Update on the bedrock geology of the Rusty Mountain and Bonnet Plume Pass (west half) areas

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Abstract

The Rusty Mountain and Bonnet Plume Pass areas are underlain by sedimentary strata of the Paleoproterozoic Gillespie Lake Group, Mesoproterozoic Pinguicula Group, Neoproterozoic Hematite Creek Group and Windermere Supergroup, and Paleozoic Bouvette Formation. Gabbro and diorite of the ca. 1.38 Ga Hart River sills intrude the Gillespie Lake Group. A swarm of east-west striking, mafic dikes intrude strata as young as the Tonian Hematite Creek Group. The main structures in the area include a steeply dipping axial-planar cleavage and upright, gently plunging folds. The northwestern part of the map area is dominated by northeast-southwest oriented structures that affected the ca. 1 Ga Hematite Creek Group, but predate deposition of the ca. 780 Ma Callison Lake Formation (Windermere Supergroup). In the southern and northeastern parts of the map area, the structures are parallel to and likely related to younger Mesozoic–Cenozoic structures.

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Introduction

Paleo and Mesoproterozoic rocks in the northern Cordillera are exposed in a series of erosional inliers surrounded by younger Neoproterozoic and Paleozoic rocks. The inliers are located along the southern margin of the Yukon stable block, a triangular region of isostatically independent and relatively thick lithosphere bounded by the Dawson fault to the south, the Yukon fault to the north, and the Richardson fault array to the east (Jeletsky, 1962; Abbott, 1997; Norris, 1997; Estève et al., 2020; Colpron et al., 2016).

This paper presents an update on the bedrock geology of the Rusty Mountain (106C/5) and Bonnet Plume Pass (106C/6; west half) areas as well as parts of adjacent map sheets 106C/3, 4, 11, 12 and 106D/1, 8. This report is a companion to the open file geological map of Ambrose (2022). The area is located at the southeast margin of the Wernecke inlier, the largest and farthest east of several inliers that span from Alaska to eastern Yukon (Fig. 1). Strata exposed in the area includes rocks as old as the Paleoproterozoic Gillespie Lake Group and as young as the Cambrian–Devonian Bouvette Formation (Figs. 2 and 3). The goal of this project is to refine structural and stratigraphic relationships and to provide geological context for mineral occurrences in the area. The new map expands to the north and east of the area previously mapped by Ambrose (2020). A summary of previous work in the area is provided by Ambrose and Bowie (2020) and Ambrose (2021). The interpretations presented here revise and supersede the reports of Ambrose and Bowie (2020) and Ambrose (2021), and the map of Ambrose (2020).

Stratigraphy

Gillespie Lake Group

The Gillespie Lake Group (Delaney, 1981) is the uppermost unit of the Paleoproterozoic Wernecke Supergroup and the oldest unit exposed in the map area (Fig. 3). It is dominated by orange, red, buff and grey weathering, thin to thick-bedded, variably silty, resistant (cliff-forming) dolostone (Fig. 4a–c). Microbial laminations are common, and stromatolites are locally abundant (Ambrose, 2021). Silicification is pervasive, particularly in the coarse-grained beds (Fig 4a). Common sedimentary structures include wavy cross-lamination (Fig. 4b) and desiccation cracks. Some beds contain evidence for soft-sediment deformation structures, most commonly intraformational breccias and slump folds. Medium to thickly bedded nodular dolostone and limestone form intervals up to 100 m thick. Beds of silicified oolitic grainstone and less commonly chert are locally found.

In addition to the typical cliff-forming dolostone, the Gillespie Lake Group also includes fine-grained siliciclastic rocks. Resistant intervals up to ~100 m thick of blue, green and grey weathering, variably calcareous/dolomitic siltstone and fine-grained sandstone are well exposed in cliff faces (see Fig. 9 in Ambrose, 2021). Recessive packages of mixed siliciclastic and carbonate rocks up to ~2 km thick occur throughout the Gillespie Lake Group (Figs. 3 and 4d,e). These intervals include both carbonate and siliciclastic dominated sections that are gradational with one another. The carbonate is primarily grey, tan, brown and orange weathering, laminated to thinly bedded, variably silty dolostone. Planar, wavy, and cross-laminations are common. Stromatolites and microbial laminations occur locally in some thicker dolostone beds. Though less abundant, the proportion of limestone in these intervals is higher than typical of Gillespie Lake Group. Siliciclastic rocks consist of laminated to medium-bedded, variably dolomitic-calcareous and carbonaceous, grey, black and orange weathering shale, mudstone, siltstone and fine-grained sandstone (Fig. 4d). A thick siliciclastic-dominated package is commonly present immediately beneath the sub-Pinguicula unconformity (Fig. 2).

Ambrose (2021) incorrectly interpreted the transition from recessive siliciclastic to carbonate rocks to be the gradational contact between the Quartet and Gillespie Lake groups, which required that the stratigraphy was repeated by northwest verging thrust faults. This implies that the Gillespie Lake Group is considerably thicker in the area than the >2 km and ~1.2 km estimates of Ambrose (2020) and Mustard et al. (1990), respectively. The revised thickness estimate for the map area is >5 km, which is more consistent with the >4 km estimate of Delaney (1981) and 4.7 km thick estimate of Thorkelson (2000) to the north.

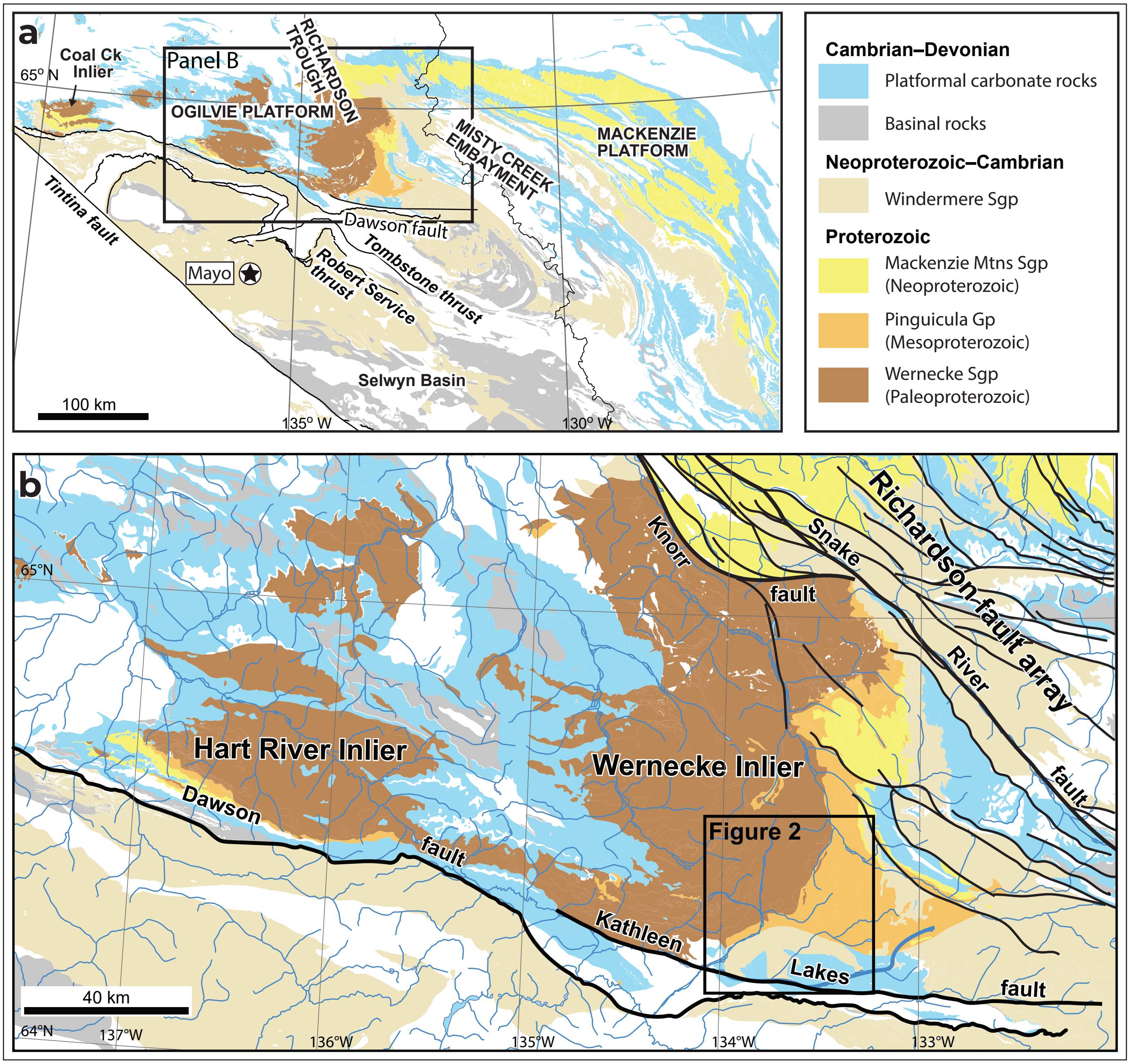

*Figure 1. **(a)** Simplified geological maps showing the distribution of Proterozoic strata in Yukon and Northwest Territories (after Moynihan et al., 2019). **(b)** Simplified geological map (extent outlined in (**a**)) of the Hart River and Wernecke Inliers. The study area (extent outlined in b) is located at the southeast margin of the Wernecke inlier, the largest and farthest east of several erosional windows that expose Paleo and Mesoproterozoic strata. Same legend is used for both figures. White areas are Late Devonian and younger rocks. Geology from Yukon Geological Survey (2021).*

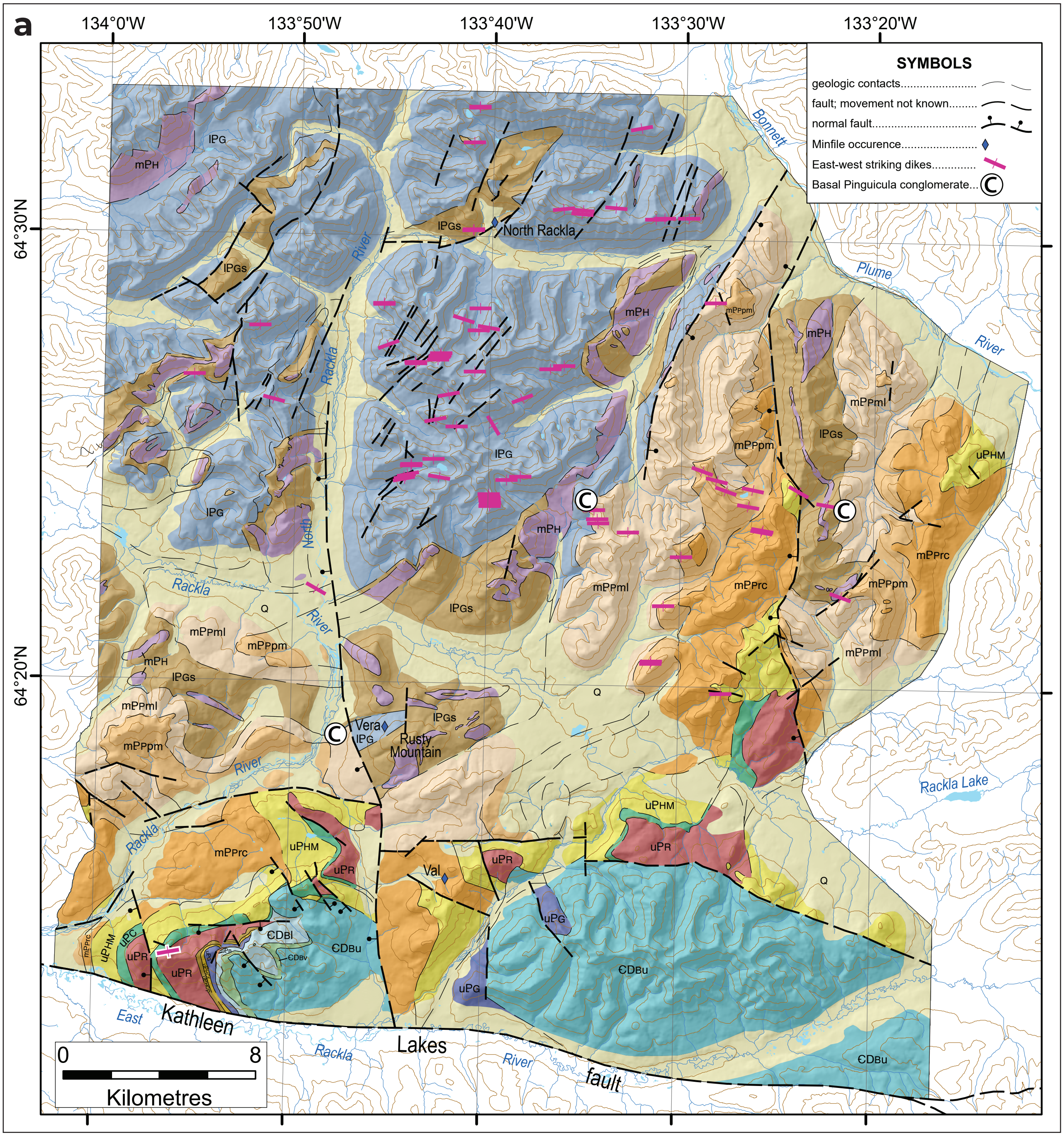

Figure 2. ***(a)*** *Simplified geological map of the study area after Ambrose (2022). Three localities where basal Pinguicula sandstone/conglomerate were observed are indicated. Legend (Fig. 2b) on facing page.*

b QUATERNARY

Q — unconsolidated alluvial, colluvial, fluvial, and glacial deposits

CAMBRIAN TO DEVONIAN

BOUVETTE FORMATION

ЄDBu — UPPER MEMBER: light to medium grey weathering dolostone; commonly thickly bedded; locally fossiliferous

ЄDBv — VOLCANICLASTIC MEMBER: grey, green and orange weathering volcaniclastic sandstone and conglomerate; locally fossiliferous

ЄDBl — LOWER MEMBER: light to medium grey weathering sugary dolostone

EDIACARAN

RACKLA GROUP

uPB — BLUEFLOWER FORMATION: brown weathering shale and siltstone

uPG — GAMETRAIL FORMATION: Well bedded and laminated grey, buff, maroon, yellow-orange, and green weathering silty lime and dolo-mudstone

CRYOGENIAN–EDIACARAN

HAY CREEK GROUP

uPHCr — RAVENSTHROAT FORMATION: grey and cream weathering dolostone, grey and black chert; local chaotic bedding and tepee structures

uPHCp — MOUNT PROFEIT DOLOSTONE/ICE BROOK FORMATION: grey and cream weathering dolostone; light-grey weathered carbonate-clast diamictite

CRYOGENIAN

RAPITAN GROUP

uPR — orange, maroon, and brown weathering clast to matrix-supported diamictite; maroon and green weathering shale, siltstone and sandstone intervals

TONIAN

CALLISON LAKE FORMATION

uPC — light to medium grey weathering dolostone with irregular chert layers; commonly laminated; locally silica replaced oolitic grainstone; locally hematite-cement conglomerate

NEOPROTEROZOIC

HEMATITE CREEK GROUP

uPHM — laminated, medium to very thickly bedded grey, purple, and orange weathering sandstone, with subordinate shale, siltstone, limestone, red-weathering stromatolitic dolostone, and orange-weathering dolostone and dolomitic siltstone

MESOPROTEROZOIC

PINGUICULA GROUP

mPPrc — RUBBLE CREEK FORMATION: dark and light grey laminated dolostone with local zebra textures

mPPpm — PASS MOUNTAIN FORMATION: well bedded, laminated, grey and orange weathering dolomitic limestone; commonly cross-laminated; minor dolomitic/calcareous shale at base

mPPml — MOUNT LANDREVILLE FORMATION: blue, brown and green-grey weathering shale, mudstone, siltstone and fine-grained sandstone; locally interbedded sandstone and conglomerate at base

HART RIVER SILLS

mPH — grey weathering, fine to medium-grained, greenish-grey gabbro sills and dikes

PALEOPROTEROZOIC

GILLESPIE LAKE GROUP

lPG — resistant, thin to thick bedded, orange, red, and grey weathering variably silty dolostone; minor intervals of recessive cream, orange, and grey weathering siltstone, dolomitic silstone, silty dolostone, and lime mudstone; intervals of resistant, grey, orange and brown weathering, variably dolomitic siltstone and fine-grained sandstone

lPGs — grey, brown, black, and terracotta-weathered shale, siltstone and fine-grained sandstone; locally phyllitic and slatey; minor thin to medium bedded carbonate

Figure 2. (b) *Simplified legend.*

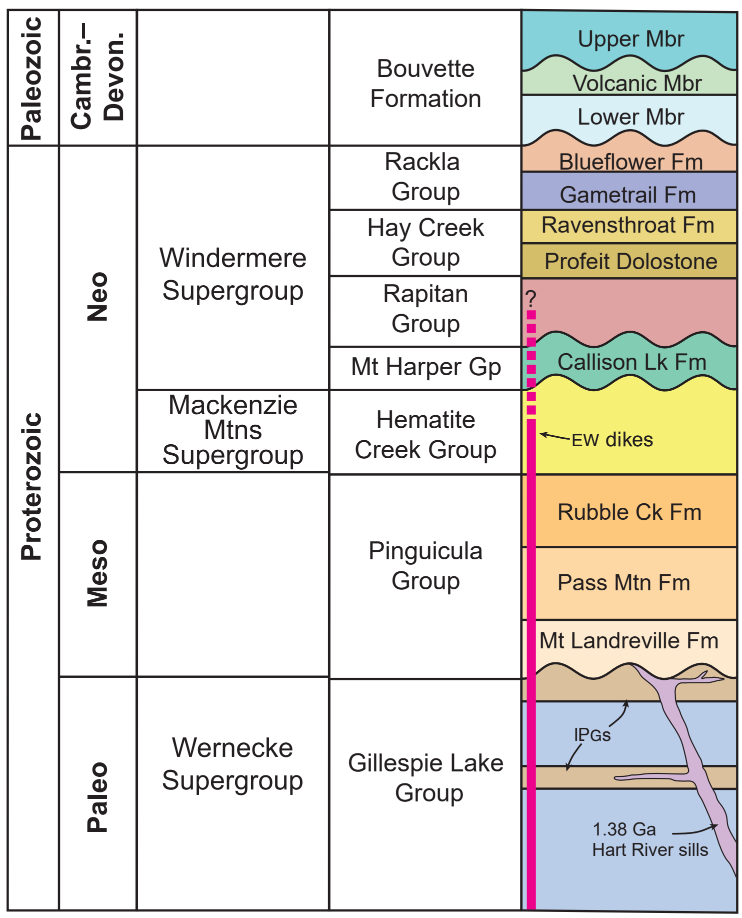

Figure 3. *Schematic lithostratigraphic column of units exposed in the map area. The east-west striking dikes intrude strata at least as young as the Tonian Hematite Creek Group; a single mafic dike in the southwestern part of the map area intrudes the Rapitan Group and suggests this suite may be younger than Cryogenian. Mbr: Member, Fm: Formation, Gp: Group, lPGs: fine-grained siliciclastic strata.*

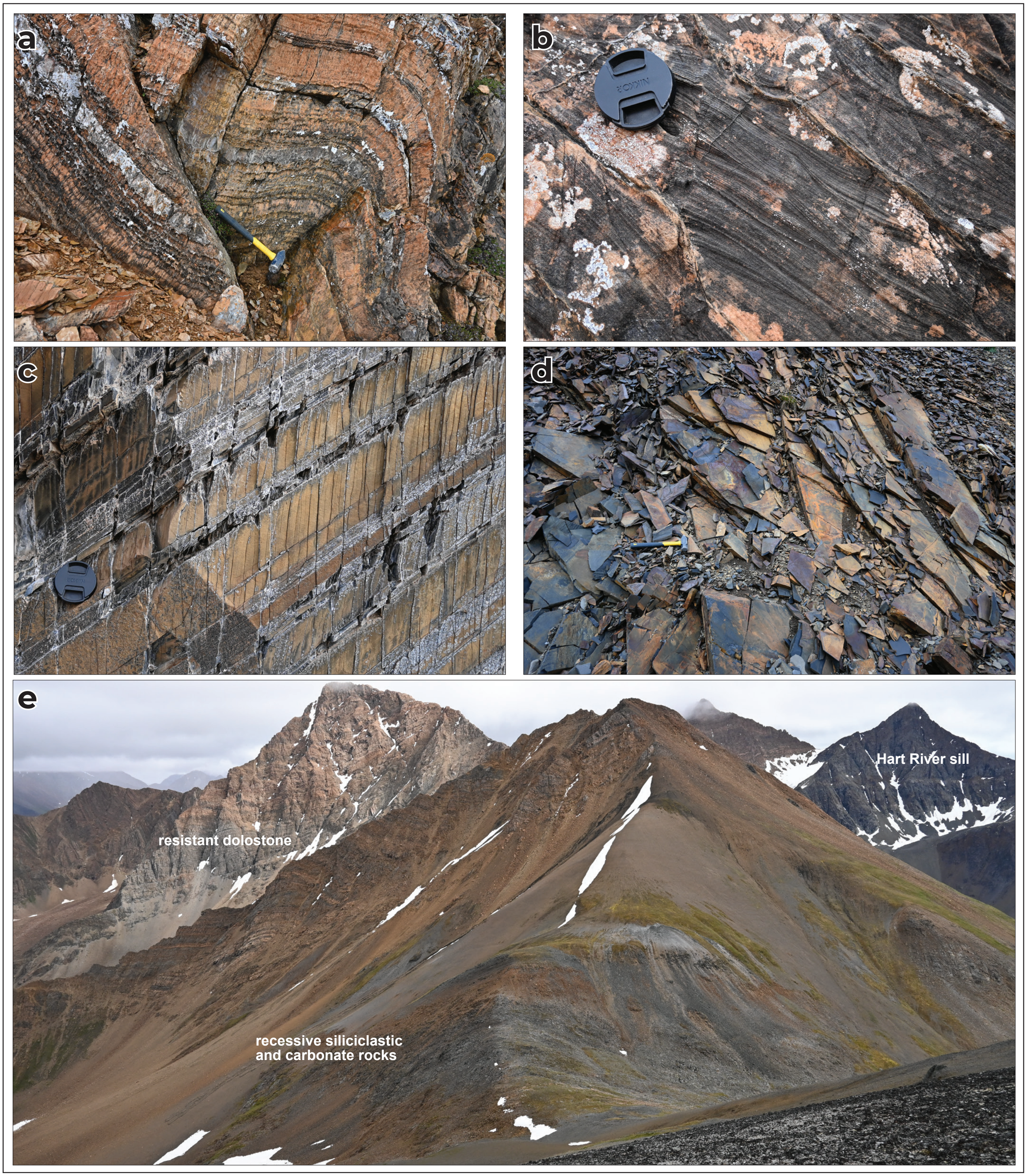

Figure 4. *Field photographs of the Gillespie Lake Group.* ***(a)*** *Minor fold in silicified dolostone. View to northeast.* ***(b)*** *Cross-laminated dolograinstone.* ***(c)*** *Vertical cleavage in dolograinstone-mudstone. View to north.* ***(d)*** *Rusty weathering carbonaceous siltstone and fine-grained sandstone from a siliciclastic interval.* ***(e)*** *Recessive, brown weathering dolomudstone and grey weathering siltstone interval (~100 m thick) below red weathering dolostone cliffs.*

Pinguicula Group

Mount Landreville Formation

The Mount Landreville Formation (Medig *et al.*, 2016; Pinguicula A of Eisbacher, 1978, 1981) is the lowermost unit of the Mesoproterozoic Pinguicula Group and overlies the Gillespie Lake Group and Hart River sills with angular unconformity (Figs. 2, 3 and 5a,b). It consists primarily of laminated to medium-bedded, grey, brown, blue, and green weathering mudstone, shale, siltstone and fine-grained sandstone (Fig. 5b). Planar parallel laminations are common (Fig. 5b). Wavy and cross-laminations are rare. A pencil cleavage is locally developed.

An interval of interbedded sandstone and conglomerate up to ~50 m thick locally marks the base of the unit (Figs. 2 and 5d,e). The sandstone is grey to brown weathering, thin to medium bedded, and fine to medium grained. The conglomerate is matrix to clast supported with granule to pebble-sized clasts of siltstone, sandstone, chert and carbonate. Where the basal conglomerate is absent, the Mount Landreville Formation can be difficult to distinguish from fine-grained siliciclastic rocks of the Gillespie Lake Group. The presence (or lack) of Hart River sills, which intrude the Gillespie Lake Group but not the Pinguicula Group, help to discriminate between the two units.

The appearance of interbedded brown and grey weathering carbonate rocks and increasingly calcareous siliciclastic rocks near the top of the Mount Landreville Formation indicate transition to the overlying Pass Mountain Formation. This upper section can resemble the recessive mixed siliciclastic-carbonate packages of the Gillespie Lake Group. The Mount Landreville Formation is up to ~2 km thick in the map area, which is considerably thicker than the ~300 m thickness measured at the type section by Medig *et al.* (2016) 40 km to the north. The monotonous nature, lack of marker horizons, and structural complexity, however, make it difficult to reliably estimate the thickness.

Pass Mountain Formation

The Pass Mountain Formation (Medig *et al.*, 2016; Pinguicula B of Eisbacher, 1978, 1981) is the middle unit of the Mesoproterozoic Pinguicula Group and gradationally overlies the Mount Landreville Formation (Figs. 3 and 6a; Medig *et al.* 2016). The basal ~50 m of the unit consists of thinly interbedded brown weathering carbonate rocks and calcareous–dolomitic siltstone (Fig. 6b). Following the definition of Medig *et al.* (2016), the basal contact is placed where carbonate rocks become dominant (*i.e.*, >50%). The proportion of siliciclastic minerals decreases upsection and the remaining ~500 m of the unit consist of thin to medium-bedded, bright orange to grey weathering, dolomitic limestone and calcareous dolostone (Fig. 6c–e). Parallel planar to wavy laminations and cross-laminations (including hummocky and swaley in places) are common (Fig. 6e). Intraformational breccia and slump folds are evidence of soft-sediment deformation in some beds. The total thickness of the Pass Mountain Formation is ~550 m in the study area. The type section, located ~15 km to the north of the map area, is estimated to be >500 m thick (Medig *et al.*, 2016). Twenty-five kilometres northeast of the type section, the unit is estimated to be only 150 m thick.

Rubble Creek Formation

The Rubble Creek Formation (Medig *et al.*, 2016; Pinguicula C of Eisbacher, 1978, 1981) is the uppermost unit of the Mesoproterozoic Pinguicula Group (Fig. 4; Medig *et al.*, 2016). The contact with the underlying Pass Mountain Formation is abrupt. The base of the unit typically consists of several tens of metres of thinly bedded to massive, light to medium grey weathering, dark grey lime mudstone with abundant white calcite veins. This passes upsection into thin to medium-bedded, light and dark grey pinstriped, locally fetid, dark grey to black dolostone (Fig. 7a,b). Trough cross-laminations are rare.

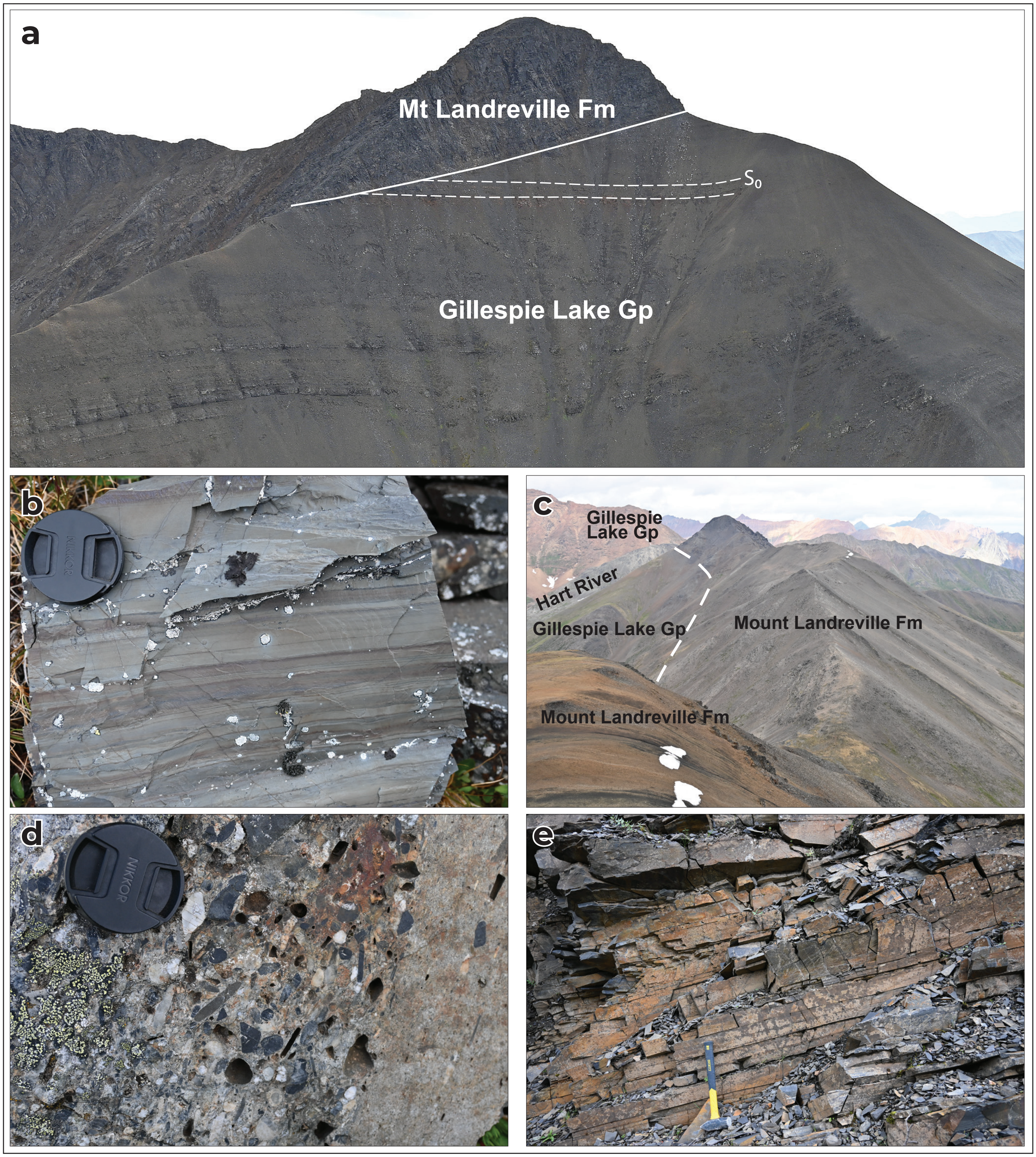

Figure 5. *Field photographs of the Mount Landreville Formation, Pinguicula Group.* ***(a)*** *Angular unconformity between siliciclastic strata of the Mount Landreville Formation and recessive silty dolostone and dolomitic/calcareous siltstone of the Gillespie Lake Group. Bottom ~50 m of Mount Landreville formation consists of interbedded sandstone and conglomerate.* ***(b)*** *Green-grey weathering laminated siltstone.* ***(c)*** *Orange and grey weathering shale, siltstone and fine-grained sandstone of the Mount Landreville Formation overlying recessive, silty dolostone of the Gillespie Lake Group. In top left of photo is red dolostone of the Gillespie Lake Group intruded by grey Hart River gabbro.* ***(d)*** *Basal conglomerate with clasts of chert and siltstone.* ***(e)*** *Basal, thin to medium-bedded sandstone.*

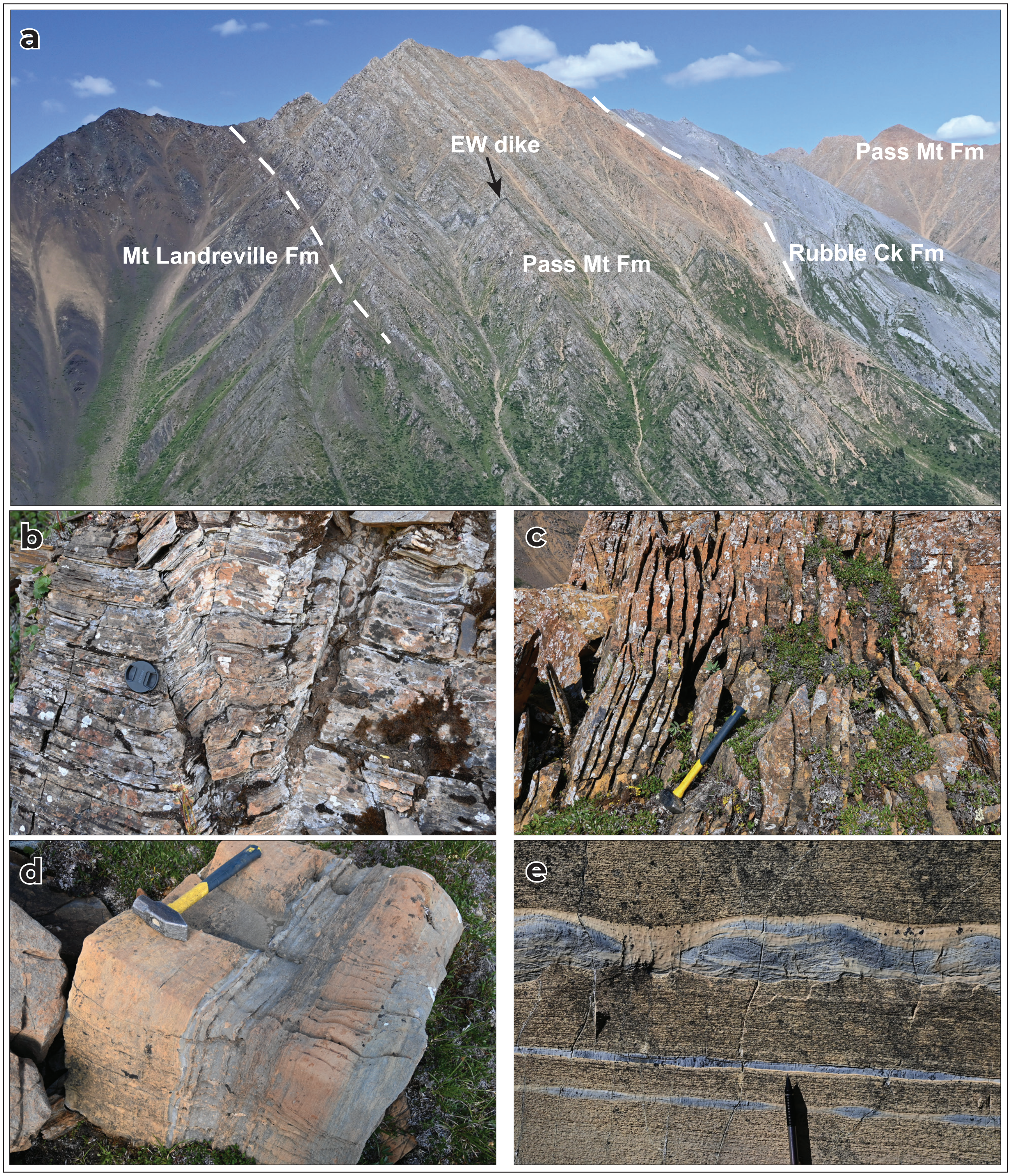

Figure 6. *Field photographs of the Pass Mountain Formation, Pinguicula Group.* ***(a)*** *A complete section of the Pass Mountain formation exposed on the flank of a syncline cored by the Rubble Creek Formation. View to north. Horizontal distance between upper and lower contacts is ~700 m.* ***(b)*** *Thinly bedded silty dolostone near the contact with the underlying Mount Landreville Formation. Fold plunges shallowly to the northeast. Located near the western boundary of the northeastern structural domain. View to northeast.* ***(c)*** *Steeply dipping cleavage in dolomitic limestone of the Pass Mountain Formation in the northeastern structural domain. View to north-northwest.* ***(d)*** *Interbedded orange-weathering dolomitic limestone and grey-weathering limestone.* ***(e)*** *Orange and grey weathering, planar and hummocky-swaley cross-laminated, dolomitic limestone.*

The dolostone is commonly replaced by millimetre to centimetre-scale bands of white and orange weathering sparry dolomite that occur as parallel to *en échelon* arrays described as zebra texture (Ambrose and Bowie, 2020). Brecciation, with a sparry dolomite matrix, and carbonate veining is locally extensive (Fig. 7c). In the northeastern part of the map area, the Rubble Creek Formation contains a discontinuous interval up to several hundred metres thick of recessive, grey and brown weathering limestone with interbedded dark weathering shale and siltstone (Fig. 7d,e). This interval also includes some beds of pinstriped dolostone with zebra texture more characteristic of Rubble Creek Formation. Microbial laminations are present in some beds.

The uppermost ~50 m of the Rubble Creek Formation consists of tan, orange and pink weathering laminated dolostone with sparse dark grey to black chert nodules. Intraformational brecciation (Fig. 7f), along with the anomalous weathering, may reflect subaerial exposure and karst development. The recognition of a karst surface to the north of the map area prompted Thorkelson (2000) to separate the Hematite Creek Group (Pinguicula D–F of Eisbacher, 1978, 1981) from the Pinguicula Group.

The Rubble Creek Formation is up to ~1500 m thick in the map area, but its thickness is regionally variable. At its type section, located 30 km northeast of the map area, the Rubble Creek Formation is 590 m thick (Medig et *al*., 2016). However, 5 km north of the type section, Thorkelson (2000) estimated a thickness of more than the 1800 m.

Hematite Creek Group

The Rubble Creek Formation is overlain by carbonate and siliciclastic rocks of the Tonian Hematite Creek Group (Figs. 2, 3 and 8; Thorkelson, 2000; Turner, 2011). The basal contact appears sharp in places but gradational elsewhere. Locally, grey weathering pinstriped dolostone that resembles the Rubble Creek Formation occurs interbedded with orange dolostone near the base of the unit. The orientation of bedding across the contact is parallel and throughout the map area the Hematite Creek Group always overlies the Rubble Creek Formation. However, in places the contact appears abrupt, consistent with evidence for subaerial exposure of the uppermost Rubble Creek Formation.

The Hematite Creek Group is stratigraphically complex in the map area. In the northeastern part of the map area, where it is well exposed, the basal section of the unit consists of ~200 m of interlayered orange weathering, variably silty dolostone, dark grey to black shale and siltstone, and grey to orange weathering sandstone (Fig. 8a,b). This transitions upsection into variable proportions of: 1) thin to medium-bedded tan, cream, orange and grey weathering, variably silty, laminated dolostone with locally abundant dark grey chert nodules (Fig. 8c), 2) very thin to medium-bedded, grey weathering, laminated limestone (Fig. 8d,e), 3) grey, and less commonly orange and purplish/pinkish weathering sandstone (Fig. 8b) and 4) grey and maroon weathering siltstone and shale with rare beds of conspicuous red weathering stromatolitic dolostone (Fig. 8f). Sandstone, which is characteristic of the unit, is more abundant in the southwestern part of the map area where it forms intervals up to several hundred metres thick (Ambrose and Bowie, 2020). Microbial laminations, cross-laminations (Fig. 8e), and mud cracks (Fig. 8g) are present in some carbonate beds. Siliciclastic and carbonate conglomerate/breccia layers, with clast sizes from granule to pebble, are found locally (Fig. 8h).

Windermere Supergroup

The Neoproterozoic Windermere Supergroup lies with angular unconformity over older strata of the Hematite Creek and Pinguicula groups. In the map area, the Windermere Supergroup includes the Callison Lake Formation and the Rapitan, Hay Creek and Rackla groups. Only the Callison Lake Formation and Rapitan Group are exposed in the area mapped in 2021. Ambrose and Bowie (2020) previously described the Hay Creek and Rackla group rocks that are exposed in the southwestern part of the map area.

Figure 7. *Field photographs of the Rubble Creek Formation.* ***(a-b)*** *Thinly bedded pinstriped dolostone.* ***(c)*** *Veined and brecciated dolostone.* ***(d)*** *Recessive, brown weathering, lime mudstone with fold highlighted by relatively resistant limestone beds. View to northeast.* ***(e)*** *Recessive, brown weathering, lime mudstone interval beneath cliffs of grey weathering pinstriped dolostone more typical of the unit. Lighting accentuates two east-west striking dikes in the foreground. Northeastern part of the map area, looking south.* ***(f)*** *Brecciated, pale tan-weathering dolostone near the contact with the overlying Hematite Creek Group.*

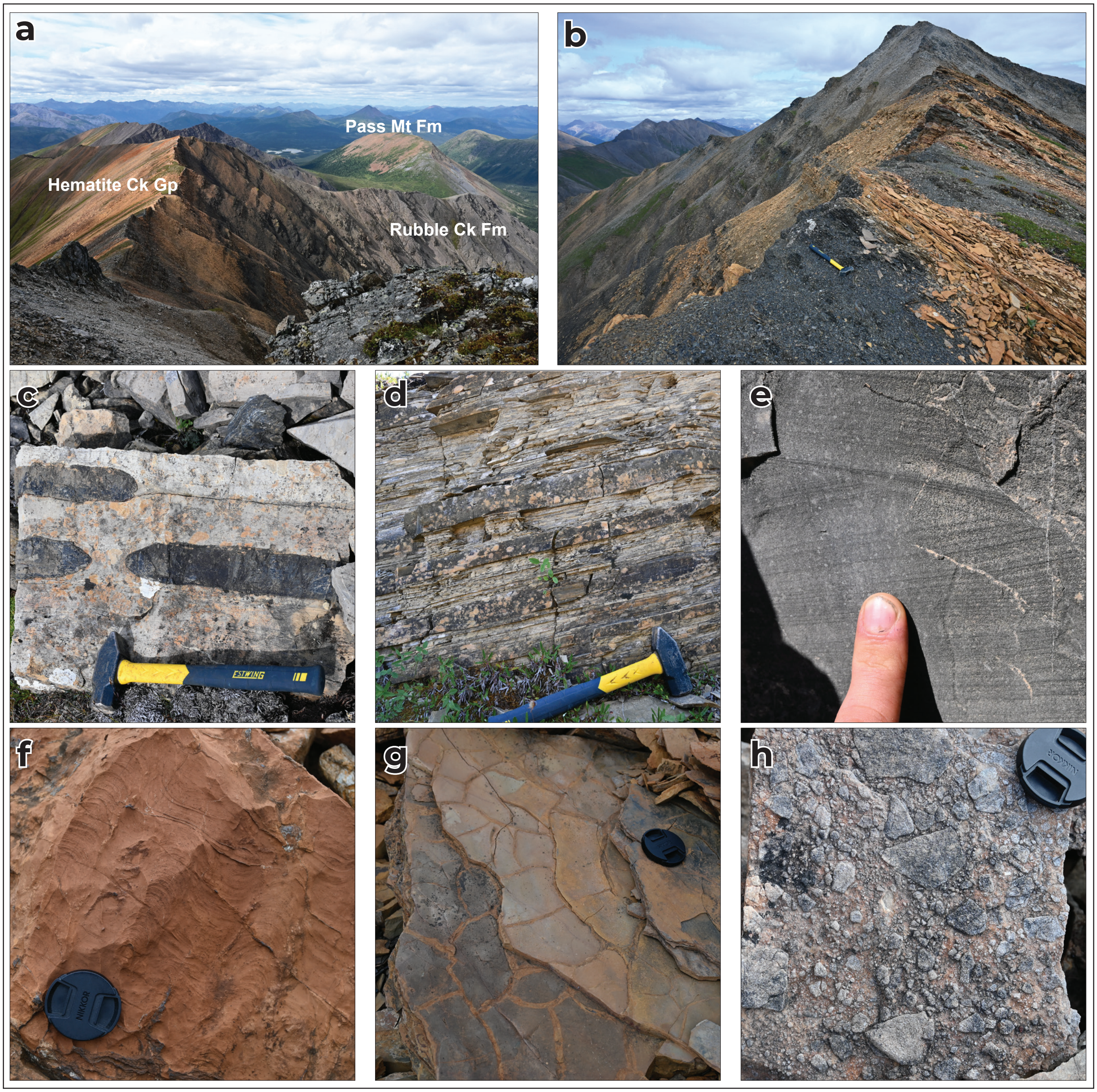

Figure 8. *Field photographs of the Hematite Creek Group.* ***(a)*** *Interbedded orange-weathering silty dolostone and black shale/siltstone of the Hematite Creek Group overlying grey-weathering dolostone of the Rubble Creek Formation. Bottom of photo is grey-weathering sandstone of the Hematite Creek Group.* ***(b)*** *Interbedded orange weathering, silty dolostone and black shale. Peak in back is grey weathering sandstone.* ***(c)*** *Black chert nodules in cream weathering laminated dolostone.* ***(d)*** *Very thin to thinly bedded lime mudstone-grainstone.* ***(e)*** *Planar cross-laminated lime grainstone.* ***(f)*** *Orange weathering stromatolitic dolostone bed.* ***(g)*** *Mud cracks in orange-brown weathering thinly bedded dolostone.* ***(h)*** *Carbonate clast conglomerate with sandy dolostone matrix.*

Callison Lake Formation

The Tonian Callison Lake Formation (Abbott, 1997; Strauss *et al*., 2015) forms the base of the Windermere Supergroup in the area (Fig. 3). The base of the unit is angular unconformity that cuts down section from the Hematite Creek Group in the west to the Rubble Creek Formation in the east (Fig. 2). Ambrose and Bowie (2020) first described the Callison Lake Formation in the Wernecke inlier; previously, it had only been documented in the Coal Creek and Hart River inliers to the west.

The Callison Lake Formation consists of grey to cream weathering, thin to thickly bedded, commonly faintly laminated, cliff-forming dolostone with irregular discontinuous dark grey to black chert layers (Fig. 9a,e). Some dolostone beds exhibit faint, planar to wavy laminations. Silicified oolitic grainstone forms irregular pods and nodules tens of centimetres wide (Fig. 9b). Beds rarely consist of grey weathering dolowackestone–floatstone (Fig. 9c). Red weathering, hematite-cemented, carbonate-clast conglomerate/breccia is present at several localities across the map area (Fig. 9d).

Rapitan Group

The Cryogenian Rapitan Group (Yeo, 1978) overlies the Callison Lake Formation and Hematite Creek Group with angular unconformity. It consists of maroon, brown, and orange weathering, matrix to clast-supported conglomerate and diamictite, and maroon, orange, grey and green weathering shale, siltstone and fine-grained sandstone (Fig. 10). Clasts in the conglomerate/diamictite range from granule to boulder size and include carbonate, chert, jasper, siltstone, sandstone and rarely stromatolitic dolostone (Fig. 10c) and mafic volcanic rocks. Sandstone and siltstone beds are commonly laminated (Fig. 10b).

Bouvette Formation

The Cambrian to Devonian Bouvette Formation (Morrow, 1999) is the youngest unit in the map area (Fig. 3). It overlies the Windermere Supergroup and Hematite Creek Group with angular unconformity (Fig. 2). Based on observations in the southwestern part of the map area, Ambrose and Bowie (2020) and Ambrose (2020) divided the formation into three members. Only the upper member is exposed in the area mapped in 2021. The lower member consists of light grey weathering sucrosic dolostone and minor chert. The volcaniclastic member consists of up to 200 m of dark green, grey and orange weathering, thin to medium-bedded, volcaniclastic sandstone and conglomerate. It is composed of fragments of mafic volcanic rock and limestone in a carbonate matrix. Fossils are locally abundant and include graptolites, brachiopods, trilobites, sponges, crinoids, bryozoans and echinoids. An assessment of the fossil assemblage indicates a Middle Ordovician to Early Silurian age (Ambrose and Bowie, 2020).

The upper member consists of light grey weathering, thin to medium-bedded dolostone and minor limestone (Fig. 11). The base of the upper Bouvette is an angular unconformity that cuts down stratigraphic section from the volcanic member in the west to rocks as old as the Hematite Creek Group in the east (Fig. 2). In contrast to the lower member, fossils are locally abundant and include corals and gastropods. The fossil assemblage from a locality in the southwestern part of the map area indicates a Silurian age. In the absence of the volcaniclastic horizon and/or fossil assemblages, it is not always possible to distinguish the lower and upper members.

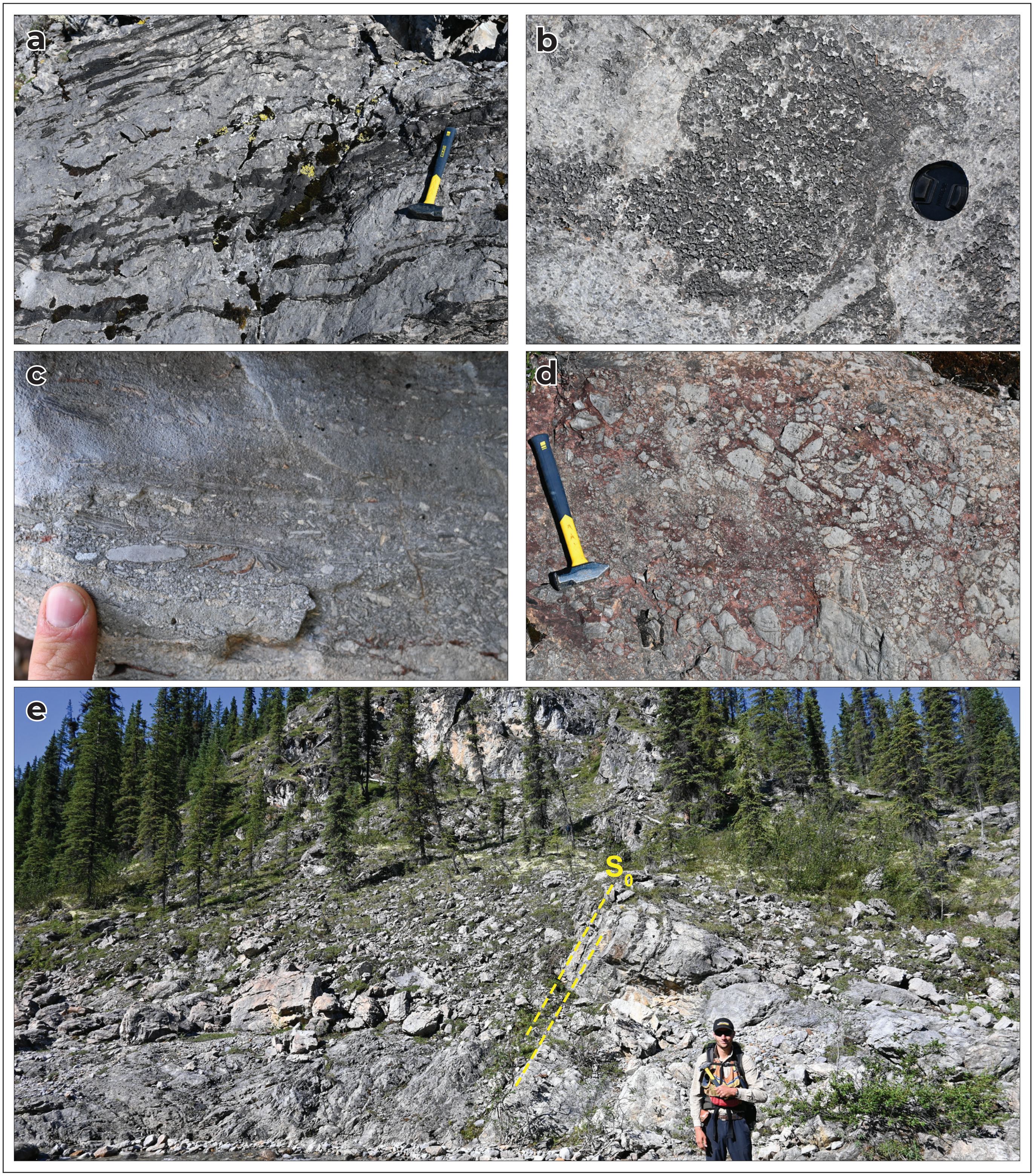

Figure 9. *Field photographs of the Callison Lake Formation.* ***(a)*** *Irregular black chert layers in light grey dolostone.* ***(b)*** *Silicified oolitic grainstone nodule.* ***(c)*** *Dolowackestone and floatstone layers.* ***(d)*** *Hematite cemented, carbonate-clast breccia.* ***(e)*** *Cliffs of Callison Lake Formation with bedding dipping steeply to the south. View to west.*

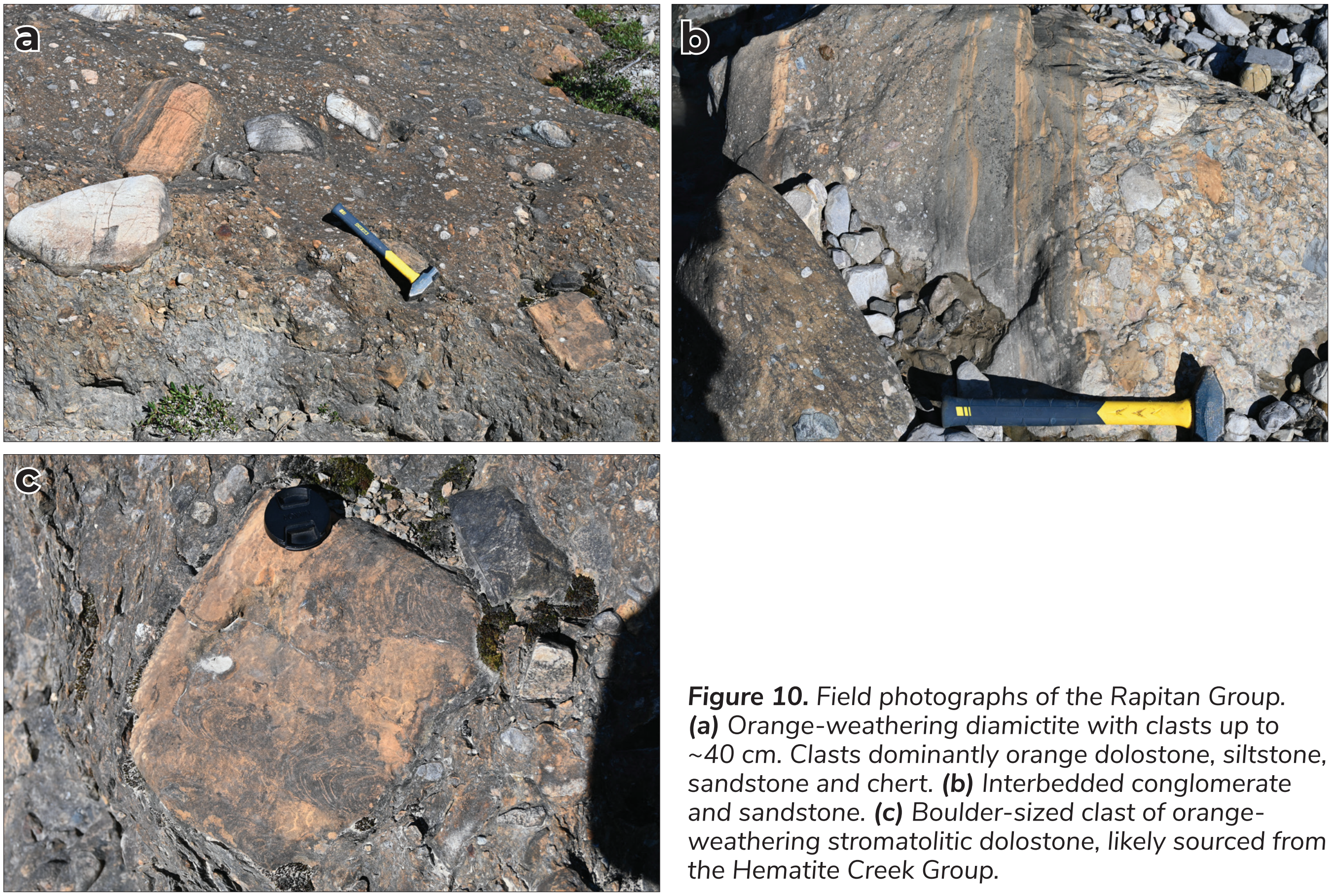

Figure 10. *Field photographs of the Rapitan Group.* ***(a)*** *Orange-weathering diamictite with clasts up to ~40 cm. Clasts dominantly orange dolostone, siltstone, sandstone and chert.* ***(b)*** *Interbedded conglomerate and sandstone.* ***(c)*** *Boulder-sized clast of orange-weathering stromatolitic dolostone, likely sourced from the Hematite Creek Group.*

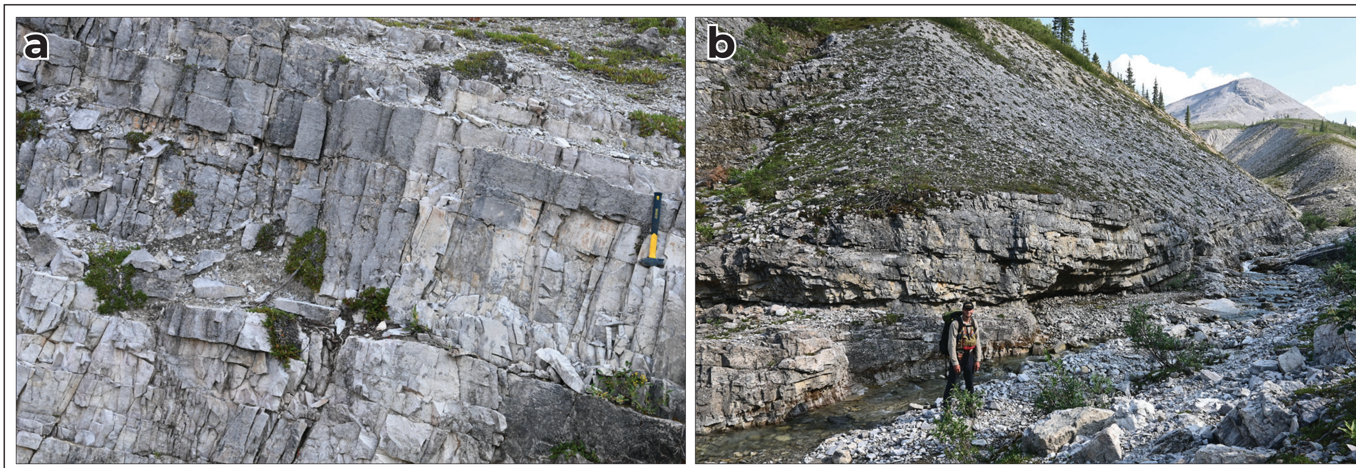

Figure 11. *Field photographs of the Bouvette Formation.* ***(a)*** *Medium-bedded, light grey dolostone.* ***(b)*** *Gently undulating, medium to thick-bedded dolostone.*

Intrusive Rocks

Hart River Sills

Gabbro and diorite of the ca. 1.38 Ga Hart River suite (Abbott, 1997; Verbaas *et al*., 2018) intrude the Gillespie Lake Group (Figs. 2, 3 and 12). Dikes are uncommon and typically only a few metres wide. Sills are up to 250 m thick, 15 km long, and preferentially intruded the recessive, mixed siliciclastic-carbonate packages (Figs. 2 and 12a,b). Adjacent to intrusions, siliciclastic rocks are commonly orange weathering and pyritic (Fig. 12a,b), and carbonate rocks are locally bright white weathering. The primary igneous mineralogy is dominantly plagioclase and clinopyroxene with minor quartz and opaque minerals (Ambrose, 2021). Secondary minerals include chlorite, epidote group minerals, sericite and carbonate. The intrusions weather light to medium grey and commonly have a slight pinkish/orange colour (Fig. 12c). Ambrose (2021) showed that the Hart River sills in the map area have the geochemical composition of mid-ocean ridge basalts comparable to sills studied by Verbaas et *al.* (2018) to the west.

Magnetic east-west striking dikes

A swarm of approximately vertical and east-west striking dikes intrude strata at least as young as the Tonian Hematite Creek Group (Figs. 2, 3 and 13). Ambrose and Bowie (2020) noted a single, intensely altered, one metre wide mafic dike with a similar orientation cutting the Rapitan Group in the southwestern part of the map area that suggests these dikes intrude into Cryogenian strata locally. The dikes are typically 2–3 m thick and weather medium to dark grey. The colour contrast with the Pass Mountain Formation and Gillespie Lake Group makes them conspicuous. In darker weathering strata, such as the Mount Landreville Formation and siliciclastic rocks of the Gillespie Lake Group, the dikes are less apparent. Their mineralogy is dominated by variably altered plagioclase and clinopyroxene with minor olivine and opaque minerals. The magnetism, presence of olivine, lack of quartz, small size and consistent orientation distinguish these dikes from the Hart River sills. In contrast to the Hart River sills, the magnetic dikes have the geochemical composition of alkali basalt similar to ocean island basalts (Ambrose, 2021).

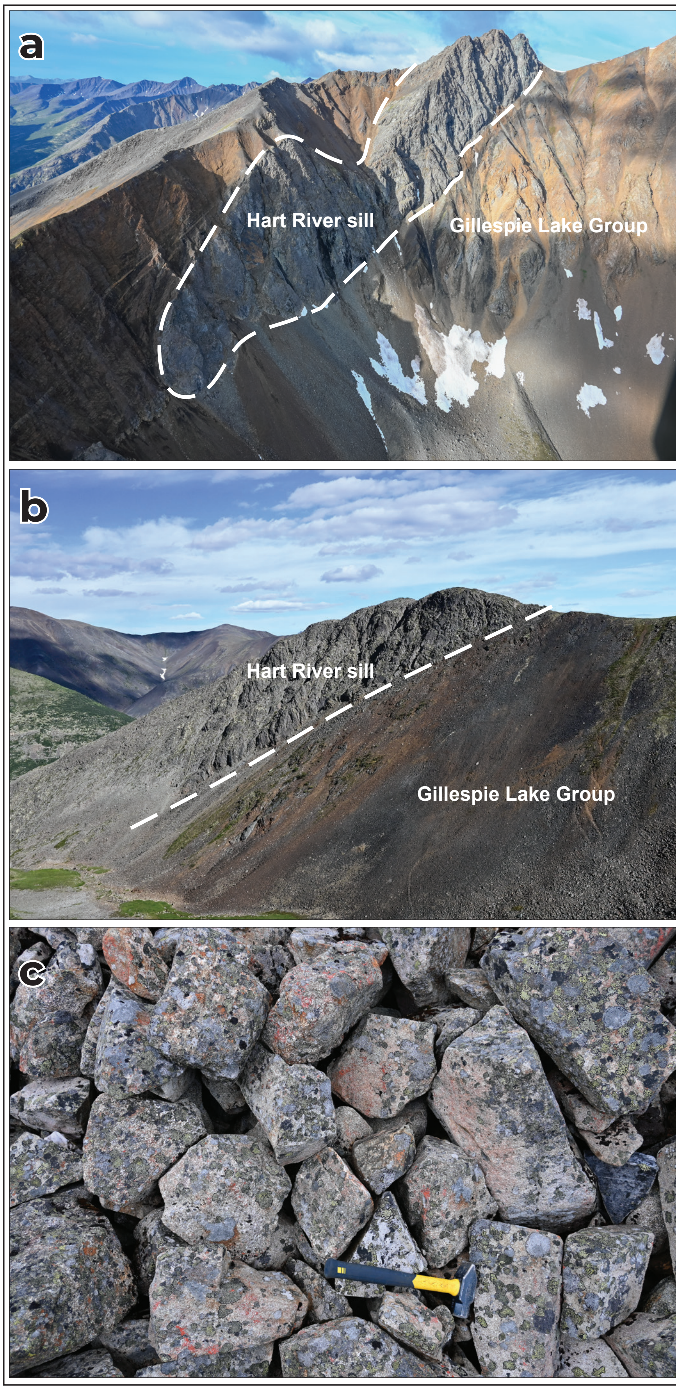

Figure 12. *Field photographs of the Hart River suite.* ***(a)*** *East-dipping mafic sill in orange weathering, recessive siliciclastic rocks of the Gillespie Lake Group. View to south. Distance from top of gabbro peak to snow at the base of the cliff is around 300 metres.* ***(b)*** *Grey weathering Hart River sill in dark and rusty weathering, fine-grained siliciclastic rocks of the Gillespie Lake Group. View to southeast. Bedding dipping to east (left of photo).* ***(c)*** *Boulders of gabbro showing the common orangey-pink colouration of weathered surfaces.*

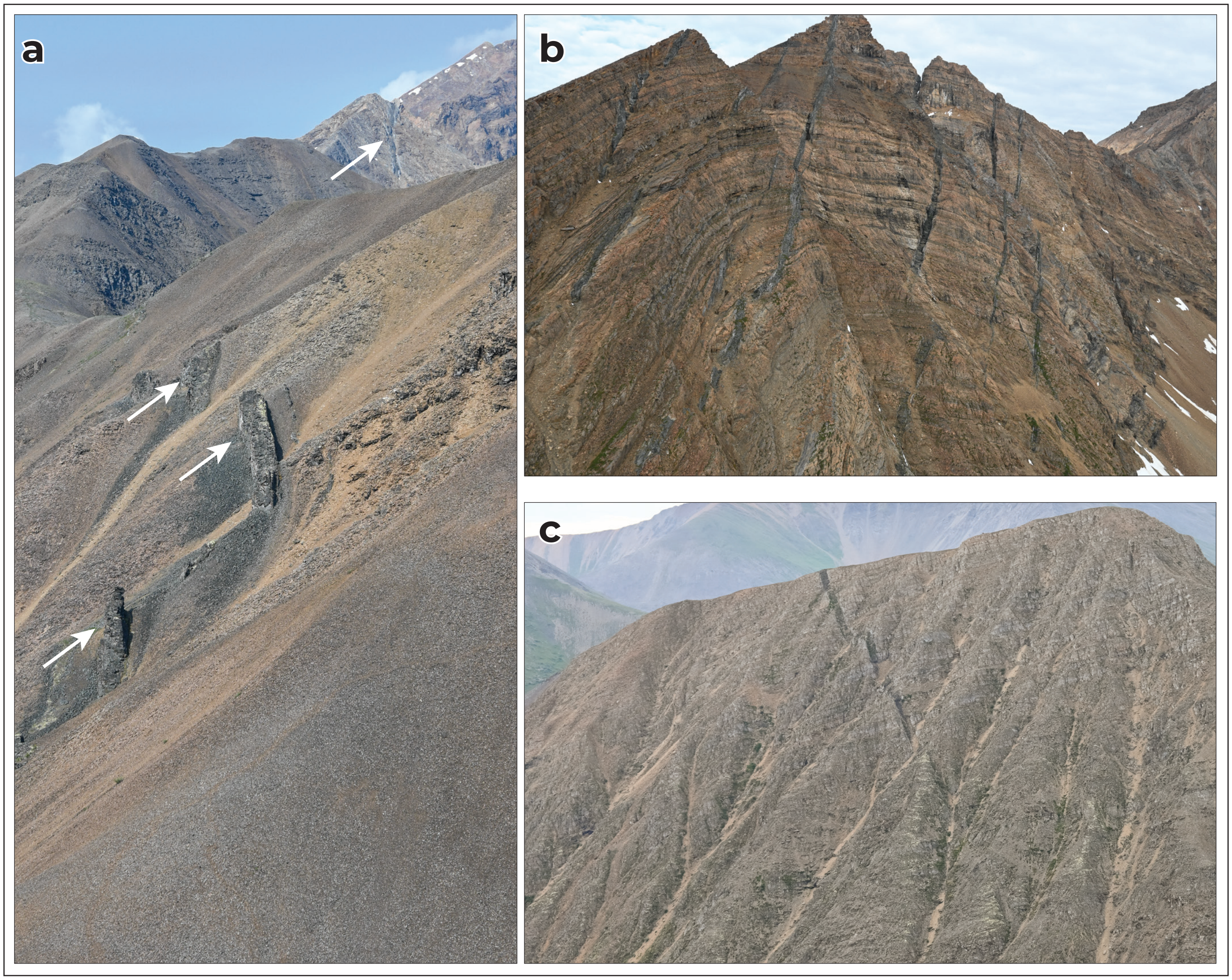

*Figure 13. Field photographs of the east-west striking dikes. **(a)** Cutting recessive mixed siliciclastic-carbonate interval of the Gillespie Lake Group. In top right of photo is cliff of red-weathering dolostone cut by dike. View to west. Bedding is folded but generally east dipping. **(b)** Dikes cutting folded Gillespie Lake Group. Note the small jogs of some dikes in the hinge zone of the fold. Cliff is ~ 400 m tall in centre of photo. View to west. **(c)** Dike cutting carbonate of the Pass Mountain Formation, Pinguicula Group. Top of ridge is ~ 500 m long. View to southeast.*

Structure

The map area can be divided into three structural domains (northwestern, northeastern, and southern) where structures have distinct orientations (Figs. 14 and 15). The boundaries between the domains are transitional and in some places the placement is somewhat arbitrary. In each domain, structures include centimetre to kilometre-scale folds and a penetrative cleavage (Fig. 16).

Northwestern domain

The northwestern domain exposes rocks mainly of the Gillespie Lake Group and Hart River sills (Figs. 2 and 14). The eastern limit of the domain also includes exposures of the Pinguicula Group. This domain is characterized by northeast-southwest oriented structures (Figs. 14 and 15). Folds are generally open to close, upright to steeply inclined, and shallowly plunging to the northeast or southwest. Major folds are best observed in the Gillespie Lake Group

(Figs. 13b, 14 and 15), but are also present in the Pinguicula Group and Hart River sills. Minor folds are uncommon but locally well developed in the Gillespie Lake Group (Figs. 4a and 16a) and Pass Mountain Formation. Sedimentary structures in the Gillespie Lake Group and Pass Mountain Formation demonstrate that bedding is generally right way up and rarely overturned on the steep limb of folds. Folds are locally cut by the east-west striking dikes (Fig. 13b). A moderate to steeply dipping, northeast-southwest striking penetrative cleavage is common in fine-grained beds of the Gillespie Lake Group (Figs. 5c, 14 and 15) and Mount Landreville Formation.

The northwestern domain also includes steeply dipping faults that are generally parallel to the dominant cleavage and fold orientation (Fig. 2). These faults are locally identified by discrete breaks in bedding orientation and the offset of grey-weathered siliciclastic intervals (see Figure 9a in Ambrose, 2021).

Northeastern domain

The northeastern domain exposes Neoproterozoic and older strata with structures that are dominantly oriented north-south to northwest-southeast (Figs. 14 and 15). Major folds are typically gentle to close, upright, and shallowly plunging to the south-southeast or north-northwest (Figs. 14 and 15). Folding is tight in the hinge zone of some major folds (Fig. 16b). Minor folds are best developed in siliciclastic and carbonate rocks of the Pinguicula Group (Fig. 6b). A steeply dipping penetrative cleavage is common in the Mount Landreville Formation, rare in the Pass Mountain Formation (Fig. 6c), and locally well developed in siltstone and the matrix of diamictite in the Rapitan Group.

Southern domain

The southern domain exposes Paleoproterozoic to Paleozoic strata characterized by east-southeast to west-northwest oriented structures (Figs. 14 and 15). Major folds are generally gentle to open, upright and plunge shallowly to the northwest or southeast. Minor folds are uncommon and poorly developed, but found locally in rocks of the Gillespie Lake Group and Pass Mountain Formation (see bottom right of

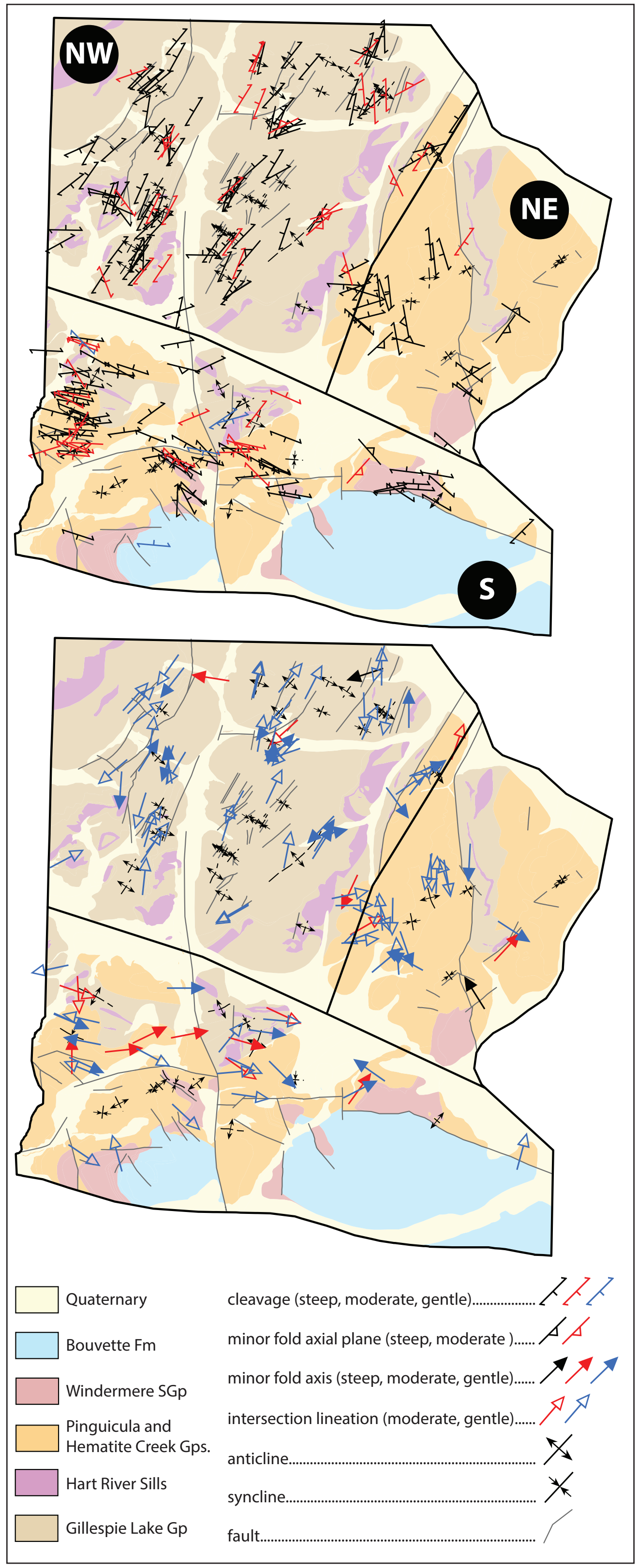

Figure 14. *Simplified geological map with three structural domains outlined in thick black line. For clarity, planar and linear structures are plotted separately.*

Figure 15 of Ambrose, 2021). A steeply dipping, southeast-northwest striking penetrative cleavage is variably developed in fine-grained siliciclastic rocks and silty carbonates of the Gillespie Lake Group, Mount Landreville Formation and Pass Mountain Formation. A well developed cleavage with the same orientation is also common within the matrix of diamictite in the Rapitan Group (see Figure 16e,f of Ambrose and Bowie, 2020). A cleavage that dips moderately to the north was observed at one locality in the volcaniclastic member of the Bouvette Formation. Northwest-southeast trending gentle folds were observed in the Bouvette Formation (Fig. 12b).

A major, east-west striking fault runs across the entire southern part of the map area. In the east, it separates Windermere Supergroup and Hematite Creek Group rocks to the north from Bouvette Formation rocks to the south. In the west, it separates Mount Landreville Formation and Pass Mountain Formation rocks to the north from younger rocks to the south. Given the similar orientation, the fault is likely related to the same event that produced folding and cleavage in the southern domain.

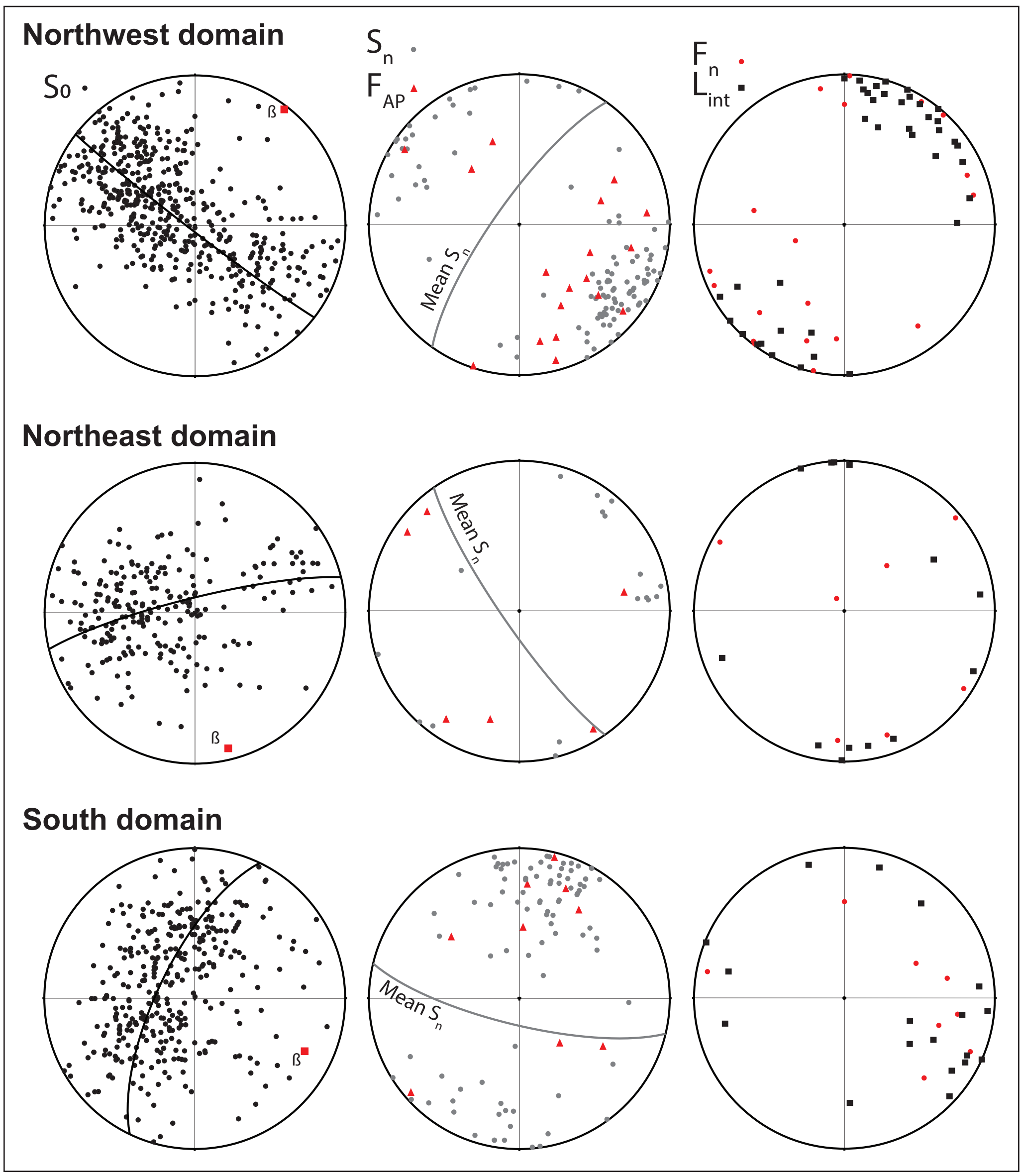

__Figure 15.__ Structural data from each domain plotted on lower hemisphere, equal area stereonets. S_0: bedding, S_n: cleavage, F_{AP}: fold axial plane, Fn: fold axis, L_{int}: intersection lineation.

Figure 16. (a) *Northeast-southwest trending minor fold of Gillespie Lake Group dolostone. Northeastern structural domain. View to southwest.* ***(b)*** *Hinge zone of a north-south trending syncline with chaotic open to isoclinal folds in dolostone of the Rubble Creek Formation. Northeastern structural domain. View to north. From the peak to the base of the photo is a vertical distance ~450 m. See Figure 6a for a more extensive view of the same mountain side.*

Timing of deformation

The oldest structures in the map area are likely the northeast-southwest oriented folds and associated cleavage in the northwestern domain. The northwest-southeast directed shortening event that produced these structures postdates deposition of the late Mesoproterozoic Pinguicula Group and is therefore younger than the ca. 1.6 Ga Racklan orogeny (Gabrielse, 1967; Eisbacher, 1978; Thorkelson et *al.*, 2005; Furlanetto et *al.*, 2013). Based on the paraconformable relationship with the Pinguicula Group, deformation also postdates deposition of the Tonian Hematite Creek Group. Deformation predates intrusion of the undated east-west striking dikes (Fig. 13b). The presence of an angular unconformity beneath the Tonian Callison Lake Formation may provide a minimum age constraint for deformation. Together, these relationships bracket the timing of deformation between ~1 Ga (deposition of Hematite Creek Group; Rainbird et *al.*, 1997; Thorkelson, 2000) and ~780 Ma (deposition of Callison Lake Formation; Strauss et *al.*, 2015), which correlates with timing of the Corn Creek orogeny to the north (Eisbacher, 1981; Thorkelson, 2000). In the southern and northeastern domains, structures are parallel and likely related to younger Mesozoic-Cenozoic structures to the south (*e.g.*, Dawson and Kathleen Lakes faults) and east (Richardson fault array), respectively.

Late faulting

A major, north-south striking normal fault runs through the centre of the map area for ~25 km. In the southern part of the map area it separates Gillespie Lake and Pinguicula group rocks to the east from younger rocks to the west. In the northwestern domain, where it coincides with the North Rackla River valley, it displaces carbonate and siliciclastic rocks of the Gillespie Lake Group and gabbro of the Hart River sills. In the northeastern part of the map area, two major north-south to northeast-southwest striking normal faults separate down-dropped Mesoproterozoic and Neoproterozoic strata from older Paleoproterozoic and Mesoproterozoic rocks to the east and west. The location of these faults roughly coincides with the boundary between the northwestern and northeastern domains.

Mineralization

The map area contains several notable Pb-Zn-Ag occurrences, including 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.

The main mineralization at Vera occurs in a steeply dipping, north-northeast striking fault-vein system in red weathering, brecciated, stromatolitic and microbially laminated dolostone of the Gillespie Lake Group. Veins consist of quartz and carbonate with massive and disseminated sphalerite, galena, tetrahedrite, siderite, ankerite and limonite (Sivertz, 1985; Kammerer and Eaton, 2011). The host dolostone is surrounded to the north, east and south by fine-grained siliciclastic rocks of the Gillespie Lake Group. The rheological contrast between the carbonate and siliciclastic rocks may have influenced faulting and mineralization. The northern and southern dolostone-siliciclastic contacts are roughly parallel with the fault-vein system and may also be faults. Vera has a historical resource estimate of 352.7 kt at 607.0 g/t Ag, 3.18% Pb and 3.47% Zn (Casselman, 2021).

Like Vera, mineralization at North Rackla is hosted in a steeply dipping, northeast-southwest striking fault-vein system in red weathering, microbially laminated and stromatolitic, brecciated dolostone of the Gillespie Lake Group (Fig. 2). Sphalerite and galena occur as disseminations and stringers along with dolomite, siderite and other Fe-Mg-Mn carbonate minerals. In high-grade zones, sphalerite and galena form the matrix of the fault-hydrothermal breccia. The mineralized zone is within carbonate rocks but is directly adjacent to a fault contact with a package of variably dolomitic-calcareous, dark weathering, fine-grained siliciclastic rocks to the northwest. As with Vera, the juxtaposition of different rock types may have provided favourable conditions for mineralization.

A collection of Pb-Zn-Ag occurrences, commonly referred to as the Val occurrences, lie to the south of Rusty Mountain (Fig. 2). Mineralization consists primarily of massive and disseminated sphalerite, galena and tetrahedrite within breccia zones and sparry dolomite veins in the Rubble Creek Formation (Sivertz, 1980; Kammerer and Eaton, 2011). The Val occurrences are proximal and may be related to the major east-west striking normal fault describe above. Val has a historical resource estimate of 20 kt at 1029 g/t Ag, 26.7% Pb and 7.3% Zn (Casselman, 2021).

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