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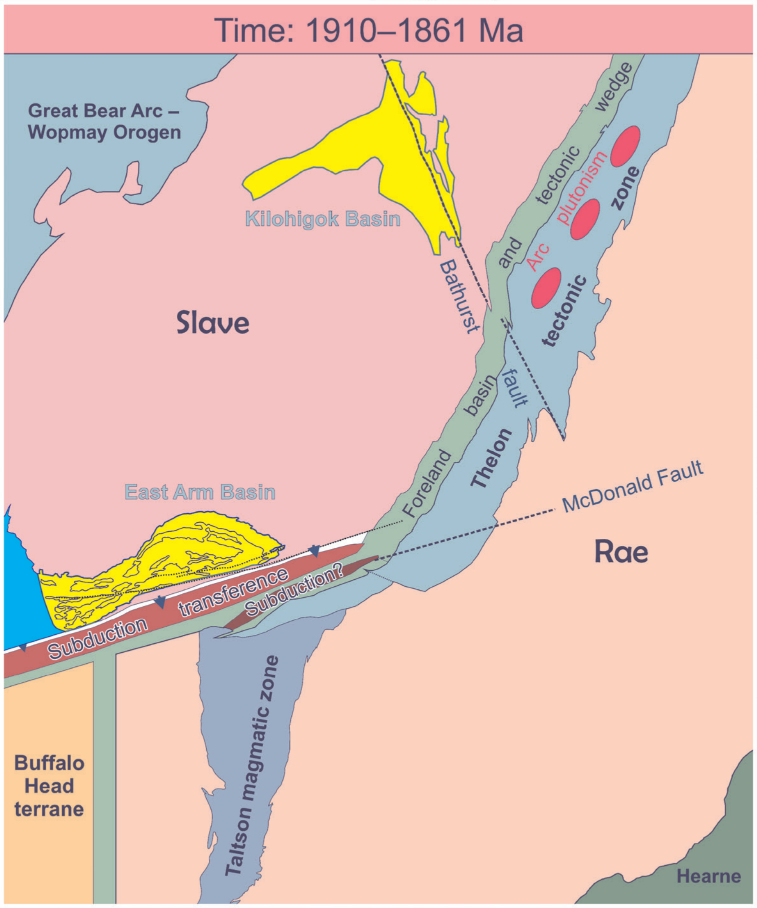

Magnetic and gravity characteristics of the Thelon and Taltson orogens, northern Canada: tectonic implications

M.D. Thomas

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Cover illustration
Proposed tectonic scenario along boundary between Slave and Rae cratons during the interval 1910 to 1861 Ma.

Critical review
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FIGURES

Magnetic and gravity characteristics of the Thelon and Taltson orogens, northern Canada: tectonic implications

Abstract: Differences of opinion concerning the relationship between the Thelon tectonic zone and the Taltson magmatic zone, as to whether they are individual tectonic elements or two independent elements, have generated various plate tectonic models explaining their creation. Magnetic and gravity signatures indicate that they are separate entities and that the Thelon tectonic zone and the Great Slave Lake shear zone form a single element.

Adopting the single-element concept and available age dates, a temporally evolving plate tectonic model of Slave–Rae interaction is presented. At 2350 Ma, an Archean supercontinent rifted along the eastern and southern margins of the Slave Craton. Subsequent ocean closure, apparently diachronous, began with subduction at 2070 Ma in the northern Thelon tectonic zone, followed by subduction under the Great Slave Lake shear zone at 2051 Ma. Subduction related to closure of an ocean between the Buffalo Head terrane and the Rae Craton initiated under the Taltson magmatic zone at 1986 Ma, at which time subduction continued along the Thelon tectonic zone. At 1970 Ma, collision in the northern Thelon tectonic zone is evidenced in the Kilohigok Basin.

From 1957 to 1920 Ma, plutonism was active in the Taltson magmatic zone, Great Slave Lake shear zone, and southern Thelon tectonic zone. The plutonism terminated in the northern Thelon tectonic zone at 1950 Ma, but it resumed at 1910 Ma and continued until 1880 Ma. The East Arm Basin witnessed igneous activity as early as 2046 Ma, though this took place more continuously from 1928 to 1861 Ma; some igneous rocks bear subduction-related trace element signatures. These signatures, and the presence of northwest-verging nappes, may signify collision with the Great Slave Lake shear zone as a result of southeastward subduction, completing closure between the Slave and Rae cratons.

Résumé : Les différences d’opinions au sujet de la relation entre la zone tectonique de Thelon et la zone magmatique de Taltson, à savoir s’il s’agit d’un seul élément tectonique ou de deux éléments indépendants, ont mené à la production de divers modèles de tectonique des plaques expliquant leur création. Les signatures magnétiques et gravimétriques montrent qu’il s’agit de deux entités distinctes, et que la zone tectonique de Thelon et la zone de cisaillement du Grand lac des Esclaves forment un seul élément.

En adoptant le concept d’un seul élément et en se servant des âges disponibles, nous présentons un modèle de tectonique des plaques évolutif de l’interaction Esclaves-Rae. À 2350 Ma, un supercontinent archéen a dérivé le long des marges orientale et méridionale du craton des Esclaves. La fermeture subséquente de l’océan, apparemment diachronique, a commencé par une subduction à 2070 Ma dans le nord de la zone tectonique de Thelon, suivie d’une subduction sous la zone de cisaillement du Grand lac des Esclaves à 2051 Ma. La subduction liée à la fermeture de l’océan entre le terrane de Buffalo Head et le craton de Rae s’est amorcée sous la zone magmatique de Taltson à 1986 Ma, alors que se poursuivait la subduction le long de la zone tectonique de Thelon. À 1970 Ma, les preuves d’une collision dans le nord de la zone tectonique de Thelon sont fournies par le bassin de Kilohigok.

De 1957 à 1920 Ma, une activité plutonique s’est manifestée dans la zone magmatique de Taltson, la zone de cisaillement du Grand lac des Esclaves et le sud de la zone tectonique de Thelon. Elle a cessé dans le nord de la zone tectonique de Thelon à 1950 Ma, mais a repris à 1910 Ma et s’est poursuivie jusqu’à 1880 Ma. Le bassin d’East Arm a été le siège d’une activité magmatique dès 2046 Ma, mais celle-ci s’est manifestée de façon plus continue entre 1928 et 1861 Ma; certaines roches ignées présentent des signatures des éléments traces liées à une subduction. Ces signatures, ainsi que la présence de nappes à vergence nord-ouest, pourraient indiquer une collision avec la zone de cisaillement du Grand lac des Esclaves causée par une subduction vers le sud-est, achevant la fermeture de l’océan entre les cratons des Esclaves et de Rae.

SUMMARY

The Thelon tectonic zone and the Taltson magmatic zone apparently form a continuous orogenic belt stretching roughly 1450 km from the Arctic coast to the western edge of the Canadian Shield near Lake Athabasca. The belt separates the Slave and Rae cratons and is visibly dextrally offset along the McDonald Fault. Opinions regarding the tectonic relationship between the Thelon tectonic zone and the Taltson magmatic zone differ. Some researchers view the zones as constituting a single tectonic element, whereas others view them as two independent elements. Regional magnetic and gravity signatures provide strong evidence that they are separate entities and that the Thelon tectonic zone and the Great Slave Lake shear zone immediately south of the McDonald Fault formed a single continuous element before displacement along the fault.

The concept of the Thelon tectonic zone and Taltson magmatic zone being a single element is examined in the context of available radiometric ages along the Slave–Rae boundary zone, and a temporally evolving plate tectonic model of the Thelon tectonic zone–Taltson magmatic zone orogenic belt is derived. The author proposes rifting of an Archean supercontinent taking place at roughly 2350 Ma along the eastern and southern margins of the Slave Craton. The pattern of rifting is compared with the pattern of geologically recent (24–21 Ma) rifting along the Red Sea and Aden rifts. Dating indicates that subsequent ocean closure was diachronous, commencing with eastward subduction of the Slave Craton in the northern Thelon tectonic zone at 2070 Ma. The next dated event apparently was southward subduction below the Great Slave Lake shear zone at 2051 Ma. A lack of dating between the Bathurst and McDonald faults precludes commenting on tectonic events in this area of the Thelon tectonic zone between the latter two dates. South of the McDonald Fault it is conjectured that eastward subduction related to ocean closure between the Buffalo Head terrane and the Rae Craton initiated under the Taltson magmatic zone at 1986 Ma, at which time subduction continued along portions of the Thelon tectonic zone. The existence of the Kilohigok Basin is evidence of a collision at 1970 Ma in the northern Thelon tectonic zone.

Plutonism in the Taltson magmatic zone from 1986 to 1959 Ma was partially coeval with plutonic activity from 2070 to 1950 Ma in the northern Thelon tectonic zone and possibly with activity in the southern Thelon tectonic zone tentatively dated at 2000 to 1900 Ma. A second period of plutonism in the Taltson magmatic zone, 1940 to 1920 Ma, falls within dates ranging from 1957 to 1920 Ma that have been determined from granites in the southern Thelon tectonic zone. The two

SOMMAIRE

La zone tectonique de Thelon et la zone magmatique de Taltson forment apparemment une zone orogénique continue qui s’étend sur environ 1450 km, depuis la côte de l’océan Arctique jusqu’à la bordure occidentale du Bouclier canadien, près du lac Athabasca. Cette zone orogénique sépare les cratons des Esclaves et de Rae et présente un net décalage dextre le long de la faille de McDonald. Les avis sont partagés quant à la relation tectonique entre la zone tectonique de Thelon et la zone magmatique de Taltson. Certains considèrent que ces zones constituent un seul élément tectonique, tandis que d’autres les considèrent comme deux éléments indépendants. Les signatures magnétiques et gravimétriques régionales fournissent des preuves solides qu’il s’agit d’entités distinctes et que la zone tectonique de Thelon et la zone de cisaillement du Grand lac des Esclaves, située juste au sud de la faille de McDonald, formaient un seul élément continu avant le déplacement le long de la faille.

Nous avons examiné le concept d’un élément unique formé par la zone tectonique de Thelon et la zone magmatique de Taltson en fonction des données de datation radiométrique disponibles le long de la zone bordière Esclaves-Rae et avons ensuite élaboré un modèle de tectonique des plaques évolutif de la zone orogénique constituée de la zone tectonique de Thelon et de la zone magmatique de Taltson. Nous proposons qu’un épisode de rifting d’un supercontinent archéen se serait produit à environ 2350 Ma le long des marges orientale et méridionale du craton des Esclaves. La configuration de ce rifting est comparée à celles de processus récents (de 24 à 21 Ma) de même nature le long des rifts de la mer Rouge et du golfe d’Aden. Les datations indiquent que la fermeture subséquente de l’océan était diachronique et qu’elle a commencé par la subduction vers l’est du craton des Esclaves dans la partie septentrionale de la zone tectonique de Thelon à 2070 Ma. L’événement daté subséquent est apparemment associé à une subduction vers le sud, sous la zone de cisaillement du Grand lac des Esclaves, à 2051 Ma. L’absence de données de datation dans la région située entre les failles de Bathurst et de McDonald nous empêche de formuler des remarques sur l’activité tectonique survenue dans cette partie de la zone tectonique de Thelon entre ces deux dates. Au sud de la faille de McDonald, nous supposons que la subduction vers l’est liée à la fermeture de l’océan entre le terrane de Buffalo Head et le craton de Rae a commencé sous la zone magmatique de Taltson à 1986 Ma, alors que se poursuivait la subduction le long de certaines parties de la zone tectonique de Thelon. Une collision dans la partie septentrionale de la zone tectonique de Thelon à 1970 Ma est démontrée par l’existence du bassin de Kilohigok.

L’activité plutonique dans la zone magmatique de Taltson de 1986 à 1959 Ma est partiellement contemporaine de l’activité plutonique qui s’est déroulée de 2070 à 1950 Ma dans la partie septentrionale de la zone tectonique de Thelon, et possiblement de l’activité dans la partie méridionale de la zone tectonique de Thelon provisoirement datée de 2000 à 1900 Ma. Une deuxième période d’activité plutonique dans la zone magmatique de Taltson, de 1940 à 1920 Ma, se situe dans l’intervalle de 1957 à 1920 Ma révélé par les âges de granites de la partie méridionale de la zone tectonique de Thelon.. Les deux périodes d’activité dans la zone

periods of activity within the Taltson magmatic zone fall within the period of magmatic activity, 2051 to 1920 Ma, in the Great Slave Lake shear zone.

From 1957 to 1920 Ma, plutonism, presumably subduction related, was active in the Taltson magmatic zone, the Great Slave Lake shear zone, and the southern Thelon tectonic zone. This plutonism terminated in the northern Thelon tectonic zone at 1950 Ma, but it resumed at 1910 Ma and continued until 1880 Ma; it was approximately contemporaneous with deposition of the youngest third of the stratigraphic section of the East Arm Basin, from about 1928 to 1872 Ma. This resumption of plutonism began with intrusion of a 1910 Ma peraluminous leucogranite, which was followed by intrusion of high-Zr granites from 1900 to 1880 Ma that form a distinct textural (post-tectonic) and 'within-plate' geochemical group marking the end of the Thelon orogenic event in this area.

As in the southern Thelon tectonic zone, dating indicates that plutonism in the Taltson magmatic zone had terminated by ca. 1920 Ma. Peraluminous 1940 to 1920 Ma S-type granites emplaced during a metamorphic event related to terminal collision dominate the central belt of the Taltson magmatic zone. Such plutonic activity possibly has parallels with the younger within-plate plutonism in the northern Thelon tectonic zone.

The nature of final closure of the section of Slave ocean south of the East Arm rift is uncertain. Igneous activity in the East Arm Basin began as early as 2046 Ma, though it was more continuous from 1928 to 1861 Ma; some igneous rocks in this region bear subduction-related trace element signatures. These signatures, and the presence of northwest-verging nappes, possibly signify collision with the Great Slave Lake shear zone brought about by southeastward subduction, completing closure between the Slave and Rae cratons.

Subduction beneath the Great Slave Lake shear zone may have terminated at roughly 1920 Ma, but some convergence continued after that, possibly due principally to pure strike-slip faulting within an accretionary wedge of scraped-off material. The subduction-related geochemical signatures in igneous rocks and the northwest-verging fold and thrust belt in the East Arm Basin suggest that post-1920 Ma subduction played a role in development of the basin. Given the relatively small size of plutonic intrusions, represented by the 1872/1861 Ma Compton intrusive suite, compared to the size of typical batholiths in magmatic arcs, the degree of subduction may have been limited. Possibly a younger subduction zone originated directly along the southern margin of the rift or by the mechanism of subduction transference. Subduction once again was probably oblique, and a possible consequence was the initiation of the McDonald Fault.

magmatique de Taltson sont comprises dans la période d'activité magmatique de 2051 à 1920 Ma dans la zone de cisaillement du Grand lac des Esclaves.

De 1957 à 1920 Ma, une activité plutonique, vraisemblablement liée à une subduction, avait lieu dans la zone magmatique de Taltson, la zone de cisaillement du Grand lac des Esclaves et la partie méridionale de la zone tectonique de Thelon. Elle s'est terminée dans la partie septentrionale de la zone tectonique de Thelon à 1950 Ma, mais a repris à 1910 Ma et s'est poursuivie jusqu'à 1880 Ma. Cette activité plutonique est approximativement contemporaine du dépôt du tiers le plus récent de la coupe stratigraphique du bassin d'East Arm, qui s'est déroulée de 1928 à 1872 Ma environ. Cette reprise de l'activité plutonique a commencé par l'intrusion d'un leucogranite hyperalumineux à 1910 Ma, laquelle a été suivie par l'intrusion de granites à concentration élevée de Zr de 1900 à 1880 Ma, lesquels forment un groupe géochimique « intraplaque » et textural distinct (post, tectonique) qui marque la fin de l'événement orogénique de Thelon dans la région.

Tout comme dans la partie méridionale de la zone tectonique de Thelon, les données de datation indiquent que l'activité plutonique a pris fin à environ 1920 Ma dans la zone magmatique de Taltson. Des granites hyperalumineux de type S datant de 1940 à 1920 Ma et mis en place lors d'un événement métamorphique lié à la collision terminale dominent la bande centrale de la zone magmatique de Taltson. Une telle activité plutonique pourrait trouver des parallèles dans l'activité plutonique « intraplaque » plus récente de la partie septentrionale de la zone tectonique de Thelon.

La nature de la fermeture finale de la portion de l'océan des Esclaves située au sud du rift d'East Arm est quelque peu incertaine. Une activité ignée a commencé à se manifester dans le bassin d'East Arm dès 2046 Ma, mais celle-ci a été plus continue de 1928 à 1861 Ma; certaines roches ignées de cette région présentent des signatures des éléments traces liées à une subduction. Ces signatures, ainsi que la présence de nappes à vergence nord-ouest, semblent indiquer qu'il y a eu collision avec la zone de cisaillement du Grand lac des Esclaves à la suite d'une subduction vers le sud-est, achevant ainsi la fermeture de l'océan entre les cratons des Esclaves et de Rae.

Il est possible que la subduction sous la zone de cisaillement du Grand lac des Esclaves ait pris fin à environ 1920 Ma, avec une certaine convergence qui se serait poursuivie par la suite, causée principalement par le jeu de failles de coulissage au sein d'un prisme d'accrétion contenant du matériel raclé. Les signatures géochimiques des roches ignées liées à une subduction ainsi que la zone de plissement-chevauchement à vergence nord-ouest dans le bassin d'East Arm donnent à penser que la subduction postérieure à 1920 Ma a joué un certain rôle dans le développement du bassin. Compte tenu de la taille relativement petite des intrusions plutoniques, représentées par la suite intrusive de Compton de 1872/1861 Ma, par rapport aux batholites typiques des arcs magmatiques, le degré de subduction peut avoir été limité. Il est possible qu'une zone de subduction plus récente ait pris naissance directement le long de la marge méridionale du rift ou par l'entremise d'un mécanisme de transfert de la subduction. Encore une fois, la subduction a probablement été oblique, avec pour conséquence possible la création de la faille de McDonald.

INTRODUCTION

The Thelon tectonic zone and the Taltson magmatic zone are Paleoproterozoic belt-like orogens along the western edge of the Rae Craton (Fig. 1). Both zones are north trending and are dextrally offset along the McDonald Fault, which runs along the northern edge of the Great Slave Lake shear zone (Hanmer et al., 1992). The Thelon tectonic zone is flanked to the west by the Archean Slave Province, whereas the Taltson magmatic zone is flanked, under the covering Western Canada Sedimentary Basin, by the Paleoproterozoic Buffalo Head terrane (McDonough et al., 2000).

Opinions regarding the relationship of the Thelon tectonic zone to the Taltson magmatic zone are varied. Hoffman (1987) considered the Great Slave Lake shear zone a continental transform structure related to oblique collision between a microcontinental Slave Province and the Churchill Province (Rae Craton), which could explain the geological and geophysical differences between the zones. Notwithstanding the differences, Hoffman (1988) interpreted the Taltson–Thelon plutonic zone as representing a composite precollisional magmatic arc and postcollisional anatectic batholith. McDonough et al. (2000) viewed the Taltson magmatic zone as being the southern continuation of the Thelon tectonic zone. This view was also held by Ross (2002), who suggested that a Slave–Rae collision is recorded by the Thelon Orogen and its continuation into the Taltson magmatic zone, further suggesting that the ductile history of indentation–accretion events kinematically links the Thelon Orogen to the Taltson magmatic zone. On the other hand, Card et al. (2014) argued that the Thelon tectonic zone and the Taltson magmatic zone did not represent parts of a single orogeny, noting that inclusion of the Taltson magmatic zone in a broader Thelon Orogeny was based partly on the apparent traceability of a prominent magnetic high correlating with the Thelon tectonic zone southward into the vicinity of the Taltson magmatic zone. They suggested that the Taltson magmatic zone is linked to an orogeny distinct from that producing the Thelon tectonic zone. Whalen et al. (2018) examined a large geochemical data set and likewise concluded that the Taltson magmatic zone is not directly correlative with the Thelon tectonic zone.

These various proposals relating to the relationship between the Thelon tectonic zone and the Taltson magmatic zone are re-examined from a geophysical perspective through investigation and discussion of magnetic (mainly) and gravity signatures associated with the two orogenic zones. The author concludes that, in agreement with Card et al. (2014), the two zones represent two tectonic units. The author also argues that the Thelon tectonic zone and Great Slave Lake shear zone do represent components of a single tectonic unit. This concept is an integral part of a model that incorporates available ages and explores the closure history of an ocean between the Slave and Rae cratons and their subsequent collision.

THELON TECTONIC ZONE

The Thelon tectonic zone extends northward from the McDonald Fault to the coast of the Arctic Ocean (Fig. 1); a short, sinistrally displaced portion is present south of the fault. The total length of the zone is about 600 km, and it ranges in width from about 40 to 105 km. North of the Bathurst fault, where age dating is most concentrated, several narrow plutonic belts ranging in age from 2070* Ma to 1950* Ma (ages that were presented as Ga, converted here to Ma for consistency, are indicated by *) represent the first phase of igneous activity; their geochemistry indicates a convergent margin (Berman et al., 2018). A later phase began with intrusion of a 1910* Ma peraluminous leucogranite; this intrusion was followed by intrusion of high-Zr granites from 1900* to 1880* Ma (Berman et al., 2018). The width of the Thelon tectonic zone is enhanced in this region by inclusion of the Mesoarchean Duggan Lake domain, interpreted as representing crust characteristic of the Queen Maud Block to the east. A few narrow belts of metasedimentary rocks are also present.

Mapping in the southern portion of the Thelon tectonic zone is mainly of the Artillery Lake map area, spanning the McDonald Fault (Henderson, 1989) and bounded to the east by longitude 106°W; and of a small area in the adjacent Healey Lake map area to the north (Henderson and Thompson, 1982). Both maps have been incorporated in a single map (Henderson et al., 1999). In the Artillery Lake map area, the Thelon tectonic zone includes a heterogeneous assemblage of severely deformed granitoid and supracrustal gneisses distributed in a series of narrow, north-northeast-trending belts (Henderson, 1989). Most are at, or have been retrograded from, granulite metamorphic grade. Some discrete younger granitic units that apparently have not undergone granulite-grade metamorphism are also present. A large granite is mapped south of the McDonald Fault. Mapping by James et al. (1988) along a transect near the northeast corner of the Artillery Lake map area, extending east of longitude 106°W, revealed similar rock types that include a heterogeneous group of supracrustal and plutonic rocks metamorphosed to granulite facies, as well as unmetamorphosed and variously deformed granitoid rocks. The far eastern end of the transect is underlain entirely by megacrystic granodiorite associated with a prominent magnetic high trending parallel to the Thelon tectonic zone. James et al. (1988) interpreted aeromagnetic patterns as indicating that this granodiorite extended to similar granodiorites some 300 km to the north.

Few age determinations are available for the Thelon tectonic zone south of the Bathurst fault. James et al. (1988) reported U-Pb ages of 1957 and 1925 Ma and a tentative emplacement age ranging from 2000* to 1900* Ma for three granitoid intrusions. Henderson et al. (1999) documented ages of 1929 Ma for a granite south of the McDonald Fault and 1950 and 1920 Ma for two granites north of the fault.

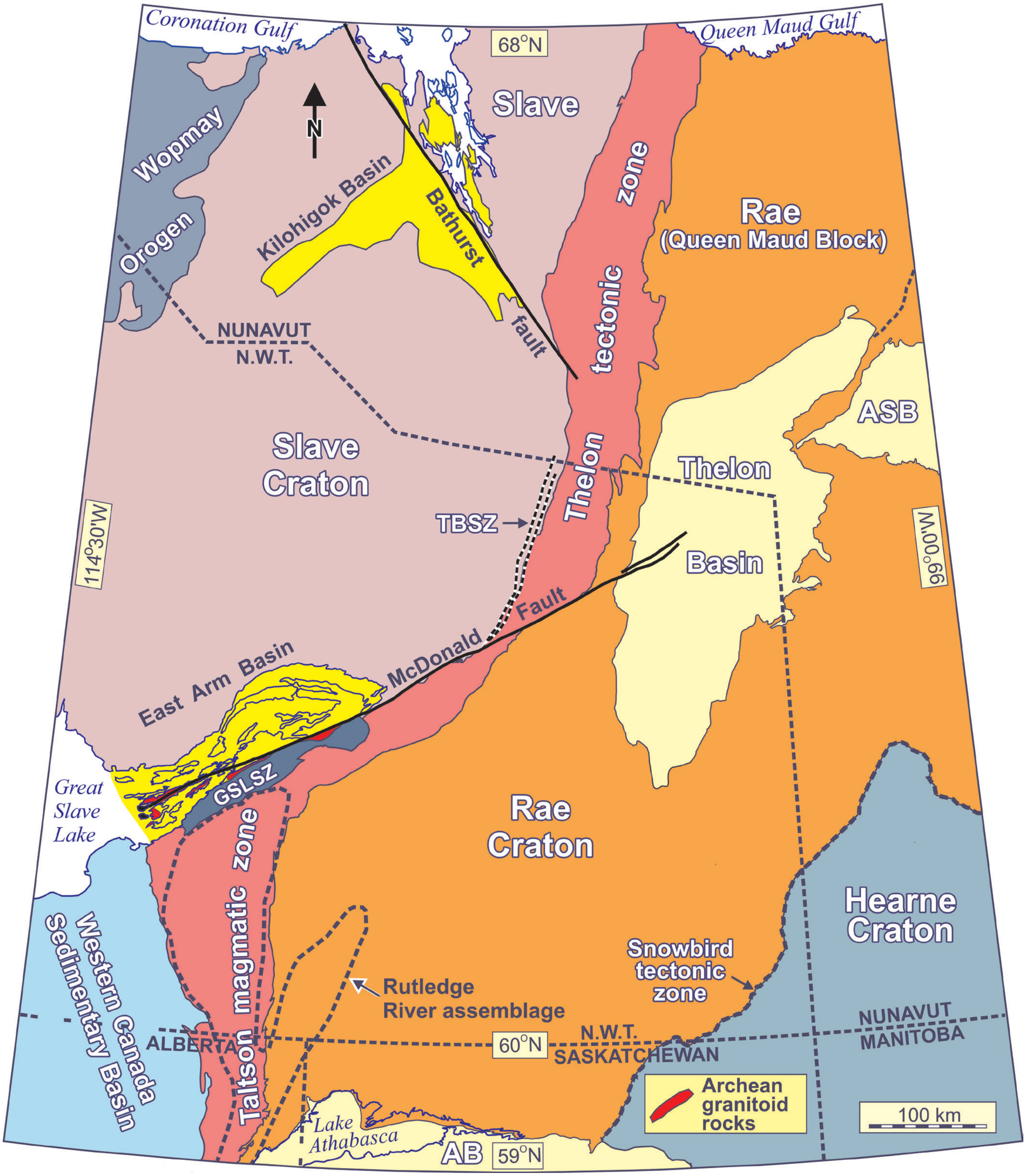


Figure 1. Regional geology map of area spanning the boundary between the Slave and Rae cratons. Boundaries of the Thelon tectonic zone are *based on* maps and/or information from Berman et al. (2015, 2018), Harrison et al. (2011, sheet 1: Geology; and sheet 3: Precambrian legend and correlation chart), and Pehrsson et al. (2014). Paleoproterozoic basins: AB, Athabasca Basin; ASB, Aberdeen Subbasin. Shear zones (*modified from* Hanmer et al., 1992): GSLSZ, Great Slave Lake shear zone; TBSZ, Thelon Boundary shear zone. Archean granitoids within the Paleoproterozoic East Arm Basin are *based on* Hoffman and Hall (1993) and Kjarsgaard et al. (2013). Dashed dark navy line labelled ‘Rutledge River assemblage’ outlines a general area containing many scattered remnants of the formation; this applies to similar areas in other figures.

The boundary between the Thelon tectonic zone and the Slave Province between the Bathurst and McDonald faults is partially delineated by a lower amphibolite- to greenschist-facies transcurrent shear zone, the Thelon Boundary shear zone (TBSZ in Fig. 1–6), which is up to 5 km wide (Hanmer et al., 1992). The shear zone is absent north of the Bathurst fault, where the Thelon tectonic zone is flanked to the west by a 20 km wide swarm of closely spaced mafic dykes, concordant with the tectonic zone.

The magnetic signature of the Thelon tectonic zone is displayed in Figure 2. Between the McDonald and Bathurst faults, the Thelon tectonic zone is dominated by a prominent belt of magnetic highs that migrates northward from the eastern to the western margin before continuing into the northern half, where it narrows and terminates roughly 150 km north of the Bathurst fault. Most of the northern half is characterized by alternating, relatively narrow, linear magnetic highs and lows trending generally northward to slightly east of north. The magnetic signature of the Thelon tectonic zone south of the McDonald Fault is displaced sinistrally from that north of the fault.

TALTSON MAGMATIC ZONE

Within the study area, the Taltson magmatic zone has a maximum width of about 110 km; its western boundary is hidden beneath Phanerozoic sedimentary rocks west of the Canadian Shield (Fig. 1). A tectonometamorphic map of the Precambrian basement of Alberta (Burwash et al., 2000), including that buried by Phanerozoic cover, portrays the Taltson magmatic zone as a relatively narrow (about 100 km wide) north-trending belt of 2000* to 1900* Ma plutonism coinciding closely with granitoid rocks defining the Taltson magmatic zone on the shield margin in the Northwest Territories and Alberta (Pehrsson et al., 2014). Card et al. (2014) displayed a map on which the Taltson magmatic zone extended westward from the shield and generally ranged in width from about 140 to 190 km.

The Taltson magmatic zone has been described as a composite continental collisional and Andean-type magmatic orogen produced by interaction between the Rae Craton and hidden Paleoproterozoic Buffalo Head terrane to the west (McDonough et al., 2000). The zone is formed mainly of plutonic rocks (1986* to 1959* Ma) and later granitoid rocks (1940* to 1930* Ma), identified as I-type and peraluminous S-type varieties, respectively (Card et al., 2014). The central portion is dominated by the peraluminous Konth granite (Bostock, 2014), and sizable units of granites termed ‘Slave granites’ (unofficial name) are present along its western, eastern, and southern margins (Bostock, 2014; Pehrsson et al., 2014). A substantial portion of the western margin of the Taltson magmatic zone is underlain by the 1986 Ma Paleoproterozoic Deskenatlata granodiorite, along with mixed gneiss composed of Slave granite and Deskenatlata granodiorite (Bostock, 2014). Scattered narrow, linear, north-trending screens of Paleoproterozoic metasedimentary rocks, belonging mainly to the Hill Island Lake assemblage (Pehrsson et al., 2014), are found throughout the Taltson magmatic zone. Most of these screens were assigned to the Rutledge River paragneiss by Bostock (2014), which together with lesser occurrences of Mama Moose paragneiss were regarded as having been deposited in an early Proterozoic rift basin termed the ‘Rutledge River Basin’ (Bostock and van Breemen, 1994). Card et al. (2014) referred to the basin succession as the ‘Rutledge River assemblage’.

The magnetic signature of the Taltson magmatic zone contrasts strongly with that of the Thelon tectonic zone, being dominated by a prominent magnetic low rather than a magnetic high (Fig. 2). This low correlates mainly with the Konth granite (Thomas, 2022). Although only a partial expression of the Taltson magmatic zone, the observed differences in magnetic signature of the exposed Taltson magmatic zone and Thelon tectonic zone raise questions regarding the definition of the two zones as a single geological or tectonic unit as advocated by Hoffman (1988), for example. Hoffman (1987) suggested that the Taltson magmatic zone and the Thelon tectonic zone were offset by 300 to 700 km along the Great Slave Lake shear zone, though they are shown to be linked by a northeast-trending section about 250 km long coinciding in large part with the shear zone (Fig. 2 in Hoffman, 1987). Part of this northeast-trending section, itself associated predominantly with strong magnetic highs, had been correlated with the principal magnetic high within the Thelon tectonic zone, a correlation leading to the suggestion of dextral displacement along the McDonald Fault of either 70 or 125 km (Thomas et al., 1976).

DISPLACEMENT OF GEOPHYSICAL ANOMALIES ALONG MCDONALD FAULT

Maps of the total magnetic field, first vertical derivative (FVD) of the magnetic field, Bouguer gravity anomaly, and FVD of the Bouguer gravity anomaly covering the southern half of the Thelon tectonic zone and the Taltson magmatic zone in the study area are displayed in Figures 3, 4, 5, and 6, respectively. The dextral displacement along the McDonald Fault has been eliminated in all maps; crustal blocks north and south of the fault have been restored to prefaulting positions on the basis of an estimated displacement of 126 km. This displacement was estimated using principally the map of the FVD of the magnetic field (Fig. 4), which affords greater precision in matching anomalies across the fault, consequent on the shorter wavelength anomalies defined by the derivative map. The line demarcating the blocks of crust north and south of the McDonald Fault (i.e. the fault line) is based mainly on the pattern of magnetic anomalies displayed in images of the total magnetic field and the FVD of the field. Much of the line follows narrow, linear magnetic lows or abrupt changes in magnetic pattern that allow precision in its definition. The map of the FVD of Bouguer gravity anomalies (Fig. 6) also displays linear anomalies trending along the line of the break, and though broader than

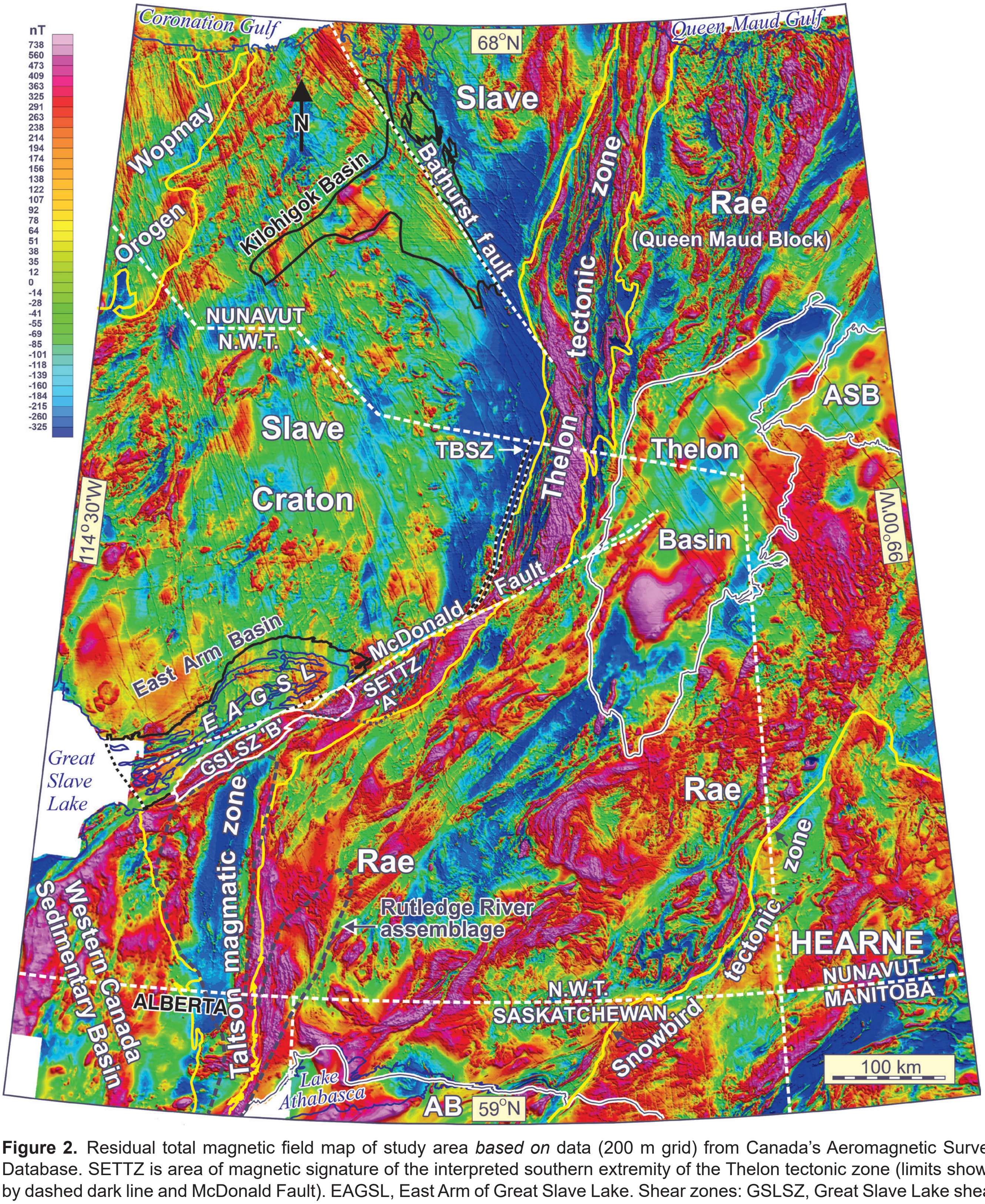


Figure 2. Residual total magnetic field map of study area *based on* data (200 m grid) from Canada's Aeromagnetic Survey Database. SETTZ is area of magnetic signature of the interpreted southern extremity of the Thelon tectonic zone (limits shown by dashed dark line and McDonald Fault). EAGSL, East Arm of Great Slave Lake. Shear zones: GSLSZ, Great Slave Lake shear zone; TBSZ, Thelon Boundary shear zone. Paleoproterozoic basins: AB, Athabasca Basin; ASB, Aberdeen Subbasin.

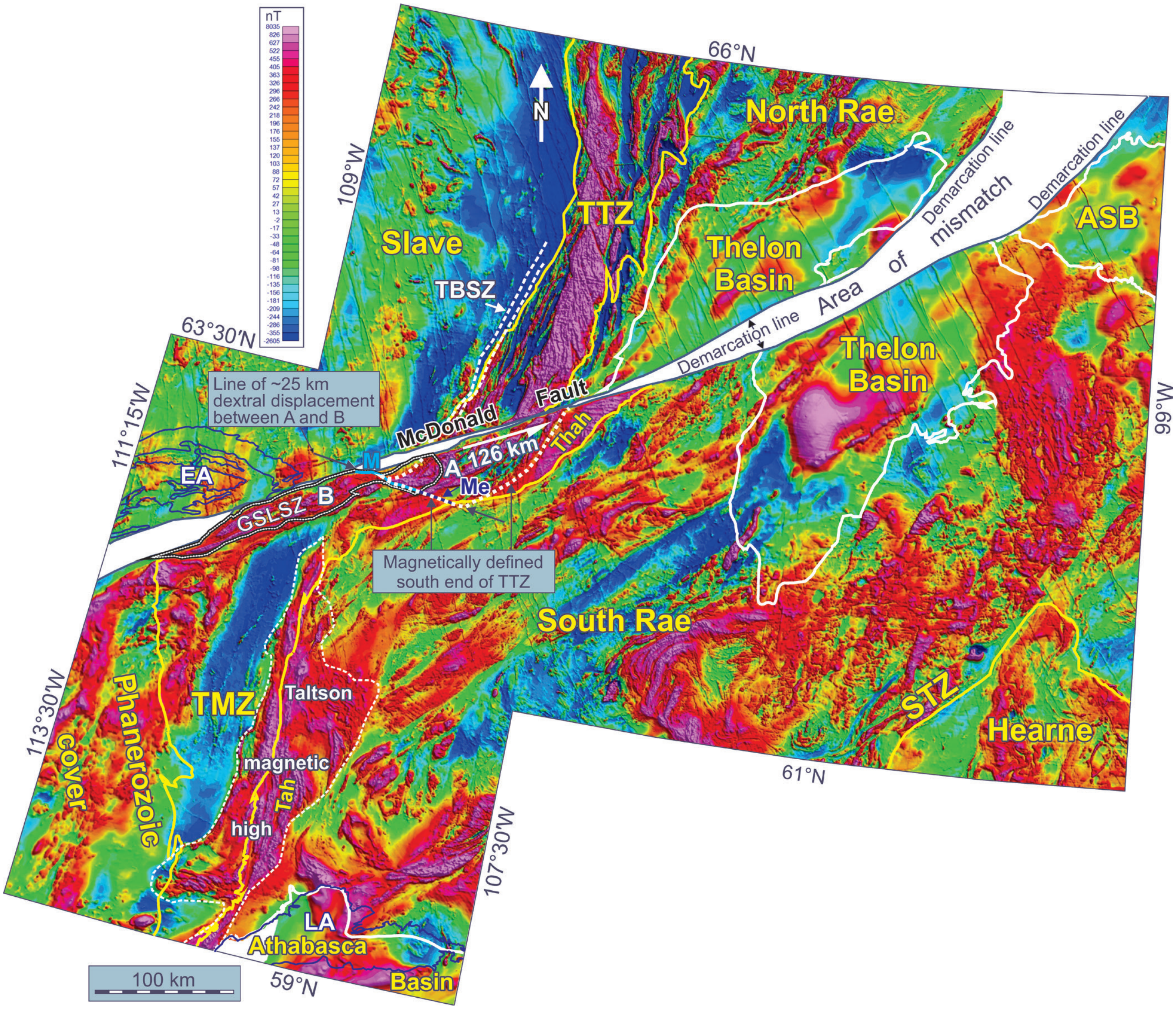


Figure 3. Residual total magnetic field map with an estimated 126 km of dextral displacement between the Thelon tectonic zone (TTZ) north and south of the McDonald Fault restored. Approximately 25 km of dextral displacement along the McKee fault zone is not restored: M, McKee fault as *defined by* Hanmer et al. (1992); Me, eastward extension of McKee fault (Pehrsson et al., 2014, sheet 1). TMZ, Taltson magmatic zone; STZ, Snowbird tectonic zone; ASB, Aberdeen Subbasin of Thelon Basin; GSLSZ, Great Slave Lake shear zone; TBSZ, Thelon Boundary shear zone. EA, East Arm of Great Slave Lake; LA, Lake Athabasca. Area 'A' south of the McDonald Fault represents the southern extremity of the principal magnetic high associated with the TTZ, which is dextrally displaced along the McKee fault from its west-southwestward continuation along a large part of the Great Slave Lake shear zone corresponding to area 'B'. The area labelled 'Taltson magnetic high' (Tah), defined by a white dashed line, and the magnetic high labelled 'Thah' immediately south of the McDonald Fault, identified as a portion of the Thelon magnetic high, are *based on* Card et al. (2014).

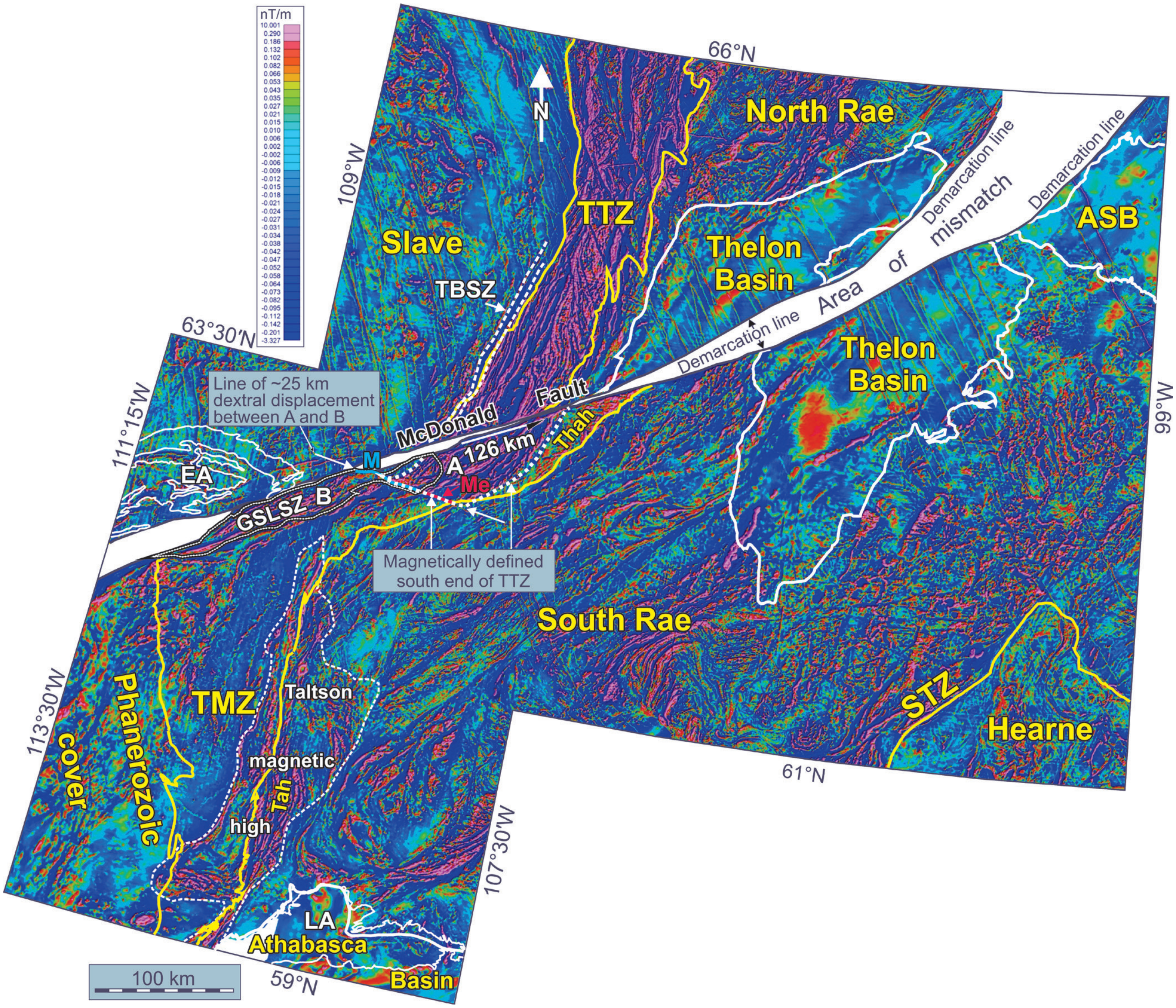


Figure 4. Map of the first vertical derivative of the magnetic field with an estimated 126 km of dextral displacement between the Thelon tectonic zone (TTZ) north and south of the McDonald Fault restored. Approximately 25 km of dextral displacement along the McKee fault zone is not restored: M, McKee fault as *defined by* Hanmer et al. (1992); Me, eastward extension of McKee fault (Pehrsson et al., 2014, sheet 1). TMZ, Taltson magmatic zone; STZ, Snowbird tectonic zone; ASB, Aberdeen Subbasin of Thelon Basin; GSLSZ, Great Slave Lake shear zone; TBSZ, Thelon Boundary shear zone. EA, East Arm of Great Slave Lake; LA, Lake Athabasca. Area 'A' south of the McDonald Fault represents the southern extremity of the principal magnetic high associated with the TTZ, which is dextrally displaced along the McKee fault from its west-southwestward continuation along a large part of the Great Slave Lake shear zone corresponding to area 'B'. The area labelled 'Taltson magnetic high' (Tah), defined by a white dashed line, and the magnetic high labelled 'Thah', immediately south of the McDonald Fault, identified as a portion of the Thelon magnetic high, are *based on* Card et al. (2014).

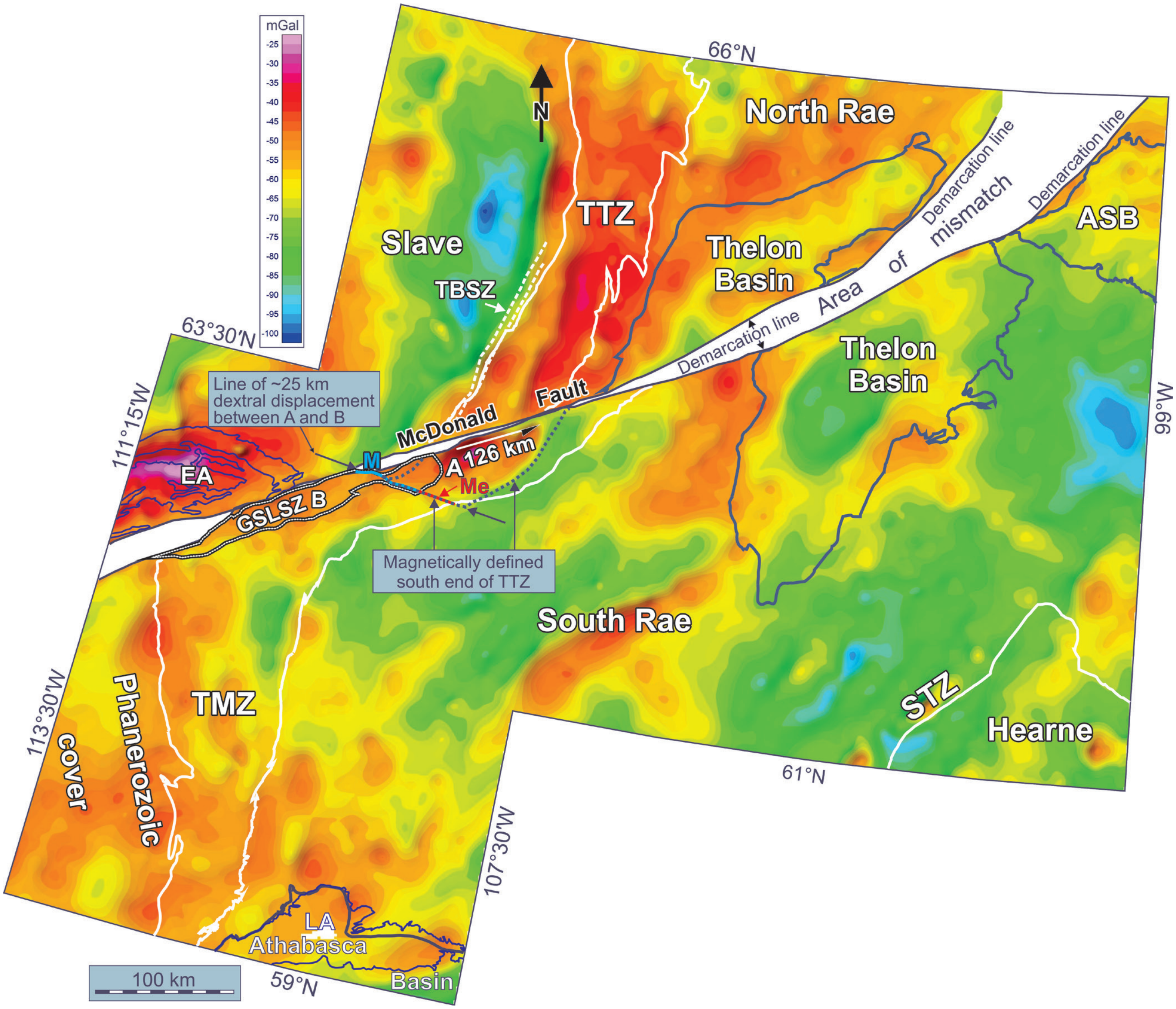


Figure 5. Bouguer gravity anomaly map with an estimated 126 km of dextral displacement between the Thelon tectonic zone (TTZ) north and south of the McDonald Fault restored. Approximately 25 km of dextral displacement along the McKee fault zone is not restored: M, McKee fault as *defined by* Hanmer et al. (1992); Me, eastward extension of McKee fault (Pehrsson et al., 2014, sheet 1). TMZ, Taltson magmatic zone; STZ, Snowbird tectonic zone; ASB, Aberdeen Subbasin of Thelon Basin; GSLSZ, Great Slave Lake shear zone; TBSZ, Thelon Boundary shear zone. EA, East Arm of Great Slave Lake; LA, Lake Athabasca. Area ‘A’ south of the McDonald Fault represents the southern extremity of the principal magnetic high associated with the TTZ, which is dextrally displaced along the McKee fault from its west-southwestward continuation along a large part of the Great Slave Lake shear zone corresponding to area ‘B’.

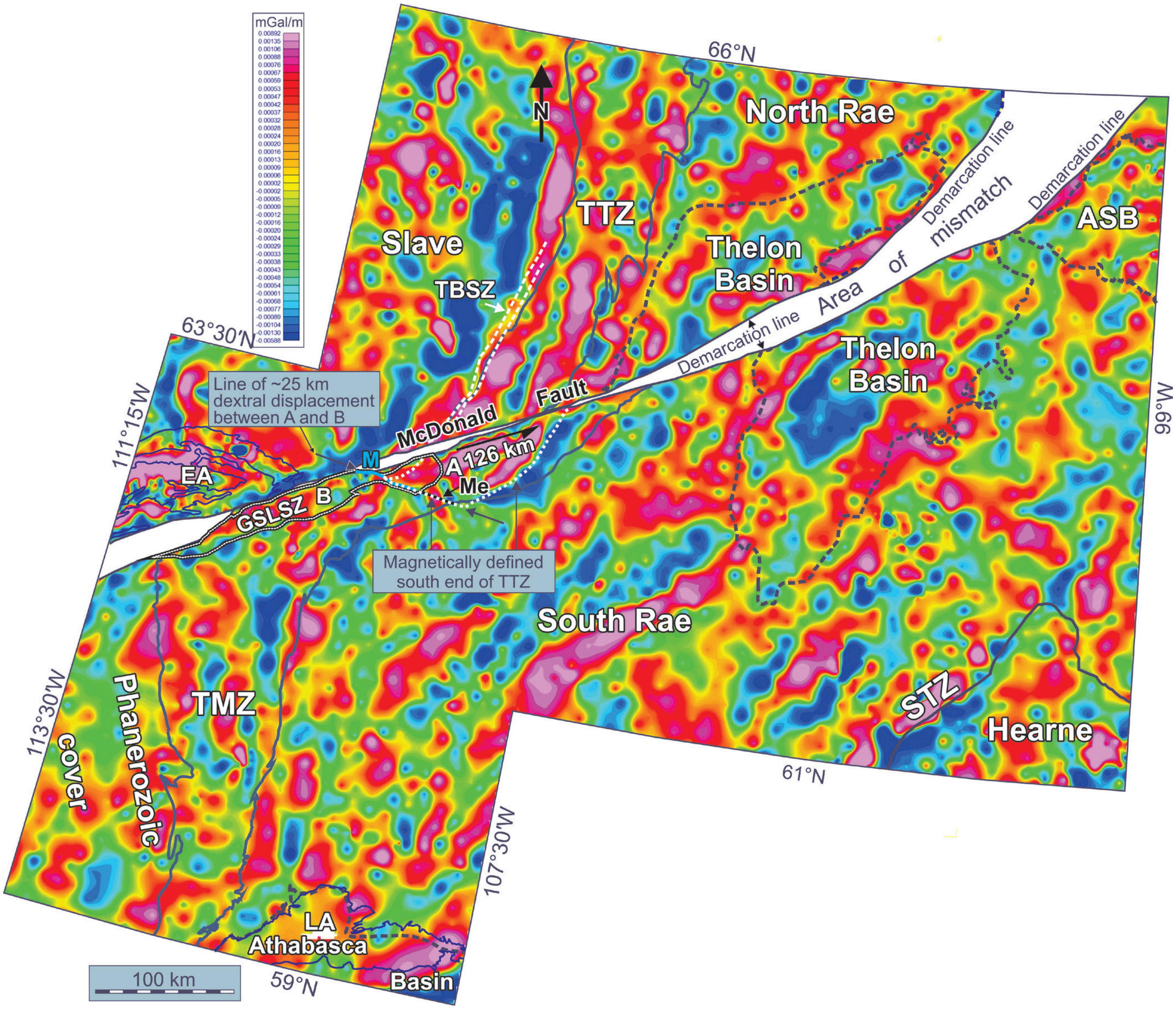


Figure 6. Map of the first vertical derivative of the Bouguer gravity anomaly with an estimated 126 km of dextral displacement between the Thelon tectonic zone (TTZ) north and south of the McDonald Fault restored. Approximately 25 km of dextral displacement along the McKee fault zone is not restored: M, McKee fault as *defined by* Hanmer et al. (1992); Me, eastward extension of McKee fault (Pehrsson et al., 2014, sheet 1). TMZ, Taltson magmatic zone; STZ, Snowbird tectonic zone; ASB, Aberdeen Subbasin of Thelon Basin; GSLSZ, Great Slave Lake shear zone; TBSZ, Thelon Boundary shear zone. EA, East Arm of Great Slave Lake; LA, Lake Athabasca. Area 'A' south of the McDonald Fault represents the southern extremity of the principal magnetic high associated with the TTZ, which is dextrally displaced along the McKee fault from its west-southwestward continuation along a large part of the Great Slave Lake shear zone corresponding to area 'B'.

FVD magnetic anomalies, the steep flanks of some are interpreted to signify the presence of a fault. Within the Thelon Basin, a narrow, linear gravity low is interpreted as being the expression of an east-northeastward extension of the fault-line break.

Along most of the interpreted break, where its position has been derived from both the magnetic maps and the FVD of gravity anomalies, the positions are virtually coincident. About 70 km east of the eastern boundary of the Thelon tectonic zone, at the McDonald Fault, the magnetic signal becomes suppressed on entering the area of the Thelon Basin, so in that location, positioning the break relies principally on interpretation of a map of the FVD of gravity anomalies. On the east side of the Thelon Basin, in the narrow area separating it from the Aberdeen Subbasin, some observed linear features related to magnetic anomalies were used to delineate the break. Alternatively, the eastward tract of the break could have been positioned slightly farther to the south along a linear path defined by the flank of an FVD gravity anomaly. The uncertainty in position in this area does not affect the correlation of the Thelon tectonic zone and Taltson magmatic zone across the McDonald Fault.

Restoration to the predisplacement position was achieved by moving the south Rae Block east-northeastward 126 km along the line of the interpreted break, thereby apparently eliminating the offset of the Thelon tectonic zone and Taltson magmatic zone along the McDonald Fault. Magnetic anomalies within area ‘A’ on the south side of the McDonald Fault (Fig. 3, 4) are matched with anomalies north of the fault associated with the Thelon tectonic zone. The close correlations apparent in the magnetic maps are reproduced in the restorations of the Bouguer gravity anomalies and of the FVD of the Bouguer gravity anomalies (Fig. 5, 6), adding support to the validity of the restorations. No rotation of the block took place. The restoration has the Thelon tectonic zone originally extending no more than about 60 km along strike, south-southwestward south of the fault. Card et al. (2014) noted that the inclusion of the Taltson magmatic zone in the broader Thelon Orogeny by previous researchers was based partly on the high aeromagnetic response associated with the Thelon tectonic zone that apparently could be traced to the south into the vicinity of the Taltson magmatic zone. Card et al. displayed this concept on an aeromagnetic map on which the ‘Thelon aeromagnetic high’ was labelled ‘Thah’. This label is placed in the same position on the maps of the total magnetic field and FVD of the field (Fig. 3, 4). The area of magnetic high labelled ‘Thah’ immediately south of the McDonald Fault has no counterpart north of the fault. It could be argued that the reconstructed displacement along the fault is incorrect and that the area of magnetic high (Thah) should indeed represent a continuation of the Thelon magnetic high. This idea is dismissed, however, because inspection of the map of the FVD of the magnetic field (Fig. 4) reveals that the texture of the area of Thah is completely different from that of the Thelon magnetic high, ruling out correlation.

Immediately north of the McDonald Fault, various alternating north-northeast-trending narrow bands of Paleoproterozoic leucogranite with minor pelitic gneiss and of granite, tonalite, quartz monzodiorite to diorite, and granulite-grade quartzofeldspathic gneiss, along with bands of Neoarchean and/or Paleoproterozoic high-metamorphic-grade metasedimentary rocks, underlie the western part of the Thelon tectonic zone (Pehrsson et al., 2014). The eastern part, where mapping is not as detailed, is formed of a broad expanse of granite, tonalite, and quartz monzodiorite to diorite. The entire width of the Thelon tectonic zone is characterized by narrow, linear to curvilinear, alternating positive and negative magnetic FVD anomalies. South of the fault, the correlative magnetic anomalies are associated with similar geological units, but those are much broader than units in the western part of the Thelon tectonic zone north of the fault. A sizable unit of granite, tonalite, and quartz monzodiorite to diorite is characterized by prominent magnetic highs, some narrow and linear or slightly curvilinear. A relatively broad, included belt of Neoarchean and/or Paleoproterozoic high-metamorphic-grade metasedimentary rocks produces a generally negative magnetic signature punctuated by distinct, narrow, linear magnetic highs. A smaller belt is characterized by a more positive, but varied, magnetic signature.

LINK BETWEEN MAGNETIC SIGNATURE OF THELON TECTONIC ZONE SOUTH OF MCDONALD FAULT AND MAGNETIC SIGNATURE OF GREAT SLAVE LAKE SHEAR ZONE

The area of positive magnetic signature ‘A’ south of the McDonald Fault (Fig. 2) represents the southern extremity of the principal magnetic high associated with the Thelon tectonic zone. The eastern extremity of the Great Slave Lake shear zone as mapped by Hanmer et al. (1992) falls within roughly the westernmost 40 km of area A. The southwestern boundary of area A is nearly coincident with the approximately east-trending McKee fault (Fig. 3), which cuts across the Great Slave Lake shear zone bounding the northeast segment of the shear zone and separating it from the Snowdrift granite and an unnamed granite to the south (Hanmer et al., 1992). The path of the fault east of the shear zone is displayed on the map of Pehrsson et al. (2014). Comparison of magnetic anomaly patterns on either side of the fault indicates about 25 km of dextral displacement, though possibly as much as 30 km. Estimation is uncertain because a westward-trending linear magnetic high at the west end of area A (Fig. 2) complicates correlation of generally northeastward-trending linear anomalies on either side of the fault. The ‘textures’ of the patterns of magnetic anomalies in area A northeast of the fault and within area ‘B’ to the southwest are nearly identical: narrow, linear alternating highs and lows characterize both areas. This similarity is particularly well seen in the map of the FVD of magnetic anomalies (Fig. 4) and provides strong evidence that the Great Slave Lake shear zone within area B and its dextrally displaced portion within area A represent the southwestern extremity of the Thelon tectonic zone. The presence of a linear positive gravity signature (Fig. 5, 6) trending along areas A and B supports this proposal.

Area B is essentially coincident with the greater part of the Great Slave Lake shear zone, lying southwest of the McKee fault (Fig. 3), described by Hanmer et al. (1992) as a corridor of granulite- to lower greenschist-facies mylonites and cataclastic fault rocks that developed deep within an early Proterozoic (2000* to 1900* Ma) magmatic arc created on the margin of the upper Rae Plate in the Slave–Rae collisional event. Although originating within an early Proterozoic setting, the northeastern section of the shear zone includes a belt of Archean strike-lineated mylonites along its northwestern margin (Hanmer et al., 1992) that is separated from a belt of dip-lineated mylonites along the southeastern margin by the 2562 ± 20 Ma Sandwich granite (van Breemen et al., 1990). Curiously, the granite intrudes the strike-lineated mylonites, thereby establishing their Archean age, but acted as protolithic material for the dip-lineated mylonites (Hanmer et al., 1992). Nonetheless, the principal protoliths of the Great Slave Lake shear zone, apparently, are 2051* to 1920* Ma granitoids, reported by Hanmer et al. (1992) to be continuous with the granitoids of the Thelon magmatic arc (2000* to 1920* Ma) and Taltson magmatic zone (1986* to 1906* Ma). Continuity with the Thelon tectonic zone is readily apparent from the described correlations of magnetic anomalies, but continuity with the Taltson magmatic zone is difficult to determine, considering that the characteristic magnetic high associated with Thelon tectonic zone rocks does not appear to extend into the Taltson magmatic zone. Seemingly, the Thelon tectonic zone and the Taltson magmatic zone are not structurally continuous, and the structural ‘disconnect’ is marked by the southern limit of the Great Slave Lake shear zone (Fig. 2–6), along which mylonites are the marginal rocks (Hanmer et al., 1992). The southern limit is nearly coincident with the southern limit of magnetic ‘domain’ B.

Hanmer et al. (1992) remarked that the Great Slave Lake shear zone lies within a belt of 2050* to 1920* Ma granites linking contemporaneous granitoids of the Thelon magmatic arc with those of the Taltson magmatic zone. They also referred to opinion favouring extension of the Thelon tectonic zone as a structural entity into the Taltson magmatic zone and to contradictory opinion highlighting structural and metamorphic differences between the two zones, apparently not offering a preference for one or the other. They did point out that the Thelon tectonic zone, a straight belt of highly deformed and transposed granulite- to upper amphibolite-facies straight gneisses, closely resembles the Great Slave Lake shear zone, an observation supported by the described geophysical correlations between the two zones. Hanmer et al. (1992) also observed that upper amphibolite- to granulite-facies straight gneisses in the Thelon tectonic zone were derived from deformation of granite and mixed paragneiss protoliths similar to those of the Great Slave Lake shear zone. Such types of similarity to the Taltson magmatic zone were not described. Hanmer et al. (1992) concluded that the Thelon tectonic zone, Taltson magmatic zone, and Great Slave Lake shear zone are components of the same magmatic arc, but their geological histories reflect different structural aspects of the interaction at the boundary between the Slave and Rae continents during the interval 2000* to 1900* Ma. On the basis of the evidence of the present study, the author proposes that the Thelon tectonic zone and Great Slave Lake shear zone are components of the same orogenic belt and that the Taltson magmatic zone is a separate, unconnected tectonic feature.

OPINIONS ON RELATIONSHIP OF THELON TECTONIC ZONE TO TALTSON MAGMATIC ZONE AND SOME PROPOSED TECTONIC MODELS

Different viewpoints regarding the relationship of the Thelon tectonic zone to the Taltson magmatic zone have been presented. McDonough et al. (2000) perceived the Taltson magmatic zone to be the southern continuation of the Thelon tectonic zone, a perspective also held by Ross (2002). To the contrary, Card et al. (2014) argued that the Thelon tectonic zone and Taltson magmatic zone did not represent parts of a single orogeny, noting that inclusion of the Taltson magmatic zone in a broader Thelon Orogeny was based partly on the apparent traceability of a prominent magnetic high correlating with the Thelon tectonic zone southward into the vicinity of the Taltson magmatic zone. The presented restorations of dextral displacement along the McDonald Fault, and the evidence that an area of positive magnetic anomaly (Thah) immediately south of the fault does not correlate with the positive magnetic signature of the Thelon tectonic zone (Fig. 3, 4), support the contention of Card et al. (2014) that the Taltson magmatic zone is linked to an orogeny distinct from that producing the Thelon tectonic zone. Furthermore, a comparative study of a large geochemical data set for Thelon tectonic zone plutonic rocks and published geochemical data sets from the Taltson magmatic zone revealed that though late (ca. 1900* Ga) Taltson magmatic zone and Thelon tectonic zone rocks are geochemically similar, early Thelon tectonic zone plutonic rocks are more mafic and characterized by more arc-like signatures not observed in most early Taltson magmatic zone plutons (Whalen et al., 2018). These differences and the fact that Thelon tectonic zone plutonism began some 80 Ma before the earliest dated Taltson magmatic zone plutonic rock (Berman et al., 2018) suggest that the Taltson magmatic zone is not directly correlative with the Thelon tectonic zone.

Accepting that the Thelon tectonic zone and Taltson magmatic zone evolved independently, Card et al. (2014) presented two potential tectonic models explaining their development. Both models assume that the original orientation of the Taltson Orogen was northwest and that the Thelon tectonic zone was never continuous with the Taltson Orogen. The first model assumes that the Thelon and Taltson orogenies developed separately from 2000* to 1900* Ma during amalgamation of the Slave and Rae cratons and the Kiskatinaw–Chinchaga–Buffalo Head terranes. Initially, the plate carrying the Slave Craton was subducted eastward beneath the Buffalo Head terrane, merging with it and producing the Thelon–Ksituan Arc in the process. Northeastward subduction of the combined Slave–Kiskatinaw–Chinchaga–Buffalo Head superterrane beneath the Rae Craton was initiated by 1986* Ma, producing arc-type plutons along a northwest-trending Taltson Arc. Terminal collision after 1959* Ma led to development of northwest-trending fabrics and 1940* to 1930* Ma high-grade metamorphism and peraluminous magmatism. A shortcoming of the model is the predicted continuation of the Kiskatinaw–Chinchaga–Buffalo Head superterrane as basement within the Thelon tectonic zone north of the Great Slave Lake shear zone, but rocks of appropriate age have not been found north of the shear zone (Card et al., 2014).

The second model proposes attachment of the Slave Craton to the Rae margin before 2300* Ma during the Arrowsmith Orogeny and then independent development of the Taltson Orogen from 2000* to 1900* Ma. But, if accretion of the Slave Craton occurred before Taltson Arc magmatism, the model does not explain how the craton escaped intrusion by Taltson-age plutons, given that the craton was part of the upper plate. For this reason, Card et al. (2014) considered the first model more plausible. Both models proposed by Card et al. incorporate subduction zones.

A radically different viewpoint was presented by Chacko et al. (2000), who proposed a model for development of the Taltson magmatic zone, and possibly of the Thelon tectonic zone, within the interior of a continental plate; in this model, magmatism was produced by crustal thickening, thus ruling out close involvement of a subduction zone. Chacko et al. (2000) likened the origin of granitoids of the Taltson magmatic zone to the intracrustal origin of Mesozoic and Cenozoic granitoids of the North American Cordillera, formed in the distant hinterland of a convergent plate margin. A current example of such a setting is provided by mountain belts of central Asia, such as the Tian Shan, produced by India–Asia collision and situated hundreds of kilometres from the plate margin. Chacko et al. (2000) based their conclusion on comparisons of geochemical and isotopic data for Taltson magmatic zone granitoids with data for other granitoids.

AN ALTERNATIVE TECTONIC MODEL

In view of the potential weaknesses of the models advanced by Card et al. (2014), a model proposed by Hoffman (1987) that is based on an analogue with India–Eurasia collision is revisited. This model involves subducting and colliding plates, in contrast to intraplate processes as advocated by Chacko et al. (2000). Support for the Hoffman (1987) model is provided by a study of plutonic rocks in the Thelon tectonic zone concluding that their chemistry is best explained by development in a convergent margin (Whalen et al., 2018) and by the presence of a neodymium-isotope signature in the Taltson magmatic zone indicative of mantle derivation that supports oceanic subduction (McDonough et al., 2000). In Hoffman's (1987) model, the Great Slave Lake shear zone is a continental transform structure involved in oblique collisional indentation of the active margin of the Churchill Province (Rae Craton) by the Slave Province. The India–Asia collisional analogue included an area of extrusion tectonics covering land north of the Bay of Bengal and the Andaman Sea (Fig. 7a). The analogue to the Great Slave Lake shear zone is represented by the Sagaing transform fault, found within the upper Sunda Plate above the subduction zone along the Java (now named 'Sunda') Trench. This analogue infers the presence of a subduction zone dipping southeastward beneath the Great Slave Lake shear zone between the shear zone and the Slave Craton, though such a subduction zone was not specifically discussed by Hoffman (1987).

A variation on the India–Eurasia analogue that does not require a subduction zone between the Slave Craton and the Great Slave Lake shear zone is an analogue in which the counterpart of the Great Slave Lake shear zone is a transform fault coinciding with the Ninety East ridge (Fig. 7b, c). This potential analogue for development of the Thelon tectonic zone and Taltson magmatic zone is manifested in a tectonic schematic of the southwest Pacific presented by Stern and Bloomer (1992) that incorporates some perspectives from Hilde et al. (1977). India and continental crust under the Bay of Bengal represent the counterpart of the Slave Province, and the Ninety East transform fault represents the Great Slave Lake shear zone. The fault, coincident with the Ninety East ridge, separated an India–Asia continental subduction zone from an oceanic–continental subduction zone in the region of the Andaman Sea and Sumatra. Much of the northern portion of the Bay of Bengal is thought to be floored by thinned (15 km thick) continental crust, injected by Mesozoic volcanism (Rangin and Sibuet, 2017). The geometric relationship of the two subduction zones and the Ninety East transform fault is speculated to be similar to that for the Slave–Rae and Buffalo Head–Rae subduction zones and the Great Slave Lake shear zone (Fig. 7d).

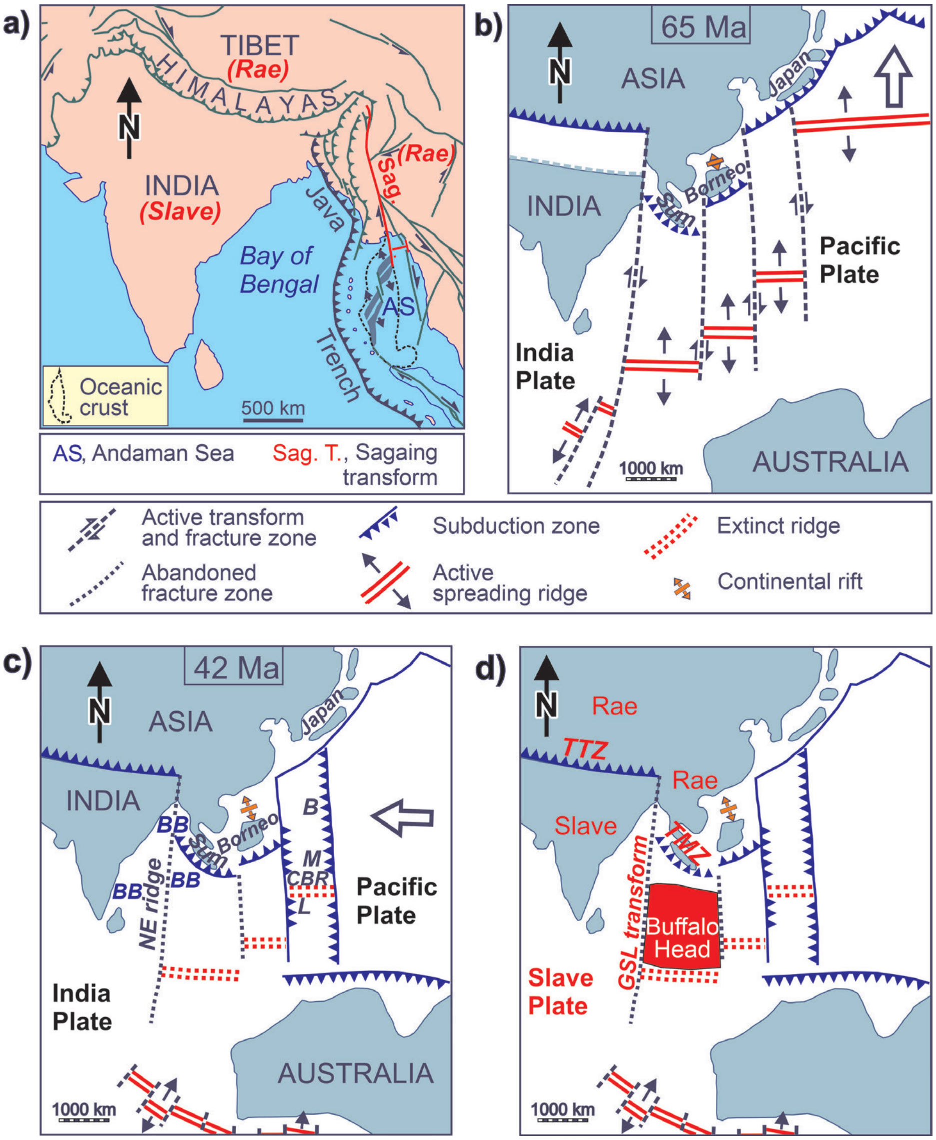


Figure 7. a) India–Asia collisional analogue for Slave–Rae collision *modified and simplified from* Hoffman (1987). **b)** and **c)** Schematic maps of tectonic elements, principally oceanic spreading ridges, subduction zones, and transform faults, in the southwest Pacific that influenced the evolution of India, Asia, and Australia. **b)** At 65 Ma and **c)** at 42 Ma. *Modified from* Stern and Bloomer (1992). **d)** Analogues for Slave–Rae collision substituted into **b)**; distance scale removed. B, Bonin Arc; BB, Bay of Bengal; CBR, Central Basin Ridge; GSL, Great Slave Lake; L, Luzon Arc; M, Mariana Arc; NE, Ninety East; Sum, Sumatra; TMZ, Taltson magmatic zone; TTZ, Thelon tectonic zone.

The tectonic setting of India–Asia collision and subduction along the Sunda Trench includes critical elements such as spreading ridges, transform faults, oceanic fracture zones, rifting, and subduction zones. The broadscale geometric pattern defined by these elements provides a template for creation of a tectonic model for development of the Thelon tectonic zone and Taltson magmatic zone. This pattern need not be precisely reproduced, but counterparts of individual elements can be incorporated in a tectonic analogue.

Geophysical signatures for Thelon tectonic zone and Taltson magmatic zone

Continental collision as a mechanism for creation of the Thelon tectonic zone is well supported by, for example, Gibb and Thomas (1977), Gibb (1978), Hoffman (1987), Culshaw (1991), and Card et al. (2014). Card et al. (2014) also proposed that the Taltson magmatic zone developed by evolution of a subduction-related continental arc, and McDonough et al. (2000) had earlier described the Taltson magmatic zone south of latitude 60°N as a composite continental magmatic arc and collisional orogeny. The radically different geophysical signatures of the Thelon tectonic zone and Taltson magmatic zone possibly signify differences in the types of colliding arcs involved in their development. The Thelon tectonic zone is dominated by a prominent, broad, singular magnetic high, nominally about 30 km wide, accompanied by narrower, alternating linear magnetic highs and lows in some areas (Fig. 2). The relationship of the principal high to geology is best observed in an area of fairly detailed geological mapping north of the Bathurst fault (Berman et al., 2018) (Fig. 1). Here, the high correlates closely with a unit of 2010* to 1990* Ma megacrystic granodiorite, quartz diorite, charnockite, and monzogranite forming roughly the eastern half of a magmatic unit termed the ‘Western plutonic belt’. The close relationship may be significantly influenced, however, by the key role played by aeromagnetic data in delineating geological units. The plutonic rocks in this belt plot in the I-type granite field (Whalen et al., 2018) of White and Chappell (1983).

In contrast, the Taltson magmatic zone is dominated by a prominent linear magnetic low, nominally some 40 km wide and 250 km long, extending along most of the Taltson magmatic zone exposed on the shield (Fig. 2). This low is associated with a large central belt of weakly magnetic 1940* to 1920* Ma S-type granitoids (Card et al., 2014), principally the Konth granite, an S-type ilmenite-series syenogranite to monzogranite (Bostock, 2014). Some areas of Slave granite (monzogranite varying locally to granodiorite or syenodiorite) having a low magnetic susceptibility, S-type signature typical of ilmenite-series granite (Bostock, 2014) also fall within the magnetic low.

The low is flanked on both sides by belts of strong magnetic highs. The western belt is associated mainly with ca. 1986* Ma Deskenatlata granodiorites, which are generally correlated with I-type granitoids of the eastern Taltson magmatic zone (Card et al., 2014). The eastern belt correlates with the apparently mainly S-type granites along the eastern margin of the Taltson magmatic zone, of which the Arch Lake granite produces an atypically particularly strong signature, and extends eastward onto the margin of the Rae Craton. Arguments for the lack of continuity between this eastern Taltson magmatic zone marginal magnetic high and the Thelon tectonic zone magnetic high have been presented.

The stark contrast in magnetic expressions of the Thelon tectonic zone and Taltson magmatic zone, seemingly, is tied closely to the different types of granitoids within the zones. Dominant I-type granitoids in the Thelon tectonic zone produce a strong positive magnetic response, and dominant S-type granitoids in the Taltson magmatic zone are expressed as a conspicuous, fairly negative magnetic response. Is a difference in granitoid geology sufficient to declare the Thelon tectonic zone and Taltson magmatic zone separate and independent entities? If it were a function of a difference in the level of crustal exposure, perhaps a case could be made that they are part of the same orogen. The evidence of a lack of continuity of the magnetic high along the eastern margin of the Taltson magmatic zone, and the partial correlation of that anomaly with basement rocks of the Rae Craton, favour independent development of the two zones, however.

The strong differences in magnetic expression are mirrored in the gravity signatures (Fig. 5, 6). The Thelon tectonic zone is associated with a paired negative–positive gravity anomaly of a type proposed as a signature of continent–continent collision and observed at several Precambrian structural boundaries (e.g. Gibb and Thomas, 1977; Gibb et al., 1983). Specifically, the positive member of the pair correlates closely with the Thelon tectonic zone and the principal magnetic anomaly along the Thelon tectonic zone. The positive anomaly is attributed to a section of crust that is thicker and more dense than crust along the eastern margin of the Slave Craton.

Values within the positive anomaly generally range from about −34 to −47 mGal, which compare to an estimate of roughly −60 mGal for a background value. The exposed portion of the Taltson magmatic zone, likewise, generally displays a positive gravity signature, but it is weaker: values range from about −44 to −60 mGal. This signature peaks most strongly in localities along the boundary with Phanerozoic cover, but peaks within the Taltson magmatic zone are more subdued. The pattern of peaks and intervening troughs within the Taltson magmatic zone signature is not easily distinguished from similar patterns of generally positive signatures over the Rae Craton to the east and buried Precambrian rocks to the west. No large complementary negative anomaly as observed in paired anomalies at structural boundaries is present. A distinct negative gravity anomaly in the northeastern ‘corner’ of the Taltson magmatic zone correlates mainly with an area of Konth granite and units, or portions thereof, of Slave granite. The negative anomaly has been modelled as a Konth–Slave granite unit attaining a maximum depth of 15 km (Thomas, 2022).

The conspicuous contrast in the geophysical expressions of the Thelon tectonic zone and Taltson magmatic zone reinforces the proposal of two collisional orogenies acting independently. This striking contrast and the differences in the types of plutonic rocks reflected in substantial development of S-type granitoids in the Taltson magmatic zone (e.g. Konth granite) compared to relatively minor development in the Thelon tectonic zone, the significantly earlier intrusion (2020* to 1980* Ma) of arc-type granitoids in the Thelon tectonic zone compared to that (1986* to 1959* Ma) in the Taltson magmatic zone (Card et al., 2014), and the geophysical evidence of a disconnect between the Thelon tectonic zone and the Taltson magmatic zone collectively favour independent tectonic development of the two belts. Recently, Whalen et al. (2018) noted that Thelon tectonic zone plutonism began some 70 Ma (80 Ma, according to Berman et al., 2018) earlier than plutonism in the Taltson magmatic zone, and though recognizing strong geochemical similarities between younger plutonic suites of the Taltson magmatic zone and the Thelon tectonic zone, Whalen et al. (2018) reported some significant differences between older plutonic phases that suggest they are not along-strike equivalents.

PROPOSED PLATE MODEL

A new model for the precollisional and collisional phases of tectonic development of the Thelon tectonic zone and the Taltson magmatic zone incorporating elements of the proposed India–Asia collisional analogue is presented in Figure 7, a principal element of which is the Great Slave Lake shear zone separating subduction systems to either side. The characteristics of the gravity field strongly support continent–continent collision for the Thelon tectonic zone, but they seemingly are inconclusive for the Taltson magmatic zone. McDonough et al. (2000), however, presented a model in which an early (ca. 2440* to 1990* Ma) Andean-type margin on the western margin of the Churchill Province is destroyed by continent–continent collisional orogenesis involving the Buffalo Head terrane and the Churchill Craton. The model displays initial collision ca. 1970 Ma, an eastward-dipping subduction slab, the I-type 1986 Ma Deskenatlata granodiorite in the Taltson magmatic zone, and the back-arc volcano-sedimentary Waugh Lake Basin formed by rifting above the subduction zone. The basin was likened to small intra-arc basins in Taiwan and Japan described by Huang et al. (1995) and Nakayama (1996), respectively, formed by extensional processes. In the case of Taiwan, intra-arc basins developed on volcanic islands (arcs) involved in arc–continent collision (Huang et al., 1995). Uyeda and Kanamori (1979) examined back-arc spreading caused by, or related to, subduction, classifying trench-arc–back-arc systems into continental arcs and island arcs, noting that continental arcs, by definition, have no back-arc basins. The significance of this definition to the present study is that if the Waugh Lake Basin does represent an inter-arc basin, the Taltson magmatic zone may have included an island arc in its tectonic setting.

A key element in creating a plate model for development of the Thelon tectonic zone and Taltson magmatic zone is the assumption that the Thelon tectonic zone north of the McDonald Fault, its southern extremity south of the fault, and the Great Slave Lake shear zone collectively represent a single orogenic unit formed along the edge of a continent. Implicit is that subduction of the Slave Craton took place beneath this composite unit. A starting point in developing a plate model is the fragmentation of Kenorland, the Neoarchean supercontinent that included the Slave and Rae cratons (Aspler and Chiarenzelli, 1998). Of particular interest to the fragmentation process is the linearity of the McDonald-Wilson fault (henceforth simply McDonald Fault) that bounds the southeastern margin of the Slave Craton and separates it from Precambrian terranes buried under the Western Canada Sedimentary Basin (Fig. 8a). These terranes, and terranes north of the fault, are truncated by the fault, intersecting it at a high angle. The fault is a substantial tectonic feature, extending more than 1100 km from the Thelon tectonic zone southwestward to the Rocky Mountains. The linearity of the fault is attributed to rifting that initiated separation of the Slave Craton (Fig. 8b).

At the time of proposed rifting, later argued to be at ca. 2350 Ma, certain terranes both north and south of the McDonald Fault were not in existence, so the nature of crust that was rifted west of the Slave and Rae cratons is open to question. Was it Archean crust? How far west did it extend? The linearity and extent of the McDonald Fault extending to the Rocky Mountains suggest that it was developed within a single large crustal unit of continental proportions. Rifting of the unit on either side of the McDonald Fault after development of the fault or its predecessor, at a high angle to the fault, may have produced Archean continental blocks that later interacted to produce the geology as now observed (Fig. 8a). This aspect of the geological history west of the Slave Craton is beyond the scope of the present study, and Figure 8a does not necessarily imply that terranes west of the Slave and Rae cratons were affected by rifting along the line of the McDonald Fault at ca. 2350 Ma, because many are younger, though they may contain Archean components (e.g. Pană, 2003).

An analogue for such rifting is the distinctively linear Red Sea rift, some 2200 km long (Fig. 8c). The Red Sea analogue is enhanced by including rifting along the Gulf of Aden (Bosworth and Stockli, 2016) that may explain the change in orientation of the proposed Slave rift from 060° along the McDonald Fault to generally 010° along the Thelon tectonic zone (Fig. 8b). Segments of rifting south and east of the Slave Craton are referred to as the Slave South and Slave East rifts, respectively. The Red Sea and Aden rifts are perceived as two separate arms of a rift–rift–rift triple junction related to the Afar plume (Bosworth and Stockli, 2016) (Fig. 8c). The third arm is represented by the Main Ethiopian rift forming the northern end of the Eastern Branch of the East African rift system, which includes the Kenyan and Gregory rifts to the south-southwest (Chorowicz, 2005). Bosworth and Stockli (2016) noted that the temporal evolution of volcanism suggests that the three arms probably evolved differently and only after ca. 15 Ma coalesced into a textbook rift triple junction.

The internal spreading mechanisms of the two rifts are noticeably different. Normal faults in the Red Sea rift trend parallel/subparallel to the rift margins, whereas faults in the Aden rift trend at a fairly large oblique angle to the rift margin. Bosworth and Stockli (2016) identified the Aden rift as an oblique rift, noted to be a type example of an oblique opening rift basin in which the difference in orientation of spreading and rift trend is 49° (Lepvrier et al., 2002). Basically, spreading ridges and extensional faults trend roughly 30° obliquely to the rift margins (Fig. 8c). In the speculative schematic diagram (Fig. 8b) of Slave–Rae opening, the Slave element has simply been displaced northwestward from the Rae Craton. The pattern of spreading may have been more complex with rifting involving spreading ridges parallel/subparallel to the rift margin and/or oblique ridges.

The date of Slave–Rae opening is speculated to predate development of a Paleoproterozoic basin that accommodated the Rutledge River assemblage. Remnants of the assemblage, commonly consisting of pelitic to quartzitic paragneiss, are scattered over a broad area of the Taltson magmatic zone and are also present within the adjacent margin of the Rae Craton (Fig. 1, 8a). Similarities in geochronology and isotope geochemistry of the western Rae Province and Buffalo Head domain and the presence of mafic to ultramafic rocks within the basin and Rae margin led Bostock and van Breemen (1994) to propose that the basin had been formed by rifting. Speculation that Slave–Rae opening preceded formation of the Rutledge River rift basin is based on the apparent absence of a counterpart within the Slave Craton. This is not compelling evidence, as the basin did not necessarily extend northward into the Slave Craton, but if it had, it could have been destroyed by plate interactions along the Slave margin. Bostock and van Breemen (1994), noting the presence of high-grade supracrustal rocks within the Thelon

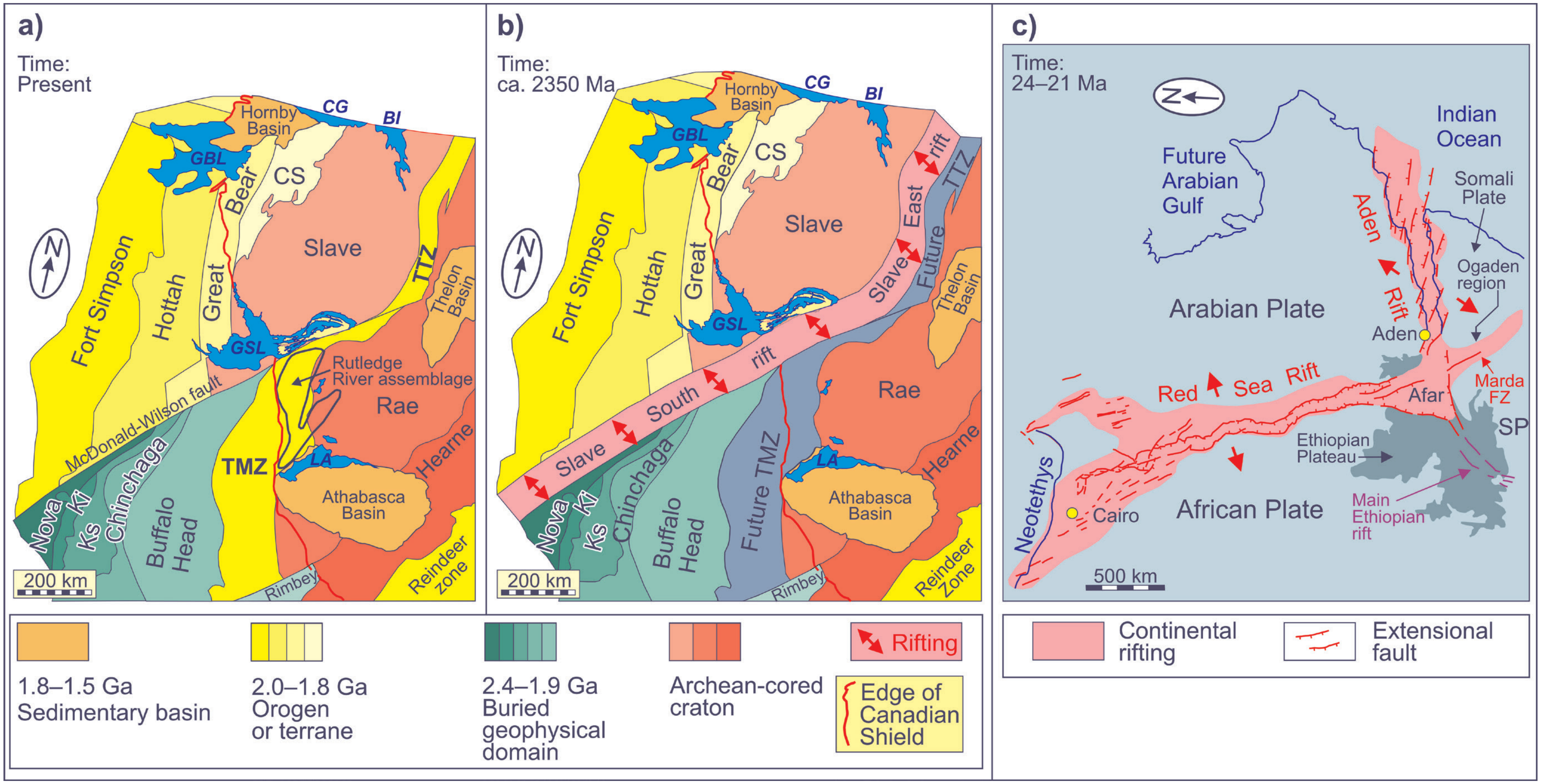


Figure 8. **a)** and **b)** Map of northwestern Canadian Shield *based on* Figure 1 of Card et al. (2014), including the Slave, Rae, and Hearne cratons, Taltson magmatic zone (TMZ), Thelon tectonic zone (TTZ), various orogens and terranes (CS, Coronation Supergroup; Ki, Kiskatinaw; Ks, Ksituan), and buried geophysical domains. Water bodies: BI, Bathurst Inlet; CG, Coronation Gulf; GBL, Great Bear Lake; GSL, Great Slave Lake; LA, Lake Athabasca. **b)** Includes schematic representation of rift breakup of Kenorland. **c)** Development of Red Sea and Aden rifts at 24 to 21 Ma, *modified from* Bosworth and Stockli (2016); FZ, fault zone.

tectonic zone, conjectured that one or more coeval sedimentary basins may have existed along the western margin of the Rae Craton before indentation of the Slave Craton.

Bostock and van Breemen (1994) concluded that deposition in the Rutledge River Basin terminated ca. 2130* to 2090* Ma, further suggesting that influx of 2150* Ma detrital zircons, probably from the west, and high-grade metamorphism accompanying basin closure at 2090* Ma signify contemporaneous eastward migration of magmatism. An age of 2340* Ma determined on a metagabbro within the western margin of the Rae Craton suggests that rifting initiated as a discontinuous process at that time (Bostock and van Breemen, 1994), and basin development may have been related to extensional episodes postdating the last regionally active magmatism in the western Rae Craton (ca. 2270* Ma). In the proposed plate model, therefore, a minimum age of 2350 Ma is assigned to Slave–Rae rifting, an age supported by the conclusion that the supercontinent Kenorland underwent protracted breakup from ca. 2450* to 2100* Ma and fragmentation from ca. 2100* to 2000* Ma (Aspler and Chiarenzelli, 1998). A much later date of 2046 Ma for the rifting apart of the Slave and Rae cratons was proposed by Sheen et al. (2019) on the basis of a recent age determined for the Union Island Group, the oldest in the East Arm Basin, considered as having formed in a continental rift setting. Regardless of which age is correct, implications for the closure history of the Slave–Rae ocean are basically unchanged.

The Slave South and Slave East rifts (Fig. 8b) are perceived as two rifts of a rift triple junction, though evidence of the third member is not apparent. Possibly any third potential rift became a failed arm of the triple junction. Positionally, the site of the present Taltson magmatic zone offers the most favourable location for a third arm, though the pattern of three such rifts does not conform to the roughly 120° difference in orientation of the arms of a typical triple junction. If certain circumstances prevailed for development of a third arm in this atypical location, it is ventured that the Rutledge River rift basin could represent the failed arm of this triple rifting event.

A feature of potential interest for Slave–Rae tectonic interaction is the Marda fault zone in the Ogaden region of the Somali Plate (Fig. 8c). The fault zone falls within a zone of continental rifting, collinear with the Red Sea rift, and extending south-southeastward beyond the Afar triple junction. Bosworth and Stockli (2016) interpreted emplacement of a local system of basaltic dykes as signifying propagation of an incipient rift from Afar toward the Indian Ocean. The position of the Marda fault zone relative to the Red Sea rift mimics that of the portion of the McDonald Fault at the south end of the Thelon tectonic zone relative to the Slave South rift. Although Slave–Rae collisional plate models favour creation of the McDonald and Bathurst faults at the time of indentation of the Slave Craton into the Rae Craton (Gibb, 1978), it is feasible that the presence of a Marda type of fault weakness at the western edge of the Rae Craton influenced later indentation-related faults.

Chronological development of Slave–Rae opening-closing

A plate model for development of the Thelon tectonic zone, Taltson magmatic zone, Great Slave Lake shear zone, and East Arm Basin is illustrated schematically in Figure 9, commencing with the geological picture at the present time (0 Ma) that includes some modifications (Fig. 9a).

Time 0 Ma, present day geology (Fig. 9a)

The modifications that this model incorporates are the following: 1) The portion of the Thelon tectonic zone, as magnetically defined (Fig. 2), that is south of the McDonald Fault is repositioned 126 km eastward along the fault to eliminate former dextral displacement. 2) The portion of the Great Slave Lake shear zone that is south of the McKee fault likewise is repositioned 25 km eastward; this creates an apparent gap between the Slave Craton and the Great Slave Lake shear zone and moves the shear zone into the area covered by the Rutledge River assemblage, but these changes are considered insignificant at the scale of investigation. 3) Portions of the Slave Craton and Kilohigok Basin north of the Bathurst fault and the northern part of the Thelon tectonic zone are repositioned dextrally 20 km along the Bathurst fault; the estimate of the length of this displacement is based on the apparent displacement of the western edge of the principal magnetic high in the Thelon tectonic zone. Tirrul and Grotzinger (1990) determined 115 km of sinistral offset by projecting the trend of stratigraphic truncations across the fault, but the 20 km value is preferred.

Time ca. 2350 Ma, opening of Slave–Rae ocean and Buffalo Head terrane–Rae ocean (Fig. 9b)

The approximate time of separation of the Slave and Rae cratons is proposed to be 2350 Ma, at which time rifting between a block of crust representing the future Buffalo Head terrane and the Rae Craton may also have occurred, though the location is uncertain. The distribution of metasedimentary remnants of the Rutledge River Basin within plutonic rocks of the Taltson magmatic zone may reflect their pre-Taltson magmatic zone distribution anchored on pre-Taltson magmatic zone basement. The remnants are distributed over a width of 170 km, considered a minimum width of the rift. If flanks of the rift had similar widths, basement of the Rae Craton may have extended 100 to 200 km west of the basin.

If ages of 2350 Ma for rifting and 2070* Ma for the next main dated event, that is, plutonism in the Thelon tectonic zone (Berman et al., 2018), are accepted, the opening and closing of the Slave–Rae ocean could span 280 Ma. If the opening phase lasted 140 Ma, and the half-spreading rate were 25 mm/a, the width of the created ocean would be 7000 km. The 25 mm/a value is a rough estimate based on a

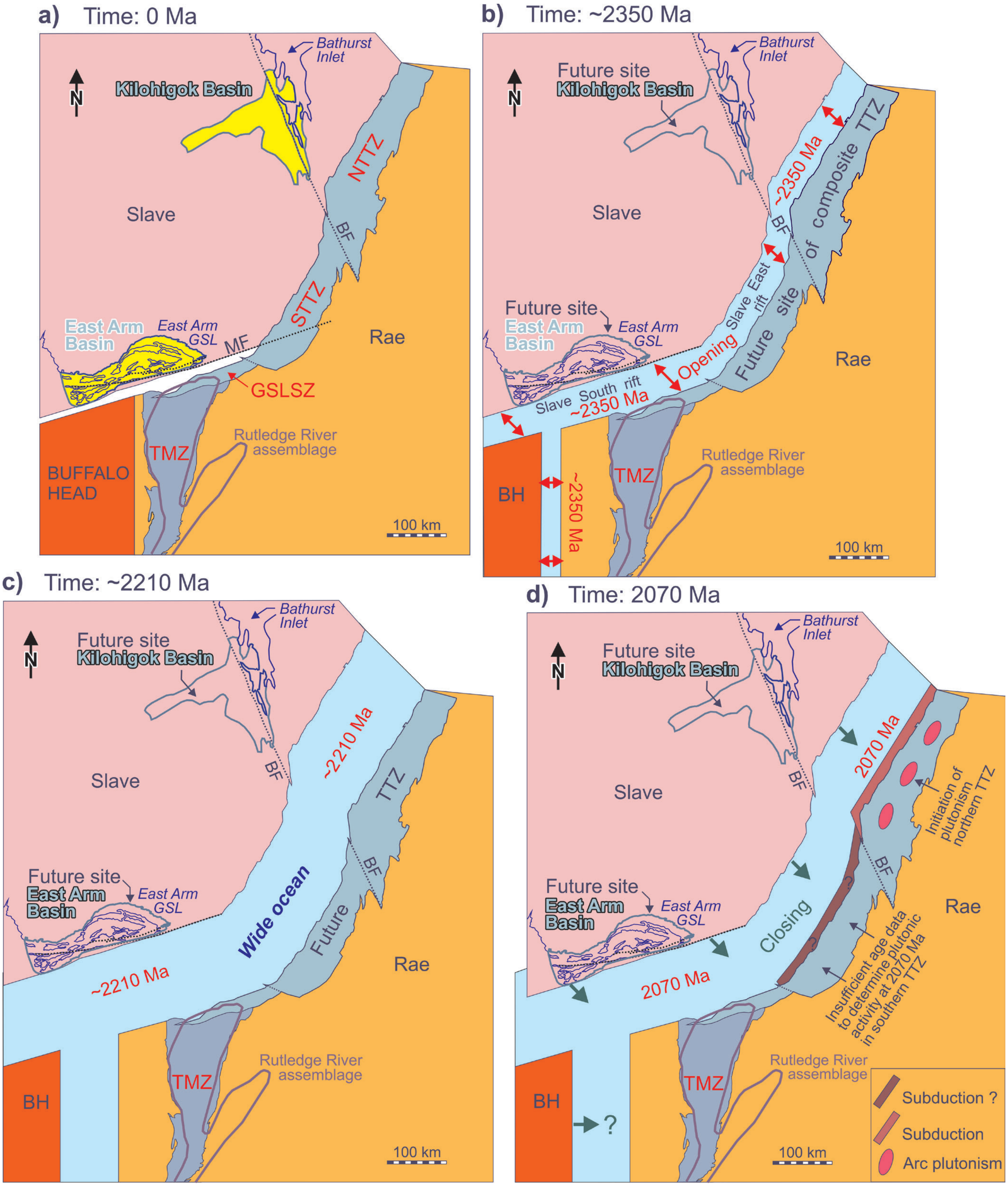


Figure 9. Schematic maps displaying sequential stages of oceanic opening and closing between the Slave and Rae cratons. BF, Bathurst fault; BH, Buffalo Head terrane; GSL, Great Slave Lake; GSLSZ, Great Slave Lake shear zone; MF, McDonald Fault; NTTZ, northern Thelon tectonic zone; STTZ, southern Thelon tectonic zone; TMZ, Taltson magmatic zone, TTZ, Thelon tectonic zone. **a)** Present time, 0 Ma; **b)** ca. 2350 Ma; **c)** ca. 2210 Ma; **d)** 2070 Ma.

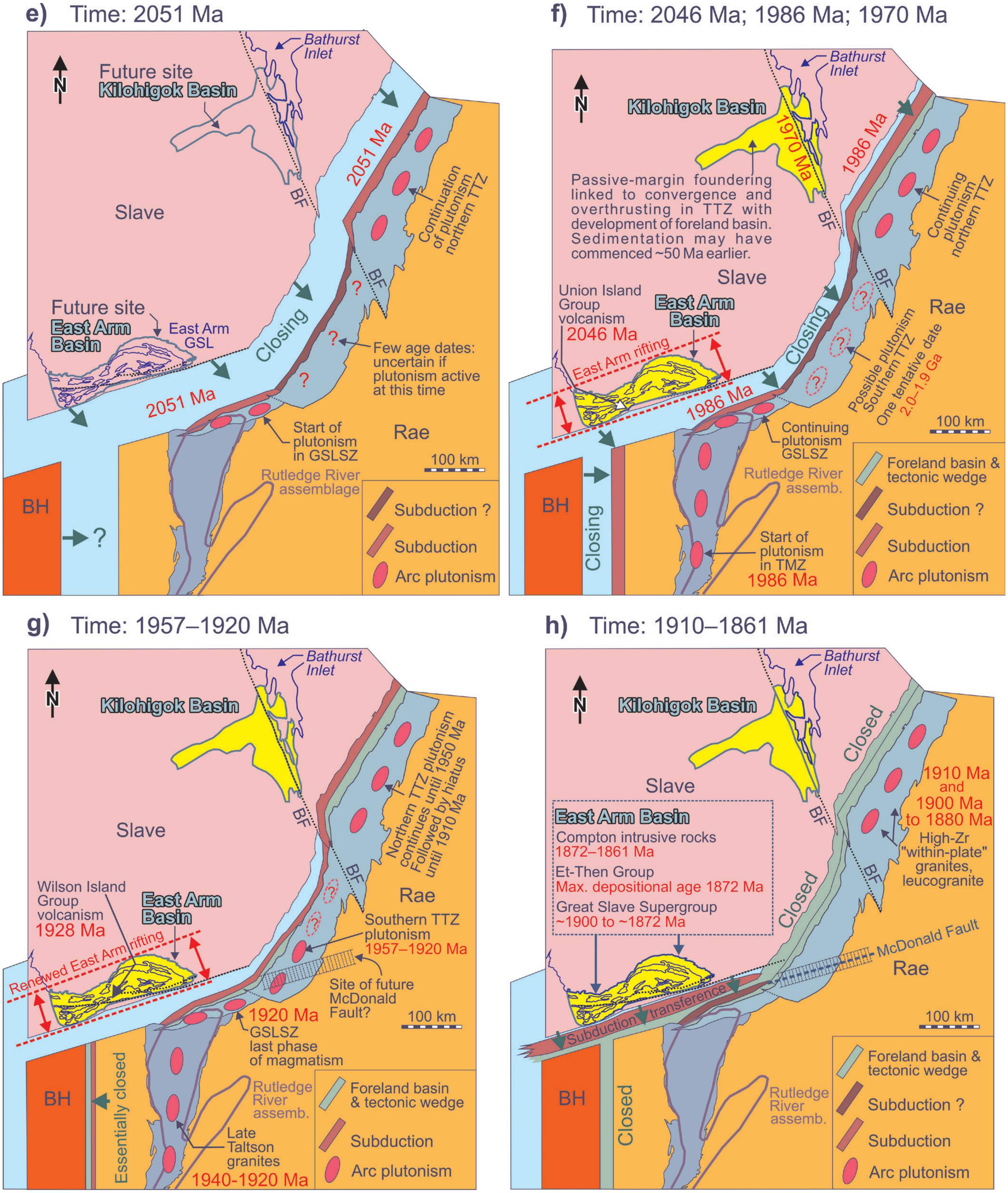


Figure 9. (cont.) e) 2051 Ma; **f)** 2046, 1986, and 1970 Ma; **g)** 1957 to 1920 Ma; **h)** 1910 to 1861 Ma.

map of half-spreading rates (Müller et al., 2008) that range generally from 10 to 40 mm/a in the Atlantic Ocean. Thus, by ca. 2210 Ma, a wide ocean separated the Slave and Rae cratons (Fig. 9c). So large a width for a Precambrian ocean, apparently, is reasonable: paleomagnetic studies indicate that the Paleoproterozoic Manikewan Ocean in the Trans-Hudson Orogen was about 5500 ± 700 km wide at one stage during ocean closure (Symons and Harris, 2005). The closure rate of 12 cm/a was much higher than the 25 mm/a selected here.

Other oceans and oceanic plates were also probably active in the early Paleoproterozoic in this region. The series of roughly north- to northeast-trending 2400* to 1900* Ma buried geophysical domains and the north-trending 2000* to 1800* Ma Taltson magmatic zone (Fig. 8a) conjure up a picture of several terranes formerly separated by intervening oceans. Subduction of associated oceanic crust is manifested in metaplutonic and subordinate felsic metavolcanic rocks (2320* to 2000* Ma) in the largely magmatic Buffalo Head terrane, metaplutonic gneisses (2180* to 2090* Ma) in the Chinchaga terrane, and characteristic plutonic rocks (1980* to 1900* Ma) in the Ksituan terrane (Ross et al., 1991). The younger ages in the Ksituan terrane and Taltson magmatic zone are attributed to outward-dipping subduction zones linked with the composite Chinchaga–Buffalo Head terrane producing younger plutonic rocks in these flanking terranes. Creation of the Taltson magmatic zone in this manner is adopted in the present plate model, which has oceanic crust present between the Buffalo Head terrane and the Taltson magmatic zone (Fig. 9b).

Time ca. 2210 Ma, full development of oceans (Fig. 9c)

At the end of the opening phase leading to creation of a Slave–Rae ocean, an ocean possibly thousands of kilometres wide separated the two crustal terranes, and a large ocean presumably separated the Buffalo Head terrane and the Rae Craton.

Time 2070 Ma, first phase of plutonism in Thelon tectonic zone (Fig. 9d)

The next significant tectonic event was creation of the Thelon magmatic arc along the western margin of the Rae Craton, initiated by eastward subduction of a plate carrying the Slave Craton. The arc includes the Thelon tectonic zone north of the Bathurst fault, the Thelon tectonic zone between the Bathurst and McDonald faults, and the southern extremity of the Thelon tectonic zone south of and ultimately displaced by the McDonald Fault, together forming a single element about 600 km long. North of the Bathurst fault, where age dating is most concentrated, subduction-related plutonism apparently began ca. 2070* Ma (Fig. 9d). Several plutonic belts dating from 2070* to 1950* Ma represent the first phase of igneous activity; the geochemistry of these rocks indicates a convergent margin (Berman et al., 2018). In the southern part of the Thelon tectonic zone, south of the Bathurst fault and not including the Great Slave Lake shear zone, few age determinations are available. In the Artillery Lake map area, Henderson et al. (1999) reported ages of 1929 Ma for a granite south of the McDonald Fault and 1950 and 1920 Ma for two granites north of the fault. Immediately east of the northeast corner of this map area, James et al. (1988) reported U-Pb ages of 1957 and 1925 Ma; they also reported a tentative emplacement date of 2000* to 1900* Ma for three granitoid intrusions. No date as early as 2070 Ma has been reported. Similarly, granites within the Great Slave Lake shear zone, protoliths of the shear zone, are younger, dating from 2051* to 1920* Ma (Hanmer et al., 1992). These existing ages suggest that closure of the ocean along the Thelon Orogen was diachronous and that initial closure was along its northern portion. A more complete database of ages may indicate a more temporally consistent age of closure along the orogen.

Time 2051 Ma, initial plutonism in Great Slave Lake shear zone (Fig. 9e)

By 2051* Ma, plutonism had begun in the Great Slave Lake shear zone within a magmatic arc developed on the upper Rae Plate (Hanmer et al., 1992), and it continued until 1920* Ma. The Great Slave Lake shear zone developed deep within the magmatic arc during its formation, and subduction with a component of southward motion was likely in progress along the northern margin of the arc. At 2051 Ma, plutonic activity continued in the Thelon tectonic zone north of the Bathurst fault, but a lack of age data precludes a definitive statement regarding the status of subduction/plutonism south of the fault. Belts of east-northeast-striking mylonites and protomylonites, derived principally from granites, tonalites, and included panels of mixed paragneiss, are distributed throughout the Great Slave Lake shear zone. The granites were emplaced during the time of tectonic activity within the shear zone. Throughout most of the Great Slave Lake shear zone, a dextral sense of shear and strike-slip displacement is indicated, and longitudinal components of the anastomosing network of greenschist-facies mylonites accommodated continued eastward displacement of the Slave continent (Hanmer et al., 1992).

Time 2046 Ma, initiation of rifting to form East Arm Basin (Fig. 9f)

An age of 2046 Ma, the oldest in the East Arm Basin, was determined by Sheen et al. (2019) for a volcaniclastic unit in the Union Island Group. Geochemical data and petrological modelling related to basaltic packages within the group indicate an extensional setting consistent with a passive continental rift origin. The 2046 Ma date is a reasonable estimate of the time of initiation of rifting that laid the foundation for the East Arm Basin.

Time 2046 to 1861 Ma, sedimentary and igneous units; tectonic activity in East Arm Basin (Fig. 9f, g, h)

The 2046 Ma Union Island Group, the oldest supracrustal package in the East Arm Basin proposed to represent an incipient rift basin sequence (Sheen et al., 2019), supersedes the ca. 1928 Ma Wilson Island Group as the oldest group in the basin. The Wilson Island Group includes a classic rift-valley assemblage of compositionally bimodal volcanic rocks and conglomerate and was viewed in the context of early stage rifting (Hoffman et al., 1977). A continental setting, based on these bimodal volcanic rocks and a geochemical continental tholeiite signature associated with a stratigraphic package of the Union Island Group, was suggested by Kjarsgaard et al. (2013). Noticeably, both groups contain volcanic rocks having strong negative Nb and Ta anomalies, though weak positive anomalies were defined in one volcanic package. Kjarsgaard et al. (2013) noted that negative Nb and Ta anomalies are typically diagnostic of subduction-related magmatism, further noting that continental tholeiite with apparent volcanic arc signatures could be produced by melting of depleted mantle (dominant) and enriched mantle (minor); mantle enrichment was attributed to subduction-related fluids and melts (e.g. Sandeman et al., 2003).

The Union Island and Wilson Island groups are the two oldest groups within the Great Slave Supergroup (Sheen et al., 2019), which consists of fluviatile and marine sedimentary rocks that include intercalated volcanic sequences. The supergroup includes four younger groups, which in decreasing age are the Sosan, Kahochella, Pethei, and Christie Bay; a sequence of volcanic rocks informally referred to as 'Seton volcanic rocks' and yielding a U-Pb date of 1857 Ma (Kjarsgaard et al., 2013) temporally overlaps the two oldest groups. In contrast, the study by van Breemen et al. (2013) of detrital zircons from a volcaniclastic conglomerate within the Seton volcanic rocks, Kluziai Formation, Sosan Group, concluded that the maximum date of deposition of the conglomerate was 1888 Ma and possibly as late as 1864 Ma. Detrital zircons from sandstone in the Kluziai Formation suggest a similar maximum date of deposition. A maximum date of deposition of ca. 1910* Ma was estimated for an arkosic sandstone from the Hornby Channel Formation, the oldest in the Sosan Group (van Breemen et al., 2013). The Christie Bay Group has its oldest formation, the Stark Formation, intruded by the Compton intrusive suite, yielding dates of 1872 and 1861 Ma, which provide a minimum age for pre-Stark Formation deposits (Kjarsgaard et al., 2013) and for the Stark Formation itself.

Huge nappes up to 70 km long in the East Arm Basin record structural deformation produced by northwestward transportation from the axial trough of a presumed former aulacogen (Hoffman et al., 1977) that produced a fold and thrust belt. Transported rocks include the four youngest groups of the Great Slave Supergroup, and the Wilson Island Group may have been involved. The Union Island Group was deposited directly on Archean granite (Hoffman et al., 1977) and may not have experienced this tectonic event. The Et-Then Group, representing the final phase of sedimentary deposition and volcanism in the basin, rests unconformably on the fold and thrust belt. A maximum depositional date of ca. 1872 Ma is indicated by dating of a zircon in the Preble Formation, the younger of the two formations in the group (Kjarsgaard et al., 2013).

In summary, available dating suggests initiation of continental rifting along the East Arm of Great Slave Lake at ca. 2046 Ma. The main period of development of the East Arm Basin, however, did not begin until much later, apparently, with deposition of the Wilson Island Group containing volcanic rocks dated at 1928 Ma (Fig. 9g). From this date, an extended period of activity, including sedimentary and volcanic deposition and igneous intrusion, endured until about 1861 Ma (Fig. 9h). Meanwhile, during most of the interval from 2046 to 1861 Ma, magmatism was active an unknown distance to the south along the Great Slave Lake shear zone, commencing at 2051* Ma and ending at 1920* Ma (Hanmer et al., 1992), potentially signifying a related subduction zone. The ocean between the Slave and Rae cratons, at least along the northern Thelon tectonic zone, may have closed by roughly 1920 Ma, as indicated by the presence of a 1910* Ma peraluminous leucogranite related to continued tectonic thickening and the presence of 1900* to 1880* Ma high-Zr granites forming a distinct textural (post-tectonic) and within-plate geochemical group marking the end of the Thelon orogenic event (Berman et al., 2018). Magmatism along the Great Slave Lake shear zone at 1920* Ma, indicating subduction and the possible continued existence of an ocean between the Slave Craton and the Great Slave Lake shear zone, suggests that the direction and/or velocity of oceanic plate motion prolonged the existence of an ocean along the southern margin of the Slave Craton.

The East Arm rift developed along the southern margin of the Slave Craton, a margin itself doubtless created by continental rifting. In Figure 9f, for simplicity, the East Arm Basin is shown in its present position at the southern edge of the Slave Craton, but at the time of rifting the craton probably extended some distance farther south, forming a southern flank to the rift. This flank, apparently, is no longer a conspicuous element of the prevailing geology. Its fate is debatable.

Two narrow belts of Archean granitoids identified as Slave Craton granitoids immediately south of the McDonald Fault (Kjarsgaard et al., 2013) possibly represent the former southern flank, or they could simply be basement to the East Arm Basin. If a southern flank existed, it may have been largely consumed by subduction beneath the Great Slave Lake shear zone during the period from 2046 to 1920 Ma. The noticeably long time (118 Ma) between rifting activity associated with the Union Island and Wilson Island groups conceivably indicates that rifting at 2046 Ma was short lived, a situation supported by the contention of Sheen et al. (2019) that the Union Island Group preserves part of a failed rift. A period of more concentrated activity within the East Arm Basin began with deposition of the Wilson Island Group at 1928 Ma and ended roughly at 1872 Ma with deposition of the Et-Then Group; the Compton intrusive suite has yielded dates of 1872 and 1861 Ma (Kjarsgaard et al., 2013).

During this period the East Arm rift may have been affected by proximal subduction. This conjecture is based on the large nappes within the basin that moved northwestward from an area south of the McDonald Fault (Hoffman et al., 1977), an appropriate mechanism for which would be plate convergence, subduction, and collision, suitably illustrated in the analogy of the thrust package of the Kilohigok Basin (Tirrul and Grotzinger, 1990). Gibb (1978) suggested that the East Arm nappes were emplaced by obduction of basin fill from the south during closure of a diminishing sea between the Slave wedge and the Churchill Craton. Here, it is proposed that the nappes are a product of collision between the Slave Craton and the Great Slave Lake shear zone, caused in part by subduction of an oceanic plate in a southeastward direction, as implied by the northwest vergence of the nappes. A weakness of this proposal is the apparent lack of igneous activity after 1920 Ma along the Great Slave Lake shear zone, though postsubduction collisional activity may have been operative for some time.

The apparent mixed continental–subduction characteristics of igneous rocks within the East Arm Basin, though posing challenges for deriving its tectonic history, hint at possible proximal subduction-related igneous activity. A history involving subduction, a magmatic arc, and possible collision is suggested by potentially subduction-related trace element signatures (negative Nb and Ta anomalies) associated with volcanic horizons distributed throughout most of the basin succession and by the northwest-directed nappes. Monzodioritic laccoliths of the Compton intrusive suite, likewise, demonstrate such trace element characteristics, representing the youngest (1872 and 1861 Ma) examples (Kjarsgaard et al., 2013). If subduction related, they are much younger than plutonic rocks (1920* Ma) related to proposed subduction beneath the Great Slave Lake shear zone and raise the question of a separate subduction zone.

The idea of a separate proximal subduction zone is contradicted, apparently, by the study of Potter et al. (2020). They recognized that the Compton intrusive suite and comagmatic Pearson Formation volcanic rocks of the Christie Bay Group fall within the fields of volcanic arc and continental arc in certain geochemical discrimination plots and have suprasubduction-zone geochemical signatures, including negative Ta and Nb anomalies. They further noted that Great Bear magmatic zone rocks of similar age on the west side of the Slave Craton plot in the same fields, and they argued, with respect to the aforementioned intrusive suite and formation, that their linear, belt-like nature and 'arc-like' geochemistry and age suggest a direct relationship with the eastward-dipping subduction zone associated with the Great Bear magmatic zone. Kjarsgaard et al. (2013) had earlier noted the contemporaneity of subduction-related volcanism and plutonism in the Great Bear magmatic zone and Pearson–Compton magmatism within the East Arm Basin, but they found it difficult to attribute the latter magmatism to subduction associated with the Great Bear zone, because the linear belts of Pearson volcanic rocks and Compton intrusions are oriented perpendicular to subduction geometry of the magmatic zone. Potter et al. (2020) countered this argument by citing examples of modern analogues in arc volcanism where magmatism occurred perpendicular or oblique to the trench axis.

Notwithstanding the viewpoint of Potter et al. (2020), an alternative explanation for apparent subduction-related signatures in the East Arm Basin involving a proximal subduction zone is examined. Before this examination, a case is presented for the East Arm Basin having a significantly greater strike extent than currently observed. Although magnetic coverage over Great Slave Lake is unavailable, maps of the residual total magnetic field (Fig. 10) and of the FVD of the field covering the East Arm and southern shore of the lake indicate southwestward extension of the basin for some 210 km to the southern shore, for a predicted total length of about 450 km. The exposed basin itself is not distinguished by a distinctive magnetic signature, partly because its northern margin is fairly thin and its signature probably reflects mainly underlying rocks of the Slave Craton. Nevertheless, several narrow, linear magnetic highs trending west-southwest to south-southwest are observed within the basin and along the south and southeast shores of the lake. The general consistency in strike direction and character of the anomalies is considered evidence that the East Arm Basin extends across Great Slave Lake (Fig. 10).

Subduction along the Great Slave Lake shear zone, apparently active from 1930 to 1920 Ma, was operative at the time of volcanic activity within the Wilson Island Group (~1928 Ma) in the East Arm Basin, and related volcanic rocks express strong negative Nb and Ta anomalies potentially indicative of subduction (Kjarsgaard et al., 2013); similar anomalies have been identified in a volcanic horizon in the 2046 Ma Union Island Group. Because volcanic rocks of the Wilson Island Group were considered bimodal in composition, however, a continental rift origin was assigned to the basin (Hoffman et al., 1977). Johnson (1990), noting the bimodal nature of the volcanic rocks and an abundance of coarse terrigenous detritus, suggested an extensional continental setting in which strata 8 km thick were deposited on stretched and thinned continental crust. Furthermore, it was suggested that the crustal strain regime at 1930* Ma was characterized by oblique transcurrent shearing with a component of extension, leading to an argument that the Wilson Island Group was probably deposited in a pull-apart or similar transtensional strike-slip basin. A tectonic model at ca. 1930* Ma displays the group forming a marginal strike-slip basin between the East Arm fold and thrust belt and the Great Slave Lake shear zone, though positioned on an upper Rae Plate and with the subducting Slave Plate descending southward beneath the fold and thrust belt. Thus, Johnson

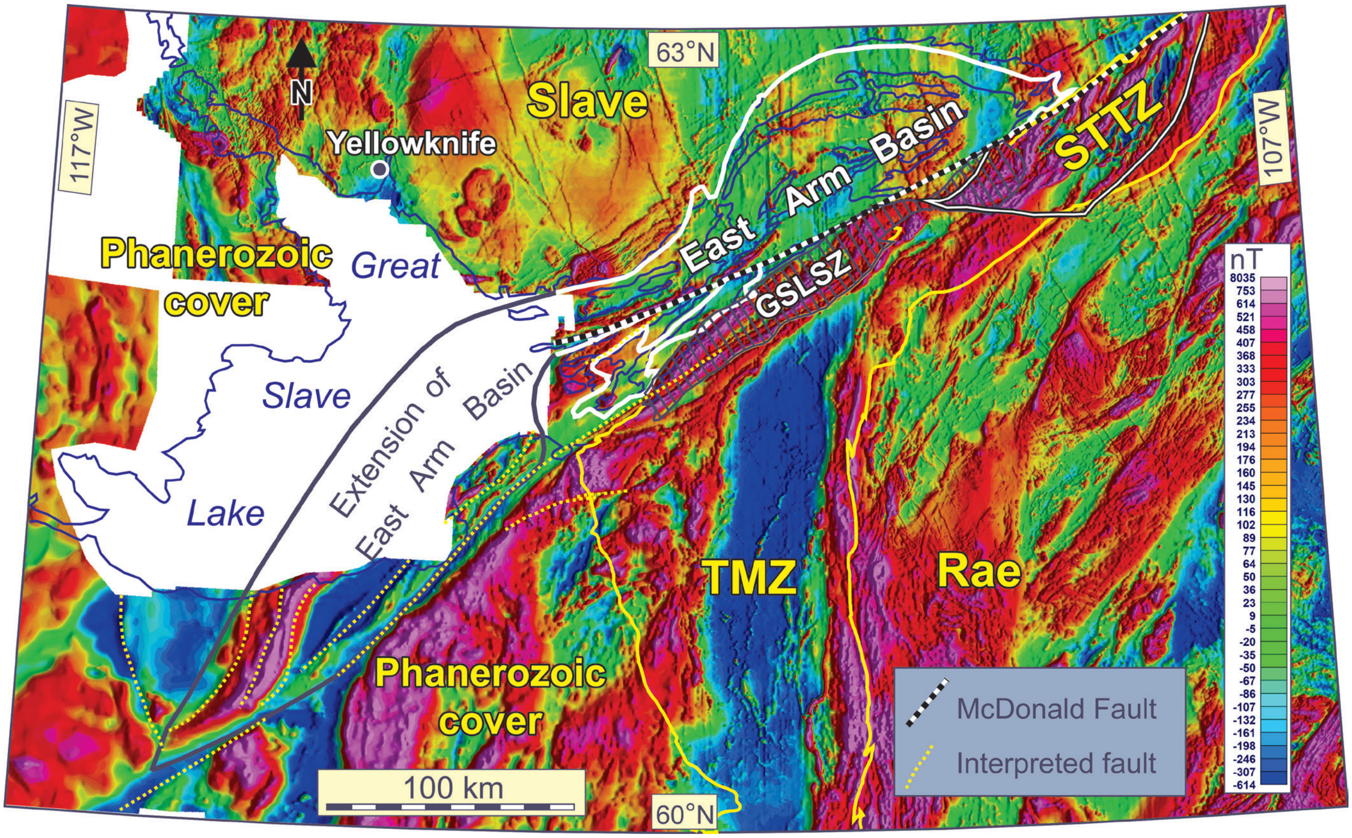


Figure 10. Residual total magnetic field map of area including and surrounding Great Slave Lake and its East Arm. GSLSZ, Great Slave Lake shear zone; STTZ, southern Thelon tectonic zone; TMZ, Taltson magmatic zone.

(1990) envisioned a link between volcanic rocks in the East Arm Basin and a proximal subduction system. Counter to this idea are results of an analysis of teleseismic observations along a northwest-trending line crossing the Slave–Rae boundary near the south end of the Thelon tectonic zone. The analysis suggested that the Great Slave Lake shear zone had gone through an early convergent phase involving intracontinental underthrusting of the Slave Craton beneath the Rae margin, but there is little evidence of subduction (Snyder and Kjarsgaard, 2013).

The youngest plutonism associated with the Great Slave Lake shear zone is 1920* Ma, so it is puzzling that, apparently, no magmatic activity is associated with the Great Slave Lake shear zone after 1920 Ma, given that igneous units potentially bearing the hallmarks of subduction, possibly as young as 1861 Ma (Compton intrusive suite), are present in the East Arm Basin. This period represents roughly 60 Ma. Possibly, the period of apparent magmatic quiescence could relate to predominantly eastward motion of the Slave Craton; a negligible component of southward subduction was available to fuel magmatism. Hanmer et al. (1992) noted that granulite-facies mylonitization in the southwest part of the Great Slave Lake shear zone could represent the strike-slip component of oblique continental convergence just before the ca. 1970* Ma Slave–Rae collision and that continued eastward displacement of the Slave Craton was accommodated by longitudinal components of the anastomosing network of younger greenschist-facies mylonites. This strike-slip activity is, however, much older than the 1920* Ma termination of magmatic activity.

The apparent elimination of the Great Slave Lake shear zone as the magmatic arc related to subduction of the East Arm Basin, or former rift flank, raises the question of how closure of an ocean between the shear zone and the Slave Craton was accomplished. The simplest solution would seem to be a younger subduction system. The diagnostic negative Nb and Ta anomalies typical of subduction-related magmatism within igneous members of the East Arm Basin suggest that the basin itself, or at least part of it, was transformed into an arc-like structure. The Compton intrusive suite is described as granitoid and categorized as volcanic arc granite on a trace element classification diagram (Kjarsgaard et al., 2013); in this classification, 'granite' can include granite in oceanic arcs and granite in active continental margins. The intrusions of the suite are best described as tabular laccoliths. These laccoliths are generally elliptical in plan view and have major and minor axes ranging up to 25 and 5 km in length, respectively. They are not the typical batholithic intrusions associated with many magmatic arcs, but they are the best candidates for a subduction-related intrusion. This concept of a local subduction zone conflicts with the contention of Potter et al. (2020) that igneous activity within the East Arm Basin is related to an eastward-dipping subduction system associated with magmatism in the Great Bear batholith.

If such a younger subduction zone operated, where did it originate? A possible scenario is provided by a Mesozoic analogue of subduction that was active in the eastern European Alps and includes two subduction systems (Fig. 11), one that subducted the Penninic Ocean and the other the Meliata Ocean (Chang et al., 2020); both systems were subducting southward. The Middle Jurassic oceanic Penninic Basin, formed by rifting of the European Plate, provides an analogue for the East Arm rift, and the oceanic Meliata Basin that opened in the Middle Triassic is an analogue for a presumed subduction system beneath the Great Slave Lake shear zone. The spatial relationship of these two systems (Fig. 11f, g) can be compared to the relationship between a proposed East Arm subduction system and Great Slave Lake shear zone subduction system (Fig. 11d, e). The ultimate fate of the southern flank of the East Arm rift would potentially be similar to that of the Austroalpine units that were thrust northwestward toward the Penninic Ocean. The plate model of Chang et al. (2020) indicates the Penninic subduction system dipping more gently at depth and extending beneath the former Meliata subduction system in the Late Cretaceous, when subduction of the Meliata system had terminated and deformation had begun to develop in the frontal orogenic wedge (Fig. 11g). An East Arm subducting system need not necessarily have extended beneath the Great Slave Lake shear zone system: it could have subducted at a steeper angle than the proposed Penninic analogue.

Another scenario for development of a younger subduction system along the margin of the East Arm Basin is subduction transference, a mechanism described by Stern (2004). In this scenario, a buoyant crustal block enters a subduction zone, becoming sutured to the original hanging wall of the zone and terminating subduction. Plate convergence may continue by lithosphere sinking elsewhere along strike of the plate margin, rupturing oceanic lithosphere outboard of the collision zone and producing a new subduction zone. The new zone is transferred away from the earlier zone, but it maintains the same polarity. In the absence of an independent subduction system at the southern margin of the East Arm Basin itself, the buoyant crust in this case could have been represented by the southern flank of the East Arm rift that thickened as it entered the Great Slave Lake shear zone subduction system, effectively ‘choking’ the system. The two scenarios for subduction produce a similar end result, the essential difference being that one subduction system originates directly at the southern edge of the East Arm rift (*see* subduction at the edge of the Penninic ocean rift in Fig. 11f, g), whereas the other forms in a similar position by subduction transference from a system subducted beneath the Great Slave Lake shear zone.

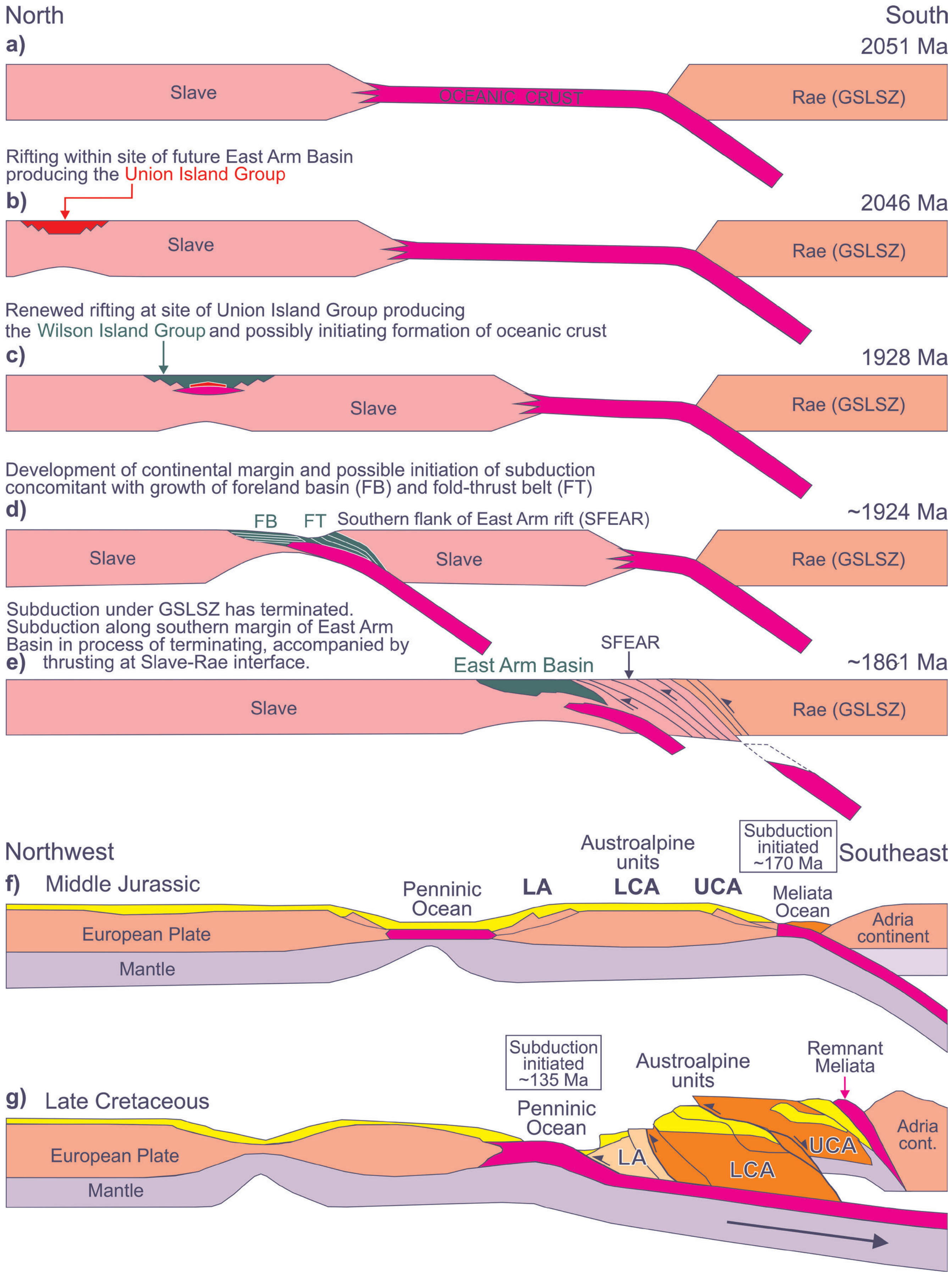
The lack of larger, more typical arc batholiths within the East Arm Basin may reflect dominantly eastward motion of the Slave Craton; a negligible component of southward subduction led to minimal production of magmatism. With respect to possible dominant eastward motion, Molnar and Dayem (2010) noted that for oblique subduction, the strike-slip component is commonly absorbed not by oblique underthrusting, but by pure strike-slip faulting within an accretion wedge of scraped-off material (overriding plate) underlain immediately below by oceanic lithosphere. It is speculated that the McDonald Fault represents such a fault and that a tectonically thickened southeastern margin of a formerly more extensive East Arm Basin represents the accretionary wedge. Hanmer et al. (1992) proposed that the age of the fault was post-1870* to 1860* Ma, roughly the same age as the Compton intrusive suite, and Whalen et al. (2018) suggested possible fault activity as early as at least 2000* Ma.

The potentially dominant eastward component of motion of the Slave Craton during development of the East Arm Basin may explain why the basin does not extend farther east than the East Arm. Syn- or postcollisional arching of the eastern margin of the craton related to eastward subduction (cf. Gordon Bay Arch and Kilohigok Basin; Tirrul and Grotzinger, 1990) may have inhibited development of the rift basin in this area; or postcollisional erosion has removed any trace of a former presence. Alternatively, its absence may indicate that the rift developed as a pull-apart basin or rhomb graben, commonly observed along substantial strike-slip fault systems (Aydin and Nur, 1982). A weakness in this proposal is that pull-apart basins (grabens) examined by Aydin and Nur (1982), ranging up to 80 km in length and 30 km in width, are noticeably smaller than the East Arm Basin. The width of rhombs is controlled by the initial fault geometry, whereas length increases with increasing fault displacement.

Time 1986 Ma, initial plutonism in Taltson magmatic zone (Fig. 9f)

Plutonism in the Taltson magmatic zone started at 1986* Ma (Card et al., 2014) (Fig. 9f), some 80 Ma later than plutonism in the Thelon tectonic zone (Berman et al., 2018), and endured until 1920* Ma. Despite different times of initiation, one period of plutonism in the Taltson magmatic zone

Figure 11. a) to **e)** Schematic cross-sections of East Arm Basin and Great Slave Lake shear zone (GSLSZ) from 2051 to ca. 1861 Ma. **f)**, **g)** Schematic cross-sections depicting plate tectonic history of southeastern part of the eastern European Alps in the Middle Jurassic and Late Cretaceous (*modified from* Chang et al., 2020). Dates of initiation of subduction zones *based on* Stüwe and Schuster (2010). LA, Lower Austroalpine domain; LCA, Lower Central Austroalpine domain; UCA, Upper Central Austroalpine domain.


North
South
a)
2051 Ma
Slave
OCEANIC CRUST
Rae (GSLSZ)
Rifting within site of future East Arm Basin producing the Union Island Group
b)
2046 Ma
Slave
Rae (GSLSZ)
Renewed rifting at site of Union Island Group producing the Wilson Island Group and possibly initiating formation of oceanic crust
c)
1928 Ma
Slave
Rae (GSLSZ)
Development of continental margin and possible initiation of subduction concomitant with growth of foreland basin (FB) and fold-thrust belt (FT)
d)
~1924 Ma
FB
FT
Southern flank of East Arm rift (SFEAR)
Slave
Slave
Rae (GSLSZ)
Subduction under GSLSZ has terminated. Subduction along southern margin of East Arm Basin in process of terminating, accompanied by thrusting at Slave-Rae interface.
e)
~1861 Ma
SFEAR
East Arm Basin
Slave
Rae (GSLSZ)
Northwest
Southeast
f) Middle Jurassic
Austroalpine units
Subduction initiated ~170 Ma
Penninic Ocean
LA
LCA
UCA
Meliata Ocean
Adria continent
European Plate
Mantle
g) Late Cretaceous
Subduction initiated ~135 Ma
Austroalpine units
Remnant Meliata
Penninic Ocean
Adria cont.
European Plate
Mantle
LA
LCA
UCA

(1986* to 1959* Ma; Card et al., 2014) was partly coeval with plutonic activity (2070* to 1950* Ma) in the northern Thelon tectonic zone (the portion north of the Bathurst fault) and possibly in the southern Thelon tectonic zone, where a tentative date of 2000* to 1900* Ma was obtained on a granodiorite (James et al., 1988). A second period of plutonism in the Taltson magmatic zone (1940* to 1920* Ma) falls within a range of dates (1957–1920 Ma) determined on granites in the southern Thelon tectonic zone (James et al., 1988; Henderson et al., 1999). The two periods of activity within the Taltson magmatic zone fall within the period of magmatic activity (2051* to 1920* Ma) in the Great Slave Lake shear zone (Hanmer et al., 1992). Subduction and related arc magmatism at 1986 Ma were, therefore, potentially active along the length of the Thelon tectonic zone, including the Great Slave Lake shear zone, and are attributed to closing of the ocean between the Slave and Rae cratons. McDonough et al. (2000) ascribed subduction and plutonism associated with the Taltson magmatic zone to closing of an ocean between the Buffalo Head terrane and the Rae Craton caused by eastward subduction of the intervening oceanic plate. These authors had noted that the neodymium-isotope signature of the 1986 Ma Deskenatlata gneiss was indicative of mantle derivation that supported subduction and that collision may have initiated as early as 1970 Ma.

Time 1970 Ma, initiation of collision in northern Thelon tectonic zone (Fig. 9f)

With respect to potential timing of collision between the Buffalo Head terrane and the Rae Craton at 1970 Ma (McDonough et al., 2000), a date of 1970* Ma was proposed for creation of the Kilohigok Basin (Fig. 9f). Tirrul and Grotzinger (1990) suggested this date on the basis of a 1967* Ma U-Pb age for a tuff within the basal part of the basin succession. They argued that the basin formed by flexural foundering of a shelf platform related to closure of an ocean along the Thelon tectonic zone that involved foreland subsidence, lithospheric arching, and emplacement of thrust nappes rooted in the Thelon tectonic zone. An initial phase of passive margin subsidence may have lasted less than 50 Ma before foundering of the passive margin and development of a foreland basin at ca. 1970* Ma.

The study by Tirrul and Grotzinger (1990) provides possible evidence of the direction of motion of the Slave Craton, an aspect of ocean closure now examined. A fundamental assumption in deriving a model for Slave–Rae collision is that the Thelon tectonic zone and the Great Slave Lake shear zone represent a single orogenic element formed along the edge of the Rae continent. Implicitly, subduction of the Slave Craton took place beneath this composite unit, and because the Thelon tectonic zone forms an obtuse angle of about 140° with the Great Slave Lake shear zone, oblique subduction is likely to have featured in the development of both. Some earlier Slave–Rae plate collisional models indicated generally eastward motion of a subducting Slave Plate (e.g. Gibb, 1978; Hoffman, 1987). The geometry of the composite Thelon tectonic zone as herein defined (e.g. Fig. 9e) supports a significant component of southward motion, given contemporaneous subduction beneath the Thelon tectonic zone and the Great Slave Lake shear zone.

Northwest vergence of thrusting within the fold and thrust belt in the Kilohigok Basin (Tirrul and Grotzinger, 1990) may indicate that the Slave Plate, at some time, had a significant component of southeastward motion. Likewise, northwest vergence of thrusting along the southern margin of the Slave Craton within the Proterozoic East Arm Basin (Kjarsgaard et al., 2013) may signify related southeastward motion. The roughly 325° orientation of the Bathurst fault, associated with an estimated 115 km of sinistral displacement (Tirrul and Grotzinger, 1990) (20 km based on displacement of magnetic anomalies), potentially implies southeastward-directed motion. Related sinistral transcurrent faults trending predominantly from roughly 320° to 340° across the Thelon tectonic zone (Thomas et al., 1976) reinforce the argument for involvement of southeastward motion.

This dominance of a particular fault trend imparts an asymmetry to the fault pattern affecting the western margin of the Rae Craton that departs from the classical symmetrical pattern predicted by slip-line field theory for plane indentation of a plastic medium by a rigid indenter (Tapponnier and Molnar, 1976). Fault slip-line patterns for various shapes of indenters are different, but all are symmetrical with respect to the front of the indenter. Gibb (1978) used mainly the wedge-shaped indenter as an analogue for Slave–Rae collision, appealing also to a flat-front indenter to explain certain aspects. The slip-line analogue as presented by Tapponnier and Molnar (1976), apparently, is consistent with several structural aspects of the collisional zone, but it does not explain the asymmetry in the pattern of transcurrent faults.

A possible explanation is provided by studies of the asymmetry of tectonic strains associated with India–Asia collision (Peltzer and Tapponnier, 1988). It was concluded that subduction zones in the western Pacific and along the Sunda Arc were unable to strongly resist eastward and southeastward movements of large Asian blocks, effectively implying that the eastern and southeastern edges of Asia were relatively 'free' (i.e. not restrained). Indentation experiments in which a rectangular, flat-front rigid indenter was driven into deformable, layered plasticine models of which one side was kept free produced some fault patterns displaying a marked asymmetry: extensive strike-slip faults of a particular orientation preferentially developed in front of one side of the indenter. These experiments offer one perspective for explaining the asymmetry of the observed transcurrent faults affecting the Thelon tectonic zone, but it would require that the Rae Craton south of the eastern end of the McDonald Fault be fairly free, that is, weakly resistive to blocks of crust escaping south-southeastward. A reason for such a condition at the time of collision is not obvious.

Time 1957 to 1920 Ma, plutonism in southern Thelon tectonic zone (Fig. 9g)

In addition to a tentative date of 2000* to 1900* Ma obtained on a granodiorite (James et al., 1988) in the southern Thelon tectonic zone, dates on five other granitoids, one situated south of the McDonald Fault, range from 1957 to 1920 Ma (James et al., 1988; Henderson et al., 1999), indicating plutonic activity in the Thelon Arc during this period. Locations of all dated samples are south of latitude 64°N. The more certain interval of 1957 to 1920 Ma for the plutonism slightly overlaps the younger portion of the interval (2070* to 1950* Ma) for subduction-related plutonism in the northern Thelon tectonic zone (Berman et al., 2018). These dates suggest that ocean closure happened later in the south than in the north, but given the few available dates for the southern Thelon tectonic zone, the comparison is based on incomplete populations and is therefore uncertain.

Time 1940 to 1920 Ma, intrusion of late Taltson magmatic zone granites (Fig. 9g)

The 1940* to 1920* Ma granites within the Taltson magmatic zone (late Taltson granites) have been linked to collision-related S-type magmatism (Card et al., 2014), suggesting that active subduction during this interval was replaced largely by collisional crustal thickening and that the granites have a within-plate origin similar to that proposed for late granites in the northern Thelon tectonic zone (Berman et al., 2018). Thus, at 1920 Ma, magmatic activity was at the point of terminating within both the Taltson magmatic zone and the Great Slave Lake shear zone, though this magmatic activity was probably related to independent subduction systems. It is proposed that the ocean between the Buffalo Head terrane and the Rae Craton had closed during a period (1940* to 1920* Ma) of high-grade granulite-facies metamorphism and magmatism and had been replaced by a belt of west-verging thrusting created within a foreland basin at the western edge of the Rae Craton. Apparently, a hiatus in plutonic activity was in effect along the northern Thelon tectonic zone during the interval 1950* to 1910* Ma, probably subsequent to closure of the ocean between the Slave Craton and the Thelon tectonic zone.

Time 1910 to 1861 Ma, within-plate granites in northern Thelon tectonic zone; Compton intrusions in East Arm Basin (Fig. 9h)

Renewed magmatic activity in the Thelon tectonic zone after a hiatus of 40 Ma was approximately contemporaneous with deposition of the youngest third (Wilson Island Group through the Et-Then Group) of the stratigraphic section of the East Arm Basin from about 1928 to 1872 Ma. This renewed activity began with intrusion of a 1910* Ma peraluminous leucogranite, followed by intrusion of high-Zr granites from 1900* to 1880* Ma (Berman et al., 2018). These intrusions form a distinct textural (post-tectonic) and within-plate geochemical group marking the end of the Thelon orogenic event. Intrusions of the Compton intrusive suite in the East Arm Basin were emplaced slightly later (1872 or 1961 Ma, Fig. 9h), derived either from a subducting slab operating along the southern margin of the basin or from a slab created by subduction transference (Stern, 2004) linked to a slab subducting beneath the Great Slave Lake shear zone (Fig. 9h).

Time post-1870 Ma, development of McDonald Fault (Fig. 9h)

The possible origin of the McDonald Fault, related to oblique subduction, and the uncertainty of its date of origin have been discussed. Whalen et al. (2018) suggested a date as early as at least 2000* Ma, Hanmer et al. (1992) proposed a date range of post-1870* to 1860* Ma, and van Breemen et al. (2013) suggested possible movement on the fault at 1827 Ma and a minimum age of 1780 Ma. Whalen et al. (2018) further proposed that the fault was an important structure separating the Thelon tectonic zone and the Taltson magmatic zone that allowed them to evolve independently over different periods. The presence of an active brittle fault ca. 2000 Ma, however, may be difficult to reconcile with possible ductile deformation at that time that created mylonites within the Great Slave Lake shear zone. Hanmer et al. (1992) determined that certain mylonites in the southwest segment of the Great Slave Lake shear zone are younger than ca. 1980* Ma; other mylonites are younger than 1924* Ma; and in the northeast segment, certain mylonites represent deformation during a narrow time window at 1977* Ma. On the basis of those dates, a brittle fault created at 2000 Ma may have been overprinted by ductile deformation.

CONCLUSIONS

Magnetic and gravity signatures have been examined along the lengths of the Thelon tectonic zone, the Taltson magmatic zone, and flanking areas. Magnetic signatures indicate that the southern extremity of the Thelon tectonic zone south of the McDonald Fault has been sinistrally displaced 126 km (Fig. 2). They also strongly suggest that the western end of the southern extremity forms part of the Great Slave Lake shear zone, notwithstanding 25 km of dextral displacement between the southern extremity and the greater part of the shear zone (Fig. 3). The northeastern end of the Great Slave Lake shear zone as mapped by Hanmer et al. (1992) falls within the magnetically defined southern extremity of the Thelon tectonic zone. With respect to the debate favouring or not favouring continuity of the Thelon tectonic zone into the Taltson magmatic zone (e.g. Card et al., 2014), the geophysical signatures indicate that they represent separate orogenic units, a conclusion supported by a geochemical study (Whalen et al., 2018) suggesting that the Thelon tectonic zone and the Taltson magmatic zone are not directly correlative.

A proposed plate tectonic model for Slave–Rae convergence and collision recognizes a composite Great Slave Lake shear zone and Thelon tectonic zone orogenic unit developed along the western margin of the Rae Craton. This concept is a fundamental criterion in developing the model, together with available age dates, which also play a critical role. The proposed plate tectonic history begins at about 2350 Ma, when the Archean supercontinent Kenorland fragmented, creating a single rift along the eastern and southern margins of the Slave Craton that subsequently developed into a wide ocean. The approximately 50° difference in orientation of the two rift segments is explained by analogy with the pattern of the Red Sea and Aden rifts, which differ in orientation by 90°. Timing of rifting is assumed to predate formation of the Rutledge River rift basin, situated primarily within the Taltson magmatic zone, that may have initiated at 2340* Ma (Bostock and van Breemen, 1994), given that the basin is not observed on the Slave Craton. Conversely, a recent date of 2046 Ma, the oldest determined in the East Arm Basin, was interpreted as the date of rifting between the Slave and Rae cratons (Sheen et al., 2019). Plutonism in the northern Thelon tectonic zone at 2070* Ma (Berman et al., 2018) indicates a stage of ocean closure when oceanic crust was beginning to be subducted eastward beneath the Rae margin. Although closure was also probably in effect along the southern Thelon tectonic zone and Great Slave Lake shear zone at this time, subduction may not have been initiated or subducting oceanic crust may not have reached the necessary depth to produce arc magmatism in those areas. Closure and collision are considered, therefore, as having been diachronous along the length of the Thelon tectonic zone. This conclusion is based on available dates, but it could be contradicted if a larger database became available. There is no evidence of plutonism in the Taltson magmatic zone at this time, which Berman et al. (2018) claimed began ca. 80 Ma later.

At 2051* Ma, plutonism began in the Great Slave Lake shear zone and continued in the northern Thelon tectonic zone, but dates as old as 2051 Ma have not been recorded in the southern Thelon tectonic zone, again suggesting diachronous closure along the Thelon tectonic zone. The next big plutonic event, at 1986 Ma, was the onset of plutonism in the Taltson magmatic zone, attributed to eastward subduction of an oceanic plate between the Rae Craton and the Buffalo Head terrane to the west (McDonough et al., 2000). Subduction and related plutonism continued along the Great Slave Lake shear zone and northern Thelon tectonic zone, and possibly along the southern Thelon tectonic zone based on tentative dating of 2000* to 1900* Ma for a biotite granodiorite (James et al., 1988). Conceivably, subduction was active along the entire composite Thelon tectonic zone–Great Slave Lake shear zone at 1986 Ma.

Evidence of initial Slave–Rae collision is provided by the subsidence history of the Kilohigok Basin (Tirrul and Grotzinger, 1990), which indicates foundering of its passive margin related to convergence, subsequent collision, and overthrusting in the Thelon tectonic zone at roughly 1970 Ma*. Foundering of the margin and development of a foreland basin at 1970* Ma were followed by initiation of the main phase of uplift in the Thelon tectonic zone just before 1920* Ma.

From 1986 to 1957 Ma, a period during which collision in the northern Thelon tectonic zone was in effect, subduction was operational along the Taltson magmatic zone, the Great Slave Lake shear zone, and possibly the southern Thelon tectonic zone. Granitoids in the southern Thelon tectonic zone suggest subduction during the interval 1957 to 1920 Ma, though they (some) could relate to postcollisional crustal thickening like certain granites in the northern Thelon tectonic zone do (Berman et al., 2018). There, an age of 1950* Ma, the youngest yielded by a plutonic suite probably related to precollision subduction, suggests termination of subduction at roughly that time. Younger granitoids, dated at 1910* to 1880* Ma, have been linked, in one case, to peak metamorphism associated with continued tectonic thickening, and others are viewed as a distinct textural (post-tectonic) and high-Zr within-plate geochemical group (Berman et al., 2018). Thus, younger granitoids may not necessarily signify precollision subduction.

In the Taltson magmatic zone, as in the southern Thelon tectonic zone, dating indicates that plutonism had terminated by ca. 1920* Ma. The central belt of the Taltson magmatic zone is dominated by 1940* to 1920* Ma peraluminous S-type granites emplaced during a granulite-facies metamorphic event related to terminal collision (Card et al., 2014). Such plutonic activity could have parallels with the within-plate plutonism in the northern Thelon tectonic zone.

The evidence of dates and nature of plutonism suggests that at 1920 Ma, tectonic activity along the lengths of the Thelon tectonic zone and the Taltson magmatic zone was postcollisional with closure of the oceans between the eastern margin of the Slave Craton and the Rae Craton and between the Buffalo Head terrane and the Rae Craton. The status of the segment of ocean between the Slave Craton and the Great Slave Lake shear zone is uncertain, partly because the tectonomagmatic affinity of granitoids in the shear zone is not described. The Great Slave Lake shear zone formed within an active magmatic arc of magnetite-series granitoids (Hanmer et al., 1992) that presumably fall into the I-type category typically associated with magmatic arcs fuelled by subduction. Hanmer et al. (1992) also referred to late (ca. 1920* Ma) syntectonic granites. These possibly represent products of collisional thickening and signify postsubduction magmatism. Hanmer et al. further noted that nonmagnetic granite was emplaced fairly late in the shear zone history, possibly signifying that the Great Slave Lake shear zone at the time of late 1920* Ma plutonism had transformed, or was transforming, into a collisional orogen. Whether 1920* Ma plutonism is subduction related or collision related, there is no evidence of younger plutonism in the Great Slave Lake shear zone, and the nature of the crust between the shear zone and the Slave Craton at that time is debatable.

In the East Arm Basin, post-1920 Ma igneous activity lasted until 1861 Ma; some igneous rocks bear subduction-related trace element signatures. These signatures and the presence of northwest-verging nappes may signify collision with the Great Slave Lake shear zone caused by southeastward subduction, completing closure between the Slave and Rae cratons. It is suggested that subduction beneath the Great Slave Lake shear zone was terminating close to 1920 Ma, any continued convergence possibly being achieved by pure strike-slip faulting within an accretion wedge of scraped-off material in the manner described by Molnar and Dayem (2010). The subduction-related geochemical signatures in the igneous rocks and the northwest-verging fold and thrust belt in the East Arm Basin indicate that post-1920 Ma subduction played a role in development of the basin. The degree of subduction may have been limited, given the relatively small size of plutonic intrusions (represented by the 1872/1861 Ma Compton intrusive suite) compared to that of typical batholiths in magmatic arcs. A younger subduction zone may have originated directly along the southern margin of the rift or by subduction transference, a mechanism described by Stern (2004) and described above. Subduction once again was probably oblique, and a possible consequence was the initiation of the McDonald Fault.

The chronology of events related to Slave–Rae divergence and subsequent convergence is limited by the available database of dates. Clearly, a larger population would significantly improve the details of the timing of events and could even modify the nature of events. An important criterion for improving the model would be better knowledge about the orientation of plate motions. Did the Slave Craton (plate) move in different directions at different times, consequent on the geometry of the original oceanic spreading centres and their history of spreading rates and periods of quiescence? Paleomagnetic studies have the potential to shed some light on these plate motions. For the moment, the plate model offers, hopefully, a template for contemplation that with refinement will result in better understanding of the tectonic events that shaped the Thelon tectonic zone, Taltson magmatic zone, and Great Slave Lake shear zone.

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