GS2024-10

Geological investigation of the Roberts Lake fault at Roberts Lake, north-central Manitoba (part of NTS 63J13)

by K.D. Reid

Summary

Metamorphic hydrothermal fluids and melts that form economically viable mineral deposits are often focused via reactivation of regional structures. Based on historical mapping and geological mapping at Roberts Lake, the history of the Roberts Lake fault is interpreted to have involved three phases. To begin, southwest-verging thrust faulting (D_{1a}) resulted in overturning of bedding in the sandstone, the development of S_1 fabrics and faulted contacts between units. Then, reactivation of the Roberts Lake fault (D_2) occurred, potentially associated with the formation of a later S_2 foliation and L_2 lineation. Last, a strike-slip fault (D_3) that merges with the Roberts Lake fault east of Roberts Lake extended to the Superior boundary zone. Regional aeromagnetic analysis identifies this late fault (D_3) as a possible translational extension of the Berry Creek shear zone east of Wekusko Lake and indicates that the earlier D_1/D_2 faults at Roberts Lake probably have deep-seated roots. Multiple reactivation of the Roberts Lake fault invariably played a role in the emplacement of orogenic gold and lithium-bearing pegmatites in the area.

In Brief:

- The northeast dip of the D_1 and D_2 faults at Roberts Lake is interpreted to be related to southwest-verging thrust faulting that brought Roberts Lake basalts southwest over younger Missi group sediments
- Multiple reactivations of the Roberts Lake fault likely played a role in the emplacement of orogenic gold and lithium-bearing pegmatites in the area

Citation:

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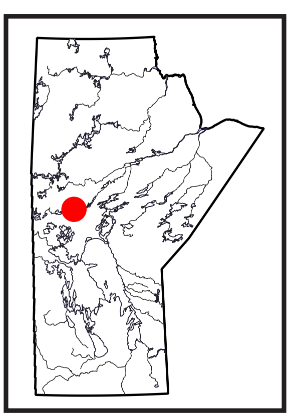
Introduction

The geological context of the rocks that lie between Wekusko Lake and the Superior boundary zone (Figure GS2024-10-1) is poorly understood, largely because of a lack of outcrop exposure and detailed geological mapping (Frarey, 1950; Bailes, 1985). The known presence of critical minerals (e.g., spodumene-bearing pegmatite) as well as base metals (e.g., volcanogenic copper-zinc) and precious metals (e.g., orogenic gold) has sparked exploration interest and research activity in the region.

In 2024, the Manitoba Geological Survey (MGS) continued targeted geological investigations at Roberts Lake (Figure GS2024-10-2) as part of a broader study to update the geology and tectonic setting of the rocks east of Wekusko Lake. Through previously completed mapping (e.g., Reid 2019, 2021, 2023) and review of historical geological maps, it has been shown that the rocks in the Roberts Lake area are lithologically diverse and structurally complex, thus inviting more focused attention. The particular emphasis of the current work is on verifying the geology as portrayed on the NATMAP compilation (Figure GS2024-10-2; NATMAP Shield Margin Project Working Group, 1998), which is largely compiled from Frarey (1950). Research objectives include examining the apparent position and vergence of the Roberts Lake fault with respect to mafic volcanic rocks on the northern side of the lake, and sandstone and mudstone on the southern side of the lake; investigating overturned bedding in Missi group sandstones directly south of the Roberts Lake fault; and reviewing the presence of mudstone rich in garnet and staurolite (interpreted as Burntwood group) along the southern shore of Roberts Lake. The work involved the review of outcrops at Roberts Lake and of historical maps (e.g., Stockwell, 1937; Frarey, 1950) as well as the analysis of data from light detection and ranging (LiDAR) and aeromagnetic surveys.



Regional geology of the East Wekusko area

The Paleoproterozoic Snow Lake subdomain is part of the Reindeer zone of the Trans-Hudson orogen in Manitoba (Lewry and Collerson, 1990). It is bounded by the Kisseynew domain to the north and the Superior boundary zone to the east (Figure GS2024-10-1). West of Reed Lake, volcanic rocks are interpreted as part of the Amisk collage (Lucas et al., 1996); Stern et al. (1995) suggested that stratigraphic and geochemical differences between the Snow Lake arc assemblage and volcanic rocks of the Amisk collage were likely the result of their having formed in distinct tectonic settings. The Snow Lake domain extends under younger Phanerozoic platform carbonate rocks to the south (Simard et al., 2010). The Snow Lake subdomain occurs as three structural panels bounded by the northeast-trending Berry Creek shear zone and Crowduck Bay fault (Figure GS2024-10-1). A northeast-trending panel of greywacke and mudstone 15–20 km wide that Ansdell et al. (1999) referred to as the Central Wekusko block (CWB) is separated from the Snow Lake arc assemblage (SLA) and the Herblet gneiss

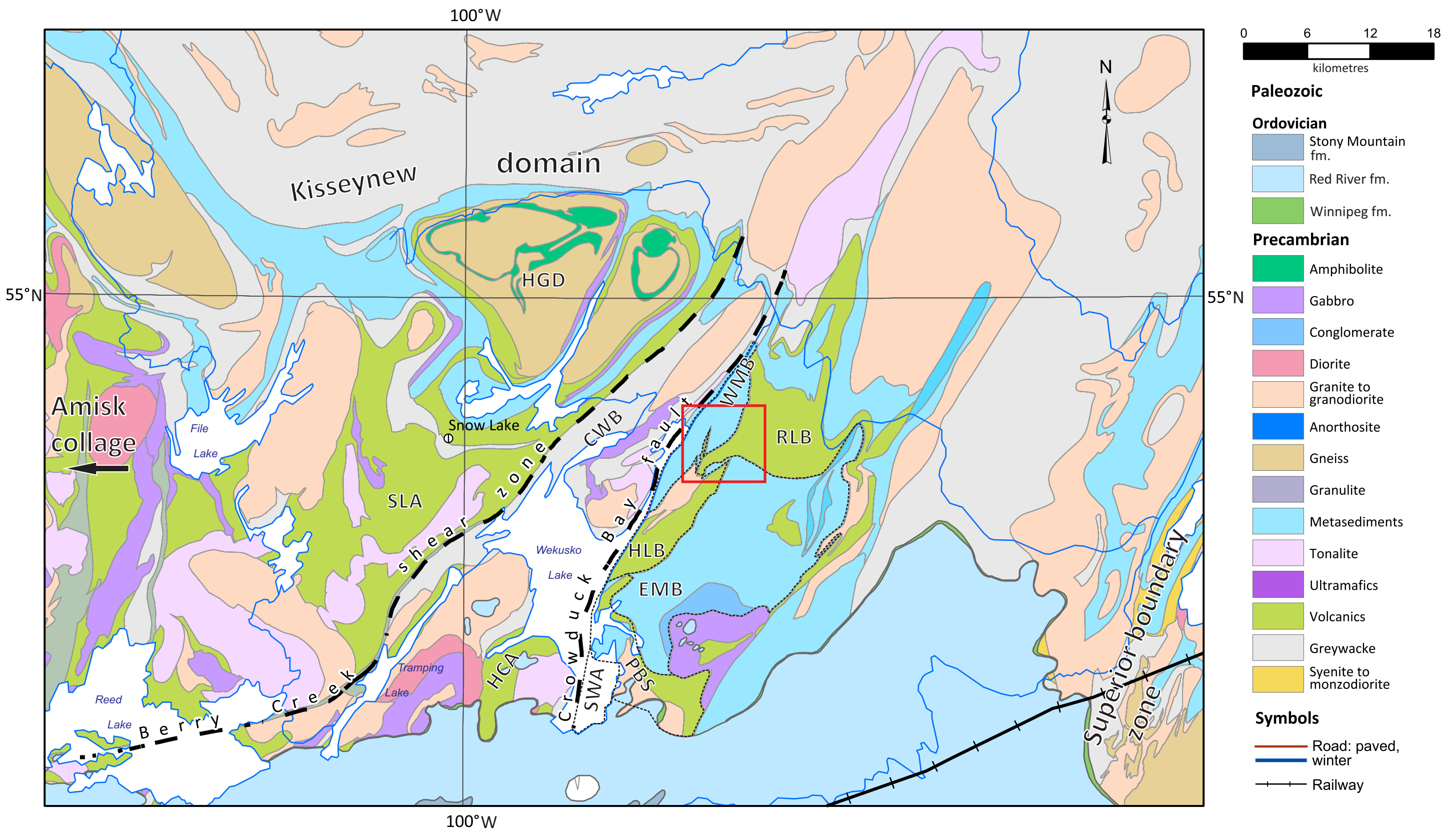


Figure GS2024-10-1: *Regional geology showing the Snow Lake domain, including the areas examined in 2024 (red polygon shows location of Figure GS2024-10-2) in north-central Manitoba (modified from Manitoba Geological Survey, 2022). Note the Kisseynew domain to the north, the Superior boundary zone to the east and Paleozoic cover rocks to the south. The Central Wekusko fault block (CWB), Eastern Missi fault block (EMB), Hayward Creek arc assemblage (HCA), Herb Lake fault block (HLB), Herblet gneiss dome (HGD), Puella Bay suite (PBS), Roberts Lake block (RLB), Snow Lake arc assemblage (SLA), South Wekusko assemblage (SWA) and Western Missi fault block (WMB) are shown relative to the Berry Creek shear zone and Crowduck Bay fault. Small dashed lines show the approximate boundaries of assemblages and structural blocks on the eastern side of Wekusko Lake.*

dome (HGD) by the Berry Creek shear zone (Figure GS2024-10-1). In the southwestern corner of the Wekusko Lake area, greywacke and mudstone are in structural contact with the Hayward Creek arc assemblage (HCA). Although no age determination is available for the Hayward Creek arc assemblage, it is thought to consist of ca. 1.89 Ga juvenile-arc rocks (Gilbert and Bailes, 2005).

The Crowduck Bay fault separates the CWB from rocks to the east and is considered a crustal-scale structure (Connors et al., 1999). Rocks east of the Crowduck Bay fault with similar lithostratigraphic elements are subdivided into fault-bounded blocks or assemblages (e.g., Connors et al., 1999; Gilbert and Bailes, 2005; Reid, 2021). These include ocean-floor basalts of the South Wekusko assemblage (SWA) and Roberts Lake block (RLB); evolved-arc volcanic rocks of the Puella Bay suite (PBS) and Herb Lake fault block (HLB); and fluvial-alluvial sedimentary rocks of the Western Missi fault block (WMB) and Eastern Missi fault block (EMB; Figure GS2024-10-1; e.g., Ansdell et al., 1999; Connors et al., 1999; Gilbert and Bailes, 2005; Reid, 2021).

The Roberts Lake area lies at the junction between rocks of the RLB, HLB, EMB and WMB (Figure GS2024-10-1). The map by Frarey (1950) indicates that a fault separates fluvial sandstone along the southern shore of Roberts Lake from pillowed basalt along the northern shore. Bedding measurements by Frarey (1950) in the Missi group sandstone and conglomerate south of Roberts Lake defined an upright synformal basin (Figure GS2024-10-2) but upon approaching the fault on Roberts Lake, the bedding is observed to be overturned. Connors et al. (1999, 2002) interpreted the Roberts Lake fault as a moderately dipping, south-verging thrust fault that places older basalt of MORB (mid-ocean–ridge basalt; unit F7a, Figure GS2024-10-2) affinity over younger sandstone and conglomerate. They also suggested that this thrusting is related to transpressional northwest-southeast shortening and the development of an extension lineation along the Crowduck Bay fault.

Field observations at Roberts Lake

A sequence of crossbedded feldspathic arenite (unit M3a, Figure GS2024-10-2) on the southern shore of Roberts Lake is overturned and youngs to the south (Figure GS2024-10-3a), consistent with the observations of Frarey (1950). With increasing biotite content in the sandstone, a bedding parallel cleavage S_0/S_1 is developed with an approximate strike of 300° and dip of

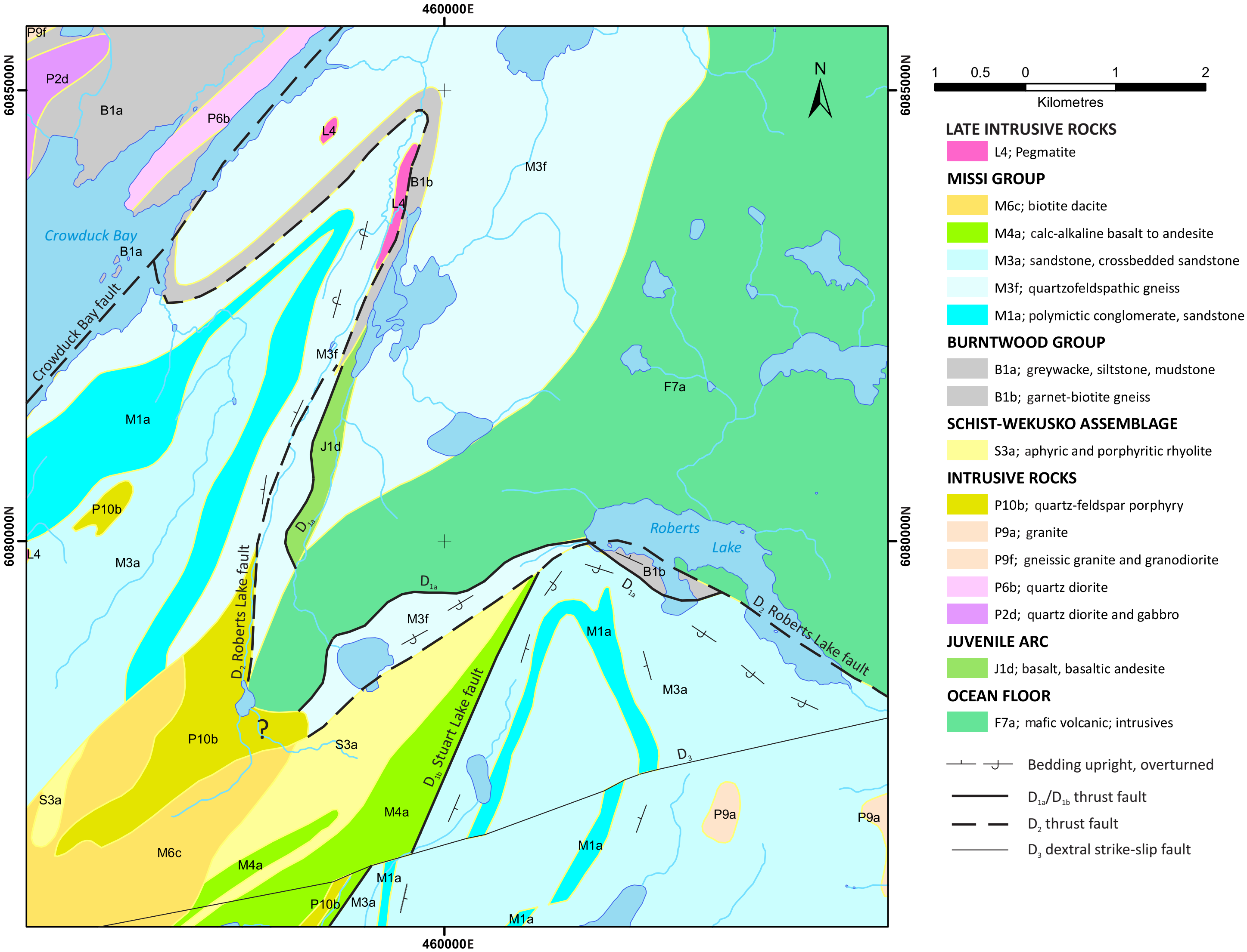


Figure GS2024-10-2: Geology of the Roberts Lake study area, including the interpretation of fault generation (geology and unit codes from the NATMAP Shield Margin Project Working Group, 1998). Bedding measurements away from Roberts Lake are from Frarey (1950).

38°, which is subsequently openly refolded, the axial plane forming an intersection lineation that trends 014° and plunges 64° (Figure GS2024-10-3b).

Directly north of the feldspathic arenite is a narrow (<100 m) unit of metamorphosed greywacke and mudstone rich in garnet and staurolite (unit B1b; Figure GS2024-10-2). The contact between the arenite and greywacke occurs between outcrops and is not exposed; however, it is believed to be relatively sharp, with no obvious increases in strain observed close to the contact (early S_1 brittle-ductile thrust?). Bedding in the greywacke and mudstone is defined by variations in garnet and staurolite content (Figure GS2024-10-3c). The local bedding strikes 282° and dips 39° and is characterized by reverse metamorphic grading (a transition from garnet-bearing sandy beds to coarse-grained beds with staurolite porphyroblasts), which is interpreted to indicate the unit youngs to the north. Close examination of quartz and biotite suggests an early S_1 foliation parallel to bedding S_0 that has been gently refolded, with 1–2 mm biotite books defining a crenulation cleavage S_2 that strikes 004° and dips 73°, nearly perpendicular to bedding S_0/S_1. This S_2 cleavage appears to gently anastomose around early formed garnet and staurolite porphyroblasts; it is considered analogous to the D_3 fabric described in Connors et al. (1999, 2002) and the D_4 fabric in Reid (2023).

The contact between the greywacke (unit B1b; Figure GS2024-10-2) and the Roberts Lake fault is not observed, but rocks on the promontory in the centre of Roberts Lake show evidence of increasing strain in the form of a carbonate-quartz-biotite-chlorite-sulphide–impregnated shear zone (Roberts Lake fault; Figures GS2024-10-2, 3d). This shear zone is a few metres wide and runs the length of the promontory, with a strike ranging from 334° to 353° and dips of 37° to 57°, while elongated streaks of carbonate within the shear zone trend 043° and plunge

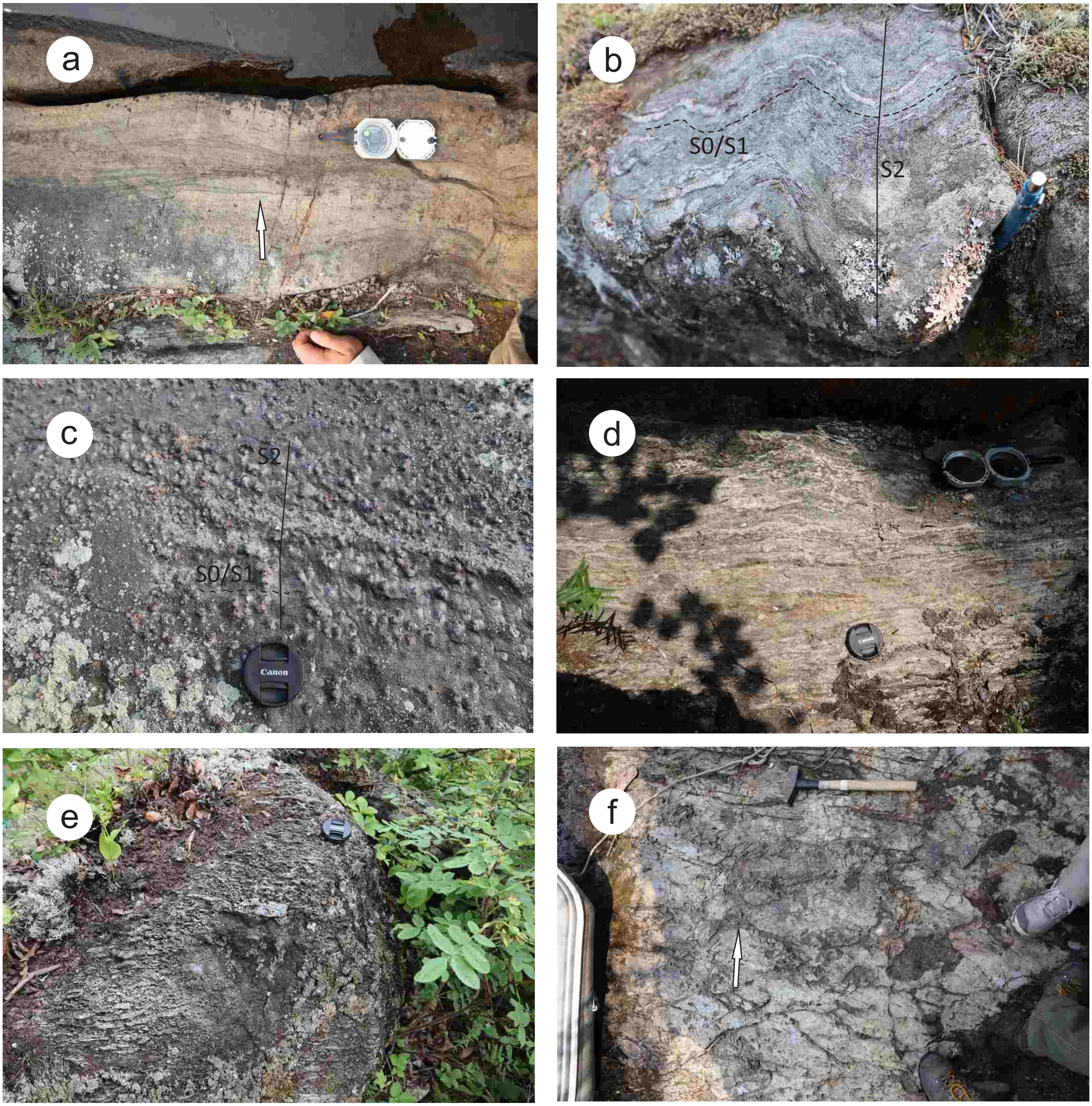


Figure GS2024-10-3: *Outcrop photographs from the Roberts Lake area:* ***a)*** *overturned crossbedded feldspathic arenite, with arrow indicating direction of stratigraphic younging (unit M3a; 461729E, 6079915N);* ***b)*** *feldspathic sandstone with increased biotite content showing S_0/S_1 refolded by F_2 (unit M3a; 461826E, 6079974N);* ***c)*** *porphyroblastic garnet greywacke with S_0/S_1 and later S_2 crenulation (unit B1b; 461826E, 6079974N);* ***d)*** *carbonate-quartz-biotite-chlorite-sulphide–impregnated D_2 deformation at the Roberts Lake fault (462566E, 6079709N);* ***e)*** *flattened (S_1) and lineated dacite lapilli in the hangingwall of the D_2 Roberts Lake fault (462883E, 6079496N);* ***f)*** *weakly flattened and sheared basalt with pillow selvages (arrow; unit F7a; 462391E, 6080419N). All co-ordinates are in UTM Zone 14, NAD83.*

48°. Directly in the hanging wall of the shear zone is a small unit containing lapilli-sized dacite clasts (Figure GS2024-10-3e), which have a distinct flattening (321°/47°) and lineation (036°/46°).

The northern side of Roberts Lake consists mainly of dark green, aphyric to very fine grained basalt with pillow selvages apparent in lower strain windows (unit 7Fa; Figure GS2024-10-3f). Measurements along the northern shore of pillow flattening/shearing show the strike ranging from 263° to 336° and the dip between 55° and 57°, while lineation in the basalt, defined by alignment of hornblende, trends 016–037° and plunges 51–55°.

Discussion

The geology at Roberts Lake (Figure GS2024-10-2) is relatively well represented by the mapping of Frarey (1950) and the NATMAP compilation (NATMAP Shield Margin Project Working Group, 1998). A unit of crossbedded feldspathic arenite along the southern side of Roberts Lake is consistently overturned and youngs to the southwest, whereas S_0/S_1 dips to the northeast. The adjacent narrow unit of garnet-staurolite–rich greywacke and mudstone has a similar S_0/S_1 cleavage dipping to the northeast but alternatively transitions to an upright structure that youngs to the northeast. The opposing facing directions across the contact between the two units would indicate that they were in fault contact prior to the development of the later north-striking S_2 cleavage. Along the northern side of Roberts Lake, S_1 manifests itself as pillow flattening and local shearing that dips to the northeast. A cleavage related to S_2 is less clearly developed in the mafic rocks; however, it is possible that the alignment of hornblende represents an intersection lineation formed at the intersection of the S_1 and S_2 cleavages.

Structural history of the Roberts Lake fault can be summarized in three phases:

1) The overturning of bedding in the sandstone; the development of S_1 fabrics in units M3a, B1b and F7a (Figure GS2024-10-2); and contacts between sandstone, greywacke and basalt are interpreted as being related to southwest-verging thrust faulting (D_{1a}; Figure GS2024-10-2) that brought (presumably) older Roberts Lake basalts of MORB affinity (unit F7a) southwest over younger Missi group sediments (unit M3a). The overturned bedding appears to be slightly folded around the synformal basin south of Roberts Lake, thus D_{1a} thrusting likely predates formation of the D_{1b} Stuart Lake fault (referred to as the Kiski fault; Connors et al. 1999). Reid (2024) interpreted the Stuart Lake anticline and fault to have formed synchronously with the emplacement of the Stuart Lake pluton at 1833.9 ±1.2 Ma, and D_1 thrust faulting at Roberts Lake is thus considered to have occurred concurrently with those events. The development of D_{1a} and D_{1b} faults as well as that of S_1 fabrics is considered to predate, or coincide with, peak metamorphic conditions and is analogous to the D_2 deformation events presented in Connors et al. (1999) and Reid (2023)

2) The carbonate-quartz-biotite-chlorite-sulphide-impregnated Roberts Lake Fault (D_2; Figure GS2024-10-2), another southwest-vergent structure, truncates the earlier D_{1a} and D_{1b} structures at the eastern and western ends of Roberts Lake as well as transecting various lithologies. The timing of this D_2 structure is less clear, but the lineation found within the fault is similar to the intersection lineation formed by S_1 foliation and F_2 fold hinges (Figure GS2024-10-3b); in addition, the lack of metamorphic recrystallization/annealing suggests that this fault postdates peak metamorphism. With the aid of LiDAR, aeromagnetic data and mapping by Frarey (1950), the D_2 Roberts Lake fault can be traced extending to Crowduck Bay, where it merges with, or is cut by, the Crowduck Bay fault (Figure GS2024-10-2). Overall, the D_2 Roberts Lake fault is considered to have been closely related to, or postdates, the D_3 deformation events described in Connors et al. (1999, 2002) and D_4 in Reid (2023).

3) Mapping by Frarey (1950) identified a brittle fault (D_3; Figure GS2024-10-2) with a component of dextral strike-slip movement that cuts the synformal basin south of Roberts Lake. It can be traced merging into the D_2 Roberts Lake fault east of Roberts Lake and extends east-northeast for approximately 50 km to the Superior Boundary zone. Interestingly, this fault not only has the same trend but also exhibits signs of the same late dextral movement as the crustal-scale Berry Creek shear zone to the west of Tramping Lake that can be traced for over 80 km to the west (Figure GS2024-10-4). The fact that the crustal-scale dextral movement along the Berry Creek shear zone west of Wekusko Lake appears to have translated into dextral movement east of Wekusko Lake along the late D_3 fault, to then merge with earlier D_1/D_2 thrust faults, suggests that the earlier D_1 and D_2 thrust faults were deeply rooted, as occurs in thick-skinned thrust systems (e.g., Pfiffner, 2017). Although no direct relationship between D_3 fault movement and lithium-bearing pegmatites has been observed, their sharp contacts and comb-like mineral texture indicate emplacement in dilatational structural sites while in the brittle-ductile to brittle environment (Silva et al., 2022; Reid, 2023). This occurred ca. 1780 ±8.1 Ma, based on analysis of columbite-group minerals in the Green Bay group pegmatites located a few kilometres northwest of Roberts Lake (Benn et al., 2019; Martins et al., 2019).

Economic considerations

Metamorphism and the development of regional structures play a significant role in the sourcing and focusing of hydrothermal fluids and melts that form economically viable mineral deposits such as the New Britannia gold mine, associated with the McLeod Road thrust (Rubingh et al., 2020), and the Tanco pegmatite, associated with the Bernic Lake shear zone (Kremer and Lin, 2006; Kremer, 2010). The combination of the metamorphic grade increasing northeast from Wekusko Lake and the structural complexity along the Roberts Lake fault is interpreted

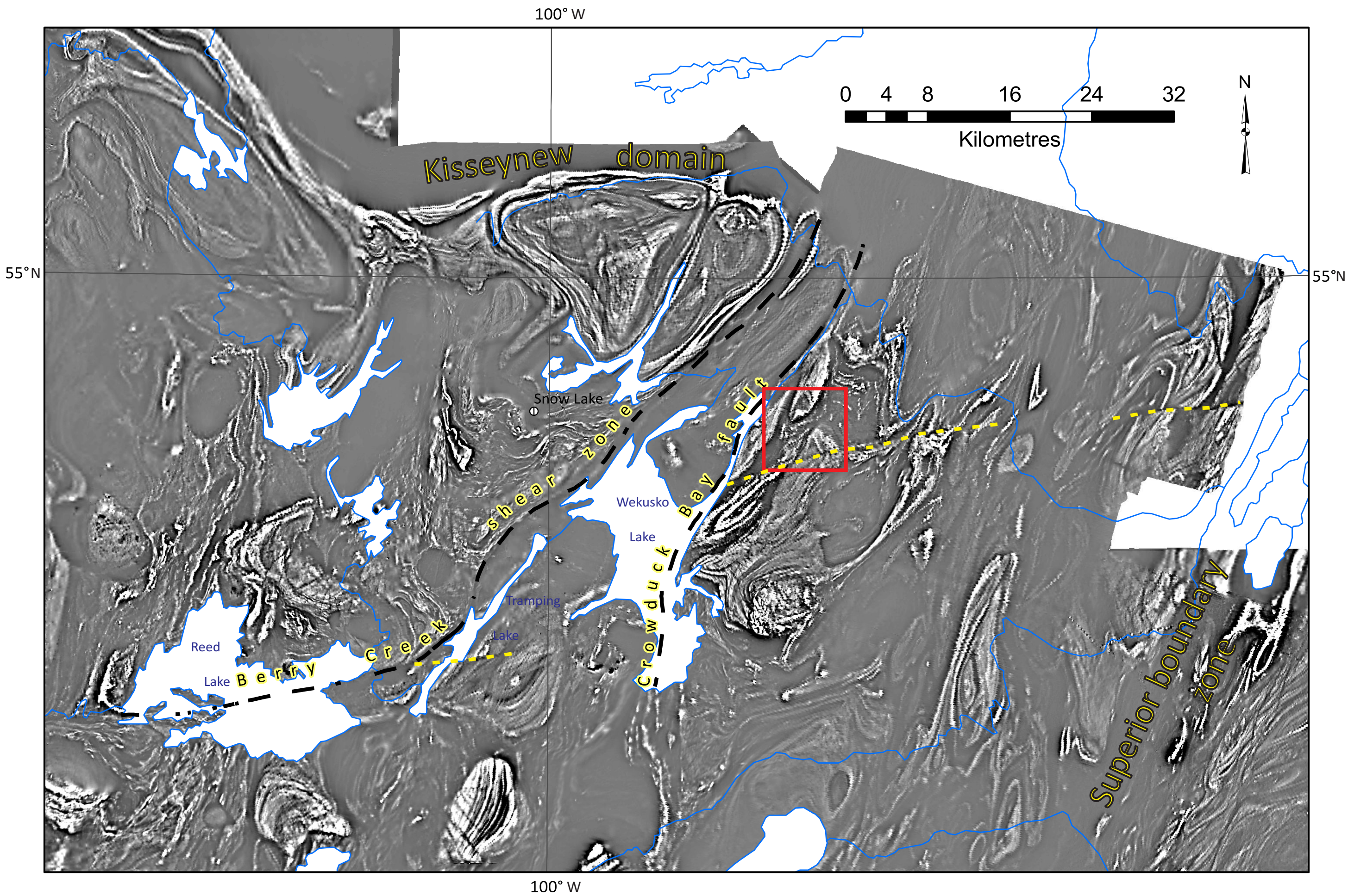


Figure GS2024-10-4: *Greyscale image showing the first vertical derivative of the magnetic field for the Snow Lake domain, data are from HudBay Minerals Inc. aeromagnetic compilation (unpublished, 2021) using data from two different survey systems: one pioneered by Spectrem Air, an airborne geophysics exploration company, and the VTEM™ (versatile time-domain electromagnetic) system developed by Geotech Ltd. Black dashed lines show the previous interpretations of the Berry Creek shear zone and Crowduck Bay fault, whereas the yellow dashed lines show the late dextral movements along the west-southwest-trending portion of the Berry Creek shear zone and the late dextral D_3 fault east of Wekusko Lake. Location of Figure GS2024-10-2 is indicated by the red polygon.*

as having played a role in the emplacement of orogenic gold and lithium-bearing pegmatites in the footwall and hangingwall of the structure (e.g., Stockwell, 1937; Benn et al., 2019; Silva et al., 2022). Southwest of Roberts Lake lie the Bachelor and McCafferty gold veins; these follow a D_1 axial plane that cuts rheologically competent felsic volcanic porphyry (see Stockwell, 1937). Alternatively, lithium-bearing pegmatites appear to postdate the D_1 and D_2 deformation events (D_2 and D_4 events; Reid, 2023) but may have been emplaced along pre-existing structures formed during the transition from brittle-ductile to brittle crustal levels, such as observed with the formation of the D_3 fault south of Roberts Lake. Interestingly, the Zoro and Violet-Thompson lithium-bearing pegmatite dikes (see Silva et al., 2022) occur in the hangingwall of the late crustal-scale brittle D_3 strike-slip fault, interpreted here to have roots that merge with the older D_1 and D_2 faults.

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