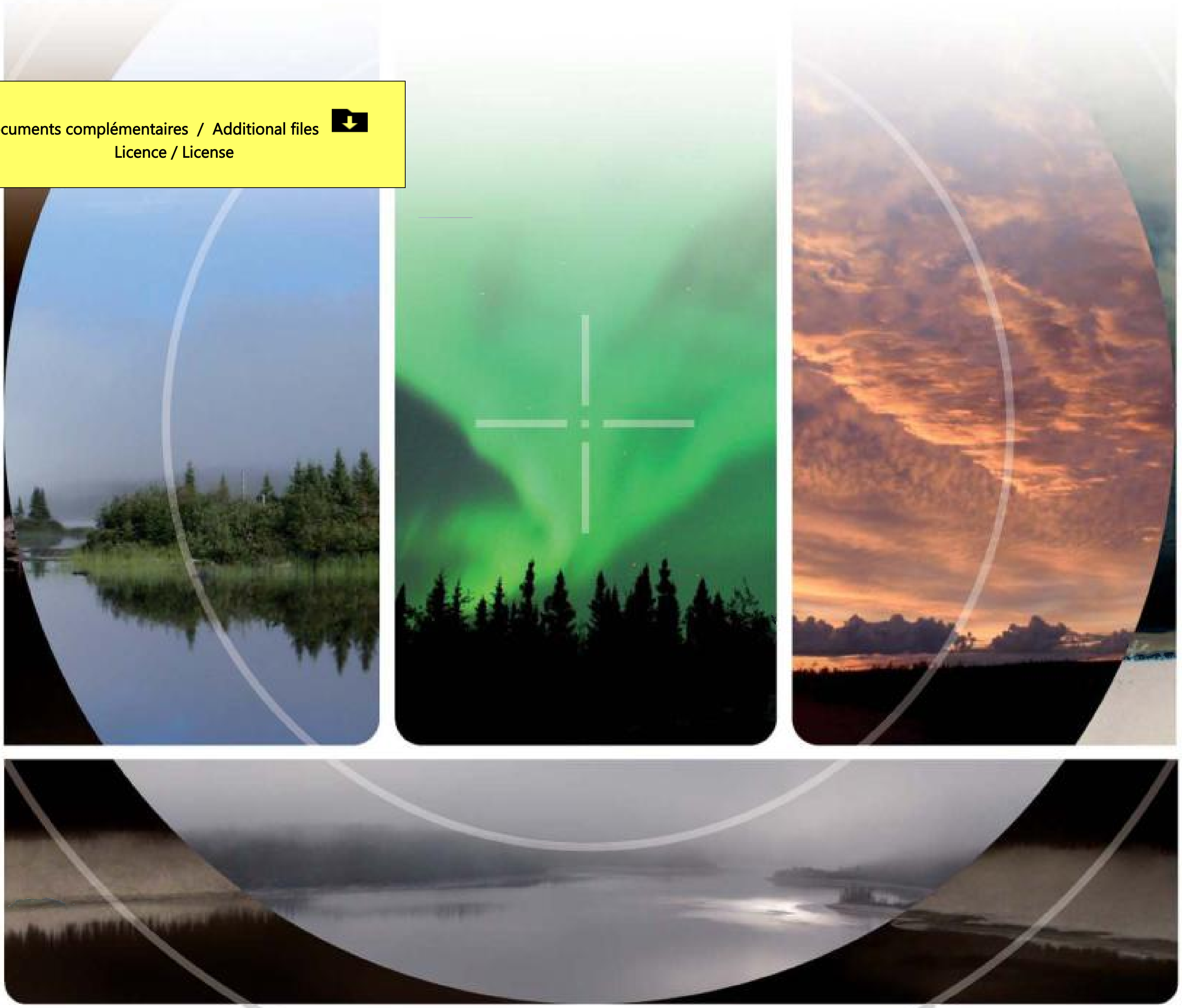
# QUALITATIVE INTERPRETATION OF AEROMAGNETIC AND SPECTROMETRIC DATA FROM THE RIVIÈRE ARNAUD AND RIVIÈRE LAFLAU AREAS, WEST COAST OF UNGAVA BAY

Siham Benahmed, Carl Bilodeau and Rachid Intissar (MERN)





PRO 2016-02

# Qualitative interpretation of aeromagnetic and spectrometric data from the Rivière Arnaud and Rivière Laflau areas, west coast of Ungava Bay

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## Introduction

In the summer of 2015, Géologie Québec conducted two new contiguous geophysical surveys in the Far North region of Québec to identify favourable strategic areas for mineral exploration (Intissar and Benahmed, 2016; Benahmed and Intissar, 2015). These aeromagnetic and gamma-ray spectrometer surveys were conducted over the Rivière Arnaud and Rivière Laflau regions and the coastal areas of Ungava Bay and Hudson Strait. They cover, in whole or in part, 42 NTS map sheets at a scale of 1:50,000, corresponding to a total surface area of roughly 22,000 km$^2$. The results of these surveys have been published in two new documents, each comprising a report covering the technical aspects of the surveys, geophysical maps at 1:250,000 scale, and the associated digital data (documents DP 2016-01 and DP 2015-08 available through E-Sigeom (Examine) at the following address http://www.mern.gouv.qc.ca/produits-services/mines.jsp).

This promotional document provides the results of a preliminary interpretation of the aeromagnetic and spectrometric data obtained from these two surveys, along with proposed targets and new favourable areas for exploration. It should be noted that a number of roughly circular magnetic anomalies, possibly representing vertical kimberlite pipes, were identified in both publications mentioned above.

## Regional geological context and mineral potential

The two surveys conducted in 2015 cover the Archean rocks of the Minto Subprovince (Superior Province) in the west, and the Archean to Paleoproterozoic rocks of the Churchill Province in the east (Figures 2a and 2b). In this area, the Churchill is composed of volcano-sedimentary rocks of the Labrador Trough (New Quebec Orogen), as well as orthogneiss and metasedimentary rocks of the Diana Structural Complex. The contact between the two provinces is represented by a major ductile deformation zone probably related to the thrusting of Churchill units over the Archean craton during the New Québec Orogen (Madore and Larbi, 2000).

The units of the Minto Subprovince are mainly of Archean age except for some Proterozoic diabase dykes. The Minto is composed mainly of plutonic and gneissic units metamorphosed to amphibolite or granulite facies. The study area is subdivided into two main lithodemic units (Figure 2b):

**1**) the Faribault-Thury Suite, composed of migmatitic tonalites; and

**2**) the Qimussinguat Complex, composed of orthopyroxene gneiss and mafic intrusions.

These two units contain several small (5 to 10 km) bands of highly deformed volcano-sedimentary rocks. The relationship between these supracrustal sequences and the adjacent plutonic rocks and gneisses is ambiguous. The Archean areas covered by the two surveys contain very few known mineralized showings. To date, only two rare earth showings and two copper showings have been reported; however, these volcano-sedimentary bands are likely fertile because several gold, silver and copper showings have been documented in metavolcanic rocks and sulphide-facies iron formations of the Faribault-Thury Suite on map sheet 24M to the south of the study area (Madore *et al.*, 1999).

The geophysical surveys also cover a segment of the Paleoproterozoic Trans-Hudson Orogen comprising the northern end of the Labrador Trough and the collision zone between the Superior and Churchill provinces (Diana Structural Complex). The northern end of the Labrador Trough consists of allochthonous units that form the Roberts and Nagvaraaluk synclinal klippes, which are dominantly basalts (Hellancourt Formation) and various sedimentary rocks, namely iron formations (Sokoman Formation), turbidites, dolomites and graphitic black shales (Menihek Formation). The basalts of the Hellancourt Formation are injected by numerous

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tabular mafic and ultramafic intrusions containing important occurrences of nickel mineralization, analogous to the occurrences in the Thompson Belt of Manitoba and the Cape Smith Belt (Ungava Trough) of Northern Québec.

Lamothe (2010) completed a mineral potential assessment of the Far North region using levelled lake sediment geochemistry data. Based on this work, the study area has strong potential for Olympic Dam–Kiruna or IOCG-type Fe-Cu-U-Au-Ag deposits, magmatic Ni-Cu deposits, and massive sulphide Cu-Zn deposits associated with volcanic rocks. Several exploration targets for these types of mineralization have been published for the area.

## Interpretation of magnetic data

The residual total magnetic field, first vertical derivative and shaded magnetic relief maps (Figures 3, 4 and 5) reveal four main magnetic zones, as described below.

**Zone 1**: The aeromagnetic maps show a zone marked by two pronounced, large ovoid anomalies at the northern end of the Labrador Trough. These correspond to the Roberts and Nagvaraaluk synclines (Figure 2b). The relatively indistinct outlines of some anomalies in the central part of the northern periclinal closure of the Roberts Syncline (map sheet 25D08 in Figure 4) indicate a shallow dip for the layers in this area. The few structural field measurements from this area also support a shallow dip. The strongest positive magnetic anomalies associated with this structure probably reflect iron formations belonging to the Sokoman Formation. The size of the anomalies suggests the iron formations are more extensive than shown on the geological map. This could be explained by the fact that some units were not documented during mapping work due to the absence of outcrops (glacial sediment cover) or the presence of a thin layer of Menihek Formation turbiditic sedimentary rocks over the Sokoman Formation iron formations.

The contact between the Proterozoic units of the Roberts Syncline and the Superior Province is marked by a saw-tooth pattern that is clearly visible on the map of the first vertical derivative (Figure 4). The pattern represents chevron folds. This contact is crossed by several relatively rectilinear kilometre-scale lineaments characterized by very low relative susceptibility values. These lineaments, which are very visible in the Archean basement further west, are oriented mainly ENE and NE. They likely represent late faults.

**Zone 2**: This zone is situated at the northeast end of the study area and corresponds to the Diana Structural Complex of the Churchill Province. The complex consists essentially of Archean orthogneiss, reworked during the Proterozoic, and bands of paragneiss (Madore and Larbi, 2000). Variations in the magnetic fabric reveal the presence of two sub-domains bounded by a NW-trending contact zone (C in Figures 3 and 4), undoubtedly representing a deformation zone. The NE sub-domain is marked by narrow, alternating NW-trending bands characterized by strong and weak magnetic susceptibility values, becoming tighter in the central part. The SW sub-domain is characterized by lower magnetic susceptibility values, irregular deformation and evidence of folding (P in Figures 3 and 4). The contrasting magnetic signature of these two sub-domains indicates a change in the style and intensity of deformation. Also noted in this sector are two main lineament directions, N-S and NE-SW. The latter family are clearly sinistral faults.

**Zone 3**: This zone is situated in the western part of the map and corresponds to the Qimussinguat Complex, which consists of tonalite gneiss and orthopyroxene granodiorite gneiss (Figure 3). This zone is distinguished from adjacent regions by high intensity values on the residual magnetic field map and a structural fabric marked by numerous folds with variable orientations. The cores of these folds are generally less magnetic than the margins. The complex pattern can be explained by a polyphase structural history and the presence of many irregularly shaped intrusions. Zone 3 is crossed by several lineaments defined by rectilinear breaks with low residual magnetic field values, which contrast sharply with the characteristically high values of the rocks of this zone (Figures 3 and 9). These lineaments, which very likely correspond to late faults, generally trend NW-SE and, to a lesser extent, WNW-ESE and NE-SW. The NW-SE structures are distinguished by their multi-kilometre scale. The fact that the drainage system coincides with some of the lineaments suggests they have significant vertical extent.

**Zone 4**: This zone comprises the rocks of the Faribault-Thury Suite and the Ungava Trough to the north. The magnetic fabric in this zone distinguishes four magnetic sub-domains (Figures 3 and 4):

**(1)** In the eastern part, between the Diana Structural Complex and the two synclines of the Labrador Trough, the 4-1 sub-domain is characterized by a NW-trending magnetic fabric and high residual magnetic field values that gradually diminish to the east. The major lineaments are oriented NW and WNW.

**(2)** At the northern end of the study area, corresponding to the Ungava Trough, sub-domain 4-2 displays an E-W magnetic fabric with low to moderate magnetic field values, probably due to the presence of sedimentary and mafic rocks.

**(3)** In the western part of the zone, sub-domain 4-3 lies between units belonging to the Labrador Trough and the Qimussinguat Complex, corresponding to part of the Faribault-Thury Suite. The magnetic fabric trends NW and displays highly variable residual magnetic field intensity. Our current understanding of the local geology does not explain these contrasts in magnetic susceptibility. In fact, the area of high susceptibility in the central part of the sub-domain does not correspond to that of any known unit. However, several mapped greenstone belts display a low to negligible magnetic signature (the magnetic susceptibility contrast with the surrounding units is very low). In this area, major lineaments possibly representing late faults are oriented NW, NE and NNE. The NW-trending lineaments are characterized by slightly positive magnetic relief that could reflect the presence of younger diabase dykes.

**(4)** At the far western end of Zone 4, in the Archean basement, sub-domain 4-4 has an elongate shape in a NW direction, and is characterized by a very low magnetic signature (-400 nT) and by high potassium, thorium-equivalent and uranium-equivalent values (Figure 7). This sub-domain is part of the Faribault-Thury Suite (Madore and Larbi, 2000).

## Interpretation of spectrometric data

The spectrometric maps show the results for three radioactive elements: potassium, thorium (more precisely, thorium-equivalent) and uranium (uranium-equivalent; Figure 7). Because the penetration depth of the spectrometric method is several tens of centimetres (about 30 cm; Minty, 1997), the results obtained correspond to the concentration of radioactive elements in surface materials, such as soil, Quaternary deposits and outcrops. In general, the U, Th and K maps show fairly similar signatures. The geometry of some of the anomalous zones appears to reflect the NE direction of glacial transport, whereas the strong response in other areas reflects the nature of the underlying bedrock.

Four main anomalous spectrometric zones were identified, and the boundaries for all four are similar on the uranium, thorium and potassium maps.

**Zone 1**: This ovoid zone occupies the entire Archean window between the Roberts and Navgaraaluk synclines (Figure 7). On the geological map, it corresponds to part of the gneissic Faribault-Thury Suite. Zone 1 seems to represent relatively continuous glacial sediment cover (till). The attenuation of element concentrations to the northeast suggests a dilution effect related to glacial transport, which converges toward Ungava Bay in this area.

It is worth noting that the known mafic volcanics of the Hellancourt Formation in the Roberts Syncline are characterized by very low thorium and potassium values, which is typical of mafic and ultramafic rocks. The negative potassium anomaly makes it possible to precisely trace the contour of the Hellancourt Formation and to determine the NE extent of the glacial dispersion trains. In contrast, the potassium, uranium-equivalent and thorium-equivalent concentrations do not distinguish the Menihek Formation turbidites from the adjacent basement, suggesting the compositions of these sedimentary rocks are analogous to those of the gneissic Faribault-Thury Suite, which could be their source.

Finally, the eastern limit of the Roberts Syncline is marked by a major NW lineament which is easily identified on all aeromagnetic and spectrometric maps (Figures 3, 4 and 7). This lineament likely marks the position of a major unmapped fault.

**Zone 2**: This WNW-trending linear zone is situated at the western end of the study area (Figure 7). It coincides with an area of low residual magnetic field intensity, and is oriented perpendicular to the direction of glacial transport. On the geological map, this anomaly marks the limit between the Utsalik and Douglas Harbour domains of the Minto Subprovince (Simar, 2008). Our current understanding of the area does not explain these observations.

**Zone 3**: Situated in the northernmost part of the survey, this zone consists of a strong triple anomaly (U-Th-K) oriented NE (Figure 7). This anomaly could be related to the presence of alkaline rocks that have yet to be observed in the field. The eastern part of the anomaly coincides with slices of Paleoproterozoic sedimentary rocks of the Ungava Bay Trough, comprising sandstones, arkoses, conglomerates and red mudstones. The oxidized nature of these rocks, particularly the mudstones, suggests a certain mobility of uranium in the sediments.

**Zone 4**: This zone, between zones 1 and 3, represents a very large triple anomaly (U-Th-K) oriented NE (Figure 7). The Zone 4 anomaly occupies a poorly drained peneplain dotted by many tiny lakes. The Quaternary cover of this area is thin and discontinuous; the spectrometric signature should therefore reflect mostly bedrock anomalies.

The sources of the uranium, thorium and potassium are uncertain because the underlying basement is composed mainly of hornblende tonalite gneiss belonging to the Faribault-Thury Suite. These rocks have low concentrations of potassium and radioactive elements. The presence of this anomaly may therefore reflect unknown units with high concentrations of these three elements, or a thick layer of glacial sediments derived from a uranium-, thorium- and potassium-rich source, for example the granitic and granodioritic gneisses of the Utsalik Domain nearly 100 km to the southwest.

## Favourable targets for mineral exploration

The qualitative study of the magnetic and spectrometric data of these recent surveys, combined with geochemical and geological data (Figure 2), identified several potentially interesting positive and negative magnetic anomalies, as well as spectrometric anomalies of different sizes. Some of these anomalies correspond to or occur near exploration targets that were previously documented by field work (for example, Madore and Larbi, 2000), or targets generated by mineral potential modelling (Lamothe, 2010).

In all, **eleven** magnetic and spectrometric targets have been identified (Figure 9). Table 1 provides the location of these targets and a brief description for each. All targets are situated in areas that are open to mineral exploration and unstaked as of January 20, 2016.

## Potential of the Diana Complex (Churchill Province) (associated with targets 2 and 3)

Although this area hosts a Cu-Ag showing (Cap Jagged showing, target 2; Table 1), the geology and mineral potential of the Diana Structural Complex remain poorly understood. The results of the magnetic surveys clearly show two sub-domains with distinct structural styles. These features are also visible on spectrometric maps because the Quaternary cover is thin. Target 3 (Table 1) corresponds to a negative magnetic anomaly in a folded zone traversed by a lineament that probably represents a late fault. The structural complexity reflects the intensity of deformation along the contact of the Churchill and Superior provinces. Suture zones of this type are preferential sites for mineralizing fluid circulation.

## Possible extensions of Archean greenstone belts (associated with targets 4, 5 and 6)

The geological map at 1:250,000 for the area covered by these surveys (Madore and Labri, 2000) shows numerous greenstone belt segments. This map was compiled using field observations and the low-resolution magnetic map of the Geological Survey of Canada. The new high-resolution surveys should eventually allow the boundaries of previously mapped greenstone rocks to be redefined, and in some cases, extensions may be proposed. Target 4 (Table 1), associated with the Buet Belt, north of the Nagvaraaluk Syncline (Labrador Trough), and targets 5 and 6 (Table 1), associated with the Trempe Belt, both affiliated with the volcano-sedimentary Arnaud Complex, are among the targets identified in the central part of the survey area. These targets, which correspond to discrete positive aeromagnetic anomalies, constitute sites of interest for metallic mineralizations or ultramafic units.

## Favourable zones for iron and magmatic Ni-Cu-PGE in the Labrador Trough (associated with target 7)

The area of the Labrador Trough covered by the two geophysical surveys includes strong positive magnetic anomalies associated with iron formations belonging to the Sokoman Formation. They occur in the eastern part of the study area and are easily identified on aeromagnetic maps by the strong magnetic contrast with the surrounding rocks. These formations are, for the most part, already known and have been the subject of exploration work. The high-resolution magnetic data indicate the presence of other high-intensity anomalies with a signature similar to that of known iron formations. These anomalies therefore represent favourable areas for iron exploration.

It is also possible that some of these anomalies represent ultramafic units of the type present in the southwestern part of the Roberts Syncline, thereby increasing the potential for magmatic Ni-Cu-PGE deposits in this part of the Labrador Trough (Table 1).

## Regional potential for rare earths (associated with targets 8, 10 and 11)

Target 8 (Table 1) is related to rare earth showings (Labbé *et al.*, 2002), whereas target 11 corresponds to a lanthanum anomaly in the secondary environment (Lamothe, 2010). Both coincide with spectrometric and magnetic anomalies in the suture zone between the Utsalik and Douglas Harbour domains (respectively west and east). This zone possibly represents a deeply rooted structure with considerable strike extension that could have been associated with the emplacement of iron oxide–copper type deposits (IOCG) or rare earth deposits. As such, these corridors would have served as channels for mineralizing fluids or the emplacement of alkaline intrusions, such as the Kimber Alkaline Suite in the Utsalik Domain. These alkaline rocks may be associated with carbonatites, but this remains to be confirmed. The elevated rare earth values obtained from the showings of target 8 (Lataille North and Lataille South) initially suggested they represented carbonatites, but metamorphosed and metasomatized sedimentary rocks are now the preferred hypothesis (Labbé *et al.*, 2002). The origin of the very strong regional spectrometric anomaly (U, Th and K channels) of target 8 remains uncertain. The physiographic setting of the area is that of a poorly drained peneplain with thin sediment cover. It is possible the radiometric anomalies originated from clays of a specific composition. This rare earth target and its associated showings warrant follow-up.

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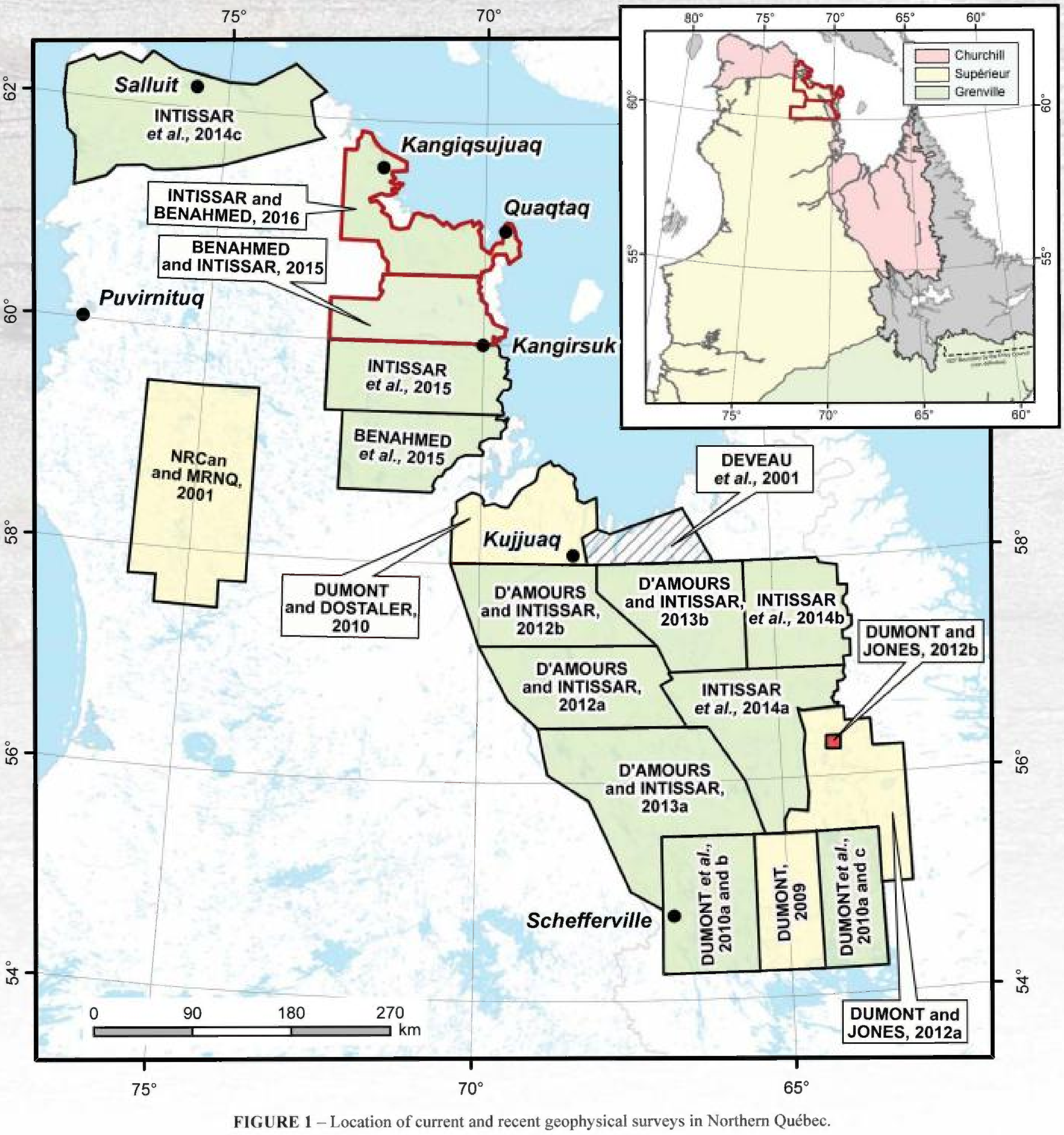


**FIGURE 1** – Location of current and recent geophysical surveys in Northern Québec.

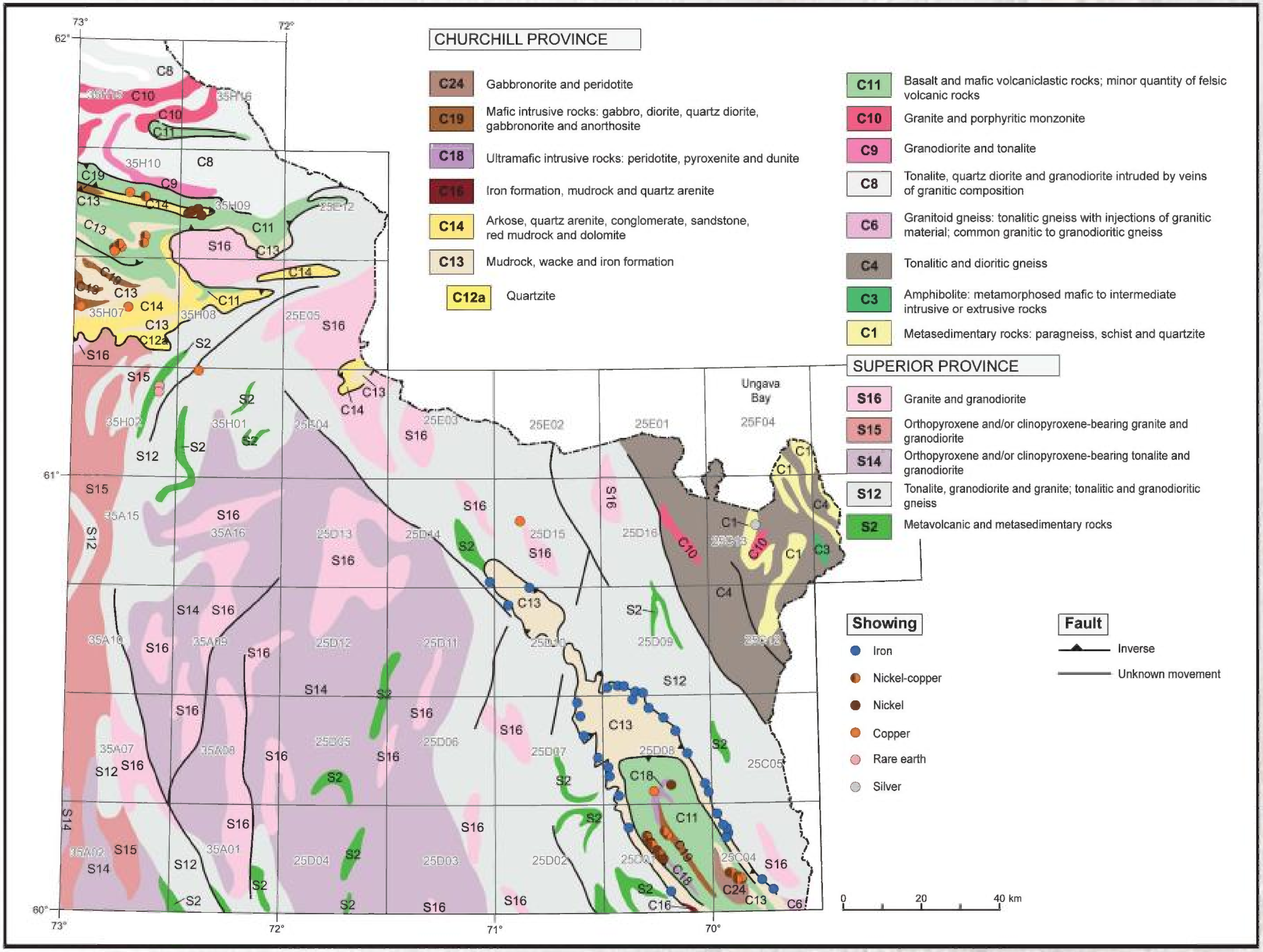


**FIGURE 2A** – Simplified geological map of the study area showing mineral occurrences (modified from Madore and Larbi, 2000).

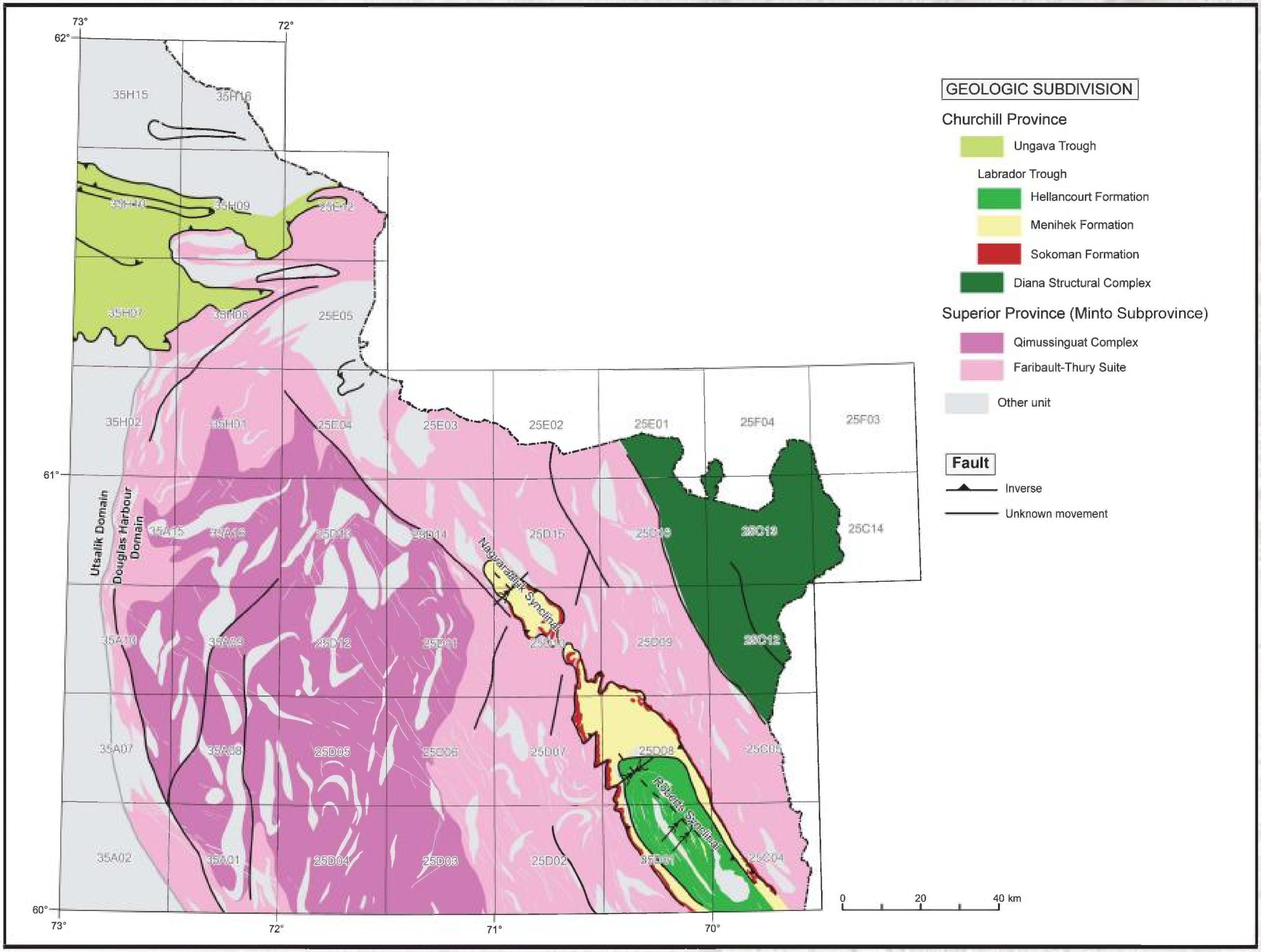


**FIGURE 2B** – Map of lithodemic units in the study area.

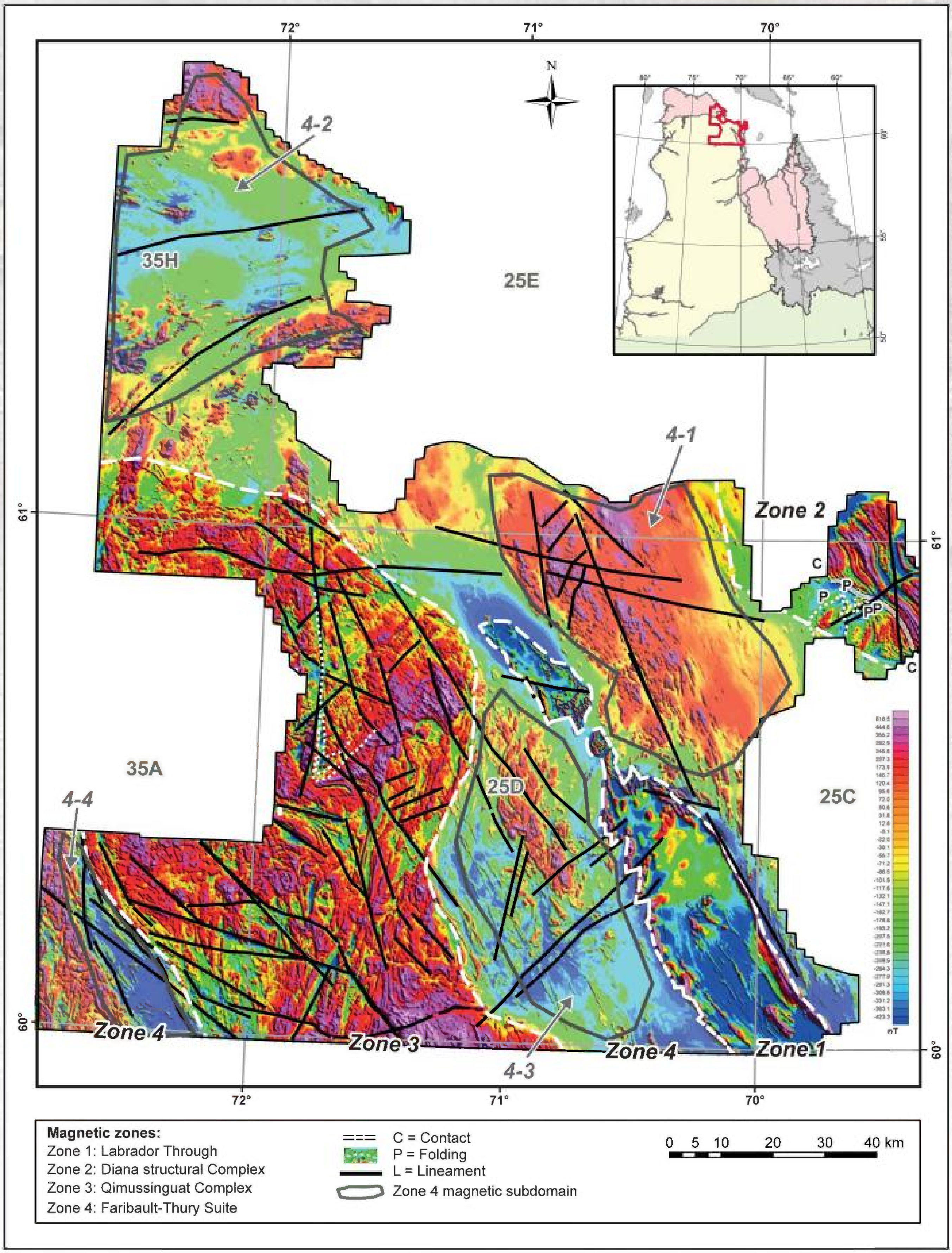


**FIGURE 3** – Map of the residual total magnetic field showing the main magnetic zones and interpreted lineaments.

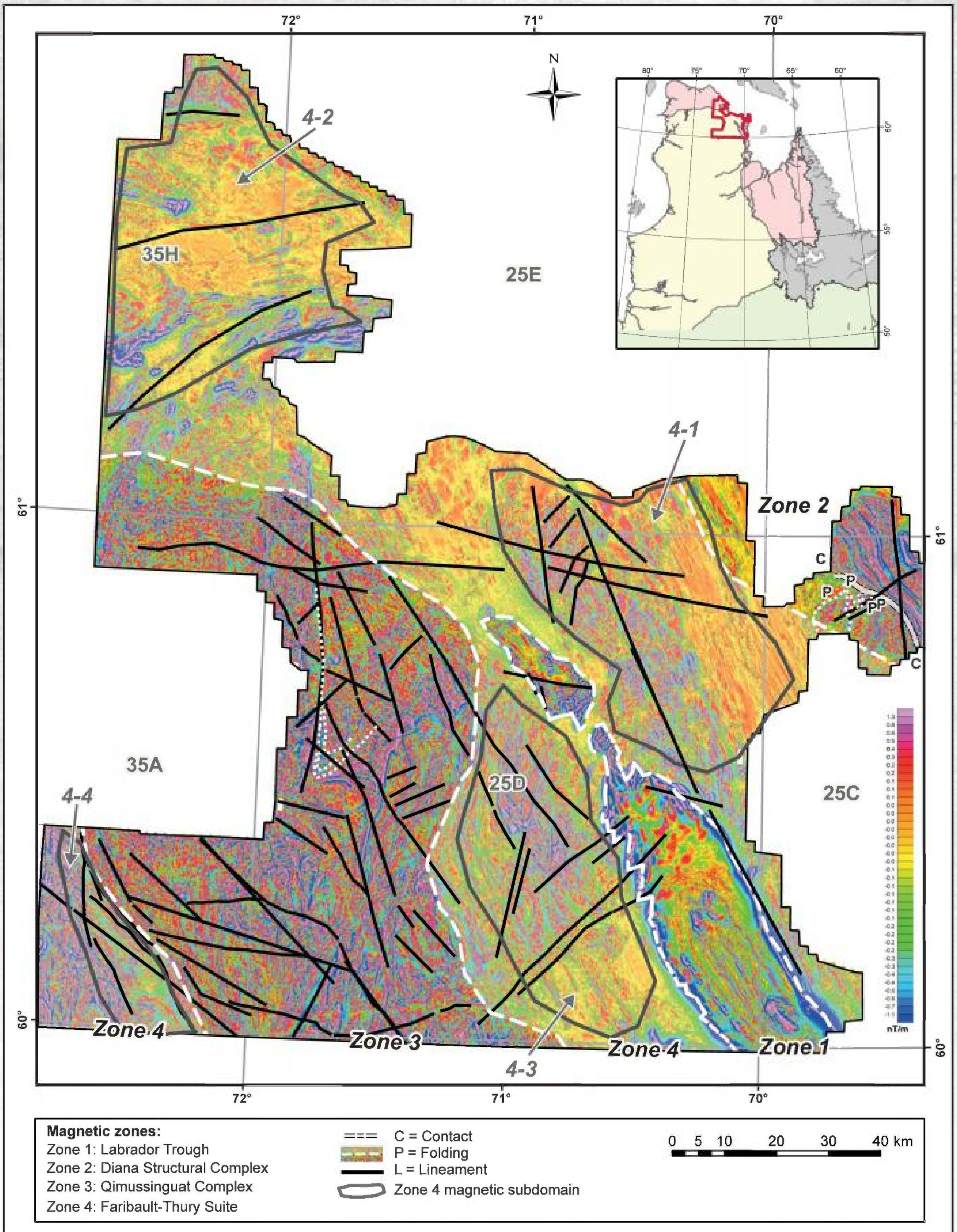


**FIGURE 4** – Map of the first vertical derivative of the residual total magnetic field showing the main magnetic zones and interpreted lineaments.

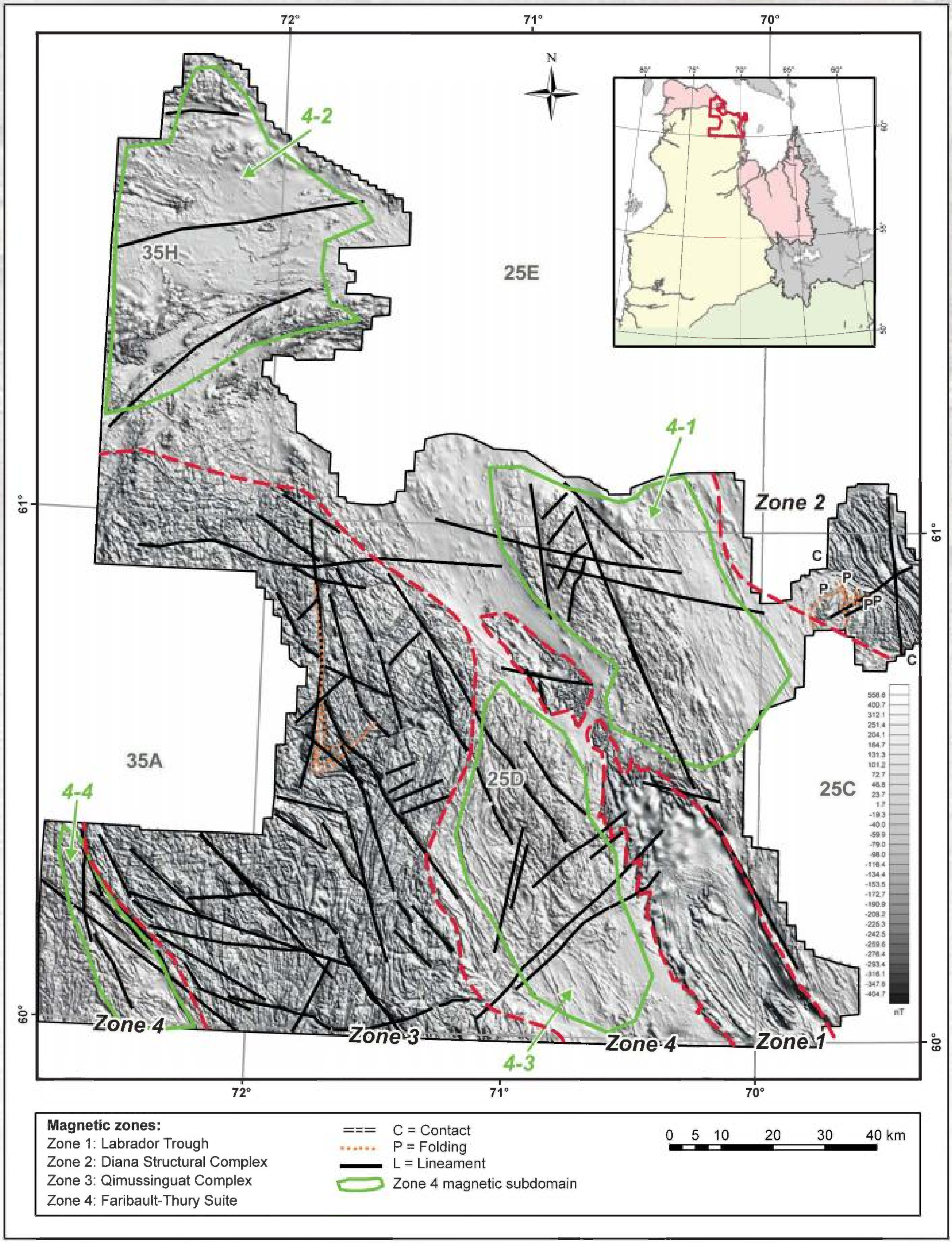


**FIGURE 5** – Shaded relief map of the residual total magnetic field showing the principal magnetic zones and interpreted lineaments.

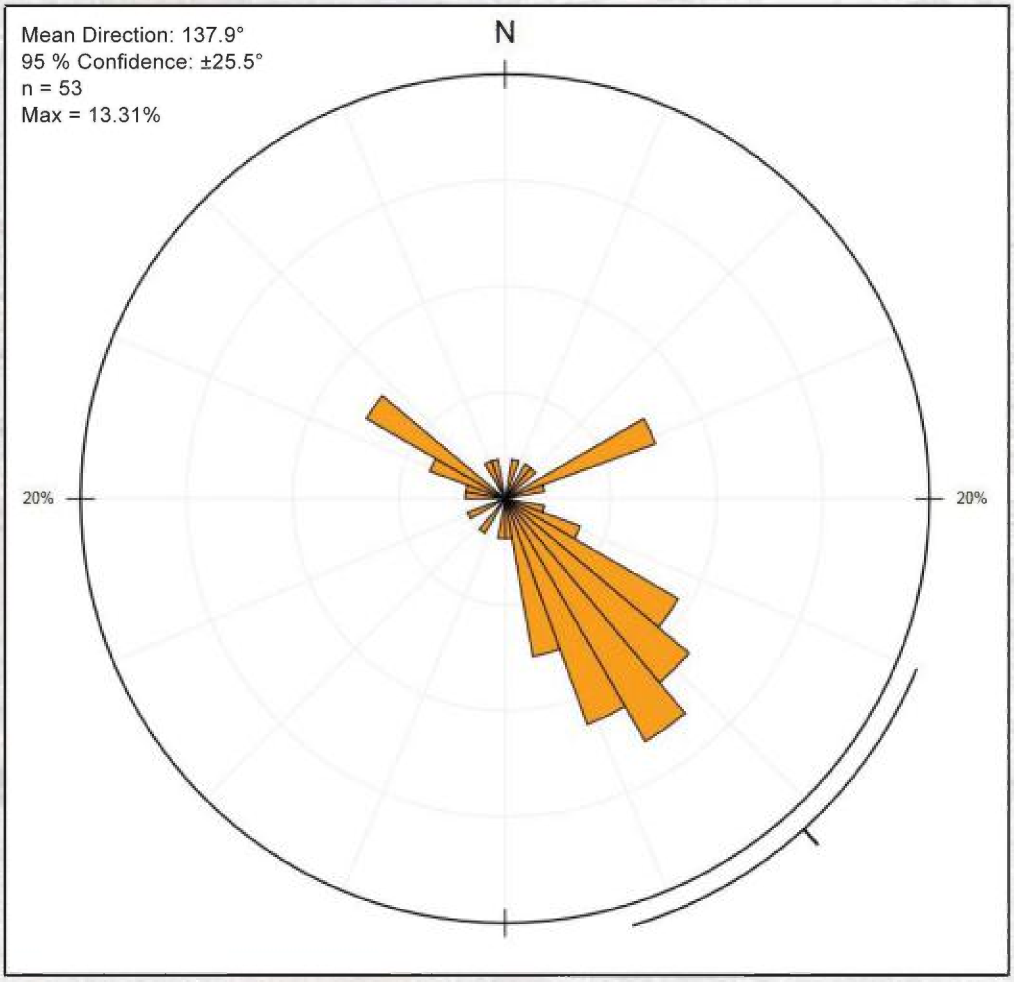


**FIGURE 6** – Rose diagram of the frequency of magnetic lineaments traced in Zone 3.

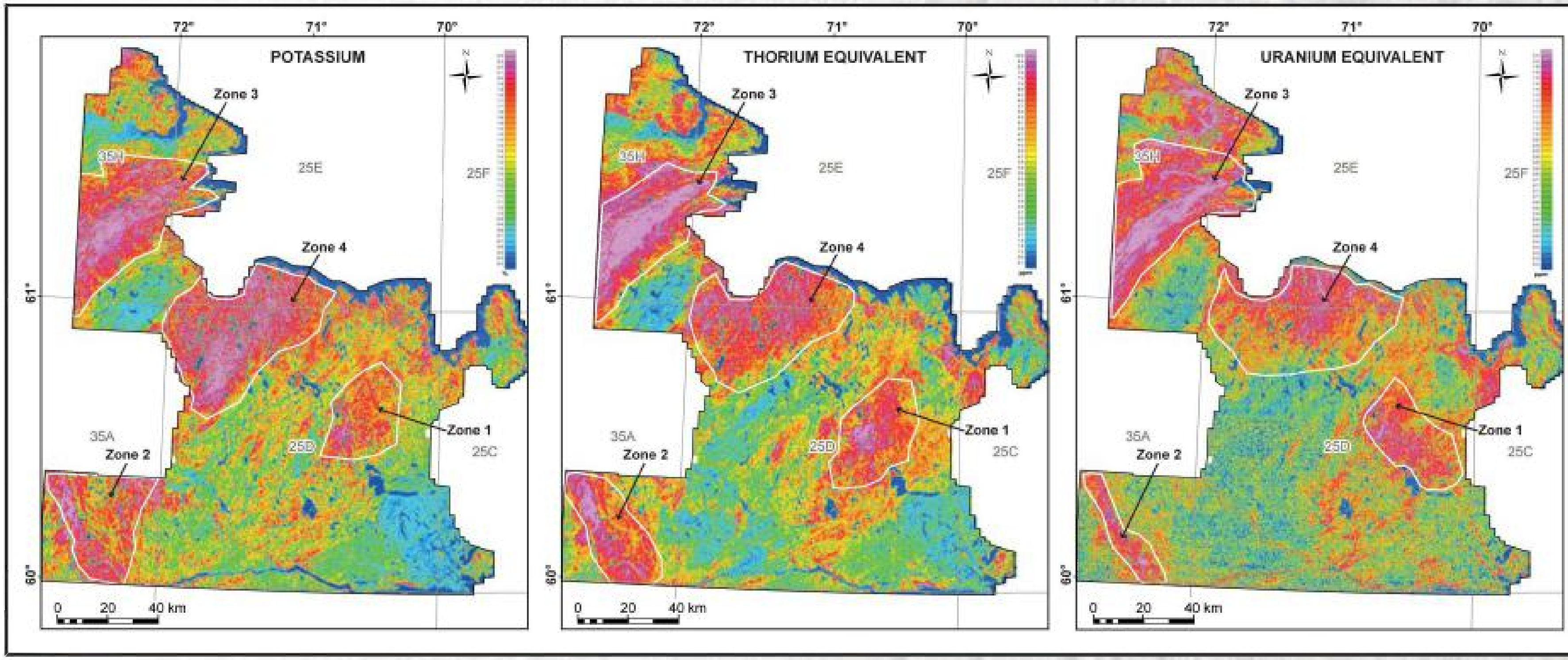


**FIGURE 7** – Location of the main anomalous spectrometric zones interpreted on maps of potassium (a), equivalent thorium (b) and equivalent uranium (c).

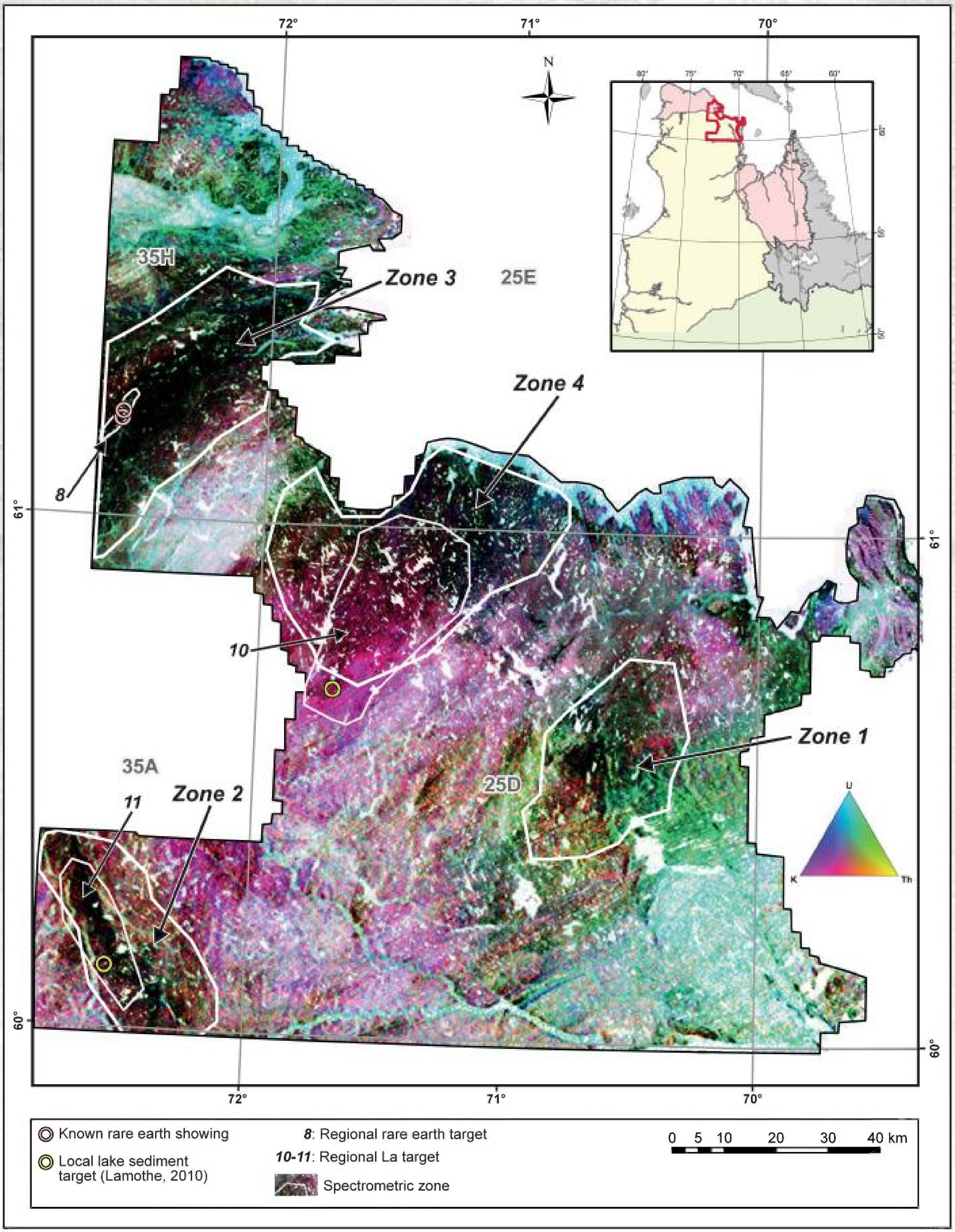


**FIGURE 8** – Ternary map of radioactive elements with the location of the main anomalous spectrometric zones and spectrometric exploration targets.

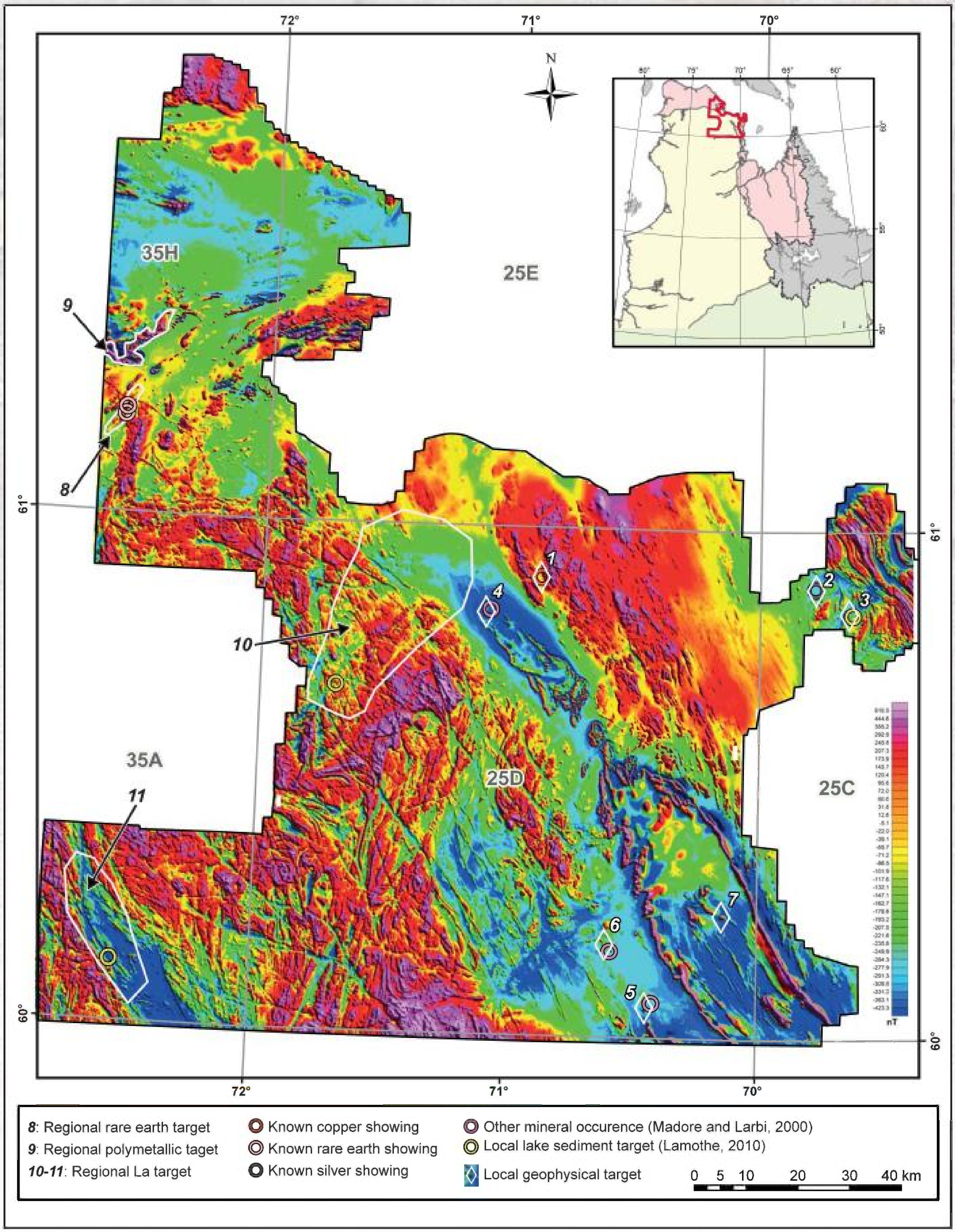


**FIGURE 9** – Geophysical exploration targets defined using aeromagnetic or spectrometric anomalies associated with lake-bottom sediment geochemistry targets and cartographic targets, superimposed on the map of the residual total magnetic field.

**TABLE 1** – Brief descriptions of aeromagnetic and spectrometric targets and their associated geochemical and cartographic targets.

| Target | Size | UTM NAD83, Z19 coordinates | | NTS Sheet | Commodity(ies) | Description |
|---|---|---|---|---|---|---|
| | | Easting | Northing | | | |
| 1 | Local | 398150 mE | 6753350 mN | 25D15 | Cu, Ag | NW-SE magnetic lineament with the Rivière Renouvé Cu-Ag showing (1.4% Cu, 5 g/t Ag; Madore and Larbi, 2000). |
| 2 | Local | 458317 mE | 6750341 mN | 25C13 | Ag, Cu, Zn | Negative magnetic anomaly associated with a folded zone. Presence of the Cap Jagged Ag showing (7 g/t Ag, 0.1% Cu, 0.08% Zn; Madore and Larbi, 2000). |
| 3 | Local | 465620 mE | 6744943 mN | 25C13 | Cu | Negative magnetic anomaly in a folded zone cut by a lineament. Cu anomaly in lake-bottom sediments of the Ni-Cu deposit type (Lamothe, 2010). |
| 4 | Local | 386039 mE | 6745796 mN | 25D14 | Ag, Cu | Strong positive NW-SE magnetic anomaly associated with the volcano-sedimentary Buet Belt (6 g/t Ag, 0.2% Cu, 0.04% As; Madore and Larbi, 2000). |
| 5 | Local | 420398 mE | 6659192 mN | 25D01 | Ni, Cr | Discrete magnetic anomaly associated with disseminated sulphides (15% PO) in ultramafics (0.2% Ni, 0.4% Cr; Madore and Larbi, 2000). |
| 6 | Local | 411630 mE | 6672729 mN | 25D02 | Zn | Discrete magnetic anomaly associated with disseminated sulphides in rusty paragneisses (0.2% Zn; Madore and Larbi, 2000). |
| 7 | Local | 437474 mE | 6678761 mN | 25D01 | Cu | Very strong positive magnetic anomaly close to Cu showings (Madore and Larbi, 2000). See Figure 2b. |
| 8 | Regional | 302991 mE - 309765 mE | 6785574 mN - 6794590 mN | 35H02 | Rare earths | NE-SW spectrometric anomaly covering a large surface area. The anomalous zone includes two rare earth showings in the Kimber Belt (Lataille North and Lataille South: 0.73% $Ce_2O_3$, 0.53% $La_2O_3$, 0.19% $Nd_2O_3$; Madore and Larbi, 2000; Labbé *et al.*, 2002). |
| 9 | Regional | 302695 mE - 315522 mE | 6803608 mN - 6810509 mN | 35H07 and 35H08 | Polymetallic | Strong NE-SW positive magnetic anomaly. This anomaly occurs near known Cu showings (GM 64736) |
| 10 | Regional | 351474 mE - 374535 mE | 6727800 mN - 6763370 mN | 25D11, 25D12, 25D13 and 25D14 | La | NE-SW spectrometric anomaly. La anomaly in lake-bottom sediments (Lamothe, 2010). |
| 11 | Regional | 307081 mE - 297683 mE | 6664582 mN - 6685283 mN | 35A01 and 35A01 | La | NW-SE spectrometric anomaly. La anomaly in lake-bottom sediments of the FeOx-Cu-U-REE type (Lamothe, 2010). |

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