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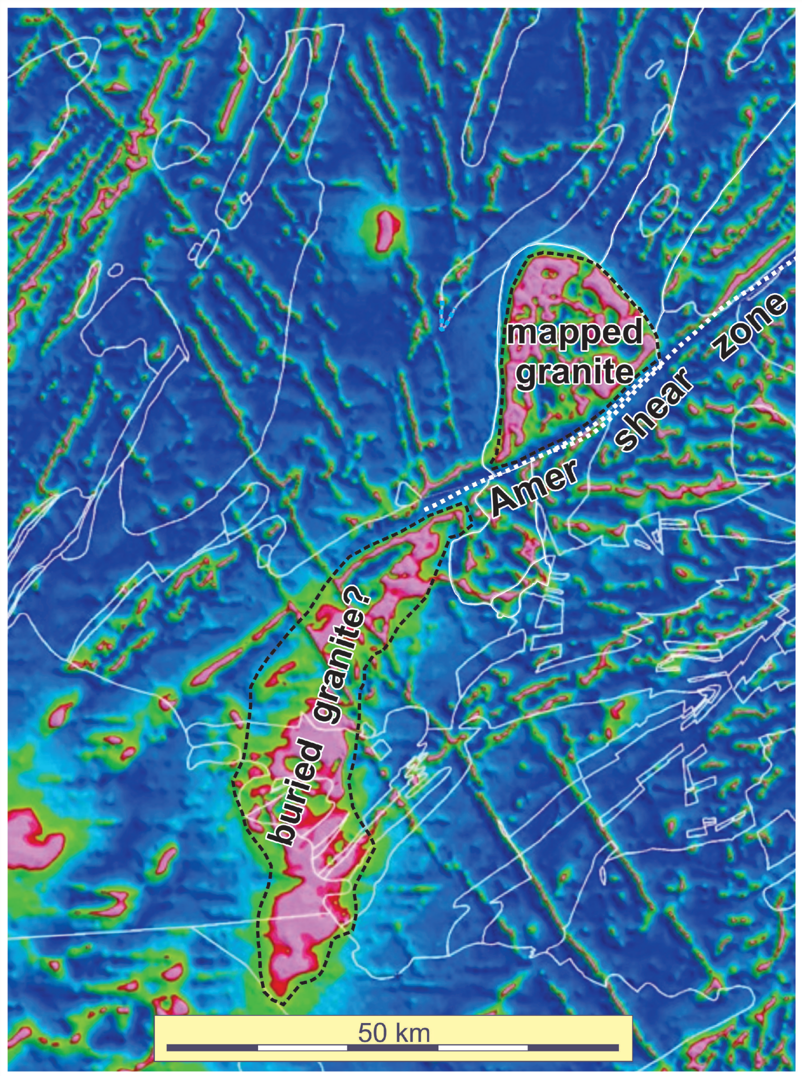


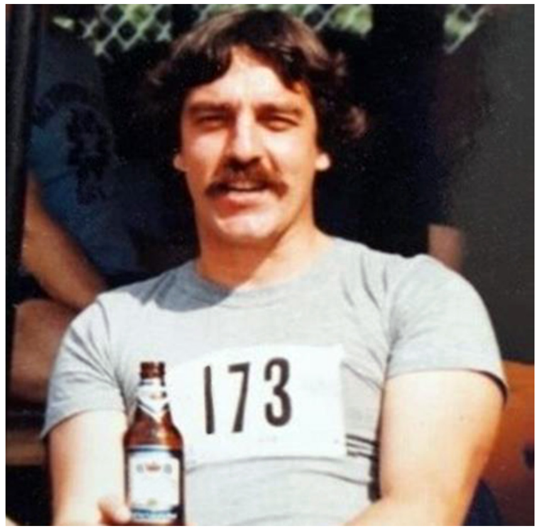
Magnetic modelling across some major faults in the northern Rae Craton, Canadian Shield, northern Canada

M.D. Thomas

2023

Canada

In Memoriam



Michael David Thomas

1942–2023

Mike Thomas joined the Dominion Observatories Branch of Energy, Mines and Resources (EMR) as a postdoctoral fellow in 1968 and was hired in 1971 as a full-time research scientist at the newly formed Earth Physics Branch of EMR, which was amalgamated with the Geological Survey of Canada in 1986. He is one of the GSC's longest-serving staff members, with over 50 years of service.

Mike's career at the GSC involved the interpretation of geophysical data at scales ranging from mining camps to continents. His early work concentrated on looking at the Canadian gravity database and analyzing the gravity field of Canada in terms of plate-tectonic models. This included elucidating the gravity signature of Precambrian plate boundaries in the Canadian Shield and providing continent-wide collisional models for the evolution of the North American landmass. Mike's work on plate-boundary crustal structure determined from gravity data resulted in the first of his five Nature publications. He then moved his focus to regional geological features and their geophysical interpretations throughout Canada, ranging from the Grenville Province in Labrador/Quebec, Sudbury, the Midcontinent Rift, Lake Superior, the Flin Flon mining belt, Manitoba, and the Athabasca Basin, to the Canadian Cordillera in central and southern British Columbia.

In recent years (the last 20!), Mike adjusted his attention to include the mining-camp scale. Starting with the New Brunswick mining camp, his careful and detailed work on many Canadian mineral deposits has clarified the often complex link between deposit type and geophysical response. Over his career, Mike contributed to most of the major initiatives within the GSC, such as NATMAP, Lithoprobe, EXTECH, GEM, and TGI. Mike will be remembered for his insightful interpretations of gravity and magnetic data, which were geologically sound and contributed to improving our understanding of Canada's subsurface.

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Cover illustration

Map of tilt of residual total magnetic field around west end of the Amer shear zone displaying 27 km dextral offset of a positive magnetic signature along the Amer shear zone. The offset portion north of the zone correlates with a mapped ca. 1.76 Ga Nueltin intrusive suite granite, and the portion to the south is interpreted to reflect buried Nueltin granite. The size of the map area is 92 km by 120 km.

Critical review

D. White

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Magnetic modelling across some major faults in the northern Rae Craton, Canadian Shield, northern Canada

Abstract: The northern tract of the Archean Rae Craton is traversed by several major faults running along flanks of prominent belts of positive magnetic anomalies. The association enables investigation of the geometry of the faults at depth by magnetic modelling, which additionally can investigate the magnetic fabric of the uppermost crust, an effective proxy for structural fabric. Two-dimensional magnetic modelling was completed along profiles crossing major faults within and traversing the length of the Queen Maud granitoid belt, the Chantrey fault zone, and the Amer and Wager Bay shear zones.

Models for all profiles display a series of narrow, near-vertical magnetic units extending to a depth of 5 km (arbitrarily selected), which suggests that structural fabric in the predominantly metamorphic rocks present along all profiles is steeply inclined. Contacts between certain modelled units aligned with steep gradients associated with large changes in the magnetic field, and unsurprisingly large susceptibility contrasts, are interpreted as faults. Several prominent magnetic lows modelled as steep, narrow (700–2000 m wide) units considered to represent heavily brecciated fault zones are attributed to oxidation of magnetite effected by enhanced circulation of water.

The two faults within the Queen Maud granitoid belt and the Chantrey fault are near-vertical with steep dips of 86°WNW, 85°ESE, and 90°, respectively. The Amer shear zone, where it is crossed by the profile in its western half, is interpreted to be a vertical, 2 km wide fault zone, whereas at its eastern profile it is a simple fault plane dipping 87°N. Offset magnetic anomalies at the extreme western end of the shear zone indicate 27 km of dextral displacement. The Wager Bay shear zone is modelled as a single fault within the zone at locations of both the western and eastern profiles dipping at 86°N and 89°S, respectively.

Résumé : L'étendue nord du craton de Rae de l'Archéen est traversée par plusieurs failles majeures qui longent les flancs de bandes de proéminentes anomalies magnétiques positives. Cette association rend possible l'étude de la géométrie des failles en profondeur par modélisation des données magnétiques, ce qui permet en outre d'examiner la fabrique magnétique de la croûte sommitale, un efficace indicateur indirect de la fabrique structurale. Une modélisation bidimensionnelle des données magnétiques a été réalisée le long de profils transversaux qui recoupent les principales failles à l'intérieur de la ceinture granitoïde de Queen Maud, ainsi que la zone de failles de Chantrey et les zones de cisaillement d'Amer et de Wager Bay.

Les modèles de tous les profils montrent une série d'unités magnétiques étroites, quasi verticales, s'étendant jusqu'à une profondeur (choisie arbitrairement) de 5 km, ce qui laisse supposer que la fabrique structurale des roches, à prédominance métamorphique, présentes le long de tous les profils est fortement inclinée. Les contacts entre certaines unités modélisées, qui s'alignent sur d'abrupts gradients magnétiques associés à de grandes variations du champ magnétique et, sans surprise, à de forts contrastes de susceptibilité magnétique, sont interprétés comme des failles. Plusieurs creux magnétiques prononcés, modélisés sous forme d'étroites (d'une largeur de 700 à 2000 m) unités abruptes qui représenteraient des zones de failles fortement bréchifiées, sont attribués à l'oxydation de la magnétite provoquée par une circulation d'eau accrue.

Les deux failles à l'intérieur de la ceinture granitoïde de Queen Maud ainsi que la faille de Chantrey sont quasi verticales avec des pendages abrupts de 86° vers l'ouest–nord-ouest, 85° vers l'est–sud-est et 90°, respectivement. La zone de cisaillement d'Amer, là où elle est recoupée par le profil dans sa moitié ouest, est interprétée comme une zone de failles verticale de 2 km de largeur, alors qu'au niveau de son profil est, il s'agit d'un simple plan de faille avec un pendage de 87° vers le nord. Des anomalies magnétiques décalées à l'extrémité ouest de la zone de cisaillement indiquent un déplacement dextre de 27 km. La zone de cisaillement de Wager Bay est modélisée comme une faille unique au sein de la zone aux emplacements des profils ouest et est, où elle présente un pendage de 86° vers le nord et de 89° vers le sud, respectivement.

SUMMARY

The Archean Rae Craton forms a significant portion of the northwestern Canadian Shield, flanked to the north and northwest by the Archean Slave Craton and to the south by the Archean Hearne Craton. Several extensive major faults and shear zones are distributed throughout the Rae Craton and along its margins. Notable examples within the northeastern half of the craton range from about 190 to 315 km in length and include the Chantrey, Amer, and Wager Bay fault/shear zones. The latter lie along the flanks of prominent positive magnetic anomalies, thereby affording a means to investigate their geometry at depth via magnetic modelling.

Two-dimensional magnetic modelling was completed along specific profiles crossing the aforementioned structural zones. In all cases, the fault/shear zones were modelled to be near-vertical and potentially attain depths of at least 5 km. Modelling also delineated several previously unmapped faults, almost all invariably near-vertical, with many probably represented by heavily brecciated zones ranging from 900 m to 2 km in width. Another revelation of modelling was definition of many steep, narrow magnetic units spanning long sections of the profiles. These were modelled to a depth of 5 km, though this depth is somewhat arbitrary, consequent on a lack of susceptibility data as a constraint for modelling. Nevertheless, the steep geometry of these near-surface units is interpreted to image a steep structural fabric in the uppermost crust. Structural fabrics mapped for some areas adjacent to the Amer and Wager Bay shear zones, and abundant steep dips of regional foliations, of gneissosity, of mineral foliation, and of foliation related to shear, support near-vertical structure.

Strike-slip relative motion has been reported along a number of fault/shear zones that include the Atorquait and Chantrey faults and the Amer, Wager Bay, and Walker Lake shear zones. All of these structures lie well within the Rae Craton, their formation potentially linked to the marginal Paleoproterozoic Arrowsmith and Archean MacQuoid orogenies within an upper-plate hinterland tectonic setting. Their strike-slip nature bears comparison with strike-slip faults in a similar tectonic environment in the Central Asian Orogenic Belt (CAOB), which are associated with mineralization. A critical characteristic of some strike-slip faults is their large depth extent, which allows them to tap into potential mineral resources in the mantle. In the CAOB, mineral systems associated with intracontinental translithospheric strike-slip faults include Au lodes, polymetallic vein deposits (W, Sn, Cu, Ag, Sb, As, Bi, Pb, Zn) and minor Hg, Ni, Co, Au, greisen Sn-W,

SOMMAIRE

Le craton de Rae de l’Archéen forme une composante importante de la partie nord-ouest du Bouclier canadien et est bordé, au nord et au nord-ouest, par le craton des Esclaves de l’Archéen, et au sud, par le craton de Hearne de l’Archéen. Plusieurs importantes zones de failles et de cisaillement de grande étendue sont réparties dans l’ensemble du craton de Rae et le long de ses marges. Certains exemples remarquables dans la moitié nord-est du craton ont une longueur d’environ 190 à 315 km et comprennent les zones de failles/cisaillement de Chantrey, d’Amer et de Wager Bay. La zone de cisaillement de Wager Bay longe les flancs d’une bande de proéminentes anomalies magnétiques positives, ce qui permet d’étudier de façon détaillée la géométrie de celles-ci en profondeur à l’aide de la modélisation des données magnétiques.

Nous avons réalisé une modélisation bidimensionnelle des données magnétiques le long de profils caractéristiques recoupant les zones structurales susmentionnées. Dans tous les cas, les zones de failles/cisaillement ont été modélisées comme étant des structures quasi verticales s’étendant en profondeur jusqu’à 5 km au moins. La modélisation nous a également permis de délimiter plusieurs failles non cartographiées auparavant, presque toutes quasi verticales, dont bon nombre sont probablement représentées par des zones fortement bréchifiées d’une largeur de 900 m à 2 km. Une autre révélation de la modélisation a été la définition de nombreuses unités magnétiques étroites et abruptes couvrant de longues sections des profils. Nous avons modélisé ces unités jusqu’à une profondeur de 5 km, bien que cette profondeur soit quelque peu arbitraire en raison du manque de données de susceptibilité magnétique pouvant servir à encadrer la modélisation. Néanmoins, la géométrie fortement inclinée de ces unités de la proche surface est interprétée comme étant la représentation d’une fabrique structurale abrupte dans la croûte sommitale. Les fabriques structurales relevées dans des secteurs adjacents aux zones de cisaillement d’Amer et de Wager Bay ainsi que les nombreuses mesures de pendages abrupts des foliations régionales, des textures gneissiques, des foliations minérales et des foliations liées au cisaillement militent en faveur d’une structure quasi verticale.

On a signalé des mouvements relatifs de coulissage le long d’un certain nombre de zones de failles/cisaillement, notamment le long des failles d’Atorquait et de Chantrey ainsi que des zones de cisaillement d’Amer, de Wager Bay et de Walker Lake. Toutes ces structures se trouvent bien à l’intérieur du craton de Rae, leur formation étant potentiellement liée aux orogenèses de marge continentale d’Arrowsmith du Paléoprotérozoïque et de MacQuoid de l’Archéen dans un cadre tectonique d’arrière-pays de plaque supérieure. Le caractère coulissant des structures est comparable à celui des failles de coulissage formées dans le milieu tectonique semblable de la zone orogénique de l’Asie centrale (ZOAC), auxquelles est associée de la minéralisation. Certaines failles de coulissage se démarquent par leur importante extension en profondeur, qui leur permet de puiser dans de possibles ressources minérales du manteau. Dans la ZOAC, les systèmes minéralisés associés aux failles de coulissage intracontinentales, de caractère translithosphérique, comprennent des gîtes filoniens d’or, des gîtes filoniens à minéralisation polymétallique (W, Sn, Cu, Ag, Sb, As, Bi, Pb, Zn) des minéralisations

carbonatites, and kimberlites. It was anticipated that the CAOB analogue might provide guidelines for mineral exploration in the Rae Craton.

Magnetotelluric investigations in the Rae Craton indicate former connections between the mantle and crust associated with mantle melting or metasomatism and the generation and intrusion of granites. Such signatures of mantle-to-crust transfer suggest that major faults would have provided pathways for the transfer of melts and could be considered favourable targets for mineral exploration. Unexpectedly, however, a plot of mineral occurrences in the study area reveals that very few are located close to the discussed major fault/shear zones, most being associated with belts of supracrustal rocks. Whether this reflects a lack of exploration near such zones or an actual deficiency of mineralization is questionable. Notwithstanding these apparently disappointing results, the CAOB analogue does favour future exploration being directed toward the fault/shear zones, particularly if some other geological or geochemical evidence near faults provides hints of mineralization.

mineures de Hg, de Ni, de Co et de Au, des greisens à Sn-W, des carbonatites et des kimberlites. On s'attendait à ce que le caractère analogue de la ZOAC puisse fournir des guides pour l'exploration minérale dans le craton de Rae.

Les études magnétotelluriques dans le craton de Rae indiquent d'anciennes connexions entre le manteau et la croûte associées à la fusion ou au métasomatisme du manteau et à la génération et à la mise en place de granites. De telles signatures de transfert du manteau à la croûte laissent supposer que les failles majeures auraient servi de voies pour le transfert des liquides magmatiques, et pourraient donc être considérées comme des zones à cibler pour l'exploration minérale. Cependant, de manière inattendue, la distribution des indices minéralisés dans la zone d'étude révèle que très peu d'entre eux sont situés à proximité des principales zones de failles/cisaillement précédemment mentionnées, la plupart étant associés à des ceintures de roches supracrustales. On peut se demander si cela témoigne d'une exploration déficiente près de ces zones ou d'une insuffisance réelle de minéralisation. Malgré ces résultats apparemment décevants, la ZOAC constitue un analogue qui incite à diriger les travaux futurs d'exploration vers les zones de failles/cisaillement, en particulier si d'autres données géologiques ou géochimiques près des failles révèlent des indices de minéralisation.

INTRODUCTION

The Rae Craton is a broad, northeast-trending belt of Archean rocks in the northwestern portion of the Canadian Shield, flanked to the northwest and southeast, respectively, by the Archean Slave and Hearne cratons (Fig. 1). It extends northeastward from the shield margin between Great Slave and Athabasca lakes to Baffin Island. It has a minimum width of about 300 km near the margin and widens northeastward to almost 900 km where it extends along Boothia Peninsula. If the Chesterfield block, apparently accreted to the Rae Craton in the latest Neoarchean (Pehrsson et al., 2013), is included, the latter width increases to about 1000 km.

Several extensive major faults and shear zones are distributed throughout the Rae Craton and along its margins (Fig. 1, 2), some positioned on the flanks of prominent magnetic anomalies, thereby offering a means to investigate their geometry at depth via magnetic modelling. A geological map of the general area (Skulski et al., 2018) displaying the principal faults is in Figure 2; a map of the residual total magnetic field, in Figure 3. These faults are unnamed (herein referred to as 'faults A and B'), appearing possibly for the first time on a preliminary geological compilation map of the northeastern Barren Grounds (Patterson and LeCheminant, 1985) and subsequently on metamorphic maps of the western Churchill Province (Berman, 2010), the Atorquait fault, the Chantrey and Chesterfield fault zones, the Amer and Wager Bay shear zones, and the Quoich River thrust. Magnetic profiles crossing faults A and B, the Chantrey fault zone, and the Amer and Wager Bay shear zones (Fig. 2, 3) are modelled to produce upper crustal cross-sections of magnetic units that serve as a proxy for geological cross-sections.

GEOLOGICAL SETTING OF NORTHERN RAE CRATON

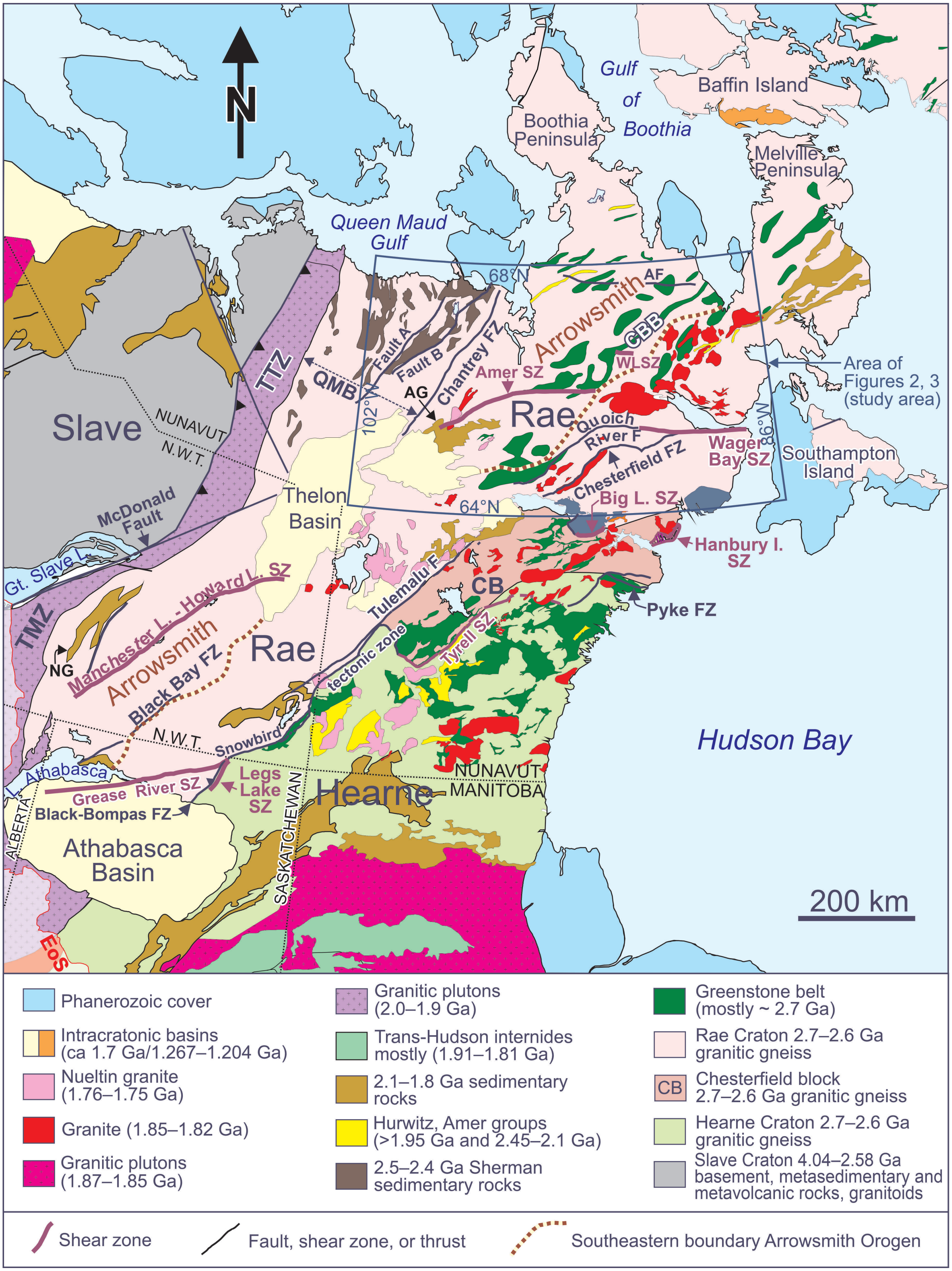
The Rae Craton consists of Meso- to Neoarchean tonalitic to granitic orthogneisses that host northeast-trending komatiite-bearing greenstone belts in the northeastern portion of the craton (Berman et al., 2013). These belts are intruded by 2.72 to 2.64 Ga tonalite and approximately 2.62 to 2.58 Ga voluminous, dominantly monzogranitic plutons distributed throughout most of the Rae Craton. Structural and metamorphic reworking of the Rae Craton was effected by the 2.56 to 2.50 Ga MacQuoid Orogeny, the 2.5 to 2.3 Ga Arrowsmith Orogeny, the 2.0 to 1.91 Ga Taltson and Thelon orogenies, and the 1.9 to 1.8 Ga Hudsonian Orogeny. The Arrowsmith Orogeny produced the Arrowsmith Orogen, running along the northwestern margin of the Rae Craton and forming more than half of the craton (Fig. 1). The large sedimentary Paleoproterozoic Thelon Basin trends broadly north-northeast across the central portion of the craton, and the sedimentary Paleoproterozoic Athabasca Basin borders the southwestern extremity of the craton.

West of the Thelon Basin, the northwestern margin of the Rae Craton is bounded by the northeast-trending McDonald fault, a brittle fault zone aligned with the dextral mylonitic Great Slave Lake shear zone (Hoffman, 1987). The southeastern margin of the craton is marked by the northeast-trending Snowbird tectonic zone. Northeast and east of the Thelon Basin the most prominent structural breaks are the Chantrey and Chesterfield fault zones, the Atorquait fault, the Quoich River thrust, and the Amer and Wager Bay shear zones (Fig. 1, 2). The Chantrey fault zone extends roughly 300 km northeast from the north end of the Thelon Basin and terminates at a unit of Ordovician–Silurian limestone near the Arctic coast (Skulski et al., 2018). The fault zone was linked with what is now known as the Great Slave Lake shear zone (Hoffman, 1987) by Heywood and Schau (1978), who referred to this composite structure as the Slave–Chantrey mylonite zone. Hoffman (1989) noted that mainly granulite-grade rocks of the Queen Maud block (Fig. 2) are juxtaposed along less deeply eroded parts of the Rae Craton along oblique east-vergent reverse faults and implied the Chantrey fault zone was such a fault. Tella (1994), mapping at the south end of the fault zone, found evidence for latest movement along the fault to be low-angle oblique slip with an apparent dextral sense of shear. The Chesterfield fault is a northwest-vergent thrust (Berman et al., 2007).

MAGNETIC FIELD OF NORTHERN RAE CRATON

The residual total magnetic field of the study area is presented in Figure 3. Thomas (2018a, b) had subdivided the magnetic field over the Archean Rae Craton on the mainland portion of the Canadian Shield (Fig. 1) into 75 magnetic domains. Those within the study area are outlined in Figure 3. Several domains were defined by, or contain, a prominent quasilinear belt (or belts) of strong magnetic highs. Images of the first vertical derivative (FVD) of the magnetic field, which enhances short-wavelength magnetic anomalies, reveal that the belts of highs, to a large degree, reflect the integrated effect of several narrow, quasilinear magnetic highs of various extent.

Figure 1. Geological map of mainland Rae Craton with labelled faults (F), fault zones (FZ), shear zones (SZ), and zones (Z) cited in text. AF, Atorquait fault; AG, Amer group; CB, Chesterfield block; CBB, Committee Bay belt; EoS, edge of Shield; NG, Nonacho Group; QMB, Queen Maud block; TMZ, Taltson magmatic zone; TTZ, Thelon tectonic zone; WLSZ, Walker Lake shear zone. I., island; L., lake. Position of Arrowsmith Orogen *based on* Berman et al. (2013).


N
Gulf of Boothia
Baffin Island
Boothia Peninsula
Melville Peninsula
Queen Maud Gulf
68°N
AF
Arrowsmith
CBB
WLSZ
Amer SZ
Fault A
Fault B
Chantrey FZ
QMB
AG
102°W
Rae
Quoich River F
Chesterfield FZ
Wager Bay SZ
86°W
Area of Figures 2, 3 (study area)
Southampton Island
64°N
Big L. SZ
Hanbury I. SZ
Pyke FZ
CB
Tulemalu F
tectonic zone
Tyrell SZ
Slave
NUNAVUT
N.W.T.
TTZ
McDonald Fault
Gt. Slave L.
Thelon Basin
TMZ
Manchester L. - Howard L. SZ
Arrowsmith
Rae
NG
Black Bay FZ
Snowbird
N.W.T.
L. Athabasca
Grease River SZ
Black-Bompas FZ
Legs Lake SZ
SASKATCHEWAN
Hearne
NUNAVUT
MANITOBA
ALBERTA
Athabasca Basin
EoS
Hudson Bay
200 km
Phanerozoic cover
Intracratonic basins (ca 1.7 Ga/1.267–1.204 Ga)
Nueltin granite (1.76–1.75 Ga)
Granite (1.85–1.82 Ga)
Granitic plutons (1.87–1.85 Ga)
Granitic plutons (2.0–1.9 Ga)
Trans-Hudson internides mostly (1.91–1.81 Ga)
2.1–1.8 Ga sedimentary rocks
Hurwitz, Amer groups (>1.95 Ga and 2.45–2.1 Ga)
2.5–2.4 Ga Sherman sedimentary rocks
Greenstone belt (mostly ~ 2.7 Ga)
Rae Craton 2.7–2.6 Ga granitic gneiss
CB Chesterfield block 2.7–2.6 Ga granitic gneiss
Hearne Craton 2.7–2.6 Ga granitic gneiss
Slave Craton 4.04–2.58 Ga basement, metasedimentary and metavolcanic rocks, granitoids
Shear zone
Fault, shear zone, or thrust
Southeastern boundary Arrowsmith Orogen

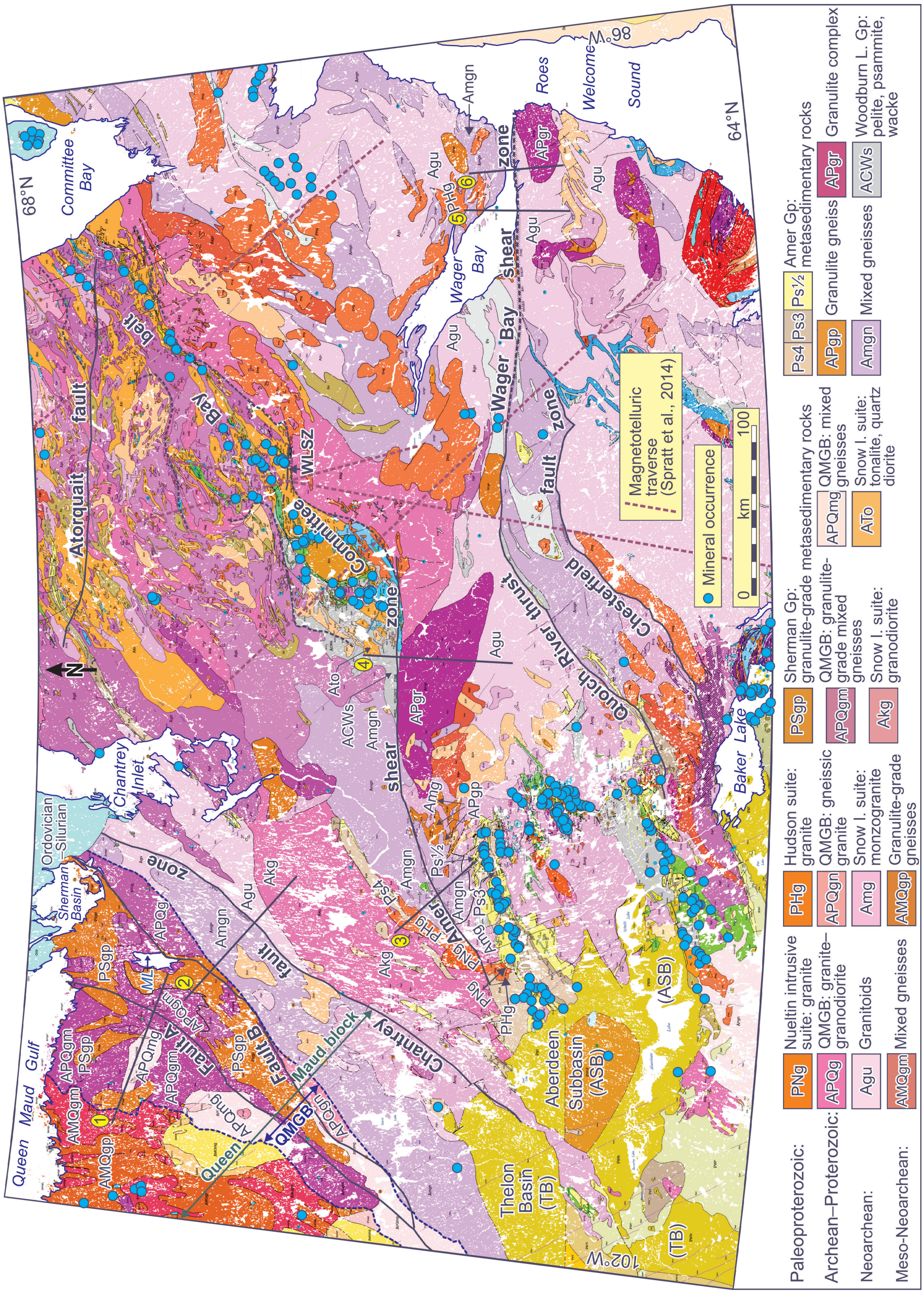

Queen Maud Gulf
Committee Bay
Chantrey Inlet
Wager Bay
Roes Welcome Sound
Baker Lake
68°N
64°N
102°W
86°W
Ordovician–Silurian
Sherman Basin
Thelon Basin (TB)
(TB)
Aberdeen Subbasin (ASB)
(ASB)
Atorquait fault
Committee Bay belt
WLSZ
Amer shear zone
Wager Bay shear zone
Chantrey fault zone
Quoich River thrust
Chesterfield fault zone
Fault A
Fault B
Queen Maud block
QMGB
ML
N
Mineral occurrence
Magnetotelluric traverse (Spratt et al., 2014)
0 km 100
Paleoproterozoic:
PNg Nueltin intrusive suite: granite
PHg Hudson suite: granite
PSgp Sherman Gp: granulite-grade metasedimentary rocks
Ps4 Ps3 Ps½ Amer Gp: metasedimentary rocks
Archean–Proterozoic:
APQg QMGB: granite–granodiorite
APQgn QMGB: gneissic granite
APQgm QMGB: granulite-grade mixed gneisses
APQmg QMGB: mixed gneisses
APgp Granulite gneiss
APgr Granulite complex
Neoarchean:
Agu Granitoids
Amg Snow I. suite: monzogranite
Akg Snow I. suite: granodiorite
ATo Snow I. suite: tonalite, quartz diorite
Amgn Mixed gneisses
ACWs Woodburn L. Gp: pelite, psammite, wacke
Meso-Neoarchean:
AMQgm Mixed gneisses
AMQgp Granulite-grade gneisses

Figure 2. Geological map of general study area *adapted from* Skulski et al. (2018). QMGB, Queen Maud granitoid belt based on the legend of this map; WLSZ, Walker Lake shear zone. A single dot may cover more than one mineral occurrence, where occurrences are close to one another. ML, McNaughton Lake. Dark navy lines labelled '1' through '6' are lines of magnetic profiles selected for modelling. Mineral occurrence information from a database compiled by Kathleen Lauzière, Geological Survey of Canada, and from Skulski et al. (2018). Sources contributing to the database: Franklin et al. (2015), Gandhi (2015), Gandhi et al. (2015), Good et al. (2015), Gosselin and Dubé (2015), Gross and Hillary (2014), Kirkham and Dunne (2015), Kirkham et al. (2014, 2015), Sangster (2015a, b), and Sinclair et al. (2014).

The study area is traversed by several such belts of magnetic highs, which are flanked by major faults/shears and are of particular interest for modelling to examine upper crustal structure in the vicinity of the faults and the geometry of the faults themselves. The magnetic highs of interest are referred to as the Queen Maud high, named for its central position within the Queen Maud block, and the Chantrey, Amer, and Wager Bay highs, named for the respective fault following one flank of the high. The Queen Maud high is also flanked by a major unnamed fault, herein termed 'fault A' (Fig. 2, 3). In this case, the high is not named for the associated fault. The Chantrey magnetic high is also flanked by a fault on the opposite flank to that associated with the Chantrey fault, an unnamed fault termed 'fault B' (Fig. 2, 3). Davis et al. (2014) used the Queen Maud high as a basis for defining the 'Queen Maud granitoid belt', though Skulski et al.'s (2018) map shows lithological units assigned to the granitoid belt extending east of fault B.

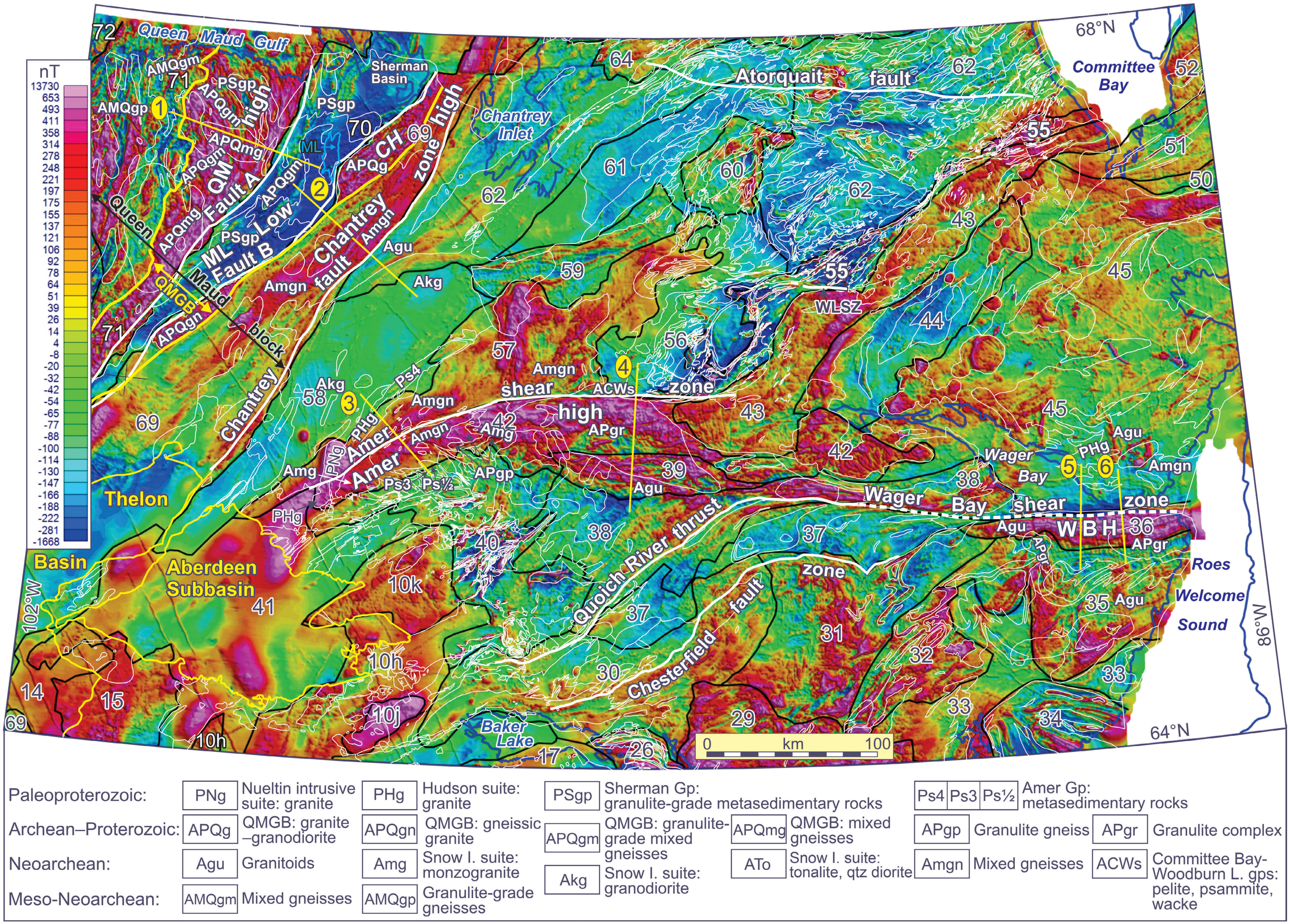
The Queen Maud and Chantrey highs, located in the northwest corner of the study area, are subparallel, oriented roughly N20°E and N30°E, respectively. The Amer and Wager Bay highs both trend essentially eastward within the eastern two thirds of the study area and are approximately centrally positioned in a north–south sense.

APPROACH TO MAGNETIC MODELLING

Magnetic modelling was conducted along six profiles crossing the various magnetic highs (Fig. 3) using a 2-D algorithm. Constraints to guide modelling are restricted to surface geological contacts, and these have somewhat limited value because certain geological units are magnetically heterogeneous. Magnetic susceptibility is the key desirable constraint for magnetic modelling, but susceptibility data for rocks in the area were not discovered. Susceptibility values within the model are, therefore, a product of modelling, their magnitude being influenced to a large extent by the depth of modelled units. In the absence of independent depth constraints, a maximum depth of 5 km below sea level for the bottom of modelled units was chosen as a compromise between too shallow and too deep, definition of which is entirely arbitrary. This aspect of the modelling imparts uncertainty to the viability of the model, and the base of the units at a uniform depth should not be viewed as a meaningful geological boundary. Susceptibilities and shapes of units may change gradually with depth, and bottoms of units may not be associated with abrupt changes in susceptibility. The main contribution of the models is that they indicate that geological units intersecting surface are probably steep for at least a few kilometres' depth. Support for this proposal is provided by steep structural fabrics observed in the areas of the Amer and Wager Bay shear zones. It is possible that these fabrics, mapped at surface, originated at various depths in the crust and collectively span a crustal section several kilometres thick.

Because the greater part of all magnetic profiles is characterized by alternating highs and lows of significant amplitude, modelled units are almost invariably narrow and near-vertical. Such a geometry facilitates matching of observed and modelled profiles, and while not necessarily unique is entirely reasonable. The validity of this approach is illustrated in Figure 4, in which decreasing the dips of units from vertical to 60° and 45° results in progressive deterioration of the goodness of fit between observed and modelled profiles. Where structural data such as regional foliations (Tella, 1994) or gneissosity, mineral foliation, and

Figure 3. Residual total magnetic field map of general study area derived from a 200 m grid calculated from data in the Canadian Aeromagnetic Data Base. Data were collected along flight lines spaced a nominal distance of 805 m apart at a mean terrain clearance of 305 m. Magnetic domains (black boundaries) defined by Thomas (2018a) and lines (yellow) of modelled magnetic profiles 1 to 6 are plotted. ML, McNaughton Lake. Identified magnetic highs are the Queen Maud (QM) magnetic high, Chantrey magnetic high, Amer magnetic high, and Wager Bay magnetic high (WBH); the McNaughton Lake (ML) magnetic low is also identified. Geological contacts (thin white lines) from the map by Skulski et al. (2018) are plotted, and only major geological units in the vicinity of magnetic profiles are labelled and appear in the geological legend. QMGB, Queen Maud granitoid belt; WLSZ, Walker Lake shear zone.


nT
13730
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-8
-20
-32
-42
-54
-65
-77
-88
-100
-114
-130
-147
-166
-188
-222
-281
-1668
Queen Maud Gulf
Sherman Basin
Chantrey Inlet
Committee Bay
Atorquait fault
68°N
64°N
102°W
86°W
Thelon Basin
Aberdeen Subbasin
Baker Lake
Roes Welcome Sound
Queen Maud block
QMGB
QM high
Fault A
ML Low
Fault B
CH zone high
Chantrey fault
Chantrey
Amer shear zone
Amer high
WLSZ
Wager Bay
Wager Bay shear zone
WBH
Quoich River thrust
Chesterfield fault zone
0 km 100
Paleoproterozoic:
PNg Nueltin intrusive suite: granite
PHg Hudson suite: granite
PSgp Sherman Gp: granulite-grade metasedimentary rocks
Ps4 Ps3 Ps½ Amer Gp: metasedimentary rocks
Archean–Proterozoic:
APQg QMGB: granite –granodiorite
APQgn QMGB: gneissic granite
APQgm QMGB: granulite-grade mixed gneisses
APQmg QMGB: mixed gneisses
APgp Granulite gneiss
APgr Granulite complex
Neoarchean:
Agu Granitoids
Amg Snow I. suite: monzogranite
Akg Snow I. suite: granodiorite
ATo Snow I. suite: tonalite, qtz diorite
Amgn Mixed gneisses
ACWs Committee Bay-Woodburn L. gps: pelite, psammite, wacke
Meso-Neoarchean:
AMQgm Mixed gneisses
AMQgp Granulite-grade gneisses

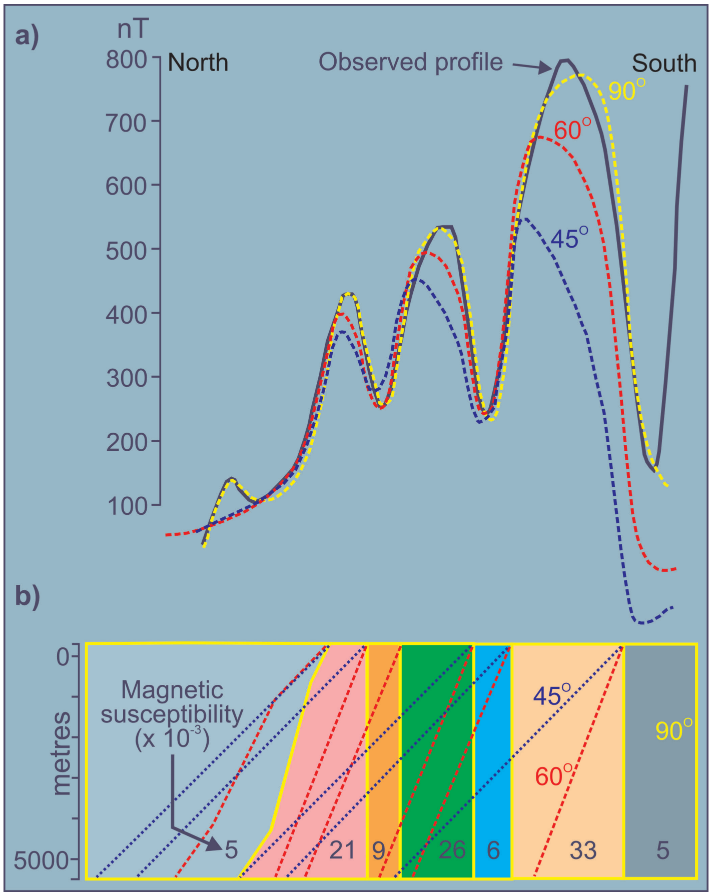


Figure 4. a) Observed magnetic profile and three magnetic profiles corresponding to the geological model in **b)** in which the contacts between modelled units dip variously at generally 90° (yellow contacts), 60° (red), and 45° (blue). As the dip of contacts decreases the goodness of fit between the observed and modelled profile degenerates.

foliation related to shear (Henderson and Broome, 1990) are available, an abundance of steep dips supports near-vertical structure.

The different magnetic susceptibilities of modelled magnetic units are presumed to represent distinct rock types. However, along sections of the observed magnetic profile that vary gently, the susceptibilities of adjacent modelled units may differ very little. In such instances, a distinct susceptibility boundary between units may not exist, but rather a gradational change in susceptibility is present. Hence, two adjacent magnetic units that might be interpreted as representing two different rock types are in fact representing the same rock type that experiences a small change in magnetite content from unit to unit, or there may be a real gradation of one rock type to another. It is difficult to define how much of a change in susceptibility could reflect a change in rock type. It would be necessary to conduct a field study to determine a realistic value. It is speculated that a change in susceptibility between adjacent units as large as 5×10^{-3} SI could take the form of a gradational change. In one of the models, changes in susceptibility range from 1 to 5×10^{-3} SI across 39 contacts between magnetic units. If many are indeed gradational, the model possibly represents a smaller number of geological units. Notwithstanding such a scenario, steep contacts associated with significant changes in susceptibility within many sections of the models are still indicative of an upper crust that potentially is generally characterized by a steep structural fabric.

MODEL OF THE QUEEN MAUD MAGNETIC HIGH

The Queen Maud magnetic high extends from Queen Maud Gulf south-southwestward for about 370 km, narrowing gradually along the eastern half of magnetic domain 71 (Thomas, 2018a) (Fig. 3). The high is underlain principally by Archean–Proterozoic granulite-grade mixed gneiss with layered orthogneiss, orthopyroxene-bearing granitoids, diatexite, and mafic gneiss of sedimentary and volcanic origin (APQgm) of the Queen Maud granitoid belt (Skulski et al., 2018). Relatively small, but significant, patches of Paleoproterozoic Sherman Group granulite-grade metasedimentary rocks (PSgp), and some larger units of Archean–Proterozoic mixed gneisses with layered orthogneiss, granitoids, paragneiss (and migmatite), diatexite, and mafic gneiss of sedimentary and volcanic origin (APQmg) of the granitoid belt are also present. The apparent continuity of narrow, short-wavelength linear magnetic highs (integral components of the Queen Maud high) from units of Archean–Proterozoic granulite-grade mixed gneiss (APQgm) across boundaries into other units (principally APQmg and PSgp) in derivative magnetic images suggests that the other units are thin and/or weakly magnetic and underlain by the mixed gneiss unit, the principal source of the highs. These potentially thin units have not been factored into the modelling (Fig. 5b) of magnetic profile 1 crossing the Queen Maud magnetic high (Fig. 5a), which more clearly displays the short-wavelength magnetic highs than does the magnetic map (Fig. 3).

The Queen Maud high is flanked to the east by the subparallel belt-like McNaughton Lake low that defines wedge-shaped magnetic domain 70 (Thomas, 2018a) and extends about 300 km southwestward from the Sherman Basin close to or along the eastern margin of the Queen Maud granitoid belt. The McNaughton Lake low coincides with the area between major faults A and B (Fig. 3). Essentially the same area covered by domain 70 was identified on an aeromagnetic map as the 'Sherman Basin' by Davis et al. (2014), who noted the association of a pronounced magnetic low with the sedimentary rocks of the Sherman Group.

The Sherman Group, comprising mainly granulite-grade, migmatized pelitic and semipelitic metasedimentary rocks with garnet-bearing melt leucosome (PSgp) (Skulski et al., 2018), covers most of the area of the McNaughton Lake low. The remainder of the low, particularly near McNaughton Lake and along its western margin, is underlain mostly by the Archean–Proterozoic granulite-grade mixed gneiss and associated rock types (APQgm) that in stark contrast, apparently, are the main source of the Queen Maud high to the west. A few small areas of Archean–Proterozoic massive to gneissic, mainly felsic plutonic rocks, together with minor paragneiss (APQg), are also present.

The entire length of approximately the western two thirds of the McNaughton Lake low is characterized by narrow, linear magnetic highs, present within all the aforementioned geological units. Those falling on the two geological units (APQgm, APQg) belonging to the Queen Maud granitoid belt are believed to relate directly to sources within the units, probably compositional variations within the gneissic rocks. Sources of linear magnetic highs over the metasedimentary Sherman Group (PSgp) are more problematical, considering how strongly this linear magnetic pattern contrasts with the predominantly relatively negative and smooth magnetic field associated with the group farther east. Possibly, the highs reflect sources within the Sherman Group that include the principal granulite-grade pelitic and semipelitic metasedimentary rocks with garnet-bearing melt leucosome. Alternatively, if the Sherman Group is thin and weakly magnetic along the western two thirds of the McNaughton Lake low, the linear highs may be linked to compositional layering within underlying gneiss-bearing geological units (APQgm, APQg) of the Queen Maud granitoid belt.

Somewhat puzzling with respect to the western margin of the low, and of domain 70, is the large protrusion of the unit of granulite-grade mixed gneiss and associated rock types (APQgm), the apparent source of the Queen Maud high, into the western margin of domain 70 and its defining magnetic low (Fig. 3). The boundary between domains 71 and 70 cuts through the unit along a fairly linear path, and the magnetic field changes by a substantial 1300 nT (Fig. 5a), on the basis of which a noticeable change in geology along the magnetic boundary would have been anticipated. The extensive fault A, roughly 280 km long within the study area, is positioned just 8.5 km from the boundary between magnetic domains, but it does not influence the large change in the magnetic field. The nature of the contact between the domains is investigated by modelling magnetic profile 1 that runs from within domain 71 into the marginal area of domain 70 (Fig. 3, 5).

Magnetic profile 1, the derived magnetic model, and geology mapped at surface are displayed in Figure 5a, b, and c, respectively. Most of the profile is characterized by alternating, distinct narrow magnetic highs and lows associated principally with units of the Queen Maud granitoid belt, but also with a moderately wide unit of the Sherman Group. Two of the strongest magnetic highs, a and b, fall on the Sherman Group. Another notable peak, c, falls on the north end of a broad unit of Archean–Proterozoic mixed gneisses (APQmg); a strong peak, d, correlates closely with a narrow unit of granulite-grade mixed gneiss (APQgm); and a prominent peak, e, spans a contact between another unit of mixed gneiss and a narrow unit of orthopyroxene granite and orthopyroxene granodiorite (APQg). There are conspicuous magnetic lows, f_1 and f_2, located near the centre of the west-northwestern unit of Sherman Group and near the west-northwestern boundary of the broad unit of Archean–Proterozoic mixed gneisses (APQmg), respectively. Another prominent low, f_3, falls at the boundary between narrow units of granulite-grade mixed gneiss (APQgm) and orthopyroxene granite and granodiorite (APQg) near the centre of the Queen Maud granitoid belt. These lows, naturally, coincide with units having significantly lower magnetic susceptibilities than adjacent units. The question arises whether these relatively weakly magnetic units reflect mainly a change in lithology or are indicative of faulting. Fault-related fracturing and brecciation increase porosity locally, leading to enhanced circulation of water and associated oxidation and hydration. Oxidation of magnetite (high susceptibility) produces hematite (comparatively low susceptibility) in an alteration process termed 'martitization' (Henkel and Guzmán, 1977). Hence, many faults are associated with linear negative magnetic anomalies.

The magnetic lows labelled 'f_1', 'f_2', and 'f_3' are the most intense along the profile and are interpreted to reflect major fault zones. Several other, less intense magnetic lows labelled 'f' are also interpreted to reflect faulting. The attribution of a fault association to all the profile lows is supported by the presence of linear magnetic lows in the appropriate locations, as displayed in the magnetic map of Figure 3.

A striking feature of the model is the steepness of the many vertical to near-vertical units modelled across the length of the profile (Fig. 5b). Magnetic susceptibilities are

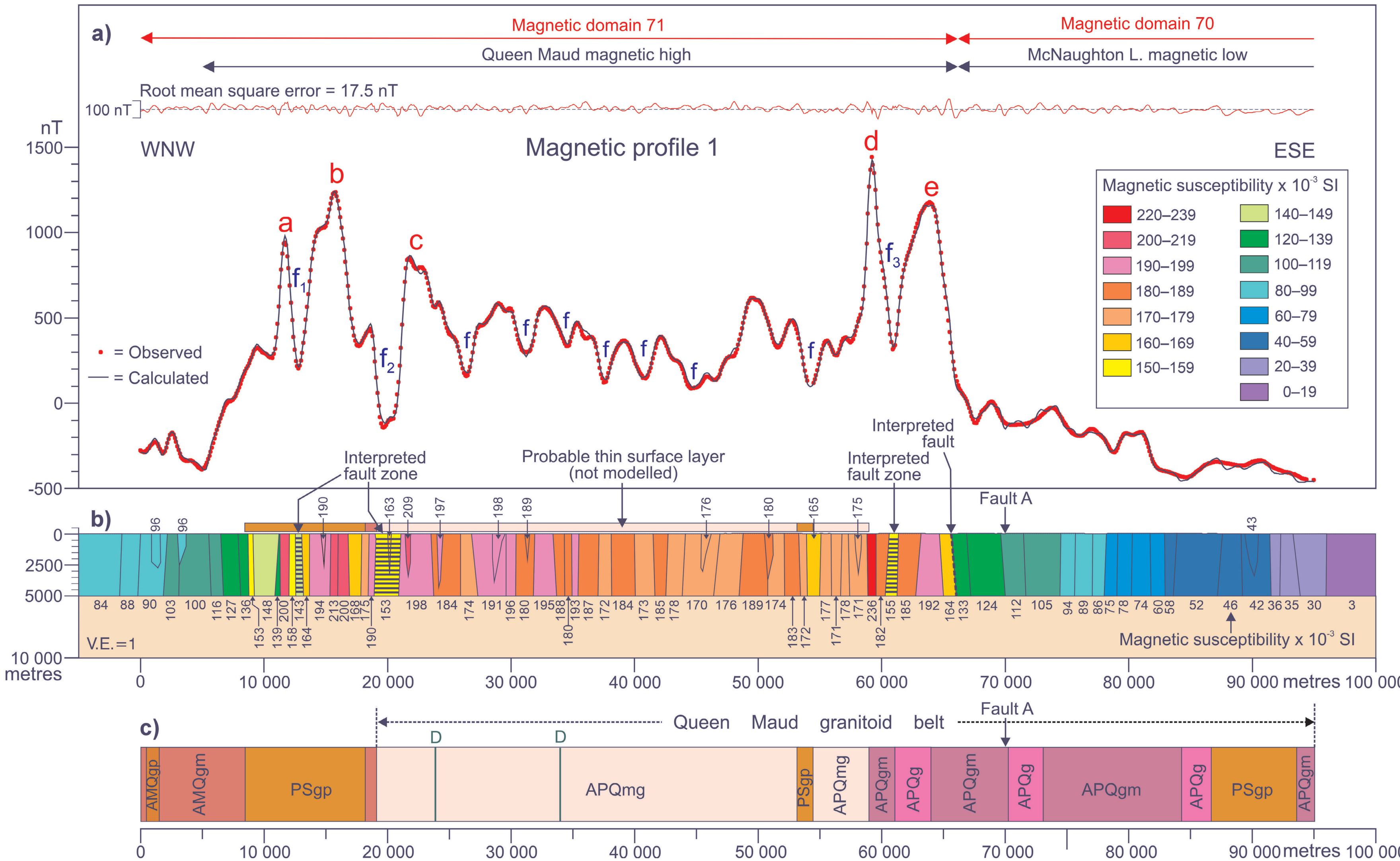


Figure 5. **a)** Observed magnetic profile 1 crossing the Queen Maud magnetic high and the Queen Maud granitoid belt, calculated magnetic profile for model, plot of root mean square error, and colour scheme for size of magnetic susceptibility; magnetic peaks are labelled in red; magnetic lows labelled with a blue ‘f’ indicate probable presence of an associated fault; **b)** magnetic model with susceptibilities (V.E. = vertical exaggeration); **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text.

predominantly very strong: 76% of the values range from 100 to 236 × 10^{-3} SI. These are almost invariably for units within the Archean–Proterozoic mixed gneisses (APQmg) forming much of the central portion of the Queen Maud granitoid belt and within the adjacent unit of Sherman Group metasedimentary rocks (PSgp) to the west. It was earlier noted that apparent continuity of narrow, linear magnetic highs from areas of Archean–Proterozoic granulite-grade mixed gneiss (APQgm) into other units indicated that the mixed gneiss is the principal source of the anomalies. The modelled magnetic units coinciding with Archean–Proterozoic mixed gneisses (APQmg) and Sherman Group (Fig. 5c) in the west-northwestern portion of the model are, therefore, probably composed predominantly of granulite-grade mixed gneiss (APQgm) underlying a thin cover of mixed gneisses (APQmg) and Sherman Group. Two of the strongest magnetic highs along the profile, a and b, fall on the unit of Sherman Group and are attributed to modelled units having susceptibilities of 200 and 213 × 10^{-3} SI, respectively, that likely are formed of mixed gneisses (APQgm). The unit of mixed gneisses (APQmg) occupies much of the geology along the profile, because it is relatively narrow and aligned along the profile and is flanked to the north and south at no great distance by Archean–Proterozoic granulite-grade mixed gneiss (APQgm) (Fig. 2). The prominent magnetic peak c, within the western margin of the broad unit of Archean–Proterozoic mixed gneisses (APQmg), like neighbouring peaks a and b, is modelled as a high-susceptibility (198 × 10^{-3} SI) unit, again probably representing granulite-grade mixed gneiss (APQgm).

Within the eastern margin of the Queen Maud magnetic high, peaks d and e, separated by the fault-related low f_3, rival peaks a, b, and c in intensity. Peak d correlates mainly with a narrow unit of Archean–Proterozoic granulite-grade mixed gneiss (APQgm) and is modelled as two adjacent high-susceptibility (236 and 182 × 10^{-3} SI) units within the mixed gneiss. Peak e spans the boundary between another unit of granulite mixed gneisses (APQgm) and a unit of Archean–Proterozoic orthopyroxene granite and orthopyroxene granodiorite (APQg). The intervening low f_3 between peaks d and e is modelled as an approximately 800 m wide unit, susceptibility 155 × 10^{-3} SI, spanning the boundary between narrow units of granulite-grade mixed gneiss (APQgm) and orthopyroxene granite/granodiorite (APQg), and interpreted to be a fault zone.

The eastern flank of peak e is very steep, is associated with a change of 1300 nT from the peak to the base of the flank, and represents the regional magnetic gradient defining the boundary between magnetic domains 70 and 71 (Fig. 3). The peak is modelled by three contiguous near-vertical units having susceptibilities of 164, 185, and 192 × 10^{-3} SI that contrast with units either side having susceptibilities of 155 and 133 × 10^{-3} SI (Fig. 5b). The flank is aligned closely with the unit boundary across which the susceptibility changes from 164 to 133 × 10^{-3} SI. This regional gradient cuts obliquely across a boundary between units of Sherman Group and granulite mixed gneisses (APQgm) just north of the profile line, suggesting it may be associated with faulting, an idea supported by the fact that the path of fault A follows the gradient closely (Fig. 3). Although the path of the domain boundary is not as smooth as that of the fault, which was copied from a 1:2 500 000 scale map (Berman, 2010), it is possible that, in detail, the fault includes local splays and en échelon sections that could coincide with the modelled fault near profile 1.

Modelled units at the extreme west end of the profile, outside the Queen Maud magnetic high, have susceptibilities ≤103 × 10^{-3} SI. At the east end of the profile, east of peak e, the magnetic field decreases gradually, but with superposed, relatively low-amplitude perturbations that image the low-amplitude, narrow, linear discontinuous highs observed along the western margin of the McNaughton Lake magnetic low (Fig. 3). Susceptibilities along this section range from 30 to 124 × 10^{-3} SI.

MODEL OF THE CHANTREY MAGNETIC HIGH

The Chantrey magnetic high lies east of the McNaughton Lake low and extends from Chantrey Inlet for about 300 km south-southwest. Together with some less extensive subparallel highs, it provides the basis for defining the northern part of magnetic domain 69 (Fig. 3). The southeastern boundary of the northern part coincides with the approximately 310 km long Chantrey fault that extends much farther south than the Chantrey magnetic high. The high correlates predominantly with a unit (Amgn) of Neoarchean mixed gneiss that includes amphibolite gneiss, hornblende-biotite gneiss, granitoid gneiss and migmatite and in part is derived from sedimentary and volcanic rocks (Skulski et al., 2018). The northwestern boundary of the unit truncates several geological units (Fig. 2). One of the magnetic highs defining domain 69 lying along its northwestern boundary immediately east of McNaughton Lake correlates with a unit (APQg) of the Queen Maud granitoid belt formed predominantly of massive to gneissic orthopyroxene granite and orthopyroxene granodiorite. The texture of its magnetic pattern, while resembling that of the overall pattern of the Chantrey high itself, namely a series of narrow, parallel linear highs, differs in that the highs are generally somewhat wider and more intense. Farther south along the boundary, a less extensive and narrower high correlates with a unit (APQgn) comprising gneissic granite, granodiorite, and quartz diorite that is also member of the Queen Maud granitoid belt. The Chantrey high dies out gradually to the southwest, where domain 69 is defined mainly by linear positive anomalies that are narrower, more widely spaced, and less intense than those within the Chantrey high (Fig. 3).

The 100 km long magnetic profile 2 is selected for modelling the Chantrey magnetic high (Fig. 3, 6a). It extends southeastward from within the McNaughton Lake low in domain

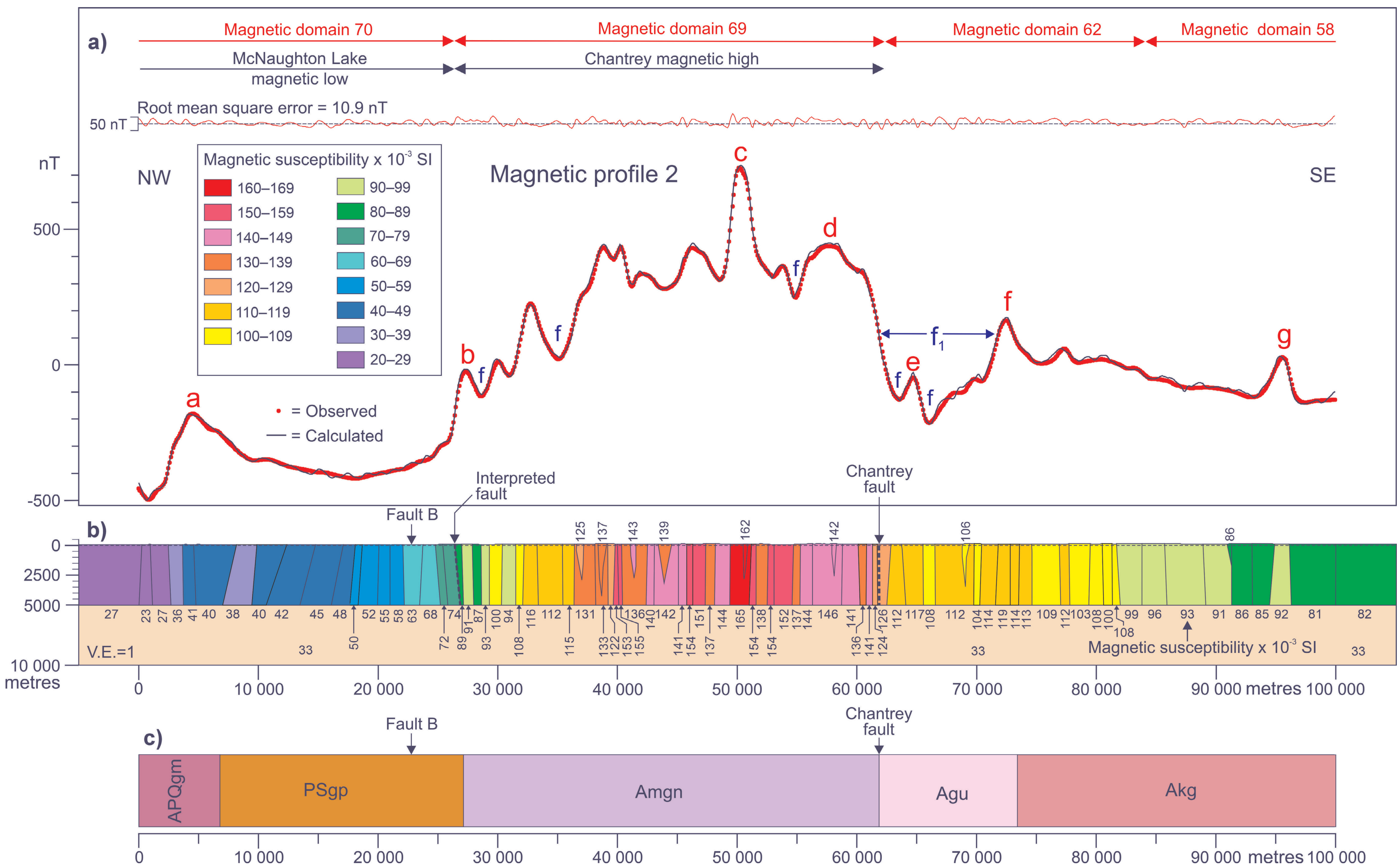


Figure 6. **a)** Observed magnetic profile 2 crossing the Chantrey magnetic high and Chantrey fault, calculated magnetic profile for model, plot of root mean square error, and colour scheme for size of magnetic susceptibility; magnetic peaks are labelled in red; magnetic lows labelled with a blue 'f' indicate probable presence of an associated fault; **b)** magnetic model with susceptibilities (V.E. = vertical exaggeration); **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text..

70 across the Chantrey high, here occupying the full width of domain 69, crosses the Chantrey fault into domain 62, and ends in domain 58. The profile emphasizes the prominence of the 35 km wide Chantrey magnetic high, which attains 1130 nT (peak c) above the nadir of the McNaughton Lake low to the northwest, and 700 to 850 nT above the magnetic field to the southeast. Like most of the highs in the other profiles, the Chantrey magnetic high includes several conspicuous superposed relatively short-wavelength magnetic highs, alternating with lows. The McNaughton Lake low to the north, apart from the prominent peak a, is generally unperturbed. At the southeast end of the profile, the magnetic field within domains 62 and 58 is also generally unperturbed, except for two prominent narrow magnetic highs, f and g (Fig. 6a), and its general level is significantly higher than that over domain 70 associated with the McNaughton Lake low (Fig. 6a).

The Chantrey magnetic high correlates exclusively with a broad unit of Neoarchean mixed gneiss (Amgn). To the northwest, the McNaughton Lake low correlates closely with a unit of the granulite-grade, metasedimentary Sherman Group, though the magnetic high a in the northwestern part of the low correlates mainly with a unit of Archean and Proterozoic granulite-grade mixed gneiss (APQgm) of the Queen Maud granitoid belt. The Chantrey magnetic high is flanked to the southeast by a moderately wide, distinct magnetic low f_1 correlating with a unit of Neoarchean granitoid rocks (Agu). A conspicuous short-wavelength magnetic high, f, on the southeastern flank of the low lies on the southeastern margin of the granitoid unit. From here the magnetic field decreases gradually southeastward across a unit of Neoarchean K-feldspar porphyritic granodiorite (Akg) to the end of the profile, near which the distinct short-wavelength magnetic high, g, is observed.

The model (Fig. 6b) comprises many narrow, near-vertical magnetic units, generally less than about 2 km wide. Susceptibilities range from 23 to 165 × 10^{-3} SI, with many of the highest (122–165 × 10^{-3} SI) associated with the southeastern three quarters of the unit of Neoarchean mixed gneiss (Amgn) that produces the Chantrey magnetic high. The variability in susceptibility is doubtless related to the heterogeneous mix of rock types constituting a unit that includes amphibolite gneiss, hornblende-biotite gneiss, granitoid gneiss, and migmatite, in part derived from sedimentary and volcanic rocks. The Paleoproterozoic Sherman Group is characterized by the lowest magnetic susceptibilities, 38 to 89 × 10^{-3} SI, and although also comprising a variety of granulite-grade rock types, the coincident magnetic field does not feature noticeable perturbations. The units of Neoarchean granitoid rocks (Agu) and K-feldspar porphyritic granodiorite (Akg) present a range of strong susceptibilities, 81 to 126 × 10^{-3} SI.

The Chantrey fault sits on the steep southeastern flank of magnetic high d that marks the biggest local change in magnetic field along the profile, about 475 nT between the top of the flank at a small shoulder of d and the bottom of the northwestern flank of a minor magnetic high e (Fig. 7a). Magnetic high d is attributed to a group of narrow, steep units, roughly 6 km wide, west of the Chantrey fault whose susceptibilities range from 136 to 146 × 10^{-3} SI (Fig. 7b). Its southeastern flank is related to the significant contrast between these relatively strong susceptibilities and weaker susceptibilities associated with adjacent units to the southeast. The latter, with one exception, are located southeast of the Chantrey fault and have susceptibilities ranging from 108 to 126 × 10^{-3} SI.

All of the aforementioned modelled units are steep, and unit contacts close to the Chantrey fault are near vertical. However, the fault does not coincide precisely with a modelled contact, and even though only 100 m from a contact, the associated susceptibility contrast is minuscule (124 compared to 126 × 10^{-3} SI), so a strong case for contrasting rock types juxtaposed by faulting cannot be made. The Chantrey fault separates two major lithological units, one comprising Neoarchean mixed gneiss (Amgn) and the other Neoarchean granitoid rocks (Agu) (Skulski et al., 2018), and is 500 m southeast of a modelled contact separating units across which the susceptibility contrast is a moderately large 17 × 10^{-3} SI. This is a more likely contact to be associated with faulting, and considering that the scale of the geological map compiled by Skulski et al. (2018) is 1:550 000, a 1 mm misplacement of the fault translates into 550 m, indicating that the fault could coincide with the contact associated with the stronger susceptibility contrast. If this were the case, the fault would be vertical and extend for several kilometres into the upper crust. Even if not the case, the predominance of modelled near-vertical boundaries near the fault suggests that it may be a product of those same tectonic forces that shaped these steep boundaries, and likewise should be very steep.

The northwest boundary of the mixed gneiss unit (Amgn) is also associated with a steep magnetic gradient defining the northwestern flank of magnetic high b (Fig. 6a, b). However, the associated change in magnetic field, approximately 260 nT, is less dramatic than that across the southeast boundary marked by the Chantrey fault. The flank can be modelled by a steep contact separating units differing in susceptibility by a sizable 15 × 10^{-3} SI, which is nearly coincident with the boundary between the mixed gneiss unit (Amgn) and Sherman Group. This contact is interpreted as a fault contact dipping 85°SE. The close correlation of the mixed gneiss unit (Amgn) with the Chantrey magnetic high and the fact that the northwestern boundary of the unit truncates several geological units on the northwestern side (Fig. 2), hinting at fault control, support the presence of a fault at this location. Fault B, though partially coincident with this boundary, deviates northwestward from the boundary by about 4 km at the location of the profile, hence cannot be directly linked to the magnetically interpreted fault. Possibly, the path of fault B on the source map from which it was copied is not entirely accurate. In spite of this lack of coincidence, magnetic modelling supports the presence of a major near-vertical fault along the northwestern margin of the unit of Neoarchean

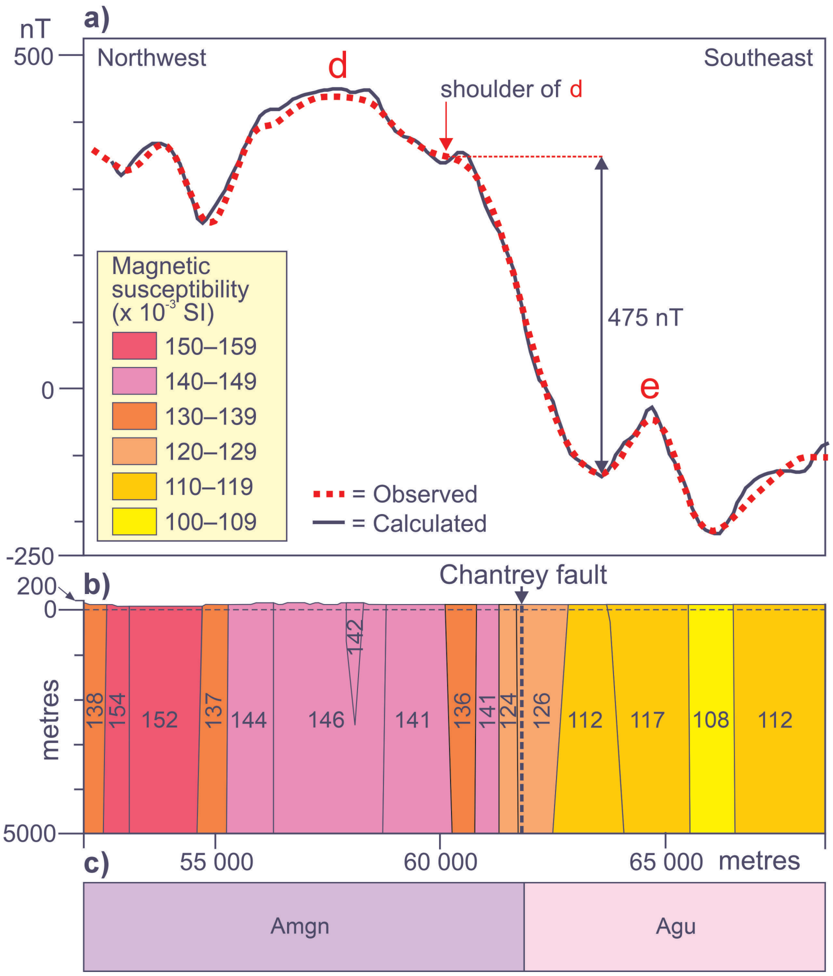


Figure 7. a) Section of observed magnetic profile 2, calculated magnetic profile for model in the vicinity of the Chantrey fault, and colour scheme for size of magnetic susceptibility; **b)** magnetic model with susceptibilities; **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text.

mixed gneiss (Amgn) at the location of the profile. The fault likely had a major role in downdropping and preserving the younger Paleoproterozoic Sherman Group along its northwestern margin.

MODELS OF THE AMER MAGNETIC HIGH

The Amer magnetic high is the dominant magnetic feature in the southern half of the general study area (Fig. 3). Significantly, practically the whole of the northern boundary of the magnetic high coincides precisely with the 270 km long Amer mylonite zone (Skulski et al., 2018) (Fig. 2). The Amer high extends from near the northern boundary of the Aberdeen Subbasin, trending initially 55°NE before curving gradually into an easterly direction, and ending near the boundary between magnetic domains 42 and 43. Over most of its extent it correlates very closely with the western two thirds of domain 42, its strong intensity contrasting with the weaker intensities of adjacent domain 40 to the south and domain 56 to the north at its eastern end, though it is generally flanked to the north by the strong magnetic signature defining magnetic domain 57. A strong signature defining magnetic domain 39 borders the east end of the Amer magnetic high to the south.

The texture of the Amer magnetic high displays a roughness related to the constituent numerous short-wavelength highs, and although the composite Amer high trends roughly northeastward to eastward, short-wavelength highs having the same trend are not highly concentrated or always extensive. Nevertheless, there are a reasonable number of short to moderately long, linear magnetic highs, and a few more extensive highs scattered throughout that collectively mimic the overall trend of the Amer high, albeit many other generally short, linear highs of different orientation are present.

Much of the western portion of the magnetic high is underlain mainly by Neoarchean Snow Island suite monzogranite and granite pegmatite (Amg) and mixed gneiss (Amgn) that includes amphibolite gneiss, hornblende-biotite gneiss, granitoid gneiss, and migmatite, in part derived from sedimentary and volcanic rocks (Skulski et al., 2018), whereas most of the eastern portion coincides with a granulite complex (APgr). Small areas of Snow Island suite and Archean–Proterozoic granulite (APgp) that include paragneiss and migmatite lie between the eastern granulite complex and mixed gneiss unit to the west. Considering the diversity of lithological rock types forming these units, the boundaries between them, seemingly, are not imaged in either the residual total magnetic field or derivative magnetic images. Patterns of the magnetic field and derivative anomalies associated with these geological units are very similar. The Amer magnetic high and Amer shear zone have been investigated by modelling two magnetic profiles, one in the west (profile 3) and one in east (profile 4) (Fig. 3). The geology along the profiles is noticeably different, as is the magnetic signature associated with the shear zone.

Model of the Amer West magnetic profile

The northwest–southeast profile 3 (Fig. 8a), 64.5 km long, crosses the western portion of the Amer magnetic high (Fig. 3). The high includes several narrow, alternating peaks and troughs, and across most of its width correlates with a unit of Neoarchean mixed gneiss (Amgn). The southeastern end of the high coincides mainly with a relatively narrow unit of Neoarchean monzogranite and granite pegmatite (Amg) of the Snow Island suite. The variability in rock types within the unit of mixed gneiss is probably accompanied by variations in magnetic susceptibility that produce the alternating pattern of peaks and troughs. The most intense peak, g, attains 665 nT above the presumed background level of the magnetic field to the southeast in magnetic domain 40 and roughly 655 nT above background to the northwest. Other prominent highs falling on the unit of mixed gneiss southeast of the Amer shear zone are d, e, h, and i, the latter spanning the boundary with a unit of Neoarchean monzogranite and granite pegmatite (Amg).

Northwest of the Amer shear zone, the magnetic field has similar characteristics to those of the Amer magnetic high, taking the form of a magnetic high perturbed by alternating narrow peaks and troughs. This is not surprising, considering that it correlates principally with the same unit of Neoarchean mixed gneisses (Amgn) that correlates with the Amer magnetic high southeast of the shear zone. It is not quite as intense as the Amer magnetic high with its strongest peak, b, attaining 530 nT above background to the southeast. Separating the Amer high and flanking high to the northwest is a narrow, conspicuous magnetic low, f_1, that correlates precisely with the Amer shear zone.

At the northwest end of the profile, the lower background values coincide with mainly Paleoproterozoic granite (PHg) of the Hudson suite (Fig. 8c). A narrow unit of Neoarchean K-feldspar porphyritic granodiorite±hornblende±magnetite (Akg) and unit of Paleoproterozoic sedimentary rocks of the Amer group (Ps4) are also present. Southeast of the Amer magnetic high, at the end of the profile, the crust is formed of Amer group sedimentary rocks.

Structural symbols plotted on a geological map (Tella, 1994) provide insight into the structural fabric in the area of the profile. These include strike/dip symbols for bedding and regional foliation. Bedding information is restricted to units of the sedimentary Amer group. Regional foliation symbols are distributed throughout the area covered by Neoarchean mixed gneiss (Amgn), spaced generally roughly 3 to 8 km apart. Symbols within 10 km of the profile line have been projected to the line, and dips of foliation are plotted in Figure 8c. Dips are the actual dips at the point of measurement and have not been transformed into apparent dips in the direction of the profile: simply the general dip direction, northwestward or southeastward, is indicated. Dips within the mixed gneiss are predominantly very steep, supporting the concept of steep modelled magnetic units. Some steep dips are present also within a unit of Paleoproterozoic granite (PHg) of the Hudson suite near the northwest end of the profile. There are only a couple of steep dips within the unit of Neoarchean Snow Island suite monzogranite and granite pegmatite (Amg) near the southeast end, with most being moderately steep. Gentle dips characterize bedding in the sedimentary Amer group at the southeast end of the model.

The magnetic model (Fig. 8b) is characterized by generally narrow, near-vertical magnetic units. Magnetic susceptibilities of units within the mixed gneisses (Amgn) are the largest in the model, most ranging from 60 to 85 × 10^{-3} SI. They are, however, significantly lower than those derived for units within the same mixed gneiss unit (Amgn) in the model derived for profile 2 crossing the Chantrey magnetic high (Fig. 6b), which range from 91 to 165 × 10^{-3} SI. The difference may reflect regional differences in the composition of the mixed gneiss unit, since the relevant Amgn units within the profiles are some 110 km apart (Fig. 2). Alternatively, the unit is significantly thinner than the arbitrarily assigned depth of 5000 m in the area of the Amer West profile, in which case susceptibilities would need to be increased to reproduce the observed magnetic signature.

As noted, the Amer shear zone correlates closely with a distinct narrow magnetic low, f_1, that is the most intense low along the profile. It is difficult to estimate its amplitude, because of the 'spiky' nature of the adjacent magnetic field to either side, but a rough estimate is about −250 nT. Its width at half of its amplitude is 2700 m. The low can be reproduced by a narrow, vertical unit approximately 2 km wide whose susceptibility (65 × 10^{-3} SI) is lower than susceptibilities of adjacent units to either side by 3 and 10 × 10^{-3} SI. It is proposed that the narrow low-susceptibility unit outlines the geometry of the Amer shear zone, a heavily brecciated fault zone in which magnetic susceptibility has been significantly reduced by oxidation of magnetite to hematite through increased circulation of groundwater.

A few tens of kilometres west of profile 3 at the western end of the Amer shear zone, the southern margin of a body of porphyritic rapakivi granite (PNg) of the Nueltin intrusive suite (ca. 1.76 Ga; Skulski et al., 2018) is conspicuously

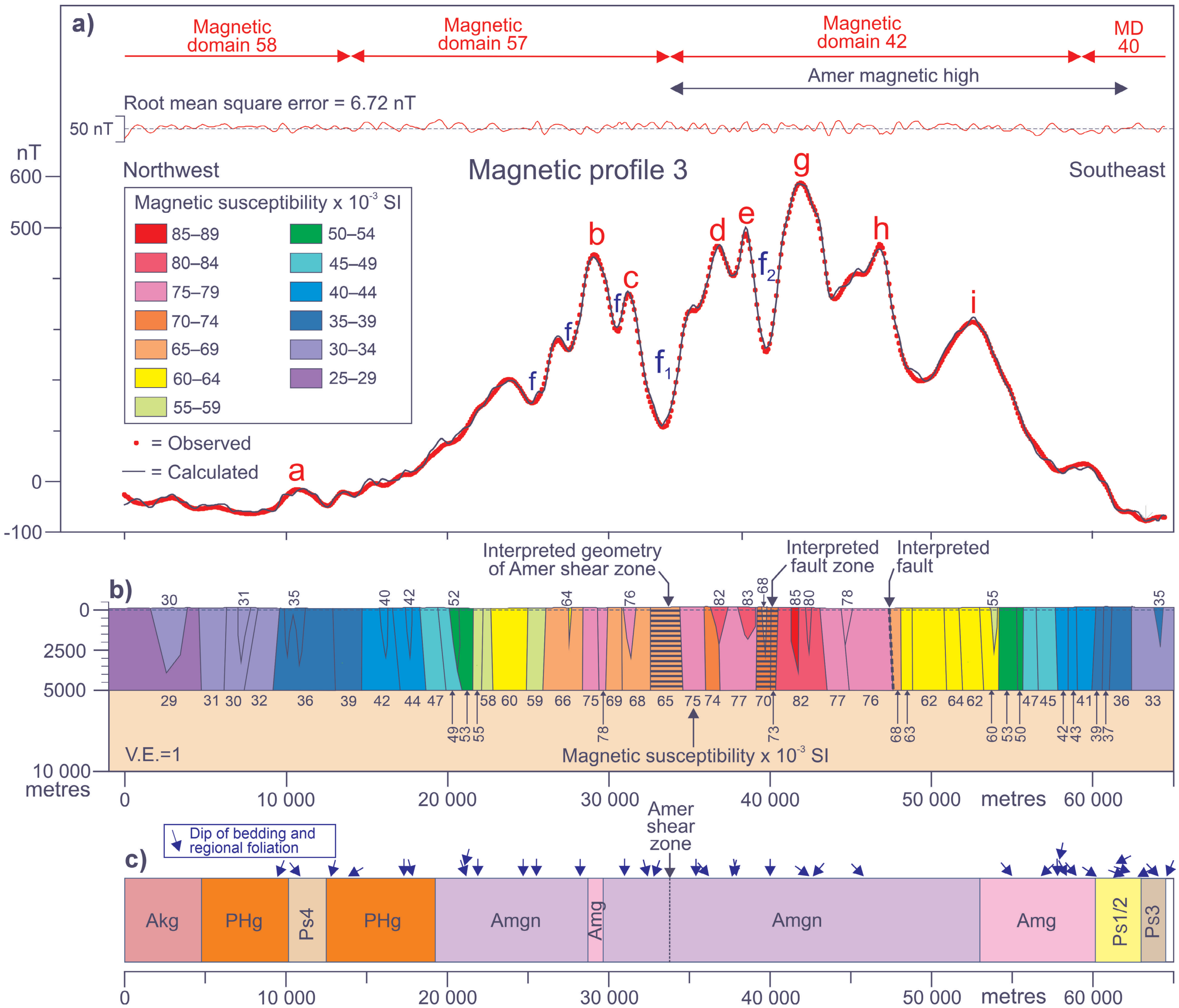


Figure 8. a) Observed magnetic profile 3 crossing the western half of the Amer magnetic high and Amer shear zone, calculated magnetic profile for model, plot of root mean square error, and colour scheme for size of magnetic susceptibility; magnetic peaks are labelled in red; magnetic lows labelled with a blue 'f' indicate probable presence of an associated fault; **b)** magnetic model with susceptibilities (V.E. = vertical exaggeration); **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text; dips of bedding and regional foliation are *based on symbols on map by* Tella (1994); dip locations are at points of arrows.

truncated at the shear zone (Fig. 2), which apparently is responsible for the semi-oval shape of the body. This body is associated with a strong magnetic high (Fig. 3). A counterpart to this granite is not observed south of the Amer shear zone, though a smaller granitic body belonging to the older (1.85–1.79 Ga) Hudson suite is in contact with the Nueltin granite at its western end, extending southward from the shear zone to meet a very small body of Nueltin granite at its southern extremity. The Hudson granite, while in an area of relatively positive magnetic field, is not associated with a distinctive singular magnetic high.

Magnetic signatures do, however, suggest that there is a counterpart to the truncated Nueltin granite south of the Amer shear zone. West of this granite, a distinct magnetic high trends southward from the Amer shear zone for approximately 55 to 60 km (Fig. 9a). Its centre (west–east sense) is about 25 km west of the centre of the high associated with the Nueltin granite at the shear zone. It is not as strong as the latter high, partly because its potential source is buried beneath mainly metasedimentary rocks of the Paleoproterozoic Amer group, and the anomaly becomes smoother southward. Nevertheless, it is a significant anomaly and a possible

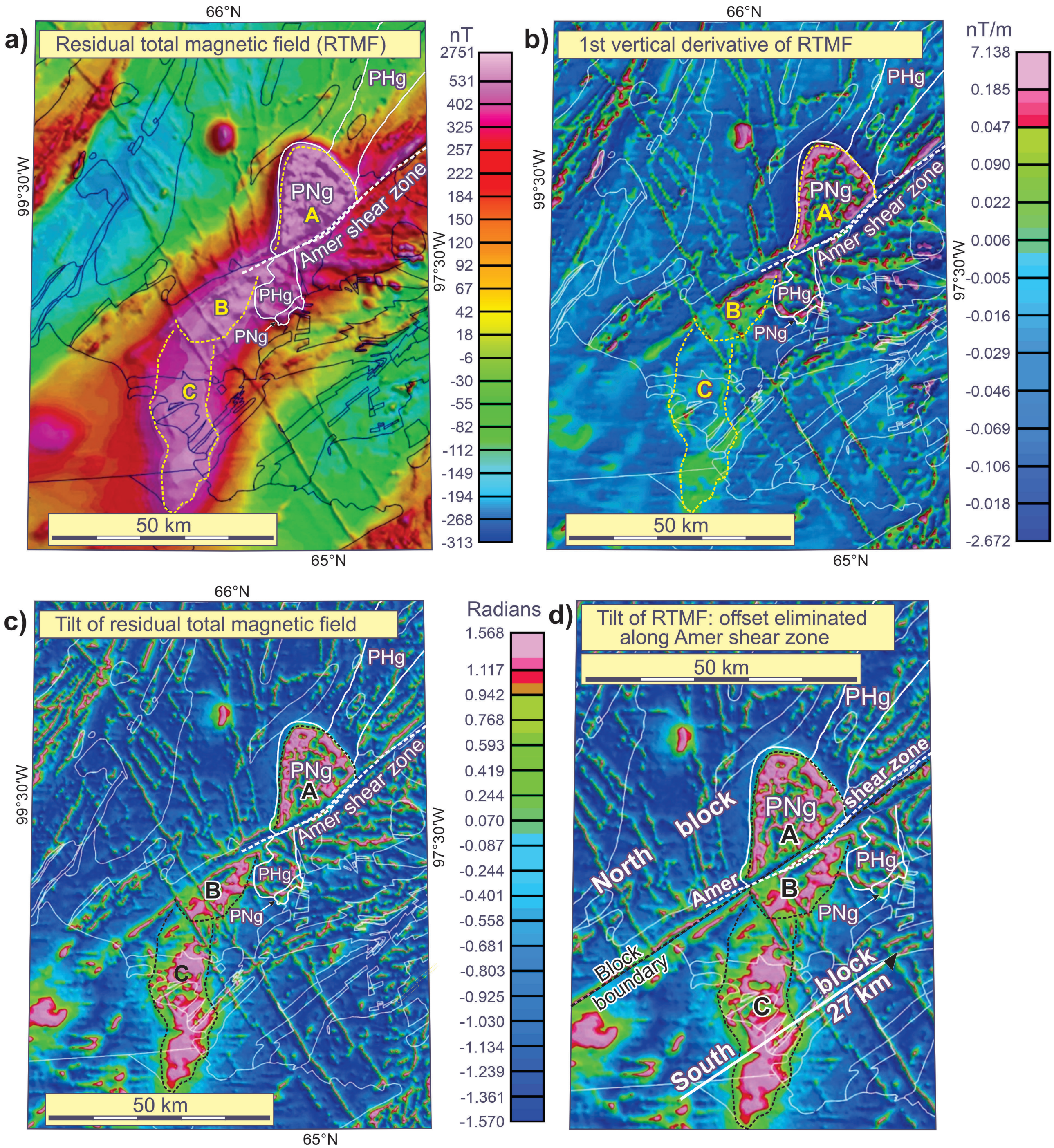


Figure 9. Maps of **a)** residual total magnetic field (RTMF), **b)** first vertical derivative of RTMF, and **c)** tilt of RTMF around west end of Amer shear zone with geological contacts of ca. 1.76 Ga Nueltin intrusive suite granite (PNg) and ca. 1.85 to 1.79 Ga Hudson suite granite (PHg) superposed. A, B, and C are areas of magnetic field discussed in text. **d)** Map of tilt of RTMF with crustal block south of the Amer shear zone moved 27 km to the northeast relative to the block to the north. Note that latitudes and longitudes differ from the top half to bottom half because of the relative movement along the Amer fault.

candidate for a link to the Nueltin granite. On the basis of images of the residual total magnetic field (Fig. 9a), of the FVD (Fig. 9b), and of the tilt of the field (Fig. 9c), this magnetic high has been tentatively divided into two subareas, B and C. The image of the FVD reveals relatively positive features within subarea B that have similar intensities to those within the Nueltin granite (subarea A) north of the shear zone. A comparison of the signatures of the tilt of the magnetic field in subareas B and A indicates a significantly stronger similarity, which extends to the signature of the tilt in subarea C.

The various magnetic images were used to determine the amount of any potential displacement of the Nueltin granite north of the Amer shear zone along the shear zone. Displacement of the magnetic tilt signature associated with subarea B south of the Amer shear zone 27 km northeastward along the zone produces a reasonable match of magnetic features north and south of the zone (Fig. 9d). The magnetic pattern within subarea A corresponding to the Nueltin rapakivi granite matches very well the pattern within subarea B. Together they produce an oval that is interpreted to represent the Nueltin granitic intrusion before faulting and displacement along the shear zone. It is speculated that the subarea C farther south coincides with a separate Nueltin granitic intrusion.

Returning to profile 3, we see that magnetic low f_2 is another intense magnetic low having roughly the same amplitude (−250 nT) as f_1, relative to the adjacent magnetic peak e (Fig. 8a). It is modelled in terms of three contiguous narrow, vertical units, susceptibilities ranging from 68 to 73 × 10^{-3} SI, flanked by units having susceptibilities of 77 and 82 × 10^{-3} SI. The three units are roughly 1300 m wide and are interpreted to represent a fault zone. There is a distinct slightly curvilinear magnetic low in the total magnetic field map oriented roughly southwest to northeast in the position of the low f_2, but it is not very extensive, perhaps a maximum of about 15 km. Nevertheless, it seems that it may be a major fracture in terms of its depth penetration.

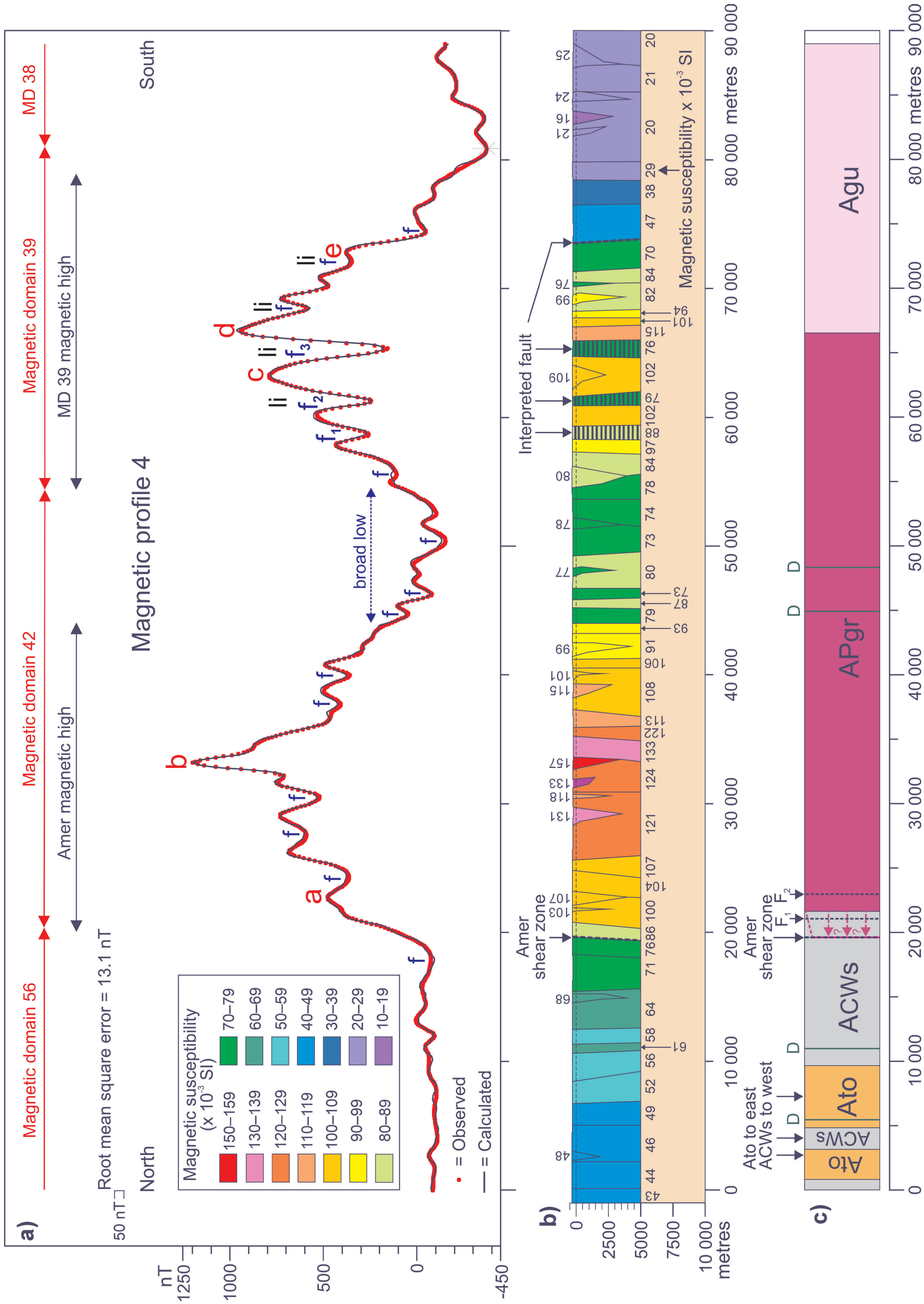
Model of the Amer East magnetic profile

Profile 4 is a second magnetic profile (Fig. 10a) across the Amer magnetic high and shear zone, located about 140 km east of the Amer West profile. It is oriented north-south and is 89 km long. At the north end, it runs southward for about 10 km along a boundary between a probable intrusive body of Neoarchean tonalite and quartz diorite (Ato) and mainly sedimentary rocks of the Neoarchean Woodburn Lake Group (ACWs) that include pelite, psammite, and wacke±intermediate tuff±quartzite (Skulski et al., 2018) (Fig. 2, 3). It then traverses the latter groups for approximately 12 km, crossing the Amer shear zone at about 10 km; continues across a broad (~45 km wide) Archean–Proterozoic granulite complex (APgr) that may include massive to gneissic hypersthene-granite, -granodiorite, -tonalite, -diorite, and -gabbro; and ends on a unit of Neoarchean undifferentiated granitoid rocks (Agu).

North of the Amer shear zone, the magnetic field is relatively flat, varying between 0 and −100 nT, but south of the zone the field increases dramatically, attaining a maximum value of 1200 nT at peak b near the centre of the Amer magnetic high (Fig. 10a). This peak is roughly 1310 and 1570 nT above background values at the north and south ends, respectively, of the profile. The overall form of the Amer high is perturbed by a series of narrow alternating highs and lows. Based on its width at its base, it correlates mainly with roughly the northern two thirds of the granulite complex (APgr) (Fig. 10a, c), whereas in the Amer West profile it correlates with a unit of Neoarchean mixed gneiss (Amgn). In spite of the different geological associations, the profiles are quite similar in that both display distinct alternating short-wavelength highs and lows. This similarity in patterns of the profiles leads to a similarity in derived magnetic models that are characterized by steep, narrow units.

To the south, the Amer high is accompanied by a similar strong magnetic high that correlates with magnetic domain 39, herein termed the ‘MD 39 magnetic high’ (Fig. 10a). It spans the southern third of the granulite complex (APgr) and a portion of an adjacent unit of undifferentiated granitoid rocks (Agu) to the south. Its principal peak, d, is 1315 nT above background at the south end of the profile. A prominent wide magnetic low is observed between the Amer and MD 39 magnetic highs, falling near the centre of the granulite complex and indicating a significant change in the nature of the rocks forming the complex in this area. Most of domain 42 between the two profiles crossing the Amer shear zone was defined on the basis of the Amer magnetic high; the aforementioned magnetic low, covering a relatively small area on the southern margin of the domain, was included within the domain, given the regional nature of the magnetic study (Thomas, 2018a), though it could have been assigned subdomain status.

Figure 10. **a)** Observed magnetic profile 4 crossing the eastern half of the Amer magnetic high and Amer shear zone, calculated magnetic profile for model, plot of root mean square error, and colour scheme for size of magnetic susceptibility; magnetic peaks are labelled in red; magnetic lows labelled with a blue ‘f’ indicate probable presence of an associated fault, though those with an additional black ‘li’ label may alternatively be related to a low-susceptibility rock unit; **b)** magnetic model with susceptibilities; **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text.



a)
Magnetic profile 4
Magnetic domain 56
Magnetic domain 42
Magnetic domain 39
MD 38
Amer magnetic high
MD 39 magnetic high
Root mean square error = 13.1 nT
50 nT
North
South
broad low
Magnetic susceptibility (x 10^-3 SI)
150–159
130–139
120–129
110–119
100–109
90–99
80–89
70–79
60–69
50–59
40–49
30–39
20–29
10–19
• = Observed
— = Calculated
nT
1250
1000
500
0
-450
b)
Amer shear zone
Interpreted fault
Magnetic susceptibility x 10^-3 SI
metres
c)
Ato to east ACWs to west
Ato
ACWs
APgr
Agu
Amer shear zone
F1
F2
D
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000 metres
90 000

Given that the Amer high, the intervening low, and the northern half of the MD 39 high all fall on the granulite complex (APgr), it is apparent that magnetic susceptibilities within the central area of the complex are lower than those within the marginal areas. It is possible also that the granulite complex is thinner in the central region, but the alternating short-wavelength highs and lows suggest that changes in susceptibility are an important factor, and for that reason modelling proceeded without incorporating broadscale variation in thickness of the granulite complex.

The model (Fig. 10b) is dominated by narrow, steep magnetic units. Magnetic susceptibilities range from 73 to 157×10^{-3} SI within the granulite complex, with just over a half greater than 100×10^{-3} SI. At the north end of the profile, where it crosses Neoarchean units of tonalite and quartz diorite (Ato) and mainly metasedimentary rocks of the Woodburn Lake Group (ACWs), susceptibilities are much lower, generally in the range 43 to 86×10^{-3} SI. They are even lower at the south end of the profile within a wide section of the unit of Neoarchean undifferentiated granitoid rocks (Agu), ranging from 16 to 47×10^{-3} SI. The steep attitudes of all modelled units, as for previous profiles, suggest that the structural fabric of the upper crust is predominantly steep.

The Amer shear zone falls on the lower part of the steep magnetic gradient that descends northward from magnetic peak a to merge with the background magnetic field (Fig. 10a). A change of 550 nT takes place across this gradient. The shear zone is located 2000 m north of the northern boundary of the granulite complex (APgr) within the unit of Woodburn Lake Group. The steep gradient suggests the presence of a steep boundary between two units having significantly different magnetic susceptibilities and thereby possibly composed of different rock types. A modelled steep boundary separating two steep units having a moderately large difference of 10×10^{-3} SI in magnetic susceptibility is interpreted to represent the Amer shear zone. It is speculated that granulite complex rocks extend as far north as the Amer shear zone below the Woodburn Lake Group (Fig. 10b).

Adjacent units to the south of the shear zone having susceptibilities consistently $\geq 100 \times 10^{-3}$ SI reproduce the peak a at the top of the steep magnetic gradient related to the shear zone (Fig. 11). A reasonably close match between observed and calculated magnetic profiles is achieved (Fig. 11a) by susceptibility contrasts across planar boundaries separating modelled units that have simple geometries (Fig. 11b), although in detail there are very minor differences between the two profiles. Modelling assumes uniform susceptibilities throughout a modelled unit and, in the interest of simplicity, attempts to keep units as large as possible. Obviously, with a larger number of smaller units, it would be possible to achieve perfect curve-matching. Notwithstanding such an option, the achieved goodness of fit indicates that the model portrays a fairly accurate picture of the geometry of the Amer shear zone, which dips at 86°N. The shear zone is 2000 m north of the strongly magnetic granulite complex and traverses mainly sedimentary rocks of the Woodburn Lake Group.

Within the MD 39 magnetic high, two strong peaks (c and d) sit either side of the boundary between the granulite complex (APgr) and the unit of Neoarchean undifferentiated granitoid rocks (Agu). The prominent narrow magnetic low f_3 lying between them is near-coincident with the boundary. The low is explained by a 1200 m wide, near-vertical magnetic unit, susceptibility 76×10^{-3} SI, which has very large differences of 26 and 39×10^{-3} SI with susceptibilities of units to either side. Rather than reflecting a distinct, lower susceptibility associated with a different rock type, a preferred interpretation of the unit is that it represents a heavily sheared/brecciated fault zone. Two other prominent narrow lows, f_1 and f_2, have also been modelled as narrow, vertical units, each roughly no wider than 1 km and having much lower magnetic susceptibilities than adjacent units. It is proposed that these units represent fault zones. However, one cannot rule out the possibility that the lows reflect narrow belts of rock types having low susceptibilities.

Near profile 4 within the area of the MD 39 high, moderately extensive, linear, short-wavelength magnetic lows alternate with parallel/subparallel magnetic highs, a magnetic pattern possibly reflecting juxtaposed belts of different rock types. The choice of attributing the lows to faults or lithological differences is difficult, but the linearity of the magnetic pattern may favour the latter as the principal control on the pattern of alternating magnetic lows and highs; these lows of uncertain association are labelled ‘f’ and ‘li’ in Figure 10a. Magnetic lows within the Amer magnetic high tend to lack an associated well defined linear magnetic high and are more confidently attributed to faulting; these lows are labelled ‘f’.

Southward from peak d in the MD 39 magnetic high there is a large (~1320 nT) and fairly steep decrease of the magnetic field to its lowest level near the boundary between magnetic domains 39 and 38. Several small perturbations are superposed on this regional gradient, one of which is the peak e. The section of the gradient south of e is the steepest, and this has been modelled by a large contrast of magnetic susceptibility of 23×10^{-3} SI across the contact of two near-vertical blocks (Fig. 10b). The contact lies within the unit of Neoarchean undifferentiated granitoid rocks (Agu) and possibly represents an unfaulted contact between units of different lithology (e.g. an intrusive contact) or could signify juxtaposition of two different lithological units by faulting: a faulted contact has been interpreted in Figure 10b.

MODELS OF THE WAGER BAY MAGNETIC HIGH

The Wager Bay magnetic high is a compact, belt-like, east–west feature about 145 km long, maximum width 23 km, running partly along the southern shore of Wager Bay and entering Hudson Bay at Roes Welcome Sound (Fig. 3). It is the magnetic feature that defines magnetic domain 36

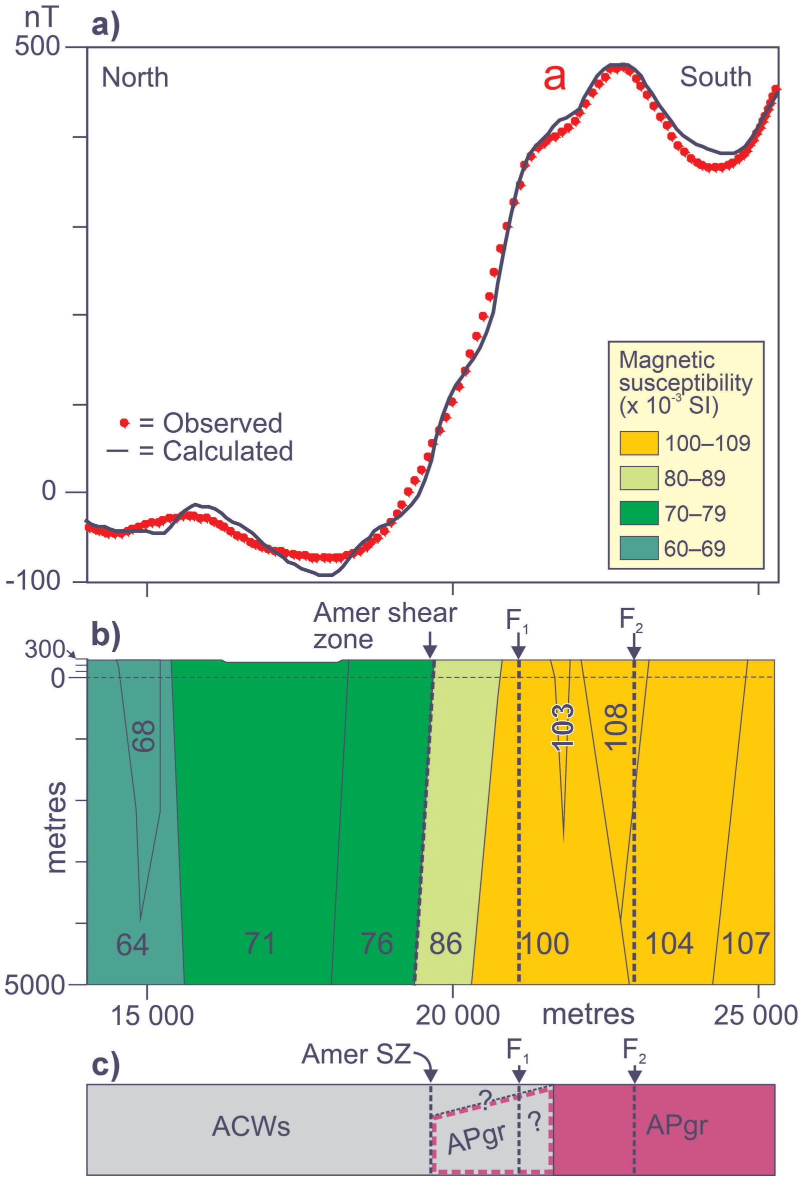


Figure 11. a) Section of observed magnetic profile 4 and calculated magnetic profile for model in the vicinity of the Amer shear zone and colour scheme for size of magnetic susceptibility; **b)** magnetic model with susceptibilities; **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text.

(Thomas, 2018a), contrasting with relatively subdued magnetic fields in adjacent marginal areas of domain 45 to the north and domain 35 to the south.

For most of its length, the northern boundary of the magnetic high is marked by the 190 km long Wager Bay shear zone. The eastern portion runs along the southern shore of Wager Bay, where it ranges in width from about 2 to 4.5 km and is crossed by the two profiles selected for modelling. The shear zone is developed mainly within a unit of Neoarchean undifferentiated granitoid rocks (Agu) that forms much of the southern shore (Fig. 2) (Skulski et al., 2018). The Wager Bay magnetic high correlates mainly with the same unit, but it coincides with a sizable area of Archean–Proterozoic granulite complex (APgr) at its eastern end. The residual total magnetic field displays a strong linear pattern relating to narrow, short-wavelength alternating highs and lows that are well displayed in the two profiles (5 and 6) crossing the Wager Bay magnetic high (Fig. 12, 13), and particularly in the eastern profile (6) (Fig. 13). The linear pattern is more strongly developed within the northern half of the wider part of domain 36, and derivative magnetic images suggest that three linear, narrow, parallel magnetic highs dominate this signature. The linearity of pattern is lost within the narrow western extremity of the domain, possibly because of disruption by cross faulting. Linearity is also absent or very broken in most of the southern half of the domain. Considering that most of domain 36 is underlain by a single geological unit of undifferentiated granitoid rocks (Agu), the differing magnetic patterns of the northern and southern halves are unexpected and are attributed to lithological differences within the granitoid unit. Linear magnetic features are, however, observed in the southern part of the domain in the coastal area where it is underlain by a portion of the broad unit of Archean–Proterozoic granulite complex (APgr).

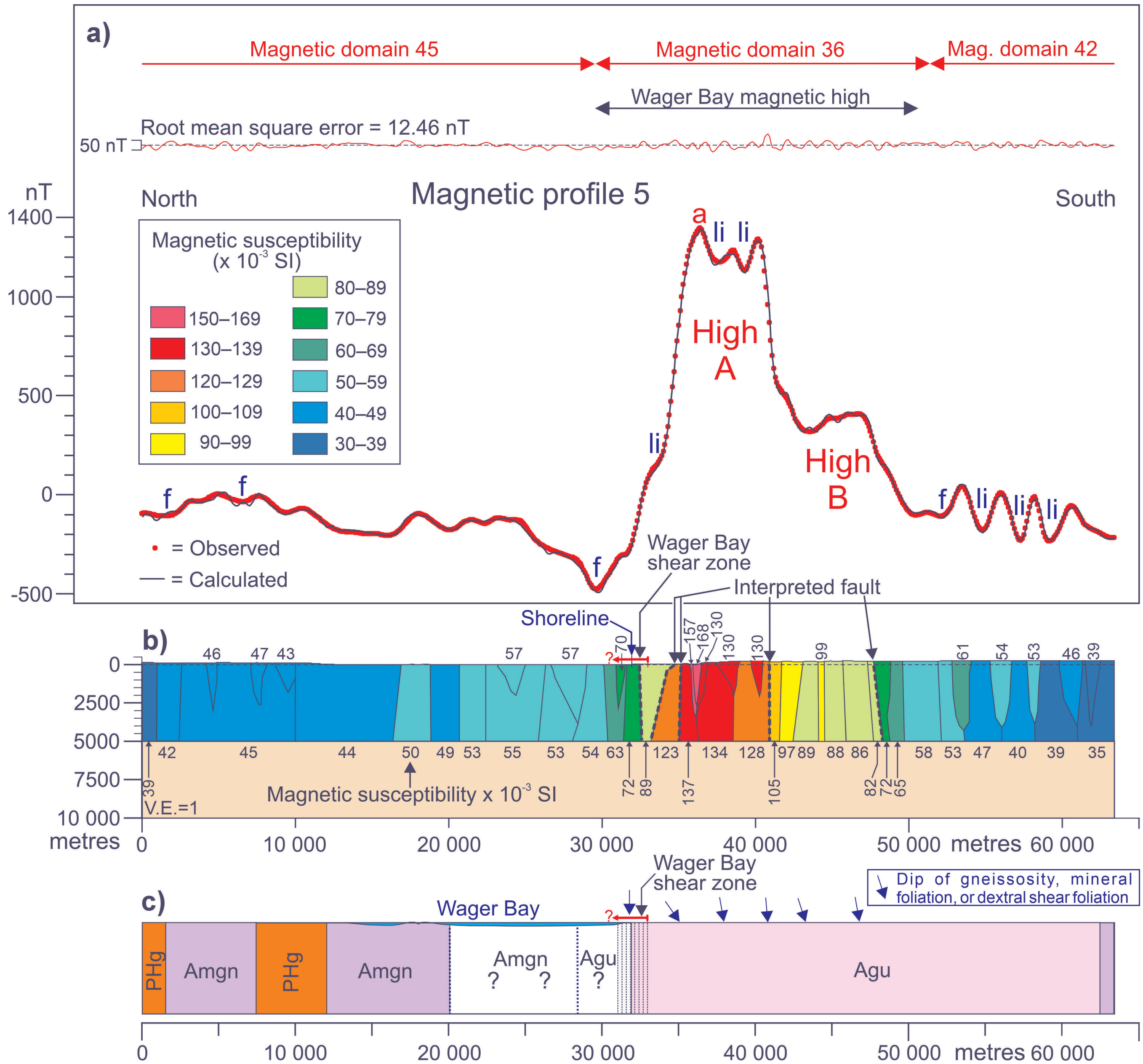


Figure 12. **a)** Observed magnetic profile 5 crossing the central part of the Wager Bay magnetic high and Wager Bay shear zone, calculated magnetic profile for model, plot of root mean square error, and colour scheme for size of magnetic susceptibility; magnetic peaks are labelled in red; magnetic lows labelled with a blue ‘f’ indicate probable presence of a fault; lows labelled ‘li’ indicate probable presence of a lower susceptibility lithological unit; **b)** magnetic model with susceptibilities (V.E. = vertical exaggeration); **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text; dips of gneissosity, mineral foliation, and dextral shear foliation are *based on symbols presented by* Henderson and Broome (1990, their Fig. 4); dip locations are at points of arrows.

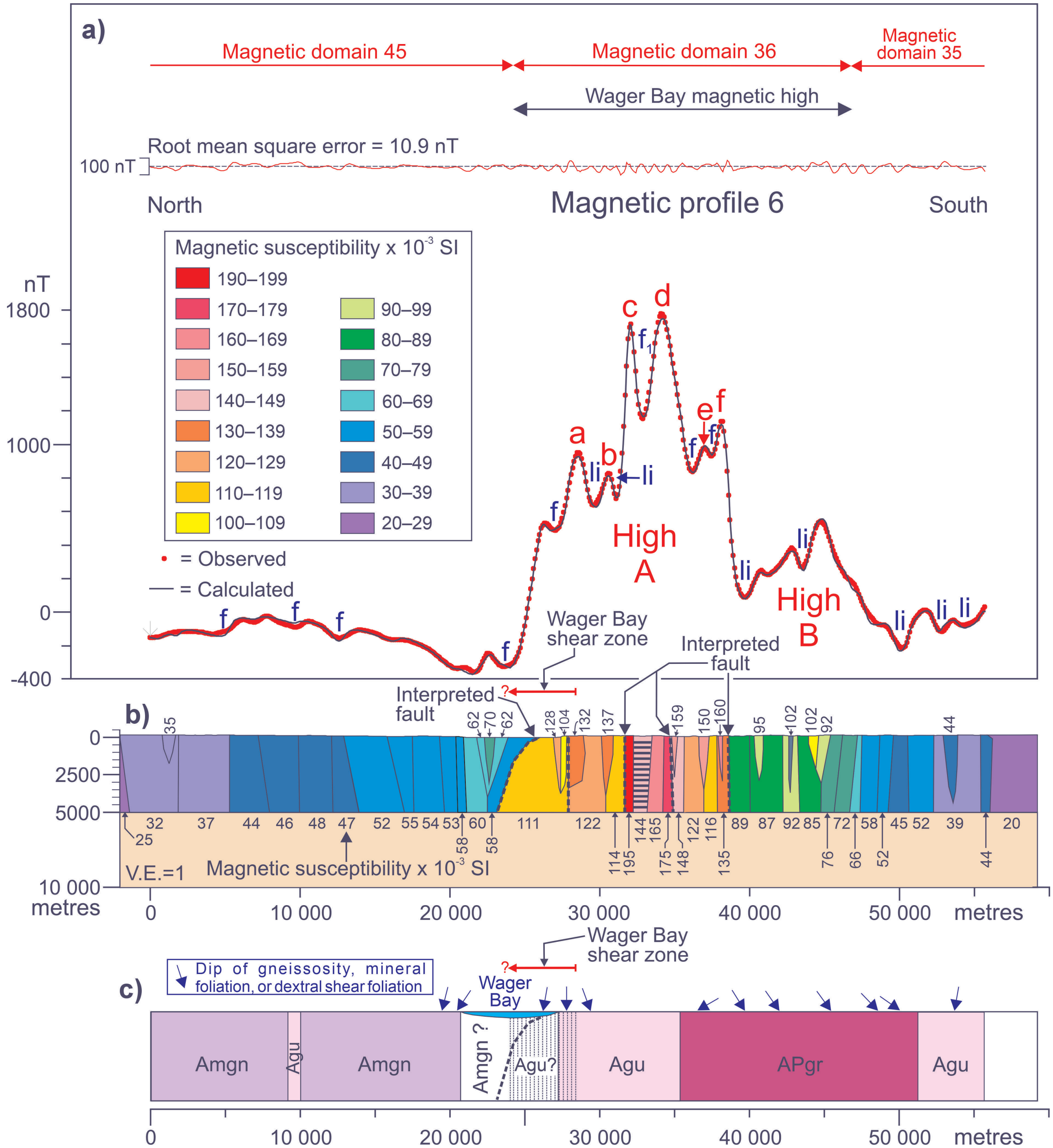


Figure 13. **a)** Observed magnetic profile 6 crossing the eastern half of the Wager Bay magnetic high and Wager Bay shear zone, calculated magnetic profile for model, plot of root mean square error, and colour scheme for size of magnetic susceptibility; magnetic peaks are labelled in red; magnetic lows labelled with a blue 'f' indicate probable presence of a fault; lows labelled 'li' indicate probable presence of a lower susceptibility lithological unit; **b)** magnetic model with susceptibilities (V.E. = vertical exaggeration); **c)** geological section (vertical contacts are schematical) *based on map by* Skulski et al. (2018); meanings of unit abbreviations are displayed in the legend of Figure 2 and relevant segments of the text; dips of gneissosity, mineral foliation, and dextral shear foliation are *based on symbols presented by* Henderson and Broome (1990, their Fig. 4); dip locations are at points of arrows.

The relatively subdued magnetic field in domain 45 to the north correlates with Neoarchean mixed gneisses (Amgn) on the mainland east of Wager Bay (Fig. 3). These gneisses form small islands offshore from the east coast of the bay (Skulski et al., 2018), suggesting that they may underlie much of the eastern portion of the bay. The magnetic field to the south over domain 35, while fairly subdued, is somewhat more perturbed than that north of the Wager Bay shear zone and includes scattered weak positive anomalies of various shapes (linear, globular, irregular) and limited extent. Most of the terrain in this area is formed of the same undifferentiated granitoid rocks (Agu) associated with the Wager Bay magnetic high, with some significant areas of Archean–Proterozoic granulite complex (APgr). The conspicuous contrast in magnetic signature over the same granitoid rock type (Agu) is somewhat surprising. Perhaps more surprising is the fact that the large unit of granulite complex spanning the southern flank of the magnetic high also displays the same contrast, its northern half associated with the magnetic high and its southern half with a subdued magnetic field. It is speculated that the upper crust in the area of the magnetic high, regardless of its component rock types, has been subjected to a process, possibly metamorphic, that has enhanced the magnetite content of the rocks.

Model of the Wager Bay West magnetic profile

The 63.4 km long western profile 5 (Fig. 12) crosses near the centre of the Wager Bay magnetic high (Fig. 3). North of the Wager Bay shear zone, the magnetic field correlates mainly with Neoarchean mixed gneisses (Amgn) and is gently undulating, with a general background level of roughly −100 nT. Just north of the shear zone, the magnetic field increases sharply southward to attain a peak value of 1350 nT within the Wager Bay magnetic high. This peak, a, is a narrow high, which along with two other narrow peaks of slightly lesser value, sits atop a broader magnetic high (high A, Fig. 12) forming the northern portion of the Wager Bay high. This is succeeded southward by another relatively broad high (high B) attaining roughly 500 nT above the general background level. Together, the two broad highs constitute the 20 km wide Wager Bay magnetic high, which correlates exclusively with Neoarchean undifferentiated granitoid rocks (Agu). South of the magnetic high, the magnetic field displays several alternating, narrow highs and lows with peak to trough differences ranging from 180 to 220 nT, all falling on the southern extension of the granitoid rocks (Agu). These anomalies are attributed to parallel bands of different rock types having different susceptibilities, the lows labelled ‘li’ to indicate that they have a lithological source, rather than being related to a fault. A conspicuous narrow magnetic low immediately north of the Wager Bay shear zone is probably a counterpart to the Wager Bay high, related to the magnetized body producing the high. In northern latitudes, where the inclination of the Earth’s magnetic field dips steeply northward, a complementary minor low may be present on the north side of a magnetic high.

The magnetic model (Fig. 12b) is everywhere characterized by units with steep boundaries. As previously reasoned, steep contacts for modelled units are favoured because they facilitate curve-matching for sections of a magnetic profile characterized by narrow, prominent magnetic anomalies. Support for steep boundaries within the Wager Bay West model is provided by structural information presented by Henderson and Broome (1990) in a figure showing structural symbols classified as 1) gneissosity–mineral foliation, 2) foliation, and 3) mineral lineation. Symbols are mapped for some 10 to 30 km south of Wager Bay, where they are distributed roughly 4 to 7 km apart. Coverage up to 30 km south is achieved everywhere east of longitude 88°W as far as Hudson Bay. Symbols lie close to profile 5 only for about 15 km south of Wager Bay; those closer than about 3 km indicate gneissosity–mineral foliation dips ranging from 55°S to 85°S (Fig. 12c). A foliation determination related to dextral shear within the shear zone itself is vertical.

Modelled units are generally broader within the northern half of the geological section, north of the Wager Bay magnetic high, where they are formed of Neoarchean mixed gneiss (Amgn) and Paleoproterozoic granite of the Hudson suite (PHg). Near the eastern shore of Wager Bay, the mixed gneiss unit can be traced for about 20 km from the north end of the profile into the bay, where it is mapped on small islands (Fig. 2). It is uncertain where it meets Neoarchean granitoid rocks (Agu) correlating with the Wager Bay magnetic high under the southern part of the bay, but based on the relatively muted magnetic signature it is speculated that the mixed gneiss unit (Amgn) may continue to the Wager Bay shear zone. The generally slightly undulating magnetic field in the northern half of the profile indicates that there is little variation in magnetization of the underlying rocks, and this is manifested in the relatively small range of susceptibilities of modelled units, which vary from 39 to 57 × 10^{-3} SI.

The steep gradient forming the northern flank of magnetic high A of the Wager Bay magnetic high (Fig. 12a) is reproduced by a southward change from the aforementioned relatively low-susceptibility units to a series of five main steep units having southward-increasing susceptibilities of 63, 72, 89, 123, and 137 × 10^{-3} SI. These yield large susceptibility contrasts across unit boundaries of 9, 17, 34, and 14 × 10^{-3} SI, and it is speculated that some of these boundaries represent faults. The interpreted fault at the boundary between the units having susceptibilities of 72 and 89 × 10^{-3} SI is perhaps the one that is directly associated with the Wager Bay shear zone as it intersects surface near the middle of the zone; it dips steeply southward at 88°. The adjacent boundary to the south surfaces 1.4 km outside the shear zone, dipping initially 40°N before abruptly steepening to dip 77°N at a depth of roughly 400 m. The succeeding boundary to the south is near-vertical and lines up with the upper portion of the steep southern flank of magnetic high A. The latter two boundaries are interpreted to be faults.

Magnetic high A correlates with the most magnetic units in the model, ranging in susceptibility from 72 to 168 × 10^{-3} SI. Its steep southern flank is modelled as a vertical contact between units having a large susceptibility contrast of 23 × 10^{-3} SI, interpreted to represent a fault. Between the fault related to the southern flank of high A and the adjacent interpreted fault to the north, susceptibilities of modelled units range from 128 to 168 × 10^{-3} SI, defining a very magnetic fault-bounded section of the northern part of the unit of Neoarchean granitoid rocks (Agu).

To the south, the less prominent high B is modelled as steep units having significantly lower susceptibilities ranging from 72 to 99 × 10^{-3} SI. Two narrow units bridging the two sets of units affiliated with the highs A and B have susceptibilities of 97 and 105 × 10^{-3} SI, resulting in a large contrast of 23 × 10^{-3} SI across the contact with an adjacent unit modelled to contribute to the high A. As noted, this contact has been interpreted to be a fault, although it may simply be a contact between two different lithological units unaffected by faulting.

The southern end of the profile, where it corresponds to magnetic domain 42, is characterized by alternating, narrow magnetic highs and lows that relate to narrow, vertical units bounded by contacts across which moderate to sizable contrasts in susceptibility are observed, most ranging from 7 to 14 × 10^{-3} SI. The lows may indicate the presence of faults, but the extensive strike-oriented lengths of the highs and lows favour the presence of narrow belts of alternating lithologies. The units within domain 42, like all modelled units south of the Wager Bay shear zone, are within the mapped unit of Neoarchean granitoid rocks (Agu). The comparative regularity of alternating lithological units signals a portion of the granitoid rocks that is compositionally different and may have a more layered structure than other parts of the granitoid unit. The layering is probably associated with a steep structural fabric.

Model of the Wager Bay East magnetic profile

The eastern magnetic profile 6 (Fig. 13a) crosses the eastern half of the Wager Bay magnetic high and also the narrow inlet connecting Wager Bay with Hudson Bay (Fig. 2, 3). The portion of the profile north of the Wager Bay shear zone, like its counterpart in the western profile, correlates mainly with Neoarchean mixed gneisses (Amgn). The profile here is gently undulating and has an average background value of about −100 nT. Southward, within Wager Bay, just a few kilometres north of the shear zone, the magnetic field increases dramatically, attaining a peak value of 1780 nT within the 22 km wide Wager Bay magnetic high. The high is characterized by several alternating peaks and troughs superposed on the two longer wavelength highs (highs A and B, Fig. 13a) that constitute the high. Some of the troughs (f) are believed to be related to faults; others (li), to lithological units. The northern high A correlates mainly with Neoarchean undifferentiated granitoid rocks (Agu), but it overlaps the northern margin of a unit of Archean–Proterozoic granulite complex (APgr) to the south. High B correlates entirely with rocks of the granulite complex. A local magnetic low in the area of Wager Bay is the presumed negative counterpart of magnetic high A.

The model derived for the Wager Bay East profile is similar to that for the Wager Bay West profile, just 25 km to the west — it is dominated by modelled units bounded by contacts that are generally near-vertical or very steep. In the northern sector of the model, where the magnetic field is fairly flat, is gently undulating, and correlates with mainly Neoarchean mixed gneiss (Amgn), units are generally noticeably wider. Structural symbols (Henderson and Broome, 1990) are available along the length of the profile; most are for ‘gneissosity, mineral foliation’, and a few are for ‘foliation, dextral shear’. Those within 3 km of the profile exhibit dips ranging from 30° to 90°, directed mostly southward. This profile traverses a corridor where dips are more gentle and offer little support for the steep modelled units. Notwithstanding this apparent contradiction, approximately 65% of gneissosity–mineral foliation dips in the area between the Wager Bay West profile and Hudson Bay are greater than 60°. This and the facilitation of curve-fitting prominent narrow magnetic anomalies by incorporation of steep contacts suggest that the shallow dips of some foliations may be related to a metamorphic event(s) postdating a major event that fashioned the steep structures indicated by magnetic modelling.

The steep northern flank of the portion of the Wager Bay magnetic high represented by magnetic high A is modelled in part by a steep, north-dipping contact between units having susceptibilities of 58 and 111 × 10^{-3} SI. The contact initially is shallow at surface, dipping at 21°N to a depth of roughly 350 m, before steepening to 52°N, which is maintained to a depth of 1600 m, below which it dips at 72°N. It lies within the northern portion of the Wager Bay shear zone and is interpreted to be a fault contact. Its geometry, with a shallow dip at surface that steepens gradually northward, is suggestive of a ramp-like feature that may have witnessed steep reverse faulting. An interpreted fault having a similar geometry, with a gentle near-surface dip and then steepening to dip 77°N, was modelled for the Wager Bay West profile (Fig. 12), but it intersects surface 1.6 km south of the shear zone as mapped (Skulski et al., 2018).

The upper part of the northern flank, descending from local peak a, is attributed to a vertical fault located close to the southern margin of the shear zone. It is probably generated mainly by fairly large changes in susceptibility from 111 × 10^{-3} SI within a conspicuously broad unit north of the proposed fault to 122 and 132 × 10^{-3} SI associated with two relatively narrow units, one lying partially above the other, immediately south of the fault (Fig. 13b).

Various peaks and lows superposed on magnetic high A are modelled as steep, narrow units. Units relating to the principal peaks a, b, c, d, e, and f have strong magnetic susceptibilities ranging from 132 to 195 × 10^{-3} SI. Most are within the unit of Neoarchean granitoid rocks (Agu), and some are in the marginal area of the adjacent unit of Archean–Proterozoic granulite complex (APgr). The steep magnetic gradient descending from local peak f and separating magnetic highs A and B falls within the granulite complex and is modelled by a vertical contact between two narrow, vertical units having susceptibilities of 89 and 135 × 10^{-3} SI. This large change in magnetic susceptibility may be accompanied by significant changes in the mineralogical composition of the granulites, but it is also believed to image a major fault.

Within magnetic high A, prominent steep gradients form the northern flank of local peak c and the southern flank of local peak d. These are related principally to a vertical contact and a contact dipping 88°S, respectively, across which large susceptibility contrasts of 81 and 27 × 10^{-3} SI are modelled. It is proposed that these contacts represent major faults. A large-amplitude magnetic low, f_1, lies between peaks c and d, and this is interpreted in terms of a roughly 1 km wide vertical fault zone. The magnetic high B, which correlates with most of the southern portion of the granulite complex, has a much smaller amplitude than magnetic high A, and this is reflected in the susceptibilities of modelled units that range from about 66 to 102 × 10^{-3} SI.

DISCUSSION

Magnetic modelling has provided new insight into the geometry of mapped fault/shear zones and the nature of structural fabric to a depth of about 5 km in the Rae Craton. Numerous modelled narrow, steep magnetic units, present in all models and widely distributed, are interpreted to reflect the apparent ubiquity of steep, mainly metamorphic, structural fabric. Structural fabrics mapped for some areas of the Amer (Tella, 1994) and Wager Bay (Henderson and Broome, 1990) shear zones, and abundant steep dips of regional foliations, of gneissosity, of mineral foliation, and of foliation related to shear, support near-vertical structure. Besides defining the geometry of the major Chantrey, Amer, and Wager Bay fault/shear zones, modelling also delineated several previously unmapped faults. The setting of the faults within a tectonic hinterland and the strike-slip nature of some have prompted comparison with strike-slip faults in a similar tectonic environment in the Central Asian Orogenic Belt (CAOB), which are associated with mineralization.

Faults in the Rae Craton

The principal faults/shear zones are the Atorquait, Chantrey, and Chesterfield faults, two unnamed faults (A and B), the Amer and Wager Bay shear zones, and the Quoich River thrust (Fig. 2). These structures range in length from 190 to 315 km; however, the noted 220 km extension of fault A outside the area gives a total length of about 500 km. Magnetic modelling suggests that all these faults and several newly identified faults are near-vertical.

Faults A and B, the Atorquait and Chantrey faults, and the Amer shear zone are located within the northwestern half of the Rae Craton, an area identified as the Arrowsmith Orogen (Fig. 1), which developed during the ca. 2.5 to 2.3 Ga Arrowsmith Orogeny within an Andean-type accretionary margin setting (Berman et al., 2013). The southeastern half of the Rae Craton, containing the Wager Bay shear zone, Chesterfield fault zone, and Quoich River thrust, is also believed to have developed in an accretionary margin setting, in this case associated with the 2.56 to 2.50 Ga MacQuoid Orogeny. Berman et al. (2013) speculated that both flanks of the Rae Craton were enduring accretionary margins, with east-southeastward-directed subduction on the west flank (Arrowsmith Orogeny) and northwestward-directed subduction on the east flank (MacQuoid Orogeny). Thus, all the faults are located on the upper plate of former convergent margins. It is probable that such an upper plate would have experienced normal, and/or reverse, and/or transcurrent faulting, potentially produced by collisional indentation as outlined in slip-line theory (Tapponnier and Molnar, 1976).

Information on the nature of the Rae faults and any associated displacements is rather limited. No commentary was discovered relating to faults A and B. For the Chantrey fault, Hoffman (1989) noted juxtaposition of mainly granulite-grade rocks of the Queen Maud block with less deeply eroded parts of the Rae Craton along oblique east-vergent reverse faults and implied the Chantrey fault zone was such a fault. Tella (1994), mapping at the south end of the fault zone, concluded that the latest movement along the fault was low-angle oblique slip with an apparent dextral sense of shear. In the Amer shear zone, field relationships and textural aspects indicate two periods of movement along the shear zone, the latest (dextral displacement) possibly as young as 1.7 Ga (Tella, 1994). A study of structural fabrics and magnetic data led Henderson and Broome (1990) to conclude that the Wager Bay shear zone is a transcurrent, ductile shear zone, claiming that net shear was dextral, and an age of 1808 ± 2 Ma for a granite cut by the shear zone is a maximum age for the zone. They further suggested that ductile dextral shearing along the shear zone may have been approximately contemporaneous with that along the Amer zone.

The faults examined in this study are extensive and magnetically modelled to be near-vertical and possibly attain depths of at least 5 km. Strike-slip relative motion has been observed on several faults, including the Amer (Tella, 1994), Chantrey (Davis et al., 2014), and Wager Bay (Henderson and Broome, 1990) fault zones, and on the Walker Lake shear zone and Atorquait faults (Sanborn-Barrie et al., 2014). All these faults lie well within the Rae Craton and presumably were formed as distal products of the marginal Arrowsmith and MacQuoid orogenies. Sanborn-Barrie et al. (2014) viewed the Committee Bay greenstone belt in the interior of the Rae Craton (Fig. 2) as a window into an upper-plate hinterland setting during the Arrowsmith, Taltson–Thelon, and trans-Hudson orogenies. The faults in such a hinterland setting invite comparison with intracontinental strike-slip faults, associated magmatism, mineral systems, and mantle dynamics in the early to mid-Paleozoic CAOB (Pirajno, 2010).

A focus of Pirajno's (2010) study was strike-slip faults in the CAOB, which is a collage of accreted fragments of microcontinents, subduction-related magmatic arc systems, fragments of oceanic volcanic islands and possibly volcanic plateaus, oceanic crust (ophiolites), and passive margin sequences. Pirajno (2010) noted Yakubchuk's (2004) comment that strike-slip faults extending for thousands of kilometres are the most outstanding features of the CAOB, noting also their temporal and spatial association with many mafic and felsic plutons believed to have played a major role in controlling emplacement of magmas and related mineral systems.

A critical characteristic of some strike-slip faults is their large depth extent, which allows them to tap into potential mineral resources in the mantle. Strong evidence provided by geochemical and petrological data, seismic profiling and tomography, and magnetotelluric soundings indicates that major strike-slip faults crosscut the Moho and deform the upper mantle (Vauchez and Tommasi, 2003), with strike-slip fault fabric present throughout most of or even the entire lithosphere thickness. Such evidence has been documented for different periods of geological history and from several continents.

Mineral systems associated with intracontinental trans-lithospheric strike-slip faults in the CAOB include Au lodes, polymetallic vein deposits (W, Sn, Cu, Ag, Sb, As, Bi, Pb, Zn) and minor Hg, Ni, Co, Au, greisen Sn-W, carbonatites, and kimberlites (Pirajno, 2010). Impingement of a mantle plume at the base of the lithosphere followed by plume migration along the base toward translithospheric breaks, such as strike-slip faults, is believed to have provided channel ways for dominantly alkaline magmatism that produced polymetallic mineral systems and Ni-Cu-PGE magmatic mineralization. It is proposed that the Rae Craton may have experienced some of the processes that contribute to Pirajno's (2010) model, though the craton represents a much deeper level of the crust than present within the CAOB. Consequently, certain types of mineralization in the younger CAOB, presumably located in shallower levels of the crust, may have been eroded in the case of the Rae Craton.

There is good evidence for deep faulting in the Rae Craton. Magnetotelluric investigations on Melville Peninsula defined several less resistive near-vertical zones that correlate with faults mapped at surface (Spratt et al., 2013), many, apparently, extending down to the base of the crust, one in the vicinity of a diamondiferous kimberlite field. In the eastern half of the study area (Fig. 2), magnetotelluric profiling (Spratt et al., 2014) was completed across the Amer, Wager Bay, and Walker Lake shear zones, the Atorquait and Chesterfield faults, the Quoich River thrust, and the Committee Bay belt, but resistivity model sections indicate that none of the faults have expression in the mantle. Of significance to mineralization, however, is the presence of near-vertical zones of reduced resistivity within the uppermost mantle that may be related to mantle melt or metasomatism linked to emplacement of Hudsonian granites. Spratt et al. (2014) modelled two upper mantle zones of decreased resistivity (roughly 40–50 km wide) beneath concentrations of 1.83 Ga Hudsonian granites, noting Peterson et al.'s (2002) proposal that the granites host mantle melt and metasomatic components. Three-dimensional conductivity modelling defines chimneys or cupolas of enhanced conductivity in at least five locations that connect pervasive mantle conductors with the near surface (Snyder et al., 2015), some of which are near known kimberlite fields, such as Amaruk and Qililuqaq or mineralized zones. Unfortunately, the granites and low-resistivity zones discussed by Spratt et al. (2014) do not correlate with any of the aforementioned Rae faults; neither do the kimberlite fields mentioned by Snyder et al. (2015).

Although information on major faults penetrating the mantle in the Rae Craton is limited, a few magnetotelluric investigations indicate former connections between the mantle and crust associated with mantle melting or metasomatism and the generation and intrusion of granites. Given these signatures of transfer from the mantle to the crust, it seems likely that major faults would be involved as pathways for such transfer and could be considered favourable targets for mineral exploration. Somewhat surprisingly, however, a plot of mineral occurrences in the study area (Fig. 2) reveals that very few occurrences are located close to the discussed major faults, most being associated with belts of supracrustal rocks. Nevertheless, the CAOB analogue does favour future exploration attention being directed toward the faults, particularly if some other geological or geochemical evidence near faults contains hints of potential for mineralization.

CONCLUSIONS

Magnetic modelling across the Chantrey, Amer, and Wager Bay fault/shear zones in the Rae Craton indicated that they are very steep and potentially have a depth extent of 5 km. Modelling also revealed the presence of several faults that had not been geologically mapped, also very steep and having a potential depth extent of 5 km. Many modelled steep, narrow magnetic units spanning the lengths (55.7–100 km) of magnetic profiles are interpreted to image a steep structural fabric in the uppermost 5 km of the crust.

The setting of the faults, some identified as strike-slip faults, in a tectonic hinterland as presented by the Rae Craton, has drawn comparison with mineralization-associated strike-slip faults in the CAOB, in anticipation of using the analogue as a guide for mineral exploration in the Rae Craton. A plot of mineral occurrences in the Rae Craton reveals, however, that they are largely associated with supracrustal and mainly metasedimentary belts. Few occurrences are located close to faults. This is not encouraging, but it should not rule out closer examination of the nature of magmatism in the vicinity of faults in the hope of identifying compositions with potential to produce mineralization.

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