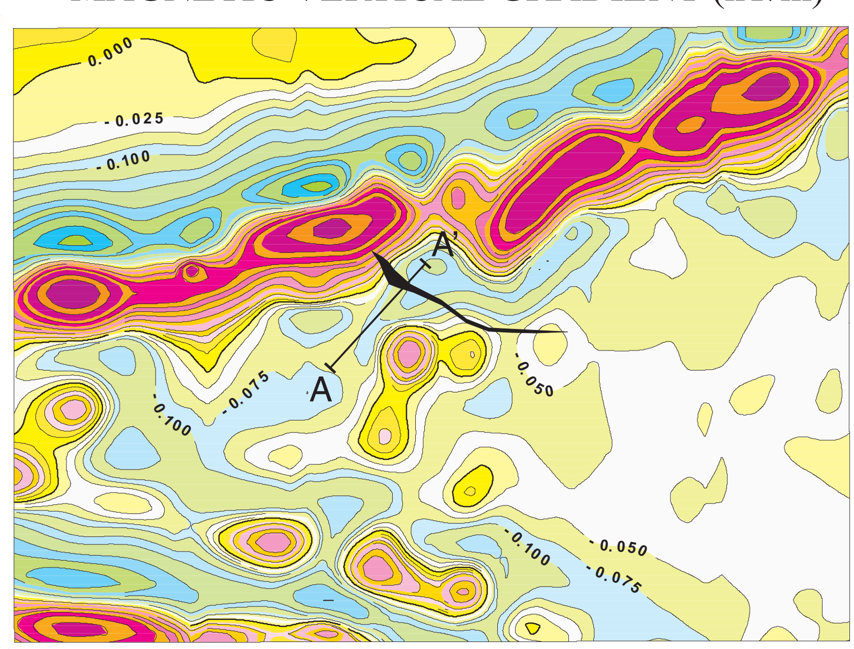
GRAVITY (mGal)



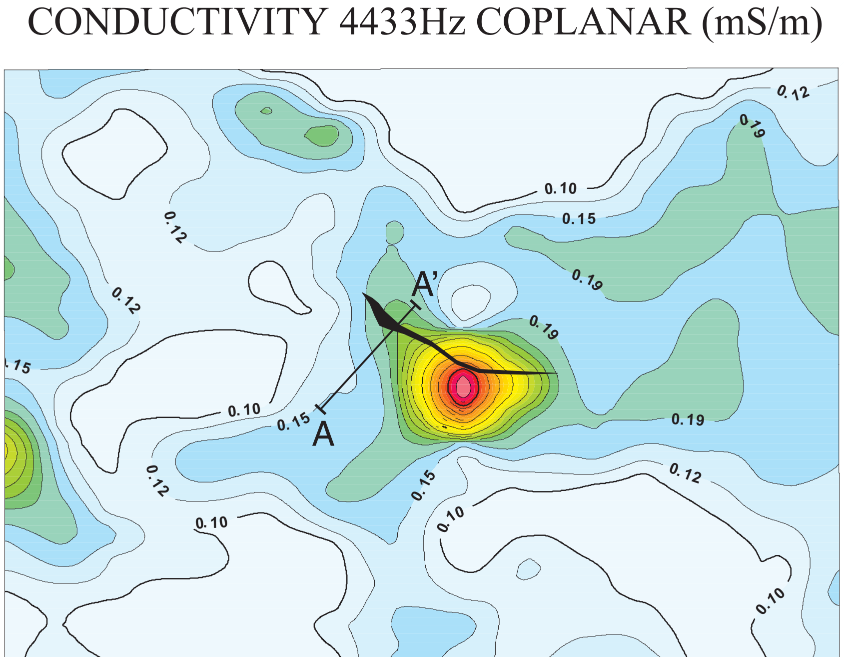
MAGNETICS (nT)



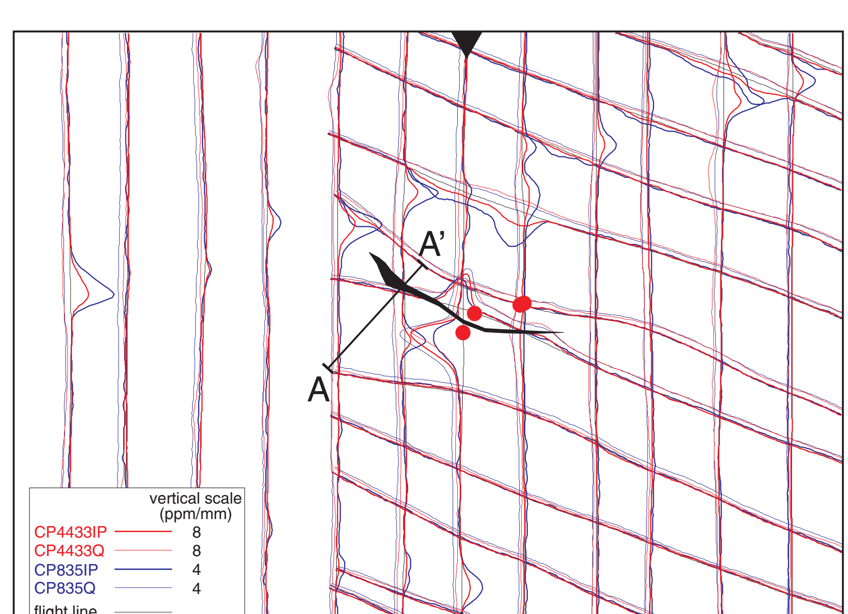
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



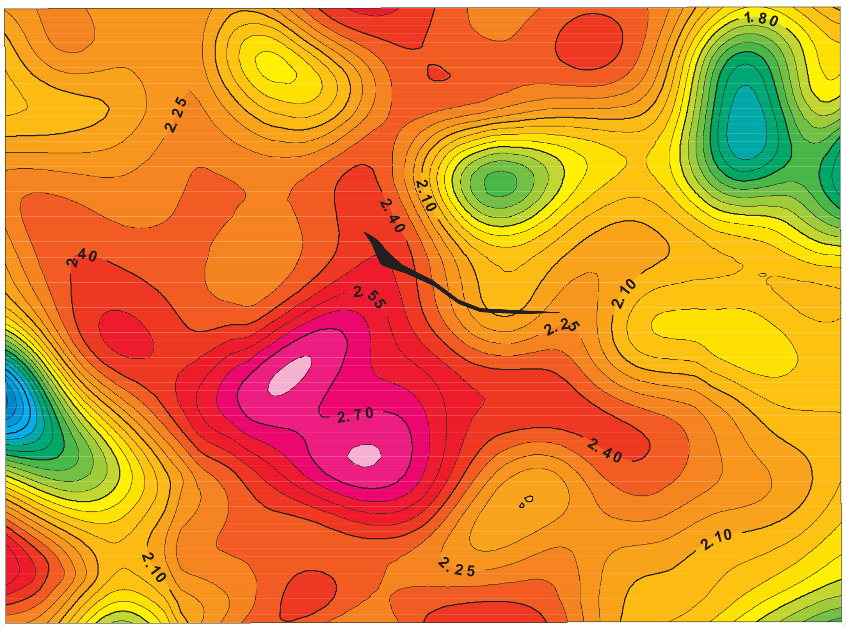
ELECTROMAGNETIC PROFILES/ANOMALIES



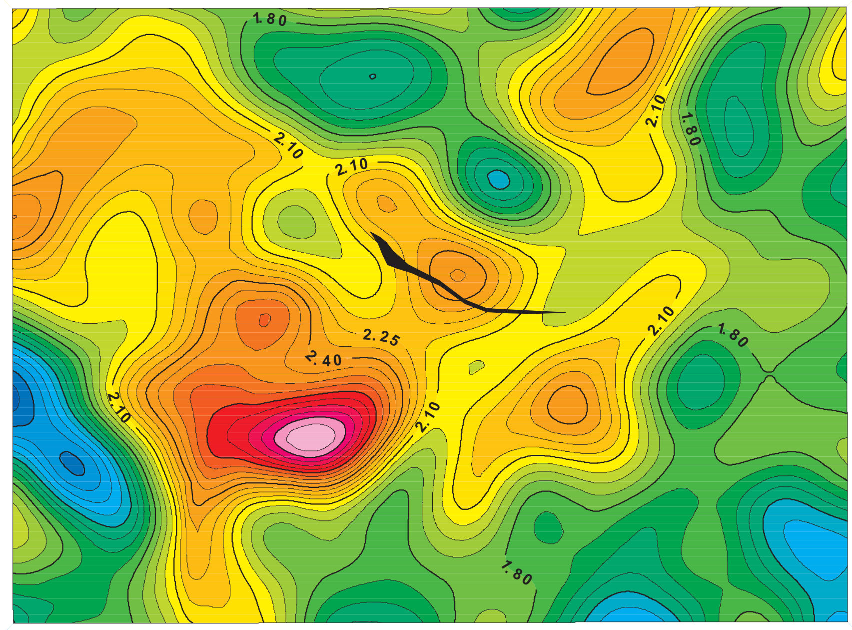
1000 m

TAYLOR BROOK

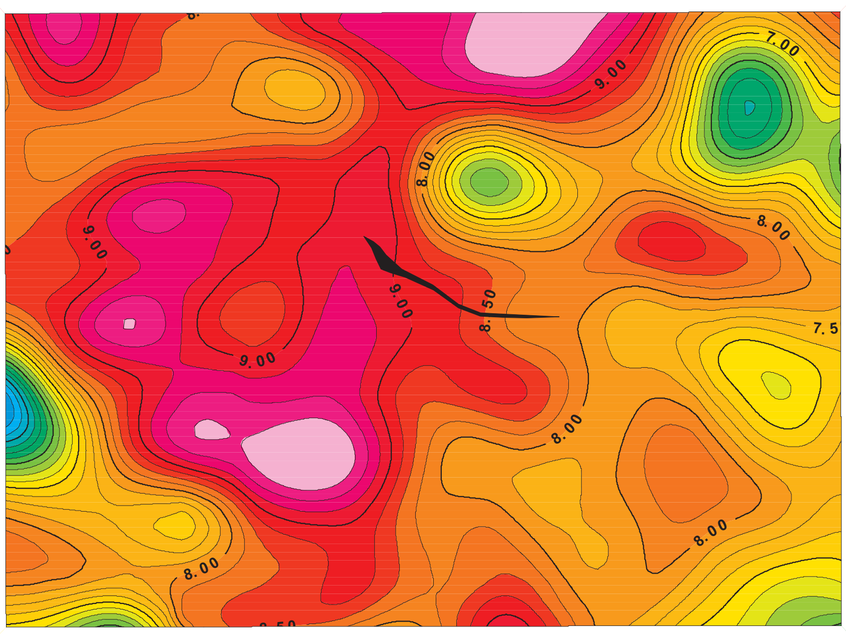
POTASSIUM (%)



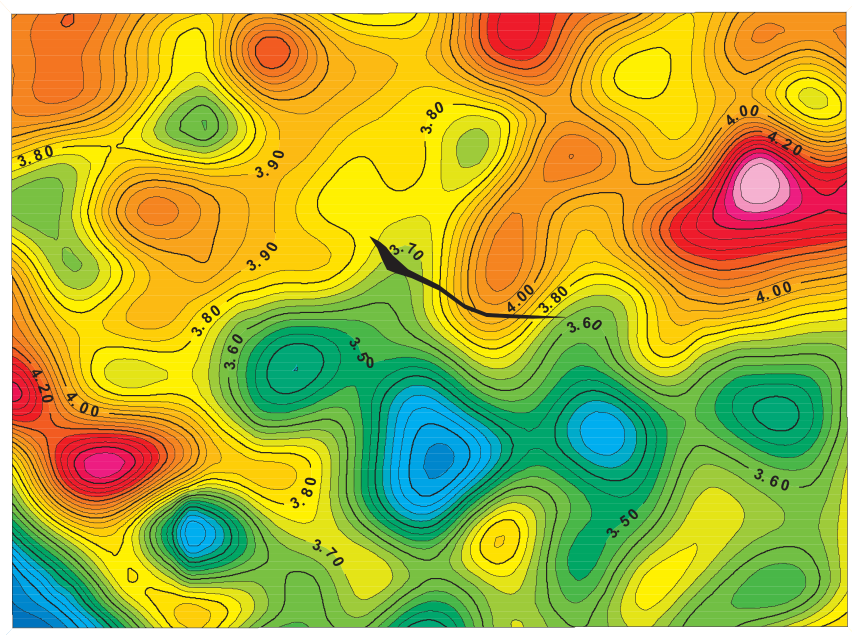
URANIUM (ppm)



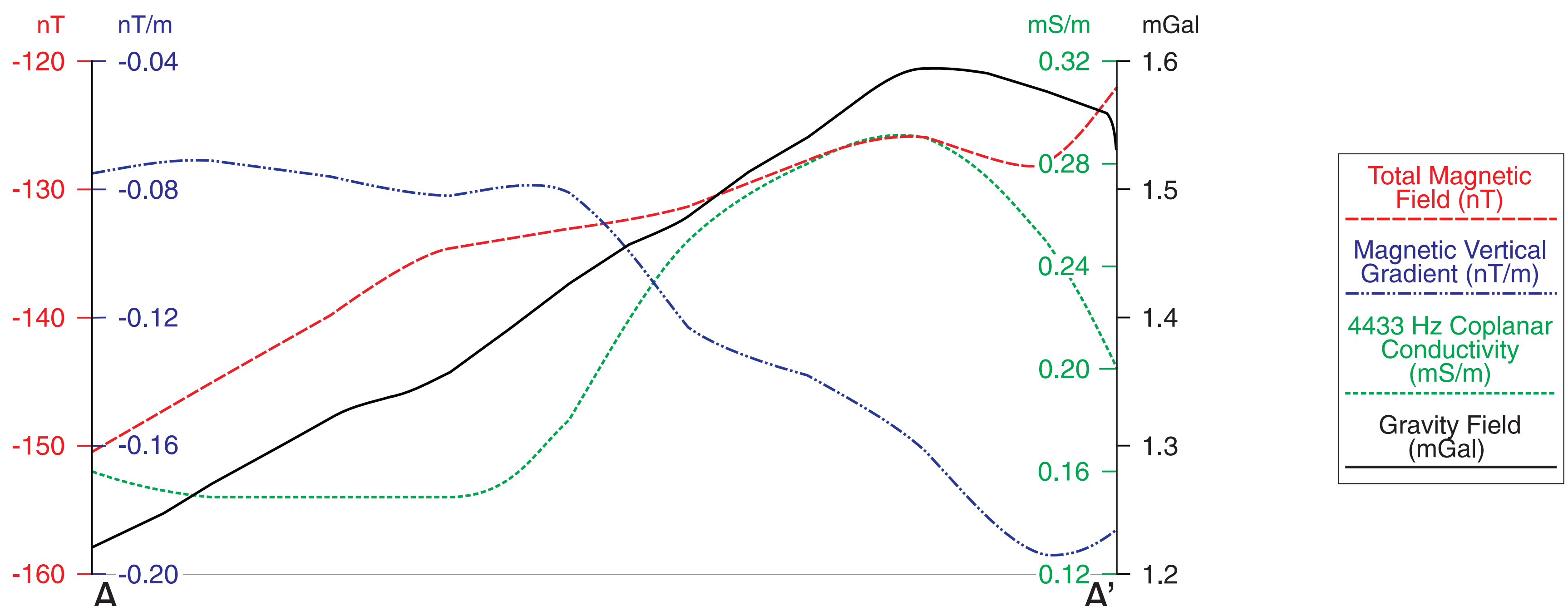
THORIUM (ppm)

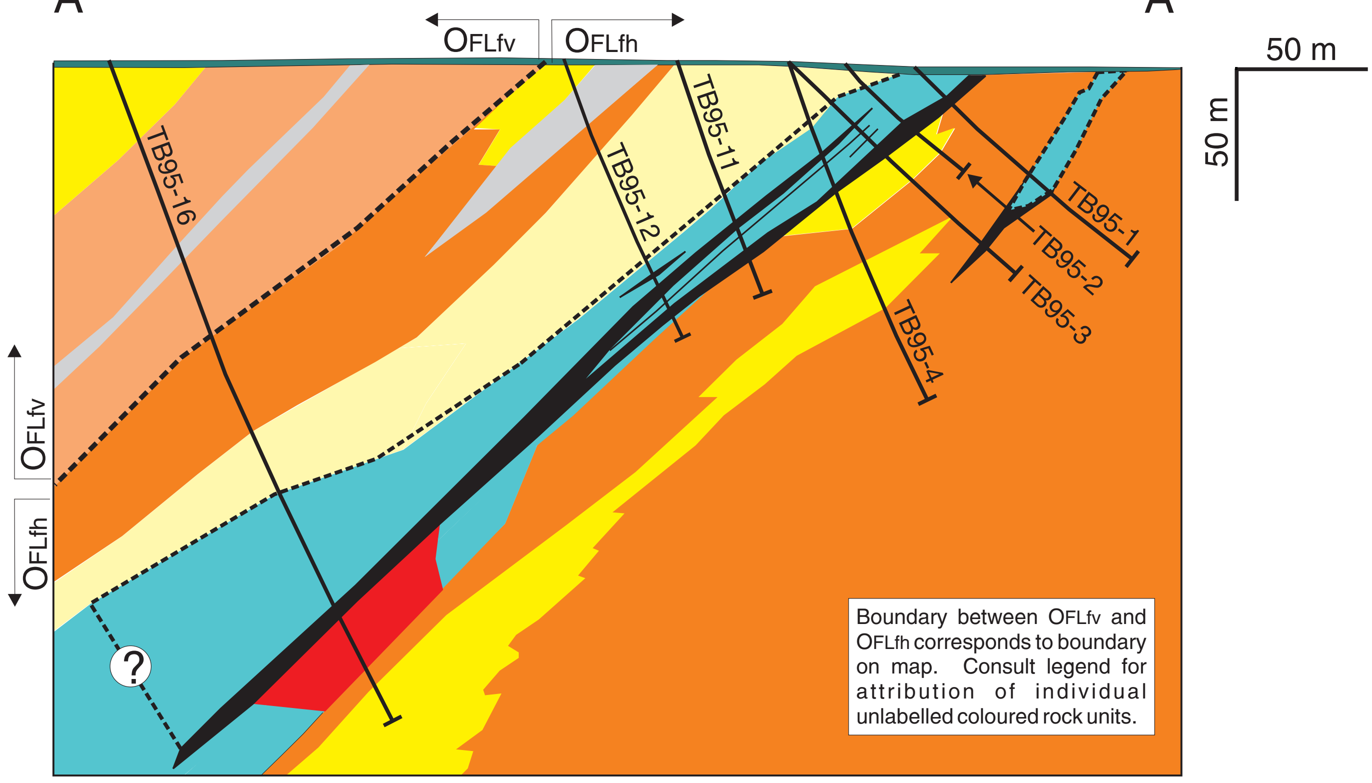


THORIUM/POTASSIUM RATIO (x 10^{-4})



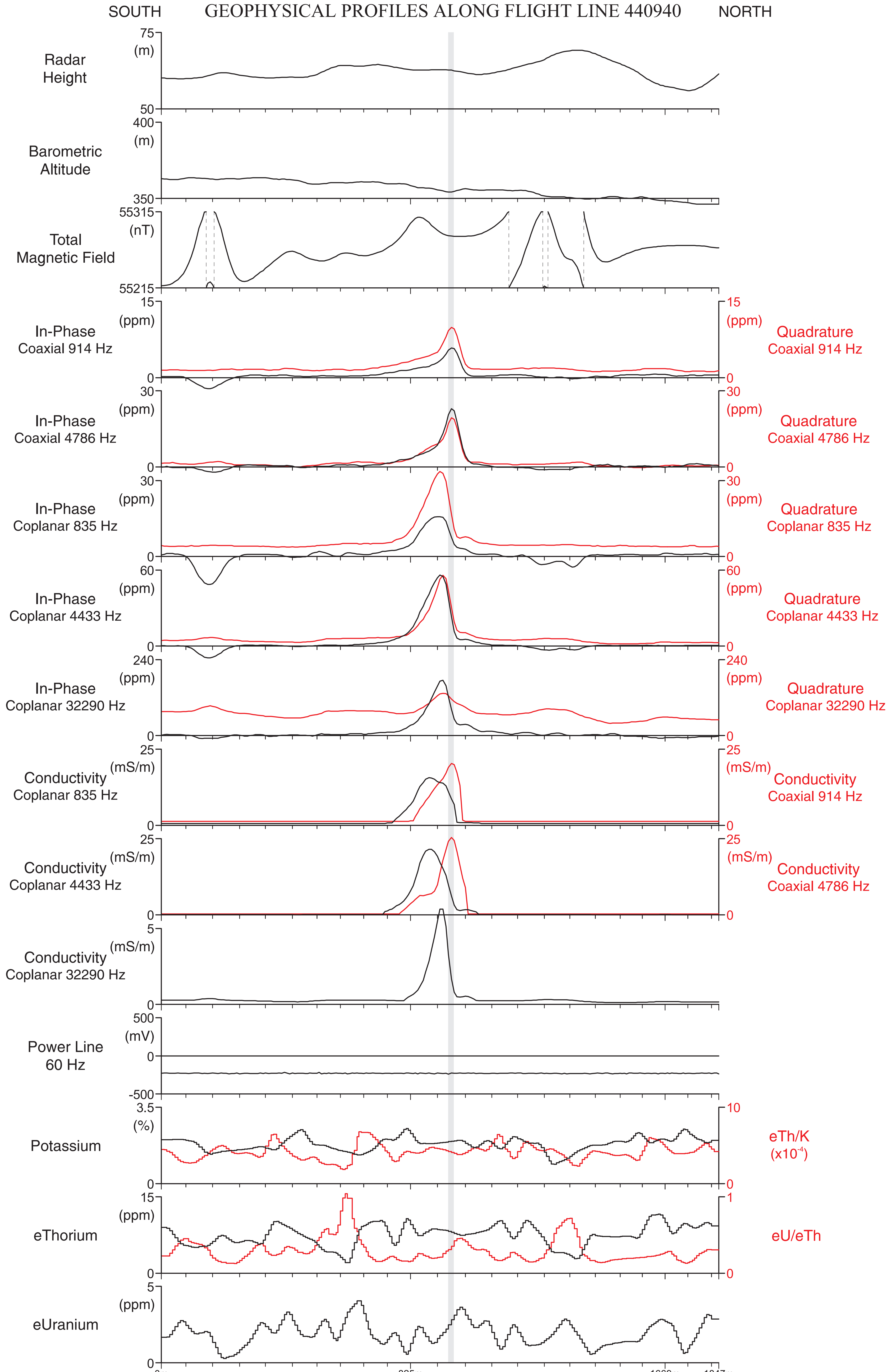
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'





Modified from Lutes (1996)

TAYLOR BROOK



WEDGE DEPOSIT

GEOLOGY

The Wedge deposit (mined between 1962 and 1968) occurs near the contact between felsic volcanic and sedimentary rocks that are thrust over a younger unit of interbedded sedimentary and mafic volcanic rocks. Following the discovery of a gossan outcrop in 1956, detection and subsequent drilling (total 6100 m) of a ground electromagnetic anomaly by Cominco resulted in the discovery of the deposit. During its lifetime the Wedge mine produced 1,503,000 tonnes grading 0.65% Pb, 1.6.% Zn, 2.88% Cu and 20.0 g/t Ag (Luff, 1995).

Massive sulphides occur at the top of the felsic volcanic-volcaniclastic sequence. Sulphide mineralogy is dominantly pyrite with lesser chalcopyrite. The sulphide lens strikes 075°, is 360 m long, 3 - 45 m in thickness and is continuous down dip for 150 m. In section the deposit is shaped like a fish-hook, and at surface is vertical to steeply-north-dipping. At 100 m depth the deposit flattens out, then dips steeply south (Douglas, 1965). Galena and sphalerite ± tennantite are minor components and were concentrated on the south side of the lens and in the east. The metal zonation in the sulphide lens, *i.e.*, Cu-rich in the north and Pb+Zn-rich in the south, coupled with chloritic alteration and pyrite stringer mineralization in the rocks to the north, confirm a southward younging direction.

The deepest part of the stratigraphic footwall sequence comprises aphyric to feldspar-phyric rhyolite with minor quartz-phyric rhyolite. These rocks are conformably overlain by, and in part interlayered with (in ascending order): (1) felsic tuffs, quartzose sandstone, thin feldspar-phyric sills/tuffs (?), (2) quartz-feldspar-phyric tuff, and (3) massive sulphides and graphitic shale; all of which are assigned to the Spruce Lake Formation. Shale, wacke and mafic volcanic rocks in the structural footwall are assigned to the Little River Formation. The tectonic contact between the ore horizon and the Little River Formation is marked by the development of a polylithic tectonic mélange, referred to as a "marker horizon" in mine terminology. The mélange is interpreted to be a D_1 thrust that appears to cut out part of the deposit. The sequence was subsequently folded by tight to isoclinal upright F_2 folds. A later D_2 thrust brings rocks of the Spruce Lake Formation over the mine sequence from the northeast. Late brittle faulting along the mélange adjacent to the sulphide lens has down-thrown the south side of the deposit.

MAGNETIC DATA

The Wedge deposit, apparently, is not expressed in the magnetic field, which is not surprising, since pyrrhotite is not reported. Sulphide mineralization is described as pyrite with associated chalcopyrite and minor sphalerite and galena (Douglas, 1965). Furthermore, associated iron formation is not developed. The map-area is dominated by felsic volcanic rocks that include rhyolite and tuff, which typically have very low magnetic susceptibilities. Consequently, it is somewhat unexpected to observe several conspicuous magnetic highs in the area, whose sources are not readily evident. Possible exceptions are a roughly circular anomaly in the southwest that may be linked with a mafic intrusion (Omi), and a small region of positive anomaly (more obvious on the vertical gradient map) centred about 300 m south-southeast of the deposit that touches on a small development of basalt, a potential source. The Wedge deposit sits near the southern edge of a curvilinear belt of positive anomalies that follows the trend of a thrust. This belt tends to be centred along a unit of interbedded felsic ash tuffs and epiclastic rocks, though its margins migrate into adjacent tectonic mélange established in sedimentary rocks to the south, and felsic volcanics to the north. Of possible interest for exploration are two oval-shaped magnetic highs about 800 m northwest of the Wedge deposit. These are the most intense anomalies (~100 nT and ~40 nT) in the map area, one of them sitting on tectonic mélange in similar fashion to the Wedge deposit. However, the absence of coincident conductivity anomalies makes them less attractive targets for exploration.

ELECTROMAGNETIC DATA

The Wedge deposit produces a strong HEM anomaly on flight-line 440491 and also on the adjacent flight-lines. The anomalies are broad and strong. At low frequencies the in-phase and quadrature coplanar responses are 176 ppm and 244 ppm, respectively, and the corresponding co-axial responses are 39 ppm and 52 ppm. At mid frequencies the in-phase and quadrature coplanar responses are 472 ppm and 344 ppm, and the co-axial responses are 124 ppm and 106 ppm. At high frequency the responses are, respectively, 1152 ppm and 608 ppm. The anomalies are wide, more than 100 m, indicating a thick conductor. This is consistent with the 25 m thickness of the sulphide deposit observed at ground surface. The apparent conductivity calculated from the mid-frequency coplanar coils is 112 mS/m. The apparent conductivity anomaly extending to the west and southeast of the deposit is attributed to the grey and black shale and wacke of the Little River Formation. The central part of the conductivity anomaly is associated with the presence of massive sulphides. The deposit was mined between 1962 and 1968 and part of the EM response could be due to tailings.

GRAVITY DATA

Gravity data for this deposit are unavailable.

RADIOMETRIC DATA

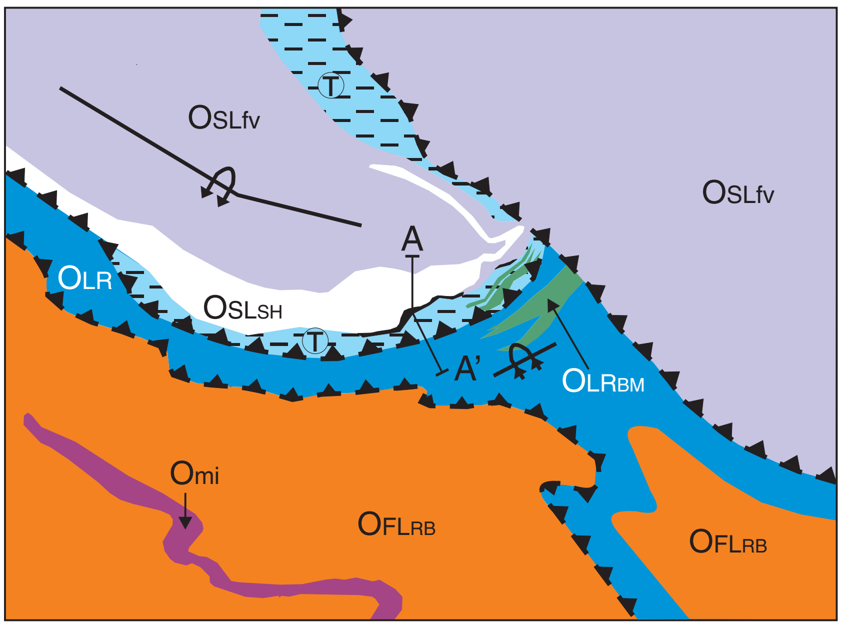
Radioelement patterns generally allow distinction between the Spruce Lake and Flat Landing Brook formations. Potassium and eTh concentrations are highest (2.75% and 11.25 ppm) about 900 m north-northwest of the deposit, over rhyolitic rocks within the Spruce Lake Formation. Low K is associated with wet, swampy ground east and northeast of the deposit. South of the Nepisiquit River, K concentrations associated with the thick sequence of pyroclastic rocks of the Roger Brook Member of the Flat Landing Brook Formation range between 1.13 and 2.7%. The lower range of K values is unexpected given the felsic volcanic geology, and defines a trend that crosses both stratigraphy and topography, with associated low eU and eTh. This reflects either variation in surficial geology or unmapped bedrock units. A discrete eTh/K anomaly 200 m north of the deposit is associated with decreasing K concentrations, near the contact between rhyolitic rocks and felsic ash tuffs and epiclastic rocks of the Shellalah Hill Brook Member. The Shellalah Hill Brook Member hosts stringer mineralization in the footwall of the deposit, suggesting an association between hydrothermal alteration and depleted K concentrations, as noted by Lentz (1994) at the Brunswick No. 6 deposit. Similar, low K, high eTh and eTh/K anomalies occur east and northeast of the deposit. Further work is required to determine if these are related to normal lithological variations or alteration. Within the map area, eU concentrations are highest (2.0 - 3.7 ppm) over the Spruce Lake Formation and somewhat lower (1.8 - 2.2 ppm) over felsic volcanic units within Flat Landing Brook Formation. No anomalies related to variations in the degree of bedrock exposure are apparent around the deposit.

SUMMARY

The sole geophysical signature of the Wedge deposit is a strong, elongate oval-shaped conductivity anomaly, the deposit itself lying slightly off-peak. The anomaly peaks within adjacent tectonic mélange developed in graphitic shale and wacke of the Spruce Lake Formation and grey and black shale and wacke of the Little River Formation. A contribution to the anomaly is probably also provided by rock waste piles from mining operations. The deposit, apparently, is not associated with a radiometric signature or with a magnetic signature, though it sits on the southern flank of a strong, elongate magnetic high. A prominent eTh/K anomaly associated with relatively low K concentrations north of the deposit may indicate footwall alteration. Gravity data are unavailable.

WEDGE

GEOLOGY



Modified from Walker and McCutcheon (1996)

GEOLOGICAL LEGEND

- Omi — mafic intrusion

TETAGOUCHE GROUP

Flat Landing Brook Formation

- OFLRB — Roger Brook Member: greyish green pyroclastic rocks, including: crystal, crystal-lithic & vitric tuff, & minor rhyolite

Little River Formation

- OLR — grey to black shale & wacke
- OLRBM — Brunswick Mines Member: massive to amygdaloidal basalt

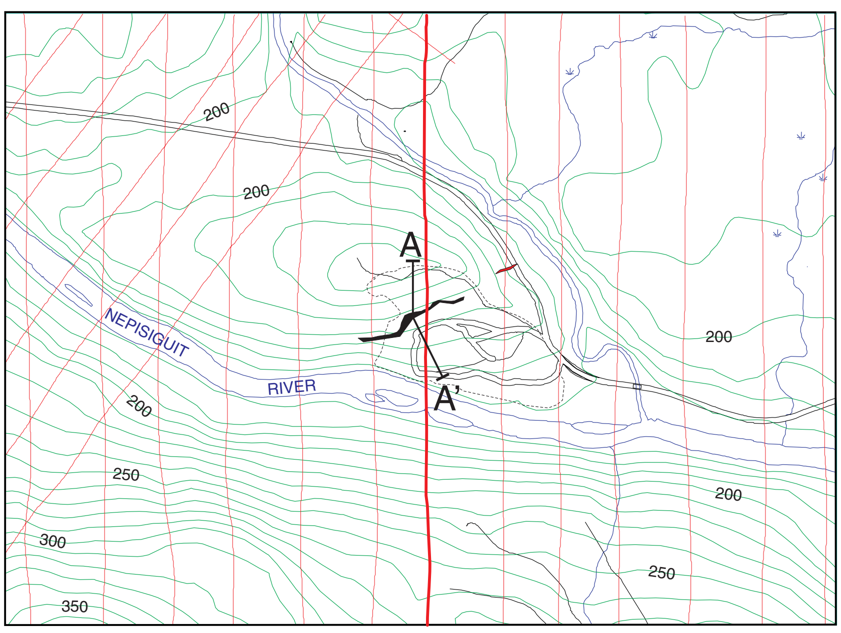
CALIFORNIA LAKE GROUP

Spruce Lake Formation

- OSLfv — fine- to coarse-grained, feldspar-phyric rhyolite & aphyric to fine-grained feldspar-phyric rhyolite
- graphitic shale & minor wacke
- OSLSH — Shellalah Hill Brook Member: felsic ash tuff & interbedded epiclastic rocks including quartz-feldspar-phyric rocks
- OSLqfp — quartz-feldspar-phyric rocks
- massive sulphide

- overturned synform
- overturned antiform
- T — tectonic mélange
- normal fault
- thrust fault

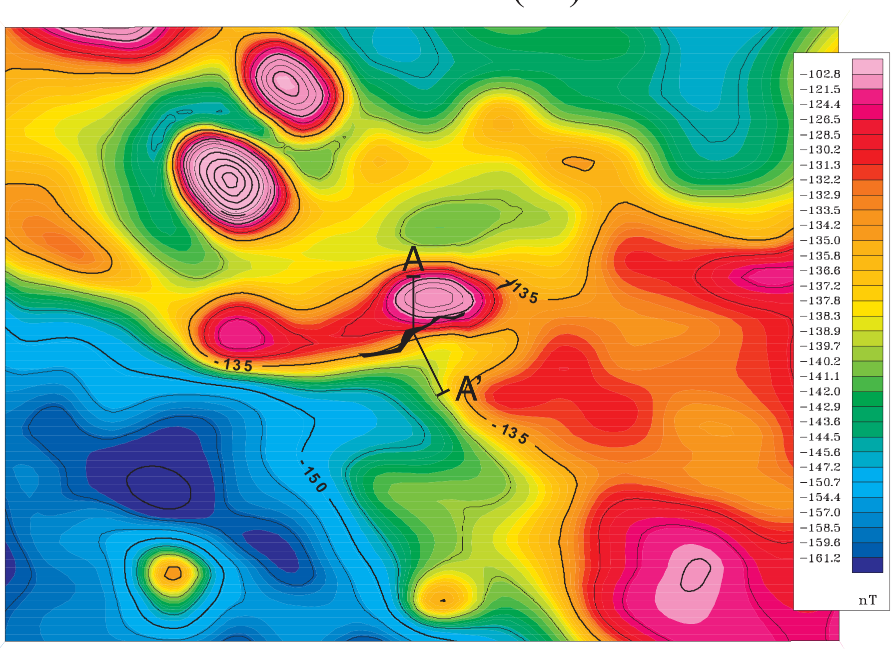
TOPOGRAPHY/FLIGHT LINES



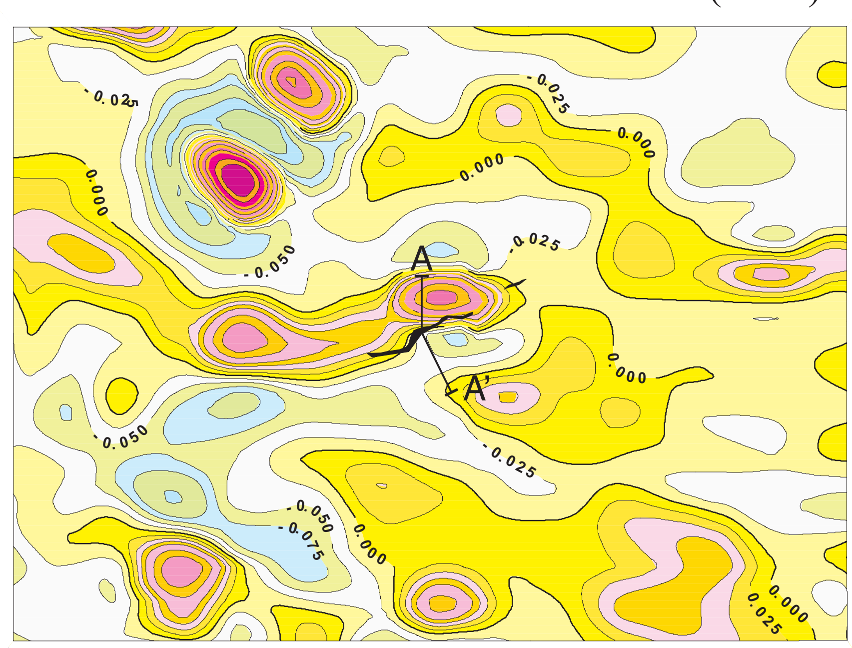
GRAVITY (mGal)

GRAVITY DATA ARE UNAVAILABLE

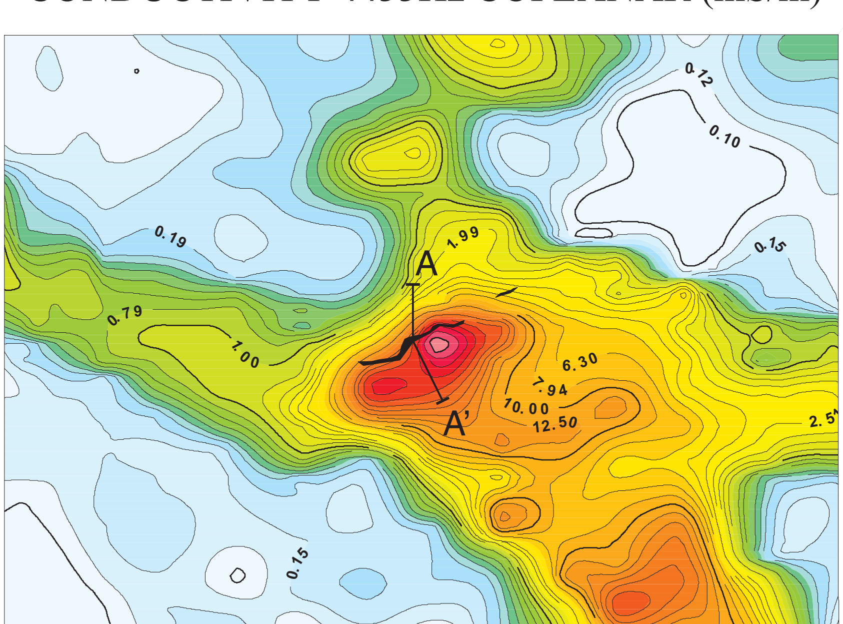
MAGNETICS (nT)



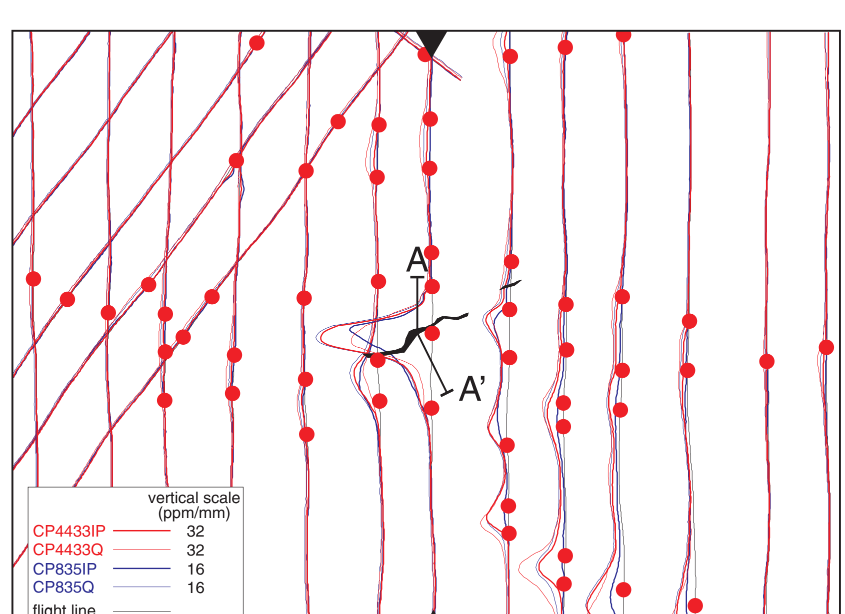
MAGNETIC VERTICAL GRADIENT (nT/m)



CONDUCTIVITY 4433Hz COPLANAR (mS/m)



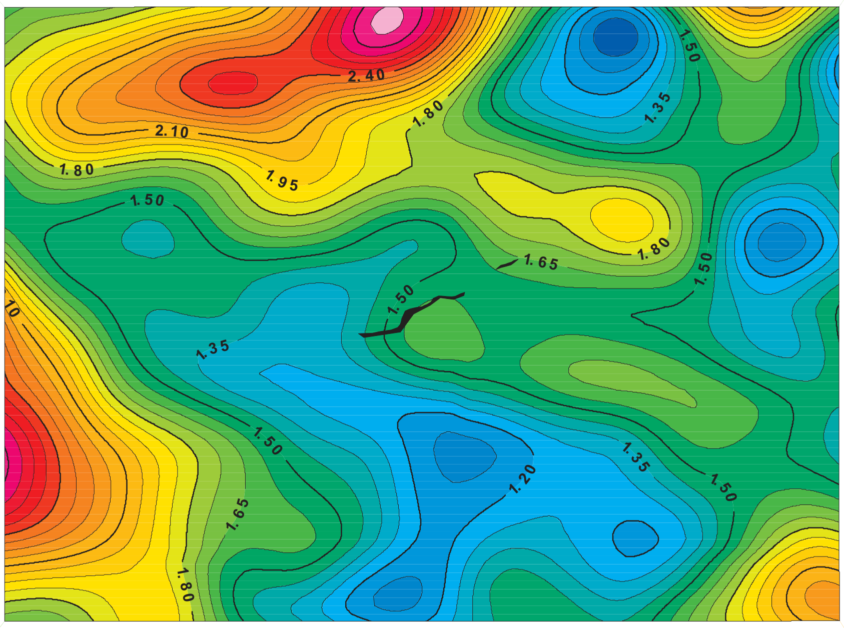
ELECTROMAGNETIC PROFILES/ANOMALIES



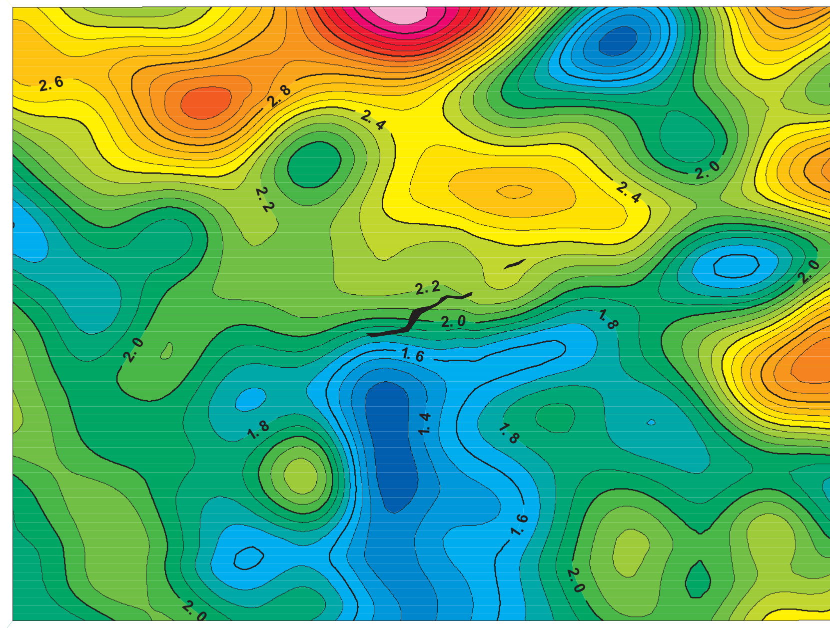
1000 m

WEDGE

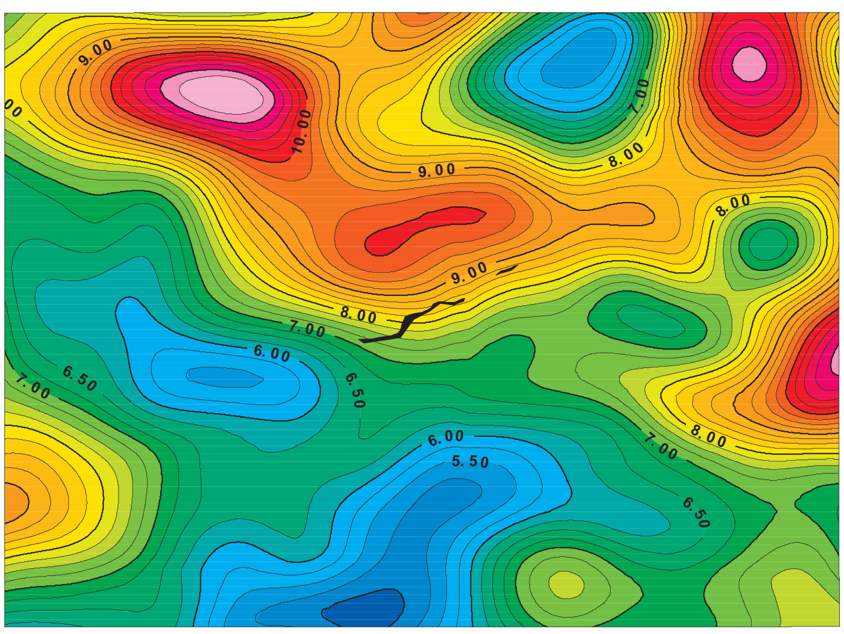
POTASSIUM (%)



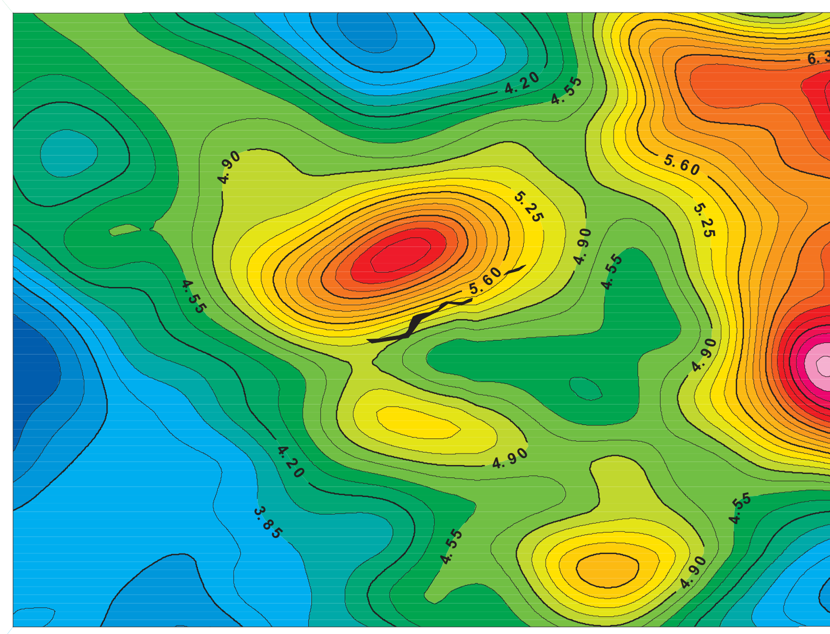
URANIUM (ppm)



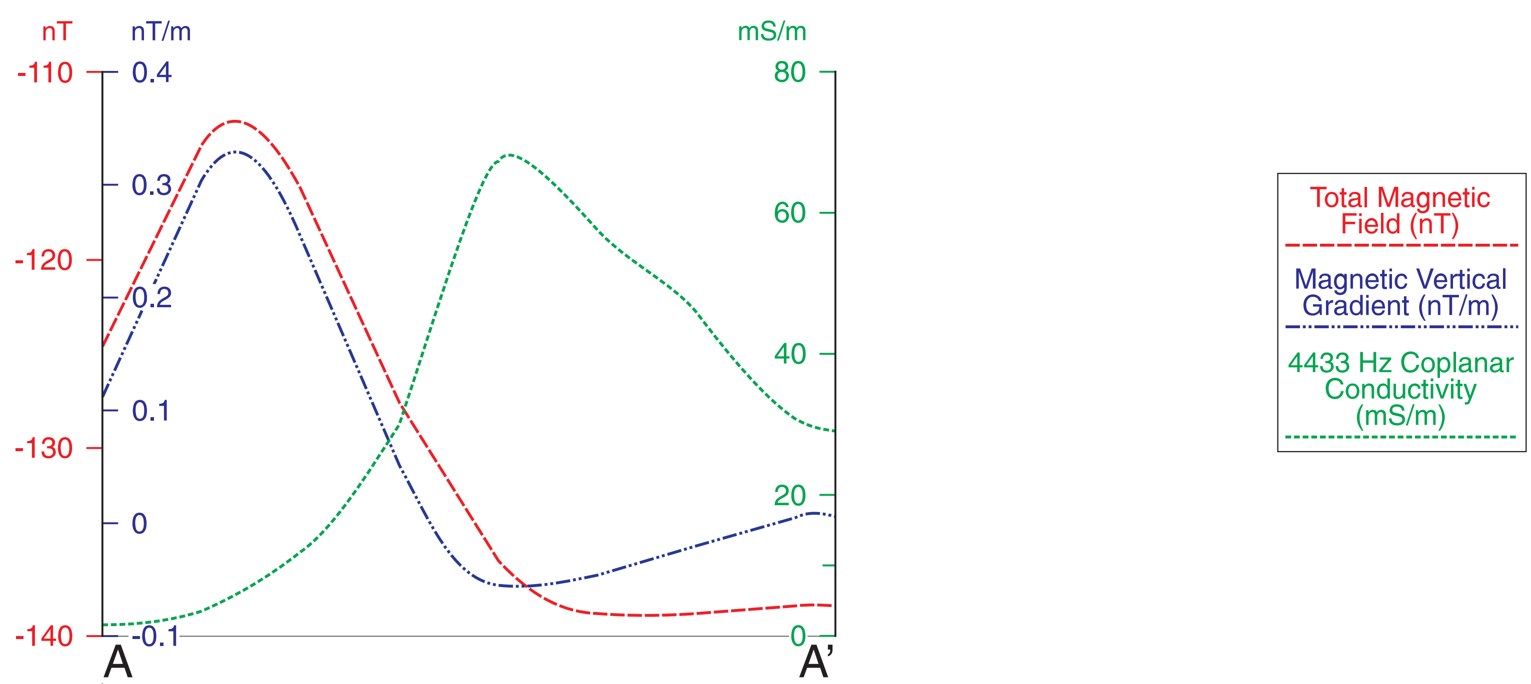
THORIUM (ppm)

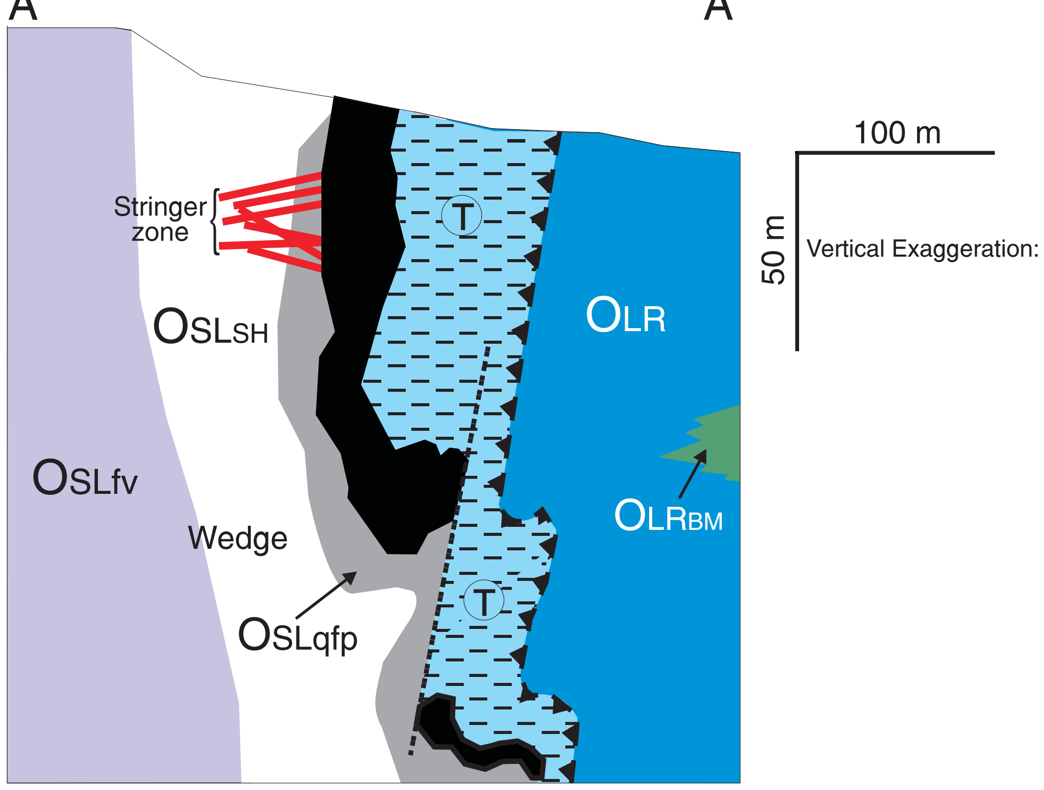


THORIUM/POTASSIUM RATIO (x 10^{-4})



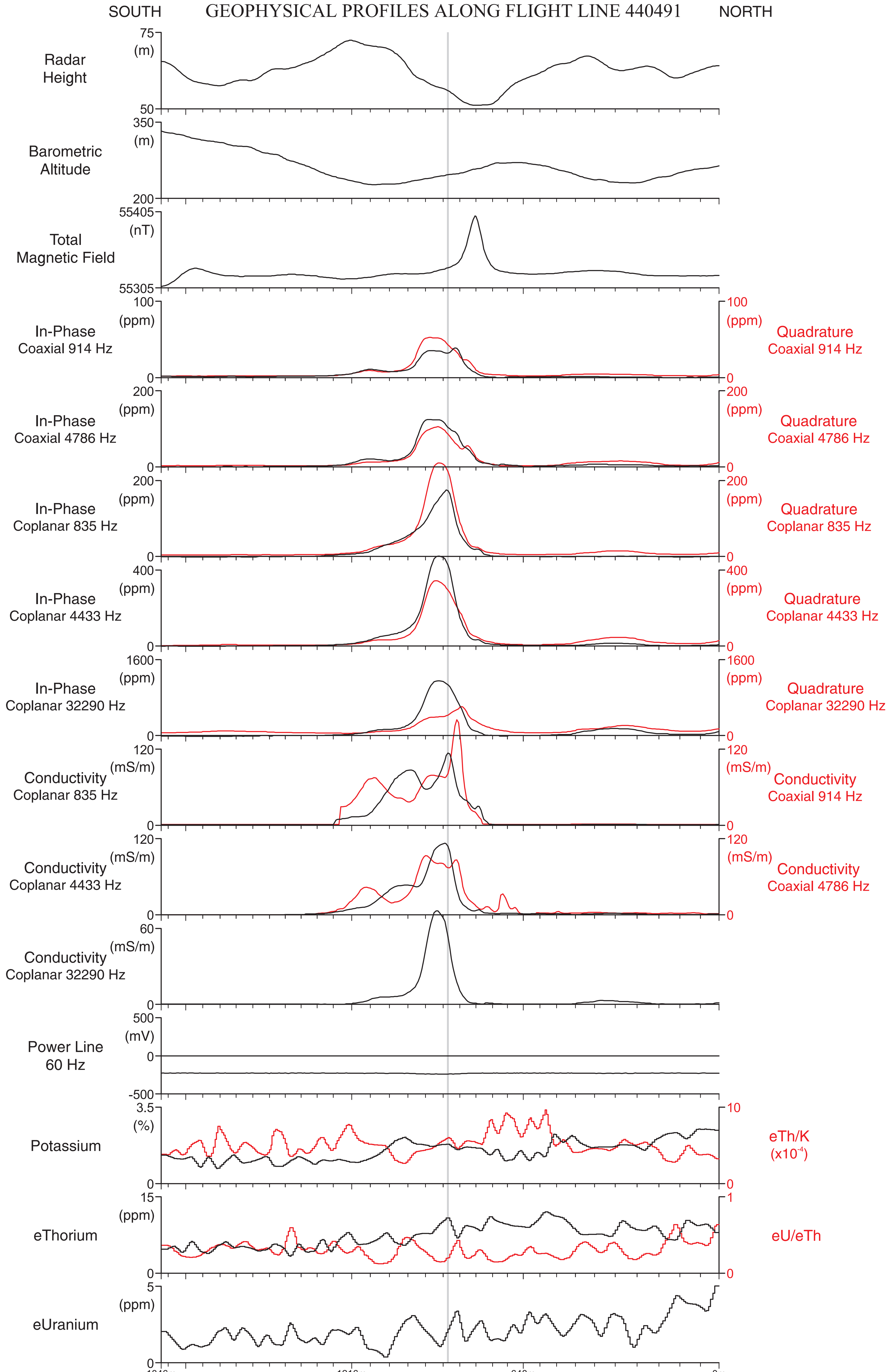
GEOPHYSICAL PROFILES ALONG GEOLOGICAL SECTION A-A'





Modified from Douglas (1965) and Walker and McCutcheon (1996)

WEDGE


SOUTH
GEOPHYSICAL PROFILES ALONG FLIGHT LINE 440491
NORTH
Radar Height
75
(m)
50
Barometric Altitude
350
(m)
200
Total Magnetic Field
55405
(nT)
55305
In-Phase Coaxial 914 Hz
100
(ppm)
0
Quadrature Coaxial 914 Hz
In-Phase Coaxial 4786 Hz
200
Quadrature Coaxial 4786 Hz
In-Phase Coplanar 835 Hz
Quadrature Coplanar 835 Hz
In-Phase Coplanar 4433 Hz
400
Quadrature Coplanar 4433 Hz
In-Phase Coplanar 32290 Hz
1600
Quadrature Coplanar 32290 Hz
Conductivity Coplanar 835 Hz
120
(mS/m)
Conductivity Coaxial 914 Hz
Conductivity Coplanar 4433 Hz
Conductivity Coaxial 4786 Hz
Conductivity Coplanar 32290 Hz
60
Power Line 60 Hz
500
(mV)
-500
Potassium
3.5
(%)
10
eTh/K
(x10-4)
eThorium
15
(ppm)
1
eU/eTh
eUranium
5
1846m
1216m
648m
0m

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Appendix 1: List of Open File Geophysical Maps Produced from the Extech-II Airborne Survey

BATHURST AREA Multiparameter Airborne Geophysical Survey Data Release	G.S.C. Open File 3294 Map Scale: 1:50 000					G.S.C. Open File 3347 Map Scale: 1:50 000							
	Apparent Conductivity	Magnetic Anomaly (Residual Total Field)	Ternary Radioelement	Equivalent Th/K	Potassium	Equivalent Uranium	Equivalent Thorium	Equivalent Uranium/Thorium	Equivalent Uranium/Potassium	Air Absorbed Dose Rate	EM In-Phase Quadrature Profile	Apparent Conductivity	Magnetic Vertical Gradient
Big Bald Mountain (21 O/01)	96-5A	96-5B	96-5C	96-5D	96-5E	96-5F	96-5G	96-5H	96-5I	96-5J	96-5K	96-5L	96-5M
Serpentine Lake (21 O/02)	96-6A	96-6B	96-6C	96-6D	96-6E	96-6F	96-6G	96-6H	96-6I	96-6J	96-6K	96-6L	96-6M
Nepisiguit Lakes (21 O/07)	96-7A	96-7B	96-7C	96-7D	96-7E	96-7F	96-7G	96-7H	96-7I	96-7J	96-7K	96-7L	96-7M
California Lake (21 O/08)	96-8A	96-8B	96-8C	96-8D	96-8E	96-8F	96-8G	96-8H	96-8I	96-8J	96-8K	96-8L	96-8M
Tetagouche Lakes (21 O/09)	96-9A	96-9B	96-9C	96-9D	96-9E	96-9F	96-9G	96-9H	96-9I	96-9J	96-9K	96-9L	96-9M
Upsalquitch Lakes (21 O/10)	96-10A	96-10B	96-10C	96-10D	96-10E	96-10F	96-10G	96-10H	96-10I	96-10J	96-10K	96-10L	96-10M
Sevogle (21 P/04)	96-11A	96-11B	96-11C	96-11D	96-11E	96-11F	96-11G	96-11H	96-11I	96-11J	96-11K	96-11L	96-11M
Nepisiguit Falls (21 P/05)	96-12A	96-12B	96-12C	96-12D	96-12E	96-12F	96-12G	96-12H	96-12I	96-12J	96-12K	96-12L	96-12M
Bathurst (21 P/12)	96-13A	96-13B	96-13C	96-13D	96-13E	96-13F	96-13G	96-13H	96-13I	96-13J	96-13K	96-13L	96-13M

BATHURST AREA Multiparameter Airborne Geophysical Survey Data Release	G.S.C. Open File 3294 Map Scale 1:20 000	
	Conductors & Apparent Conductivity	Aeromagnetic Total Field
21 O/01 a,b	96-14A	96-14B
21 O/01 c,d	96-15A	96-15B
21 O/01 e,f	96-16A	96-16B
21 O/01 g,h	96-17A	96-17B
21 O/02 g,h	96-18A	96-18B
21 O/07 a,b	96-19A	96-19B
21 O/07 g,h	96-20A	96-20B
21 O/08 a,b	96-21A	96-21B
21 O/08 c,d	96-22A	96-22B
21 O/08 e,f	96-23A	96-23B
21 O/08 g,h	96-24A	96-24B
21 O/09 a,b	96-25A	96-25B
21 O/09 c,d	96-26A	96-26B
21 O/09 e,f	96-27A	96-27B
21 O/09 g,h	96-28A	96-28B
21 O/10 a,b	96-29A	96-29B
21 P/04 c,d	96-30A	96-30B
21 P/04 e,f	96-31A	96-31B
21 P/05 a,b	96-32A	96-32B
21 P/05 c,d	96-33A	96-33B
21 P/05 e,f	96-34A	96-34B
21 P/05 g,h	96-35A	96-35B
21 P/12 a,b	96-36A	96-36B
21 P/12 c,d	96-37A	96-37B
21 P/12 e,f	96-38A	96-38B

Copies of these maps may be obtained by contacting the Geophysical Data Centre, Geological Survey of Canada, 615 Booth Street, Ottawa, Ontario, K1A 0E9 or the New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, P.O. Box 6000, Fredericton, New Brunswick, E3B 5H1, or from the NBDNR&E regional office, P.O. Box 50, 495 Riverside Drive, Bathurst, New Brunswick, E2A 3Z1.

The geophysical data used to compile these maps are available in digital form from the Geophysical Data Centre, Geological Survey of Canada, or from the New Brunswick Department of Natural Resources and Energy in Fredericton.