Update on the bedrock geology of the Rusty Mountain area, southern Wernecke Mountains, Yukon (parts of NTS 106C/4, 5, 12 and 106D/1, 8)

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Abstract

The Rusty Mountain area is underlain by sedimentary strata of the Paleoproterozoic Wernecke Supergroup, Mesoproterozoic Pinguicula Group, Neoproterozoic Hematite Creek Group and Windermere Supergroup, and Paleozoic Bouvette Formation. Three suites of intrusions are documented: (1) 10–200 m thick, subalkaline, mafic sills and dikes of the *ca.* 1380 Ma Hart River suite intrude the Wernecke Supergroup; (2) 2–3 m wide, vertical, east-west striking, alkaline, mafic dikes that are geochemically distinct from the Hart River suite intrude the Wernecke Supergroup; and (3) a 30 cm thick, mafic, porphyritic dike intrudes the Wernecke Supergroup at one locality. The main structures in the Wernecke Supergroup are northwest-verging folding and thrusting and a steeply dipping axial-planar cleavage. This deformation affected the Hart River sills, but not the east-west striking dikes. The main structures in the Pinguicula Group and younger strata are northwest-southeast trending gentle folds and a steeply dipping axial-planar cleavage.

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Introduction

This paper presents an update on the bedrock geology and stratigraphy in the Rusty Mountain area following the completion of a second field season of 1:50 000-scale mapping. The new map area covers approximately 200 km^2 to the north of, and contiguous with, the previous map of Ambrose (2020), and includes the northern part of NTS 106C/5 (Rusty Mountain) and the southern extent of 106C/4 (Gillespie Creek).

The map area is located in the southern Wernecke Mountains, ~120 km NE of Mayo (Figs. 1 and 2). Access is by fixed-wing plane from Mayo to the Rackla airstrip (64.22°N, 133.21°W) and helicopter from that point. The map area is located at the southeast margin of the Wernecke Inlier (Fig. 2). The Wernecke Inlier is the largest of several Proterozoic inliers along the southern margin of the Yukon stable block, a triangular region of relatively thick lithosphere (Jeletsky, 1962; Estève et al., 2020) that is bound to the east by the Richardson fault array and by the Dawson fault to the south. This paper focuses on rocks of the Paleoproterozoic Wernecke Supergroup, the oldest stratigraphic unit in the northern Cordillera and the only sedimentary unit exposed in the northern part of the map. These rocks are overlain to the south by Mesoproterozoic and younger rocks previously mapped by Ambrose (2020) and described in Ambrose and Bowie (2020). The new mapping reported here brings revision to the map of Ambrose (2020) to the south.

Previous work

Blusson (1974a) previously mapped the area as part of a series of five 1:250 000-scale maps of east-central Yukon. Blusson (1974b) mapped parts of the region east of the current study area (NTS 106C/6, 7, 10, 11, 13, 15)

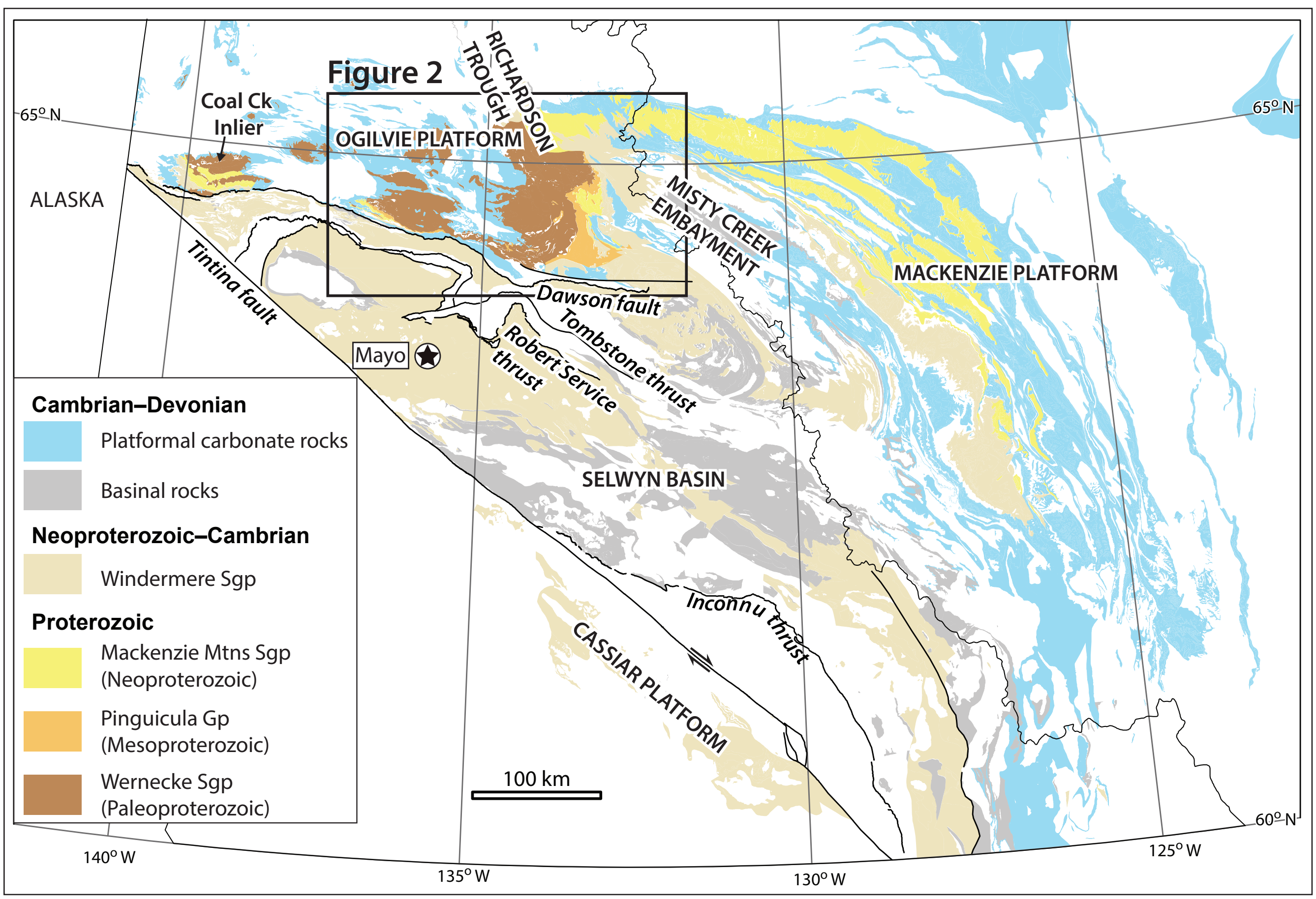


Figure 1. Simplified geological map showing the distribution of Proterozoic through to Devonian assemblages in Yukon and NWT (after Moynihan et al., 2019). The study area is located within the Wernecke Inlier, the farthest east, and largest of several erosional windows that expose Paleoproterozoic and Mesoproterozoic rocks.

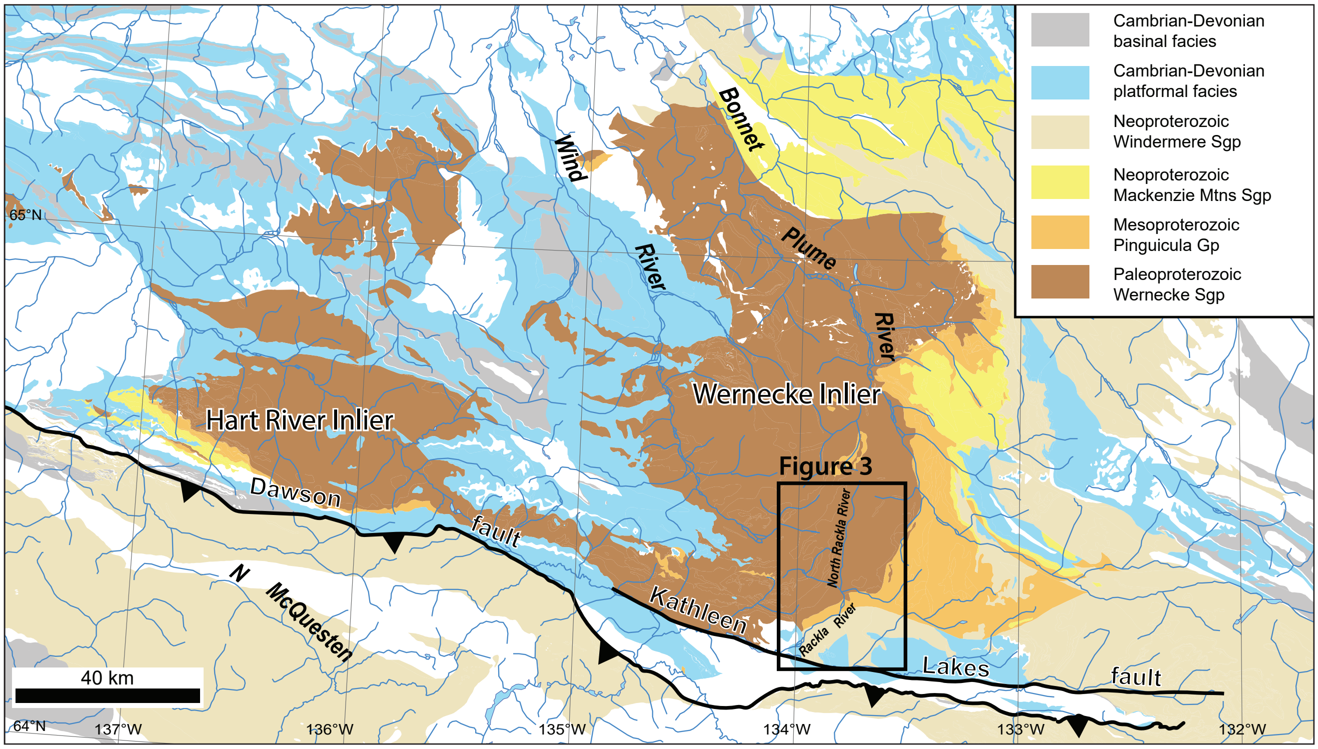


Figure 2. *Simplified geological map of the Wernecke and Hart River inliers. White areas are Late Devonian and younger rocks. Location is shown in Figure 1. The map area (outlined) is located north of the Dawson and Kathleen Lakes faults and across the southern margin of the Wernecke Inlier. Geology from Colpron et al. (2016).*

at the more detailed 1:50 000 scale. Abbott (1997) and Thorkelson (2000) mapped Proterozoic stratigraphy in the Hart River (116A/10, 11) and northern Wernecke (106D/16, 106C/13–14) inliers, respectively. Roots (1990a,b) mapped the adjacent, 1:50 000-scale sheets to the west (eastern half of NTS 106D/7, 8) of the current map area.

Delaney (1981) described and subdivided the Wernecke Supergroup into the Fairchild Lake, Quartet, and Gillespie Lake groups. Furlanetto et al. (2013) used detrital zircon and Lu-Hf garnet geochronology to show that the Wernecke Supergroup was deposited after 1640 Ma and metamorphosed at ca. 1600 Ma and 1370 Ma. Abbott (1997) and Verbaas et al. (2018) provide descriptions, geochemical analyses, and geochronology of the Hart River sills from the Hart River and Wernecke inliers. Eisbacher (1981) described the Pinguicula Group and divided it into units A–F. Thorkelson (2000) documented an unconformity between Pinguicula C and D, and reassigned units D–F of the Pinguicula Group into the newly defined Hematite Creek Group. Turner (2011) formalized the Hematite Creek Group and assigned it to the Mackenzie Mountain Supergroup. Medig et al. (2016) formalized formations in the Pinguicula Group and described type sections for them. Medig (2016) presented a detrital zircon study of the Pinguicula Group to constrain a maximum depositional age of 1322 Ma.

Stratigraphy

Only the upper two units of the Wernecke Supergroup are present in the map area and described below. Descriptions of the Pinguicula Group are also given below as the new mapping brings revisions to previous work by Ambrose (2020) and Ambrose and Bowie (2020).

Quartet Group

The Paleoproterozoic Quartet Group is the middle unit of the Wernecke Supergroup and oldest unit exposed in the map area (Figs. 3 and 4). The Quartet Group

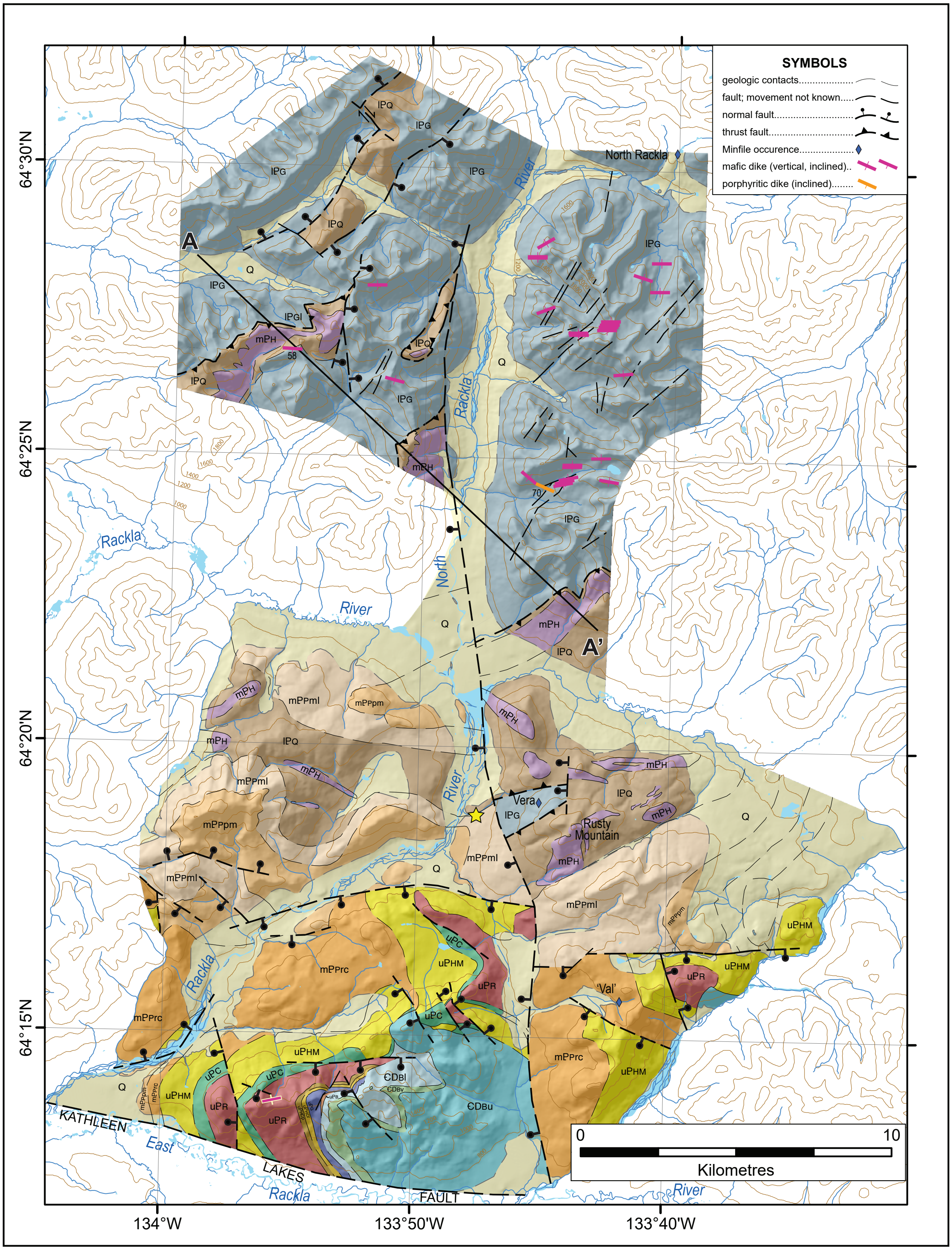


Figure 3. *Simplified geological map of the Rusty Mountain area. Yellow star to the west of Rusty Mountain marks the location of interbedded conglomerate and sandstone at the base of the Mount Landreville Formation (see text for discussion).*

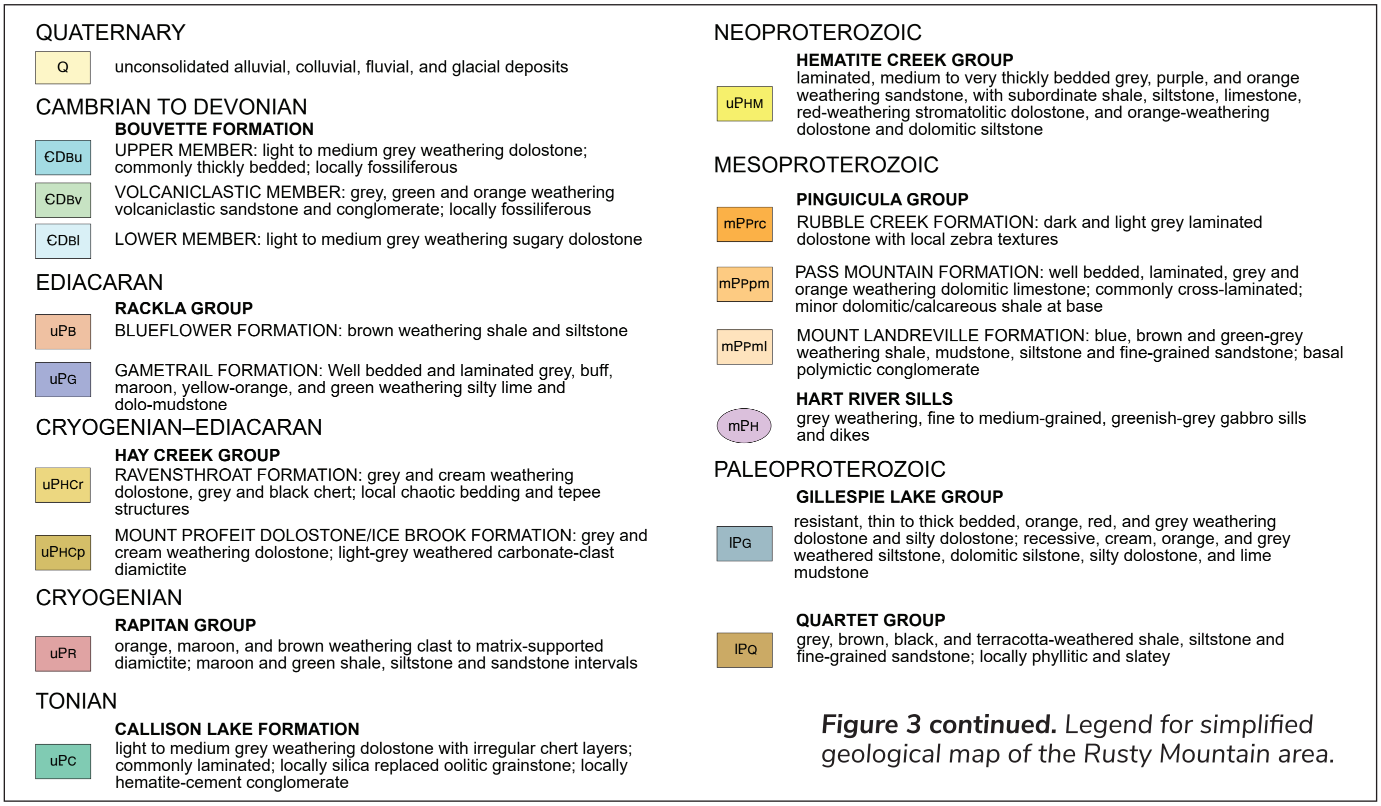


Figure 3 continued. *Legend for simplified geological map of the Rusty Mountain area.*

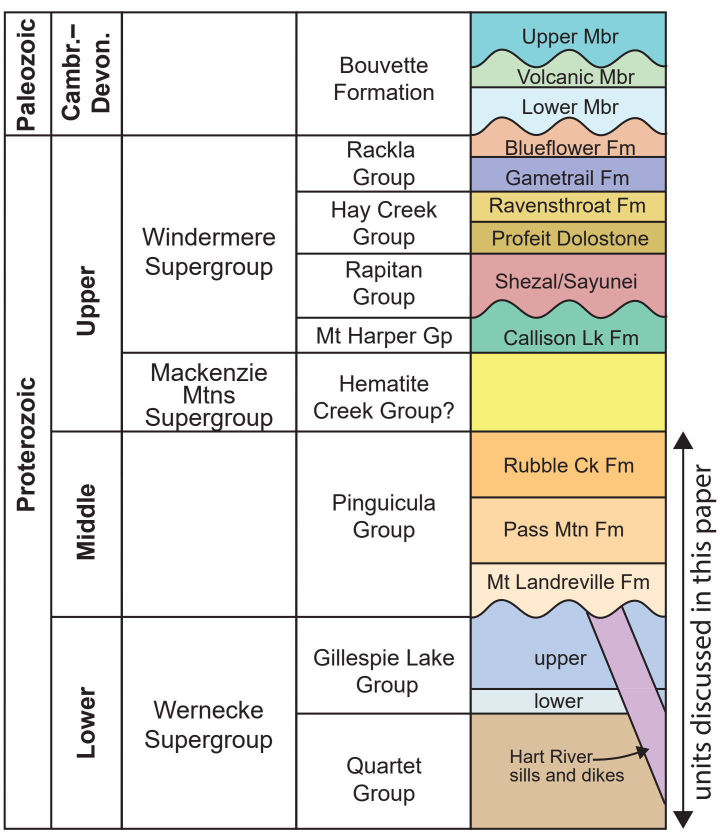


Figure 4. *Schematic lithostratigraphic column of units exposed in the map area.*

comprises black, grey and brown weathering, planar-parallel laminated mudstone, shale and siltstone with less common sandstone and carbonate (Fig. 5). The basal stratigraphic contact with the underlying Fairchild Lake Group (oldest unit of the Wernecke Supergroup) is not exposed in the map area. Unlike the Fairchild Lake Group, which is locally metamorphosed to greenschist facies, the Quartet Group is unmetamorphosed. Towards the contact with the overlying Gillespie Lake Group, the Quartet Group becomes increasingly dolomitic and calcareous (Fig. 5c,d). This increase in carbonate content is reflected by a colour change, from dark weathering typical of the Quartet Group into tan weathering near the contact with the overlying Gillespie Lake Group (Fig. 6). To the north, Delaney (1981) estimated the Quartet Group to be >5 km thick and Thorkelson (2000) estimated it to be >3.4 km thick from a section with a faulted basal contact.

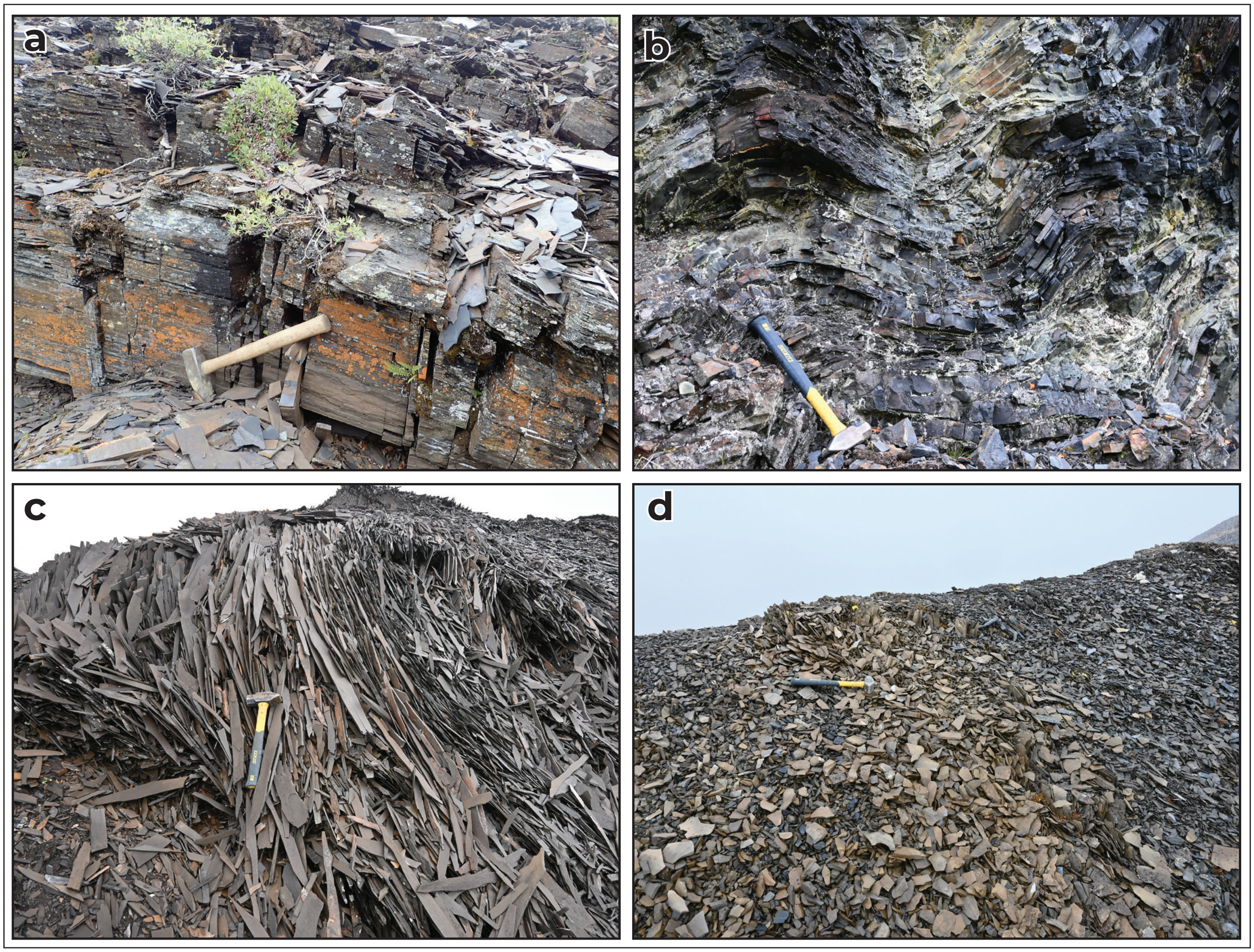


Figure 5. *Representative field photos of the Quartet Group.* ***(a)*** *Brown weathering siltstone.* ***(b)*** *Gently folded dark weathering siltstone.* ***(c-d)*** *Cream-grey weathering dolomitic and calcareous siltstone near the top of the Quartet where it transitions into the Gillespie Lake Group.*

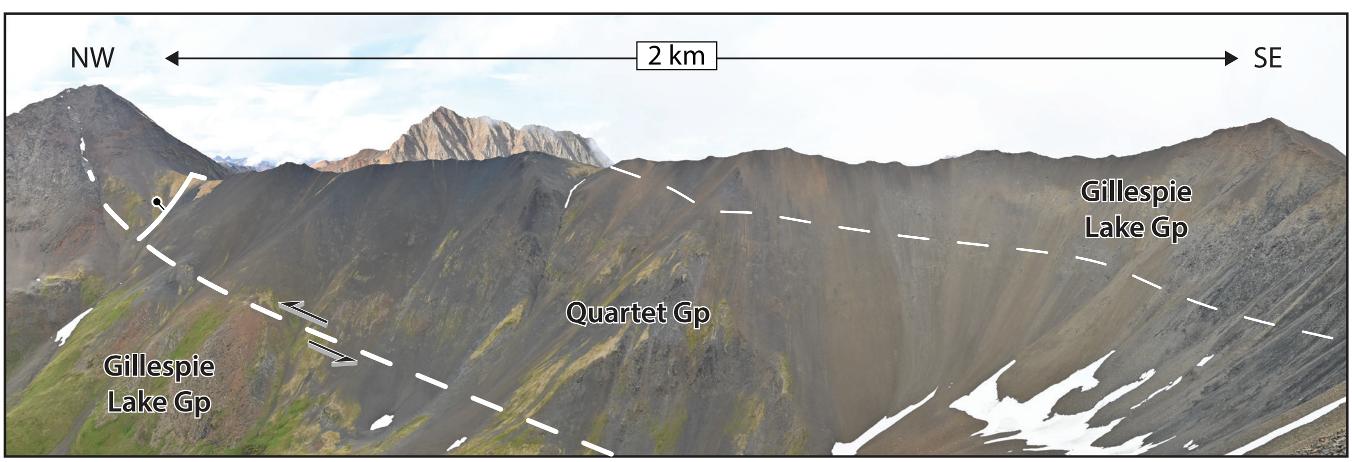


Figure 6. *Gradational contact between the dark weathering siltstones of the Quartet Group, and the cream-weathering dolomitic siltstones and silty dolostones of the lower Gillespie Lake Group. Thin dashed white line marks the stratigraphic contact between the Quartet and Gillespie Lake groups. Thick dashed line marks a sinistral strike-slip fault.*

Gillespie Lake Group

The Paleoproterozoic Gillespie Lake Group is the uppermost unit of the Wernecke Supergroup and consists of orange, red, buff and grey weathering dolostone and silty dolostone with less common dolomitic siltstone, dark-weathering siltstone, and grey limestone (Fig. 4). The contact with the underlying Quartet Group is gradational (Fig. 6). The base of the Gillespie Lake Group, as defined by Delaney (1981), is marked by the first appearance of orange-weathering silty dolostone (Fig. 7a).

The basal several hundred metres of the Gillespie Lake Group typically comprises recessive, thin to medium bedded, grey, cream, orange and black weathering dolomudstone, silty dolostone, dolomitic siltstone, and siltstone (Fig. 7). Intervals of well-bedded, variably dolomitic, grey to orange-weathering lime mudstone are also common in the basal Gillespie Lake Group. Cross-lamination, often lenticular, is abundant in some beds. The remainder of the Gillespie Lake Group comprises resistant, cliff forming, thin to thick-bedded, typically orange and red, and less commonly buff and grey weathering, variably silty dolomudstone and dolograinstone, and dolomitic siltstone (Fig. 8). Above the basal interval, the Gillespie Lake Group contains abundant stromatolites and microbially laminated dolostone (Fig. 8b,c). Coarsening and thickening upwards sequences that, in general, pass from thinly bedded, fine-grained, silty dolomudstone at the base (Fig. 8d–e) to thicker bedded silty dolowackestone–grainstone (Fig. 8f), microbially laminated dolostone (Fig. 8b), and stromatolitic dolostone (Fig. 8c) at the top, are common. Well developed sequences are up to 10 m thick, though they are often incomplete and only 10s of cm thick. Medium to thickly bedded nodular limestone and dolostone occur as intervals up to ~100 m thick.

At the outcrop scale there is a textural continuum from planar-parallel, mechanical laminations (Fig. 8d), through to crinkly, irregular, microbial laminations (Fig. 8b). In places, microbially-laminated dolostone passes along the same bed into stromatolites (Fig. 8c). Silicified oolitic grainstone (Fig. 8f) and, rarely, chert occur as thin beds. As seen in Figure 8b and e, silicification results in a distinct relief on weathered surfaces, with the darker, finer grained, more silicified layers being more resistant than coarser grained orange weathering dolowackestone–grainstone.

The Gillespie Lake Group contains conspicuous intervals of grey-weathering dolomitic mudstone and siltstone (Fig. 9a). These rocks are typically planar-parallel laminated, weather blue, brown and green-grey (Fig. 9b,c), and consist of clay minerals, quartz,

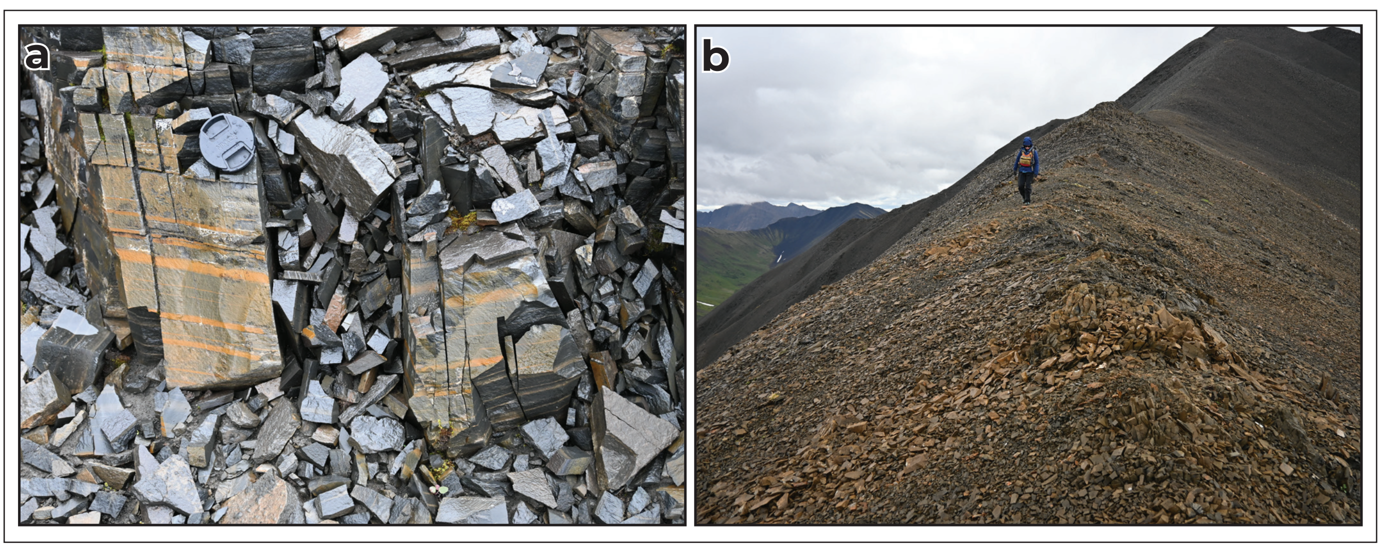


__Figure 7.__ Field photographs of the lowermost Gillespie Lake Group. __(a)__ Thin beds of orange weathering dolostone that marks the base of the Gillespie Lake Group. __(b)__ Orange weathering dolomitic siltstone and silty dolostone from the base of the Gillespie Lake Group.

Figure 8. *Field photographs illustrating common features of the Gillespie Lake Group.* ***(a)*** *Well bedded silty dolostone. Hammer for scale.* ***(b)*** *Crinkly, microbially laminated, orange weathering, silty dolograinstone and silty, dark grey weathering dolomudstone.* ***(c)*** *Stromatolitic dolostone.* ***(d)*** *Thinly interbedded, dark weathering, resistant dolomudstone, and orange weathering dolograinstone–wackestone.* ***(e)*** *Nodular to thinly interbedded, resistant, dark grey weathing dolomudstone and orange weathering dolograinstone–wackestone.* ***(f)*** *Silicified, oolitic grainstone.*

and carbonate grains. Depositional contacts between these intervals and the dolostone more typical of the Gillespie Lake Group are gradational. As highlighted by Figure 9a, these intervals act as local marker beds that allow for the recognition of vertical faults (Fig. 3).

The basal stratigraphic contact with the Gillespie Lake Group is exposed along several ridges in the northwestern part of the map area, but its top is truncated by faults (Fig. 3). The stratigraphic thickness of Gillespie Lake Group is estimated to be at least 2 km in the map area. In the type area to the north, Delaney (1981) estimated the thickness to be more than 4 km. Based on three incomplete sections to the west of the map area (106D/7, 8), Mustard et *al.* (1990) estimated a thickness of ~1.2 km. In the Fairchild Lake area (106C/13), Thorkelson (2000) estimated the Gillespie Lake Group to be up to 4.7 km thick.

Pinguicula Group

Mount Landreville Formation

The Mount Landreville Formation (Pinguicula A of Eisbacher, 1978) is the oldest unit of the Mesoproterozoic Pinguicula Group (Fig. 4). It consists of mudstone, shale, siltstone and fine-grained sandstone (Medig et *al.*, 2016). North of the present study area, the Mount Landreville Formation weathers conspicuous green and maroon colours (*e.g.*, *see* Figure 5 of Medig et *al.*, 2012). In the Rusty Mountain area, the fine-grained siliciclastic rocks of the Mount Landreville Formation are difficult to distinguish from the Quartet Group as both units weather to variable shades of greenish, blueish and brownish grey. Thorkelson (2000) and Medig et *al.* (2016) described the local occurrence of up to 20 m of interbedded sandstone and polymictic conglomerate

Figure 9. *(a)* *Panorama of red-weathering silty Gillespie Lake Group dolostone with intervals of grey-weathering dolomitic siltstone. Thin dashed lines indicate bedding. Thick solid lines indicate faults.* ***(b–c)*** *Planar laminated siltstone and dolomitic siltstone from intervals within the Gillespie Lake Group.*

at the base of the Pinguicula Group. Ambrose and Bowie (2020) described a thin interval of interbedded sandstone and polymictic conglomerate at one locality to the southwest of Rusty Mountain (see yellow star on Fig. 3). These coarse-grained rocks were assigned to their "lower siliciclastic unit" and tentatively correlated with the Quartet Group. This conglomerate is now interpreted to mark the base of the Mount Landreville Formation.

Pass Mountain Formation

The Pass Mountain Formation (Pinguicula B of Eisbacher, 1978) is the middle unit of the Pinguicula Group (Fig. 4). It gradationally overlies the Mount Landreville Formation and comprises orange weathering, variably silty, dolomitic, thin to medium bedded, platy limestone (see Ambrose and Bowie, 2020). Ambrose and Bowie (2020) assigned these rocks to their "lower carbonate unit" and correlated them with the Gillespie Lake Group. Mapping to the north shows that the "lower carbonate unit" is distinct from the Gillespie Lake Group and is reassigned here to the Pass Mountain Formation.

Red and orange weathering, stromatolitic dolostone northwest of Rusty Mountain that was assigned to the "lower carbonate unit" of Ambrose and Bowie (2020) is probably still correlative with the Gillespie Lake Group. These rocks occupy a low structural level beneath fine-grained siliciclastic rocks of the Quartet Group intruded by Hart River sills and may be exposed within a thrust window (Fig. 3).

Rubble Creek Formation

The Rubble Creek Formation (Pinguicula C of Eisbacher, 1978) gradationally overlies the Pass Mountain Formation and is the uppermost unit of the Pinguicula Group (Fig. 5). Ambrose and Bowie (2020) correlated their "Val dolostone" with the Rubble Creek Formation, a correlation reinforced by the stratigraphic adjustments proposed above. Ambrose and Bowie (2020) provide a more detailed description of the Rubble Creek Formation.

Intrusive Rocks

Hart River Sills

The ca. 1380 Ma Hart River sills and dikes consist of resistant, greenish, medium to dark grey weathering gabbro and diorite (Figs. 10 and 11). The primary igneous mineralogy is dominated by plagioclase and clinopyroxene, with minor quartz and opaque minerals (Fig. 10). Plagioclase grains have been variably altered to saussurite (albite + clinozoisite) and sericite. Clinopyroxene is variably replaced by chlorite. Quartet Group rocks are commonly pyritic and orange-weathering along the margins of Hart River sills and dikes (Fig. 11). The sills and dikes, which range from 10 to ~200 m thick, commonly occur in the hanging wall of, but do not cut, northwest-verging thrust faults (Figs. 3 and 11), suggesting that faulting postdates emplacement. The gabbro is always separated from the thrust fault by tens of metres of Quartet Group siltstone (Figs. 3 and 11).

East–west striking dikes

The Wernecke Supergroup is also intruded by dark grey weathering, relatively magnetic (compared to Hart River sills), nearly vertical, east–west striking, 2–3 m wide mafic dikes (Fig. 12). The colour contrast with the Gillespie Lake Group make them conspicuous and easy to identify in cliff faces (Fig. 12a,b). In hand sample, the east-west striking dikes are generally finer grained, but

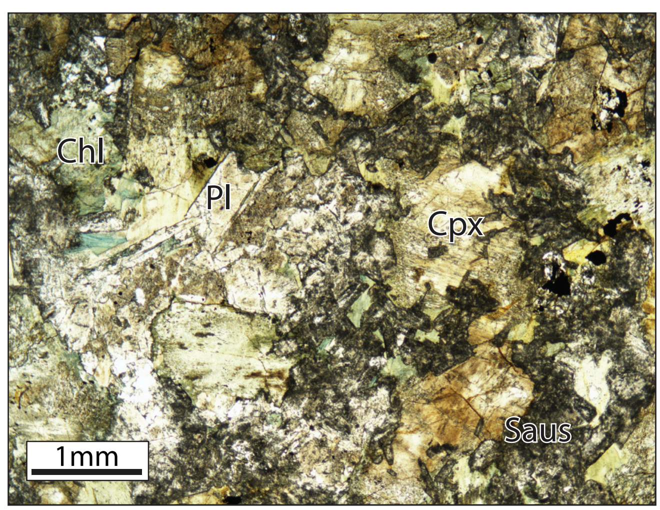


Figure 10. *Photomicrograph of Hart River gabbro showing clinopyroxene (Cpx), plagioclase (Pl), chlorite (Chl), and saussurite (Saus). Plain-polarized light (PPL).*

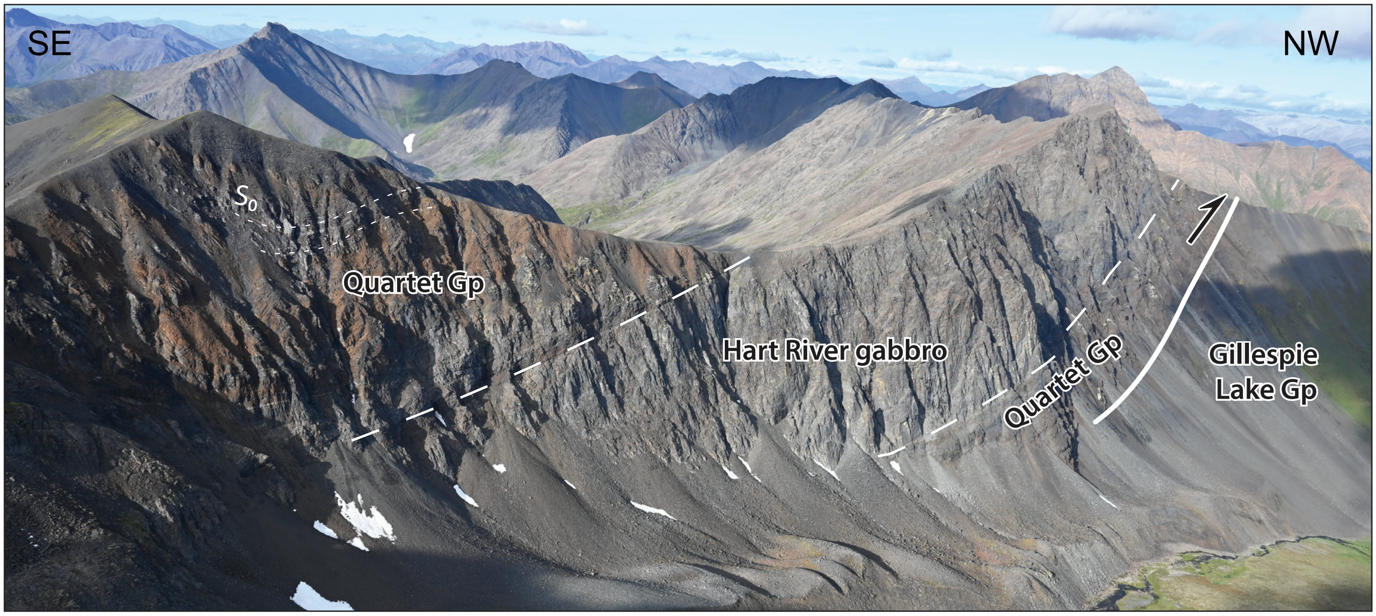


Figure 11. *Quartet Group intruded by Hart River gabbro and thrust faulted over the Gillespie Lake Group. Photo taken in the northwest part of the map area. Solid line indicates thrust fault. Thick dashed line indicates intrusive contact. Thin dashed line in Quartet Group indicates bedding.*

otherwise appear similar to the Hart River sills. The original igneous mineralogy of the dikes is dominated by plagioclase with lesser amounts of clinopyroxene, olivine and opaque minerals (Fig. 12c). Clinopyroxene has been replaced by chlorite and plagioclase has been altered to saussurite and sericite (Fig. 12c). A subset of dikes of dikes are plotted on Figure 3. Many of the dikes occur in cliff faces and thus their orientation is approximate. The precise age of the dikes is unknown; they are only constrained to be younger than the <1640 Ma Wernecke Supergroup rocks that they intrude (Furlanetto *et al.*, 2013). The consistent orientation (Fig. 3) and lack of evidence of folding (Fig. 12b) and thrusting suggests the dikes postdate the dominant phase of deformation of the Wernecke Supergroup. A single dike mapped by Ambrose (2020) to the south has similar composition and orientation and intrudes the Rapitan Group. If this dike is related to the east-west striking dikes mapped north of Rusty Mountain, then these dikes may be Neoproterozoic or younger.

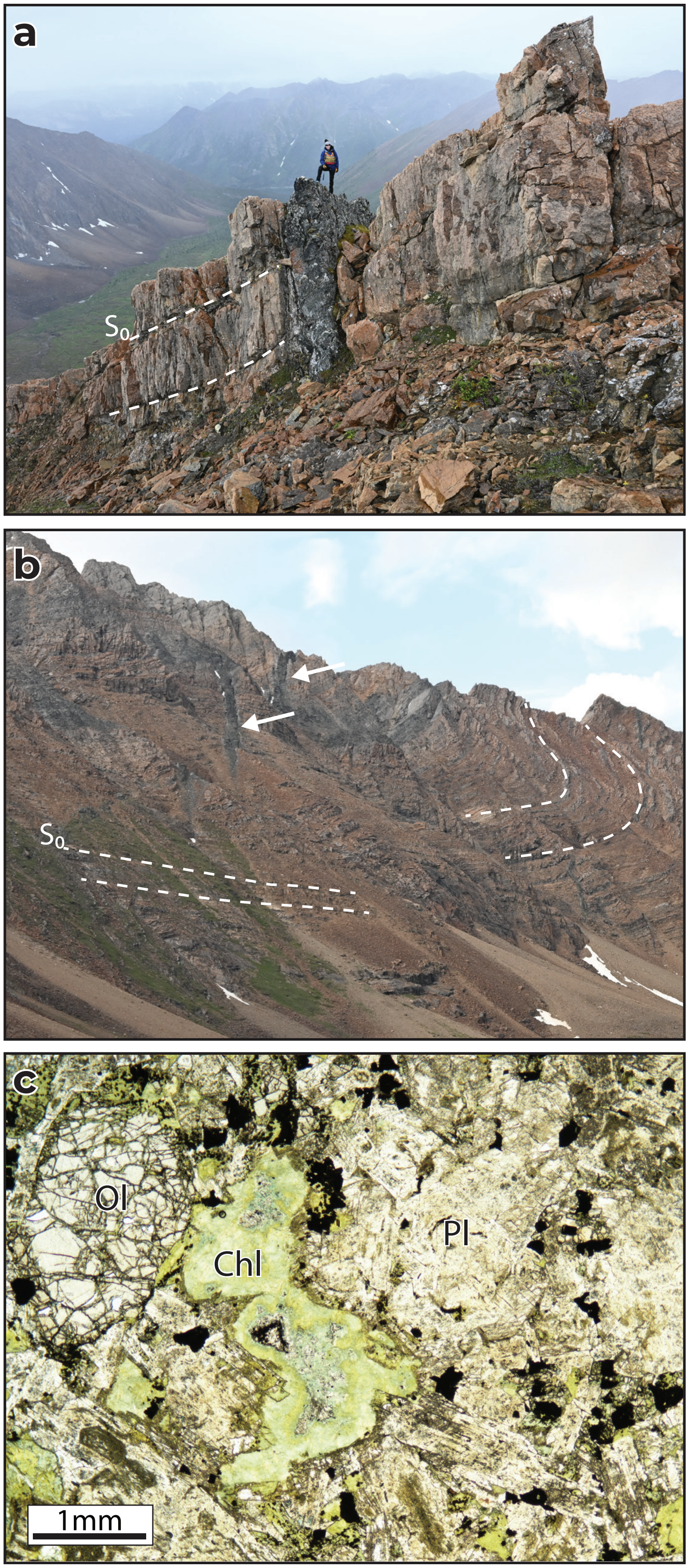
Porphyritic dike

A 30 cm wide, medium-grey weathering, porphyritic dike was observed at one locality to the east of the North Rackla River (Figs. 3 and 13). Pervasive carbonate alteration makes determining the primary mineralogy of this dike difficult. It consist of a fine-grained spongy matrix and phenocrysts or xenocrysts up to ~5 mm across that are replaced by carbonate (Fig. 13b). This dike is petrographically distinct from the Hart River sills and the east–west dikes.

Geochemistry of Intrusive Rocks

Thirteen mafic intrusive samples collected over two field seasons were selected for geochemical analyses (Table 1). Two samples were filtered out due to alteration (LOI >5%). Of the remaining samples, 5 are from Hart River sills and 6 are from the east–west striking mafic dikes.

Results for our Hart River samples are compared with those of Verbaas et *al.* (2018; grey triangles) on the modified Zr/Ti *vs.* Nb/Y diagram of Pearce (1996; after Winchester and Floyd, 1977; Fig. 14a). All samples plot in the basalt field and overlap with those published by Verbaas et *al.* (2018). In contrast, most samples of the east-west striking dikes plot within the alkali basalt field, with the exception of sample 20TA005 which plots in the basalt field.



Spider plots presented in Figure 14b further illustrate the geochemical distinction between the Hart River gabbro and the east-west striking dikes. The Hart River sills are characterized by flat trace-element profiles that are similar to mid-ocean ridge basalt. Sample 20TA106-2 has a distinct, more enriched trace element profile with slight positive Nb and Ti anomalies compared to the other Hart River samples. Overall, the trace-element patterns of Hart River samples compare well with those of Verbaas et *al.* (2018).

In contrast, the east-west striking dikes have trace-element signatures similar to ocean island basalt (OIB), with negative slopes, generally slightly positive Nb anomaly, and a slight negative Ti anomaly (Fig. 13b). Sample 20TA005 is distinct with a slightly more depleted trace-element pattern and a negative Nb anomaly.

Structure

The dominant structures in the Wernecke Supergroup are oriented approximately perpendicular to structures in younger strata (Fig. 15). As mentioned above, Wernecke Supergroup strata are primarily exposed in the northern part of the map, whereas younger rocks are exposed in the south. Thus, the distinct orientation of structures may reflect either spatial domains or multiple phases of deformation.

Figure 12. *Field photographs and photomicrograph of east-west striking dikes.* ***(a)*** *Thin (~2 m wide) mafic dike intruded into thick-bedded silty dolostone of the Gillespie Lake Group. Looking east.* ***(b)****Thin mafic dike (white arrows) cutting folded Gillespie Lake dolostone. Dashed white lines mark bedding.* ***(c)*** *Plain-polarized photomicrograph showing olivine (Ol), chlorite (Chl), plagioclase (Pl) and opaque minerals.*

Table 1. *Geochemical analyses for intrusive rocks from the Rusty Mountain area.*

	Hart River sills and dikes					east-west striking dikes					
Sample Number	19TA039-2	19TA053-1	19TA211	20TA106-2	20TA019-1	20TA004	20TA005	20TA010	20TA029-2	20TA137-1	20TA151
Lat.	64.317	64.342	64.327	64.458	64.379	64.411	64.415	64.417	64.453	64.439	64.448
Long.	-133.675	-133.761	-133.914	-133.892	-133.738	-133.713	-133.739	-133.720	-133.735	-133.859	-133.919
SiO_2	49	48.49	48.21	47.87	47.84	45.77	49.88	45.38	47.44	44.69	44.81
Al_2O_3	13.94	13	14.32	11.68	14.92	14	12.84	15.22	15.08	14.8	14.27
Fe_2O_3	14.83	12.58	9.65	21.96	9.67	15.06	15.82	14.59	13.64	10.43	14.26
MnO	0.31	0.19	0.15	0.31	0.19	0.25	0.2	0.05	0.16	0.17	0.16
MgO	6.3	7.89	8.53	2.91	7.64	4.86	4.64	5.63	5.44	5.74	4.72
CaO	7.16	10.5	11.75	4.86	14.15	8.49	6.97	4.53	5.2	11.15	10.05
Na_2O	3.01	2.12	2.21	3.39	1.61	3.28	3.48	3.03	2.82	2.98	1.83
K_2O	1.14	1.42	1.04	0.42	0.8	1.68	1.52	4.19	3.21	1.62	2.04
TiO_2	1.28	1.04	0.66	3.74	0.77	2.41	2.73	2.45	2.61	2.03	2.57
LOI	2.15	1.8	2.22	2.02	1.61	2.97	1.49	3.68	3.11	4.55	4.11
TOTAL	99.52	99.72	99.09	100.95	99.52	99.99	100.3	100.3	100.3	99.39	100.05
Th	0.48	0.46	0.28	1.16	0.34	7.47	4.39	7.53	8.08	6.16	8.42
Nb	3.8	2.7	1.6	11.5	2.5	65.1	13.4	68	64.2	59.5	80.5
La	4.1	3.1	2.2	8.8	2.9	58.5	17.6	60.2	61.7	49.6	64.4
Ce	10.8	8.6	5.8	23.2	7.2	116	41.2	119	122.5	96.4	126
Pr	1.52	1.22	0.86	3.41	1.1	13.55	5.51	13.55	14.1	11	14.4
Nd	7.4	6.2	4.3	17.3	5.5	52.5	24.8	52.2	55.1	42.5	56.1
Sm	2.32	2.1	1.52	5.34	1.63	9.95	6.41	9.96	10.1	8.16	10.5
Zr	62	50	32	153	40	228	210	218	243	190	257
Hf	1.7	1.4	0.9	4.2	1.1	5.5	5.7	4.8	5.6	4.3	5.7
Eu	0.87	0.88	0.53	1.93	0.68	2.79	1.78	2.82	2.99	2.24	2.7
Gd	3.17	3.09	2.03	6.37	2.3	8.79	7.48	7.99	8.83	6.9	9.02
Tb	0.55	0.48	0.33	1.12	0.4	1.29	1.3	1.21	1.21	1.04	1.31
Dy	3.18	3.05	2.17	7.15	2.82	7.8	8.54	6.6	7.07	6.17	7.65
Y	18.8	17.5	12.5	37.7	13.3	37.1	44.3	32.7	33.1	28.9	37.3
Er	2.08	2.01	1.44	4.11	1.61	3.96	4.96	3.43	3.69	3.28	3.96
Yb	1.84	1.91	1.27	3.92	1.4	3.55	4.41	2.95	3.05	2.74	3.47
Lu	0.26	0.27	0.19	0.6	0.19	0.51	0.7	0.41	0.43	0.42	0.47

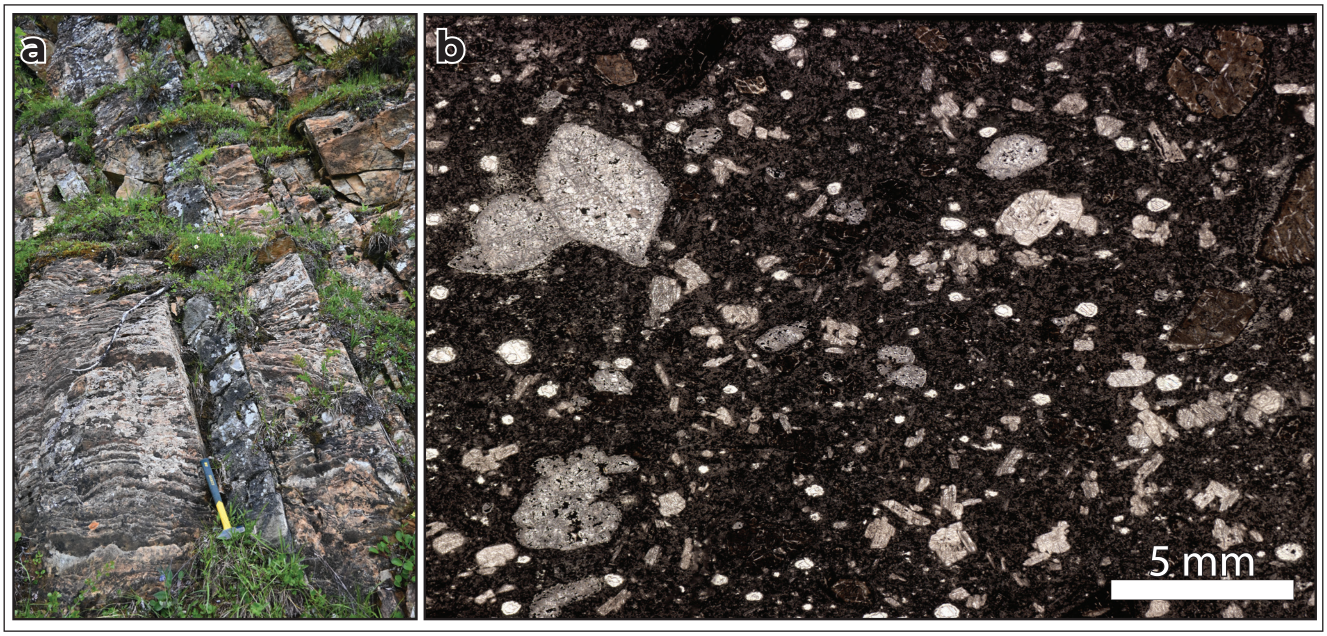


Figure 13. *(a)* *Field photograph and* ***(b)*** *thin section slide scan (PPL) of a medium-grey, 30 cm thick, intensely carbonate altered, porphyritic dike cutting Gillespie Lake Group dolostone.*

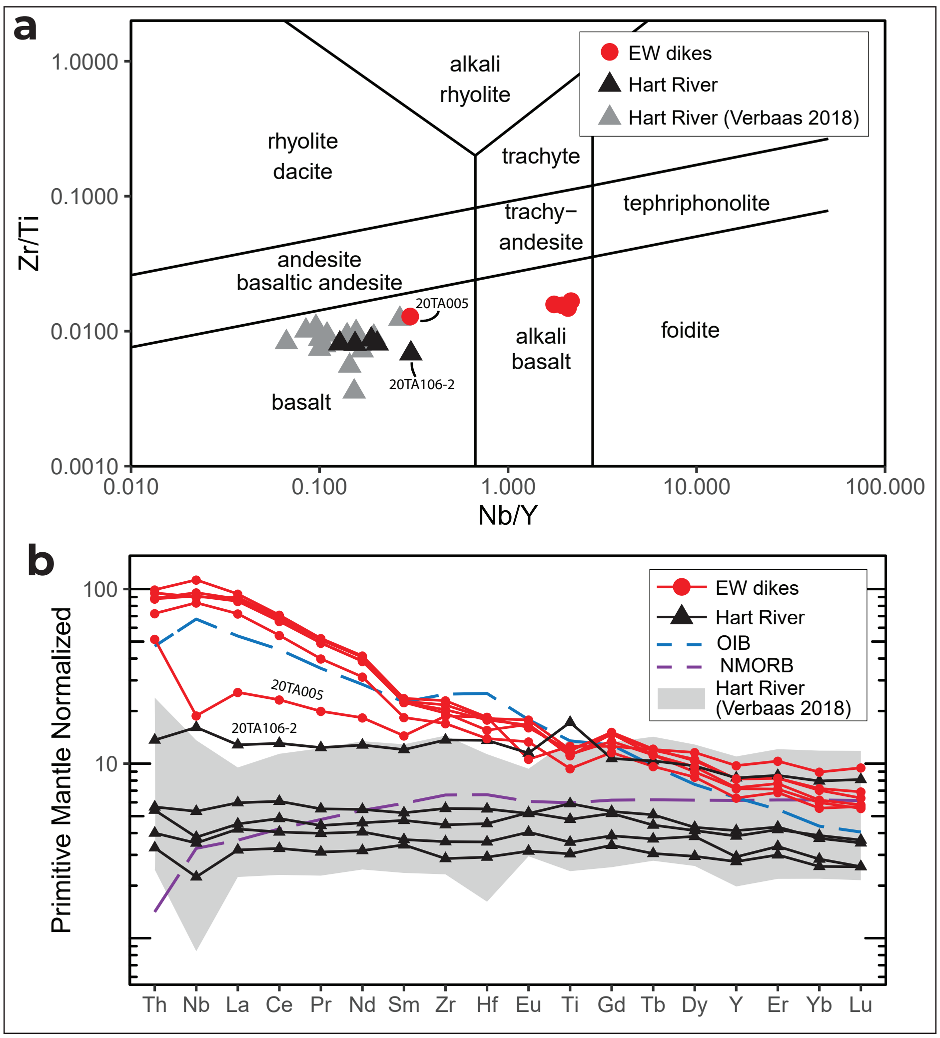


Figure 14. *Trace-element geochemical diagrams for Hart River sills and east-west striking dikes.* ***(a)*** *Modified Winchester and Floyd (1977) diagram of Pearce (1996). For comparison, samples from Verbaas et al. (2018) are plotted as grey triangles.* ***(b)*** *Immobile trace-element patterns normalized to primitive mantle values (Sun and McDonough, 1989). See text for discussion on samples 20TA005 and 20TA106-2 (labelled). The range of compositions of Hart River samples from Verbaas et al. (2018) is shown in grey. Values for ocean island basalt (OIB) and normal mid-ocean ridge basalt (N-MORB) are from Sun and McDonough (1989).*

Northwest-verging folding and thrusting

The dominant structures in the Wernecke Supergroup are oriented southwest-northeast (Fig. 15). Folds range from gentle to close and are generally upright, but locally inclined (Figs. 9a, 12b and 16). Folds are typically shallowly plunging and have steeply dipping axial planes (Fig. 15). Outcrop-scale folds are locally abundant, but generally uncommon in Wernecke Supergroup rocks (Fig. 15). A steeply dipping, northeast-southwest striking, penetrative cleavage is variably developed within the Quartet Group and silty intervals of the Gillespie Lake Group. Sedimentary structures, which are common in the Gillespie Lake Group, show that bedding is generally right way up and rarely overturned on the short limb of asymmetric folds.

The Wernecke Supergroup is imbricated by northwest-verging thrust faults (Figs. 3, 11, 16 and 17), consistent with fold orientations (Fig. 15). These thrusts place dark-weathering siliciclastic rocks of the Quartet Group over recessive carbonate and siliciclastic rocks of the Gillespie Lake Group (Figs. 11 and 17). Where exposed, the thrusts are bedding parallel and only evident from the repetition of stratigraphy. In each instance, a sill of Hart River gabbro intrudes the Quartet Group rocks 100–200 m above the thrust (Figs. 10, 15 and 17). As also demonstrated by Roots (1990) to the west, the Hart River sills do not cut the thrusts, suggesting that thrusting post dates the ca. 1380 Ma intrusions.

Northeast-southwest folding

The dominant structures in Pinguicula Group and younger rocks are oriented southeast-northwest (Fig. 15). A steeply dipping penetrative cleavage is variably developed in the Mount Landreville and Pass Mountain formations and Rapitan Group. Outcrop-scale folds are rare in Pinguicula Group rocks and not observed in younger rocks (Fig. 15; Ambrose and Bowie, 2020). Folds are typically gentle and upright, with a

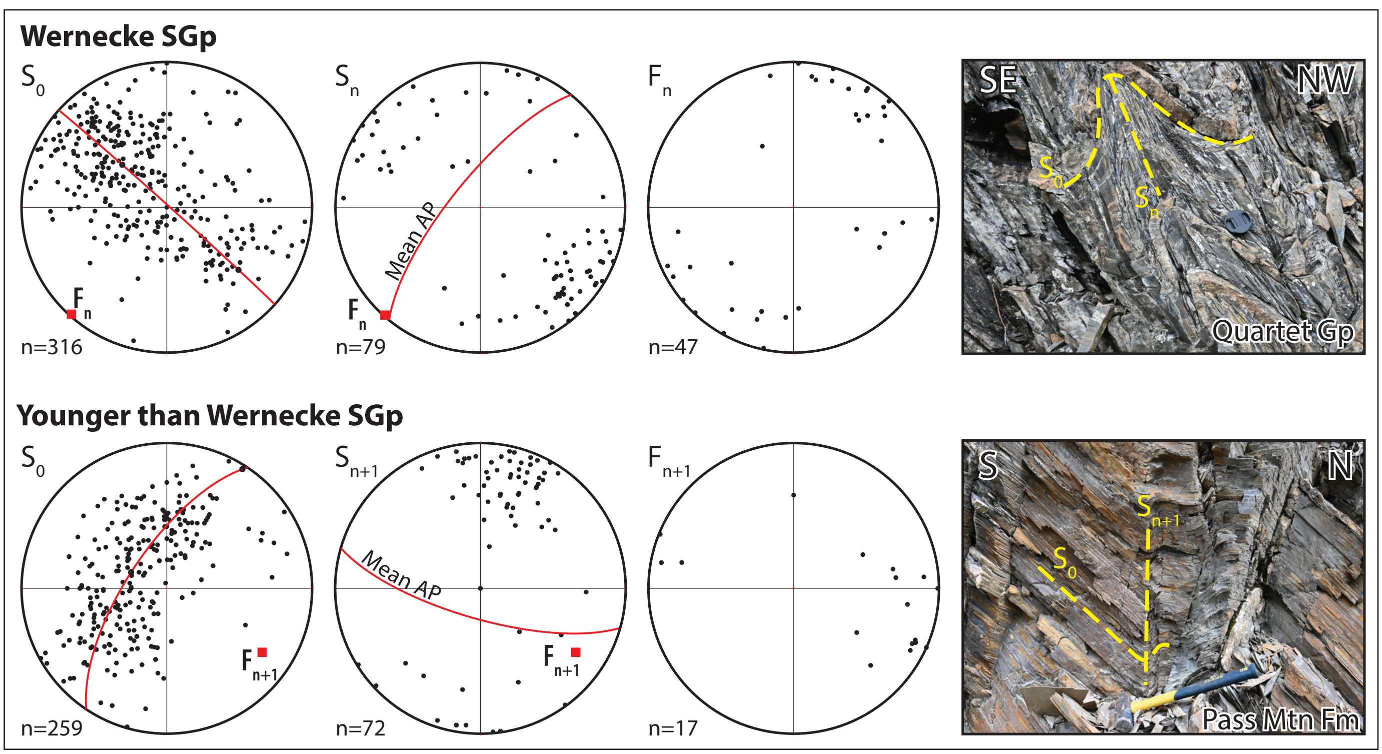


Figure 15. *Structural data plotted on lower hemisphere, equal area stereonets and examples of small-scale folds. Measurements and photo are split into two groups: Wernecke Supergroup and younger than Wernecke Supergroup. Top photograph is of Quartet Group siltstone, and bottom is of Pass Mountain Formation dolomitic limestone.*

mean fold axis that plunges gently to the southeast, and a mean axial plane that dips steeply to the southwest (Fig. 14), consistent with northeast-southwest directed shortening that is approximately perpendicular to the orientation of folding and thrusting in the older units (Fig. 14).

Late faulting

The map area is also cut by late, steeply dipping, strike-slip and normal faults (Fig. 3). A major, north-south striking, normal fault runs through the centre of the map area for ~30 km. In the south, this separates Mesoproterozoic Pinguicula Group rocks to the east from Neoproterozoic and Paleozoic rocks to the west. In the central part of the map area, near Rusty Mountain, the fault coincides with the Rackla River and separates the Wernecke Supergroup to the east from Pinguicula and Quartet group rocks to the west. In the northern part of the map area, where it roughly coincides with the North Rackla River, the fault separates the Gillespie Lake Group in the east from thrust imbricated Quartet Group, Gillespie Lake Group and Hart River suite rocks

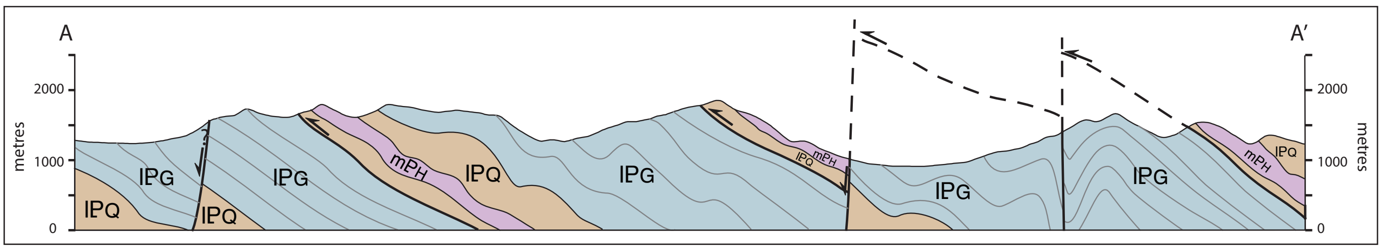


Figure 16. *Cross section illustrating structural and stratigraphic relationships. Location is indicated on Figure 3. See Figure 3 for legend.*

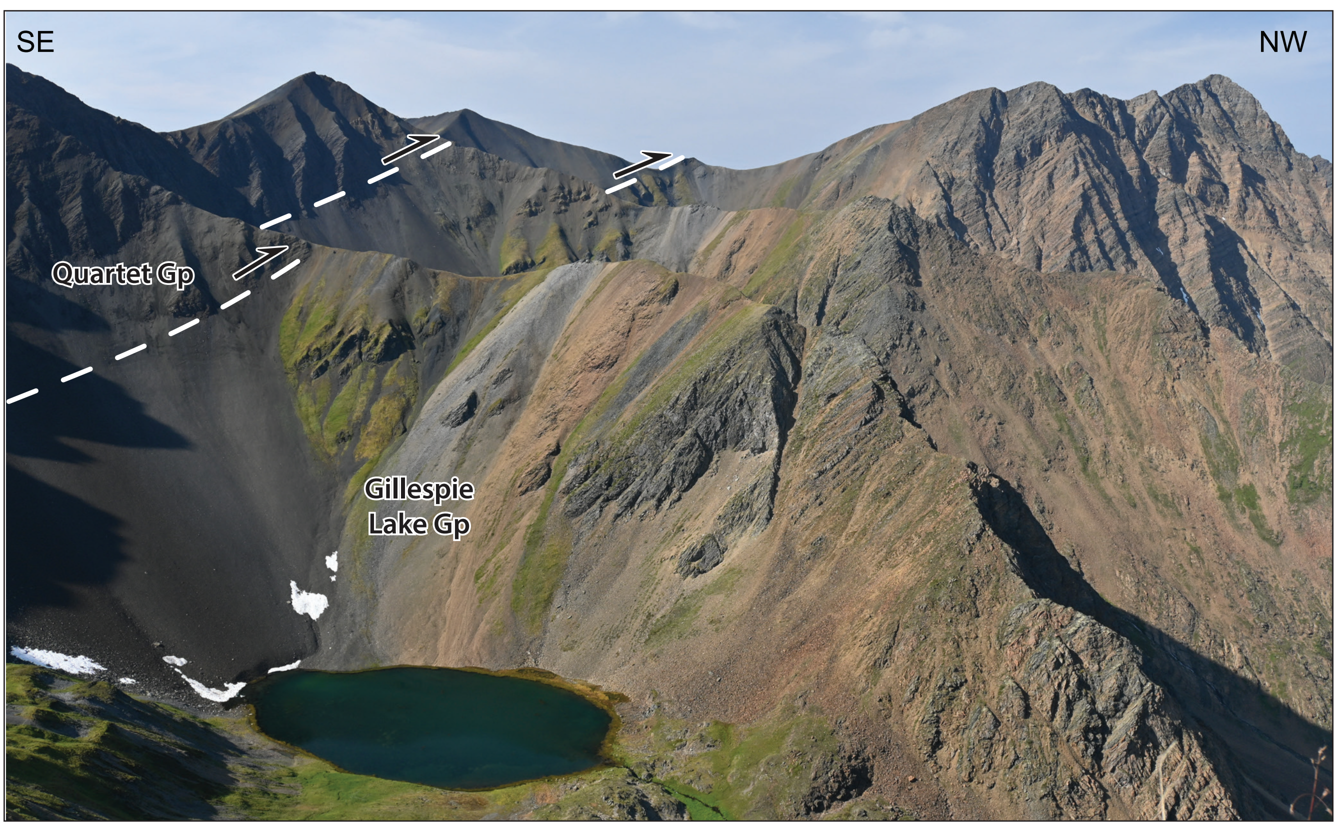


Figure 17. *Field photograph illustrating structural relationships in the northwest part of the map area. Quartet Group siliciclastic rocks thrust over recessive, mixed dolostone and siliciclastic rocks of the Gillespie Lake Group silty.*

to the west. Another major fault that runs east–west through the southern part of the map area separates the Mount Landreville and Pass Mountain formations to the north from younger rocks to the south.

Steeply dipping, northeast-southwest striking faults are common within the Gillespie Lake Group in the northeastern part of the map area (Fig. 3). The faults are highlighted by discrete breaks in bedding orientation and the offset of grey weathering intervals of siliciclastic rocks (Fig. 9a). These faults have a similar strike to the northwest-verging structures mapped west of the North Rackla River (Fig. 3).

Mineralization

The map area contains several notable mineral occurrences. The most significant mineralization is centred on the Vera (Yukon MINFILE 106C 083, 114 and 137–148), North Rackla (Yukon MINFILE 106C 088, 108 and 110–113), and “Val” (Yukon MINFILE 106C 085, 115–119, 131, 133–136, 149 and 150) occurrences (Fig. 3).

The main Vera occurrences comprise Pb-Zn-Ag mineralization hosted in red weathering, brecciated, stromatolitic and microbially laminated dolostone of the Gillespie Lake Group. Mineralization includes quartz-carbonate veins that contain massive and disseminated sphalerite, galena, chalcopyrite and tetrahedrite (Sivertz, 1985). Veins with Pb-Zn-Ag mineralization also occur within and adjacent to Hart River sills that intrude siliciclastic rocks of the Quartet Group (Kammerer and Eaton, 2011). Vera has a historical resource estimate of 392 667 t at 607.0 g/t Ag, 3.18% Pb and 3.47% Zn (Casselman, 2018).

As with the Vera occurrences, the most significant Pb-Zn-Ag mineralization at North Rackla occurs within the Gillespie Lake Group. Mineralization consists of a steeply dipping zone of massive sphalerite and galena within red-weathering stromatolitic and microbially laminated dolostone. The mineralized zone is adjacent to an interval of darker weathering dolomitic siltstones and mudstones, such as those shown in Fig. 9a.

A collection of Pb-Zn-Ag occurrences, commonly referred to as Val, lie to the south of Rusty Mountain (Fig. 3). Mineralization at the main group of Val occurrences (near the Big Red zone; Yukon MINFILE 106C 115) consists primarily of massive and disseminated sphalerite, galena and tetrahedrite within breccia zones and sparry dolomite veins of the Rubble Creek Formation (Sivertz, 1980; Kammerer and Eaton, 2011). To the north, at the Siltstone occurrence (Yukon MINFILE 106C 135), sphalerite, galena, tetrahedrite and chalcopyrite occur within quartz-carbonate veins that cut fine-grained siliciclastic rocks of the Mount Landreville Formation. Val has a historical resource estimate of 19 964 t at 1029 g/t Ag, 26.7% Pb and 7.3% Zn (Casselman, 2018).

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