Stratigraphy and structural geology of the upper Hyland River area (parts of 105H/8, 105H/9), southeast Yukon

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ABSTRACT

The upper Hyland River area of southeast Yukon is mostly underlain by rocks of the Neoproterozoic-Cambrian Hyland Group. The Yusezyu Formation, which forms the lower part of the Hyland Group, was previously undivided; however, good exposure in the upper Hyland River area facilitates the identification of marker horizons, including marble/limestone layers and thick units of quartz granule-pebble conglomerate. A new 1:50 000-scale map of part of the area includes ten stratigraphic subdivisions in rocks previously assigned to the Yusezyu Formation. From northeast to southwest, the structure of the area is characterized by: (1) a southwest-vergent fold and thrust belt; (2) a central region with upright, northwest-trending folds; and (3) a highly deformed region characterized by tight-isoclinal folding, in which folds and stretching lineations are at a high angle to the trend of the orogen. This deformation was accompanied by amphibolite facies, low-pressure metamorphism. A steeply-dipping fault with long strike-length is coincident with the upper Hyland River valley.

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INTRODUCTION

Large parts of eastern Yukon are underlain by rocks of the Hyland Group, a thick sequence of Neoproterozoic-Cambrian clastic and lesser carbonate rocks that form part of the Windermere Supergroup (Fig. 1). The Windermere Supergroup records sedimentation during extension that eventually led to the breakup of the Supercontinent Rodinia and the formation of the ancient Laurentian margin (Ross, 1991). The Hyland Group is the upper part of the Windermere sequence in Yukon and British Columbia. It is exposed in the core of the Selwyn fold-thrust belt, east of the Tintina fault and south of the Yukon stable block (Fig. 1).

The Hyland Group is overlain by rocks that record sedimentation in the Selwyn basin, an embayment in the Laurentian margin that was fringed by carbonate platforms from late Early Cambrian until the Middle Devonian. Rocks deposited in Selwyn basin were subsequently uplifted and eroded during rifting that accompanied deposition of the Devonian-Mississippian Earn Group. During the Mesozoic, the formation of the Cordillera led to development of the Selwyn fold-thrust belt and the emplacement of numerous mid-Cretaceous granitic intrusions (Gordey and Anderson, 1993; Rasmussen, 2013).

Gordey and Anderson (1993) defined the Hyland Group in the Little Nahanni River area (105I; Fig. 1) and recognized two major units – a lower unit with abundant coarse clastic rocks (Yusezyu Formation), overlain by fine clastic rocks of the Narchilla Formation. A thin limestone member at the top of the Yusezyu Formation was recognized (Gordey and Anderson, 1993) and a thicker limestone sequence in the same stratigraphic position was later defined as the Algae Formation in the Niddery Lake area (105O) to the north (Cecile, 2000).

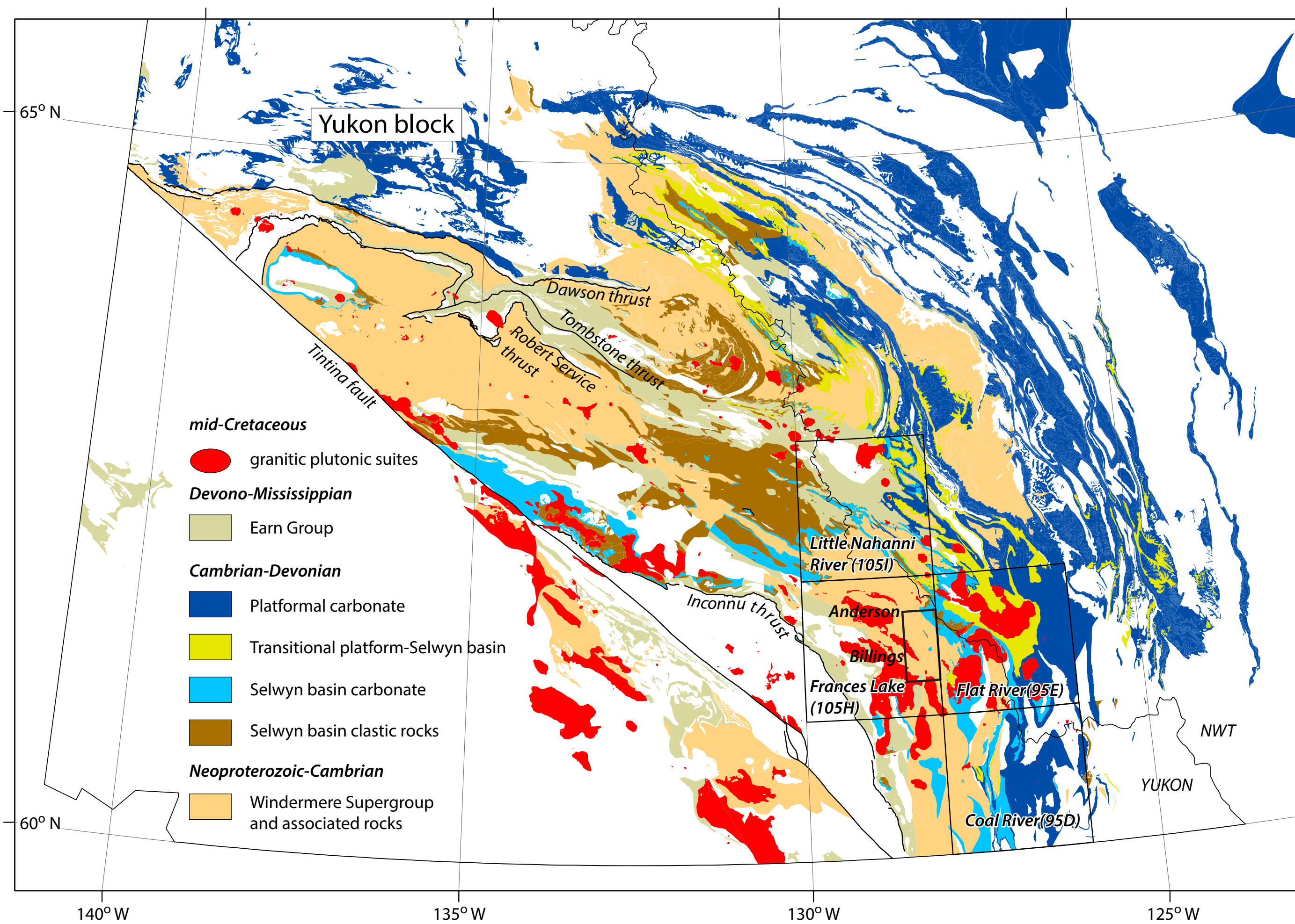


Figure 1. *Simplified geology of the Selwyn fold and thrust belt. Only major faults discussed in the text are shown for clarity. The small black box within the Frances Lake area shows the combined outline of 105H/8 and 105H/9. The plutons/batholiths shown are those of the mid-Cretaceous Cassiar, Hyland, Anvil, Tombstone, Tungsten, Tay River and Mayo plutonic suites. The largest intrusions in the Frances Lake area are the Billings and Anderson batholiths of the Hyland suite (labelled).*

The Yusezyu Formation comprises an ostensibly monotonous sequence of brown shale, sandstone, grit and subordinate calcareous rocks. Gordey and Anderson (1993) estimated a stratigraphic thickness of at least 3 km in the Little Nahanni River type area, but the base was not observed. The lack of stratigraphic subdivisions of the Yusezyu Formation presents an impediment to understanding the structure of the interior part of the Selwyn fold-thrust belt. Large structures (*e.g.*, the Dawson, Robert Service and Tombstone thrust faults; Fig. 1) have been recognized where the Hyland Group is juxtaposed with younger (Palaeozoic-Mesozoic) units, but the absence of known marker units in the Yusezyu Formation prevents recognition of faults and characterization of the structural geometry elsewhere.

This report contains preliminary results on the structure and stratigraphy of the Hyland Group and overlying units in the upper Hyland River area of southeast Yukon (Frances Lake map area, 105H). The report is based on mapping (Fig. 2) that was carried out from two-person fly camps during the summer of 2015 and the latter part of the summer of 2014. It accompanies a 1:50 000 scale open file map covering parts of NTS sheets 105H/8 and 105H/9 (Moynihan, 2016b; summarized in Fig. 2). Previously, bedrock geology of the Frances Lake area (105H) had only been mapped at a scale of 1:250 000 (Roots *et al.*, 1966).

A broad area around the Billings and Anderson batholiths (Fig. 1) is affected by syn to post-kinematic, low-pressure amphibolite-facies metamorphism (Moynihan, 2013) and this includes the western part of the mapped area (Fig. 2). Metamorphic grade increases structurally downward towards the batholiths, though their intrusion post-dates the syn-kinematic metamorphism. In order of increasing grade, metapelitic rocks belong to the Crd+Bt, And+Crd+Bt, And+Bt, And+St+Bt, Sil+St+Bt and Sil+Kfs+melt (muscovite-free) zones. Outside of this area, the regional metamorphic grade is low (chlorite zone). This report focuses on stratigraphy and structure of the area, and a full account of metamorphism will be given elsewhere.

STRATIGRAPHY

The oldest rocks in the map are currently included in the Yusezyu Formation, which extends across the map boundary from Little Nahanni River type area into Frances Lake. As a large structural culmination underlies eastern Frances Lake map sheet (centred on the Billings and Anderson batholiths), the area is likely to include deeper parts of the stratigraphy than is exposed in Little Nahanni River (105I).

Mountainous terrain in the mapped area allowed recognition of ten stratigraphic units below the Yusezyu Formation-Narchilla Formation boundary. The most prominent stratigraphic marker is a thick marble, informally referred to here as the 'Hyland marble' that appears to be widely distributed in 105H. A thick marble marker horizon was not mapped by Gordey and Anderson (1993), and it is likely that it is occurs at a lower stratigraphic level than was observed in 105I. Rather than referring to the entire sub-Narchilla stratigraphy as Yuseyu Formation, here the term is only applied to rocks between the Hyland marble and the Narchilla Formation. This allows distinction between rocks described by Gordey and Anderson (1993), which are characterized by the presence of abundant coarse grit layers and older rocks, which are not. Rocks stratigraphically below the 'Hyland marble' are assigned to the sub-Yusezyu Fm portion of the Windermere Supergroup. Future work will determine the extent to which the provisional stratigraphic subdivisions identified in this area can be traced regionally.

UNDIVIDED WINDERMERE SUPERGROUP (UNDERLYING THE HYLAND MARBLE)

Heterolithic schist in the western part of the area has been affected by amphibolite-facies metamorphism and intense penetrative deformation. This area is dominated by compositionally layered, rusty brown weathering, quartzofeldspathic and micaceous schist (uPs; Fig. 3a). Schist is mostly psammitic and semipelitic, containing thin folia/layers of pelitic schist and some white quartzite layers; marble and calc-silicate schist is also common. White to pale grey weathering, pale to medium grey, coarsely crystalline marble forms layers ranging from <1 m to several tens of metres thick. Thick, continuous bands of marble were mapped separately as unit uPm (Fig. 3b).

Metapelitic layers are thin in the heterolithic schist unit (uPs), but the area contains at least two intervals predominantly composed of orange-brown to rusty-brown weathering metapelitic and semipelitic schist (uPmp; Fig. 3c) The thickest of these bands (in western 105H/8) contains a distinctive unit, approximately 20 m thick, of laminated rock (meta-chert?) comprising alternating quartz-rich and argillitic layers (uPbq; Fig. 3d). This was referred to as banded argillite by MacLeod (1982).

HYLAND MARBLE (uPHm)

The thickest marble layer that was encountered can be traced across the mapped area and beyond, forming a distinctive stratigraphic marker. This marble approximately coincides with the upper limit of the low-pressure, amphibolite facies metamorphism that affects low structural levels (*i.e.*, most of the rocks west of the Hyland River).

The Hyland marble (Fig. 3e) is composed of pale grey to white weathering, coarsely crystalline, grey banded marble and calc-silicate. In some places, the unit is represented by a discrete band of marble/calc-silicate, tens of metres thick, under and overlain by rusty brown weathering schist units. Elsewhere, the unit is characterized by a mixed zone containing intercalated marble/calc-silicate and schist up to 200 m thick. This intercalation and variation in thickness is attributed to tight to isoclinal infolding of marble/calc-silicate with surrounding clastic metasediments. The Hyland marble is notably discontinuous where it is exposed in steep slopes overlooking the east side of the Hyland River in 105H/8. The lenticular nature of the unit here may result from boudinage of this layer.

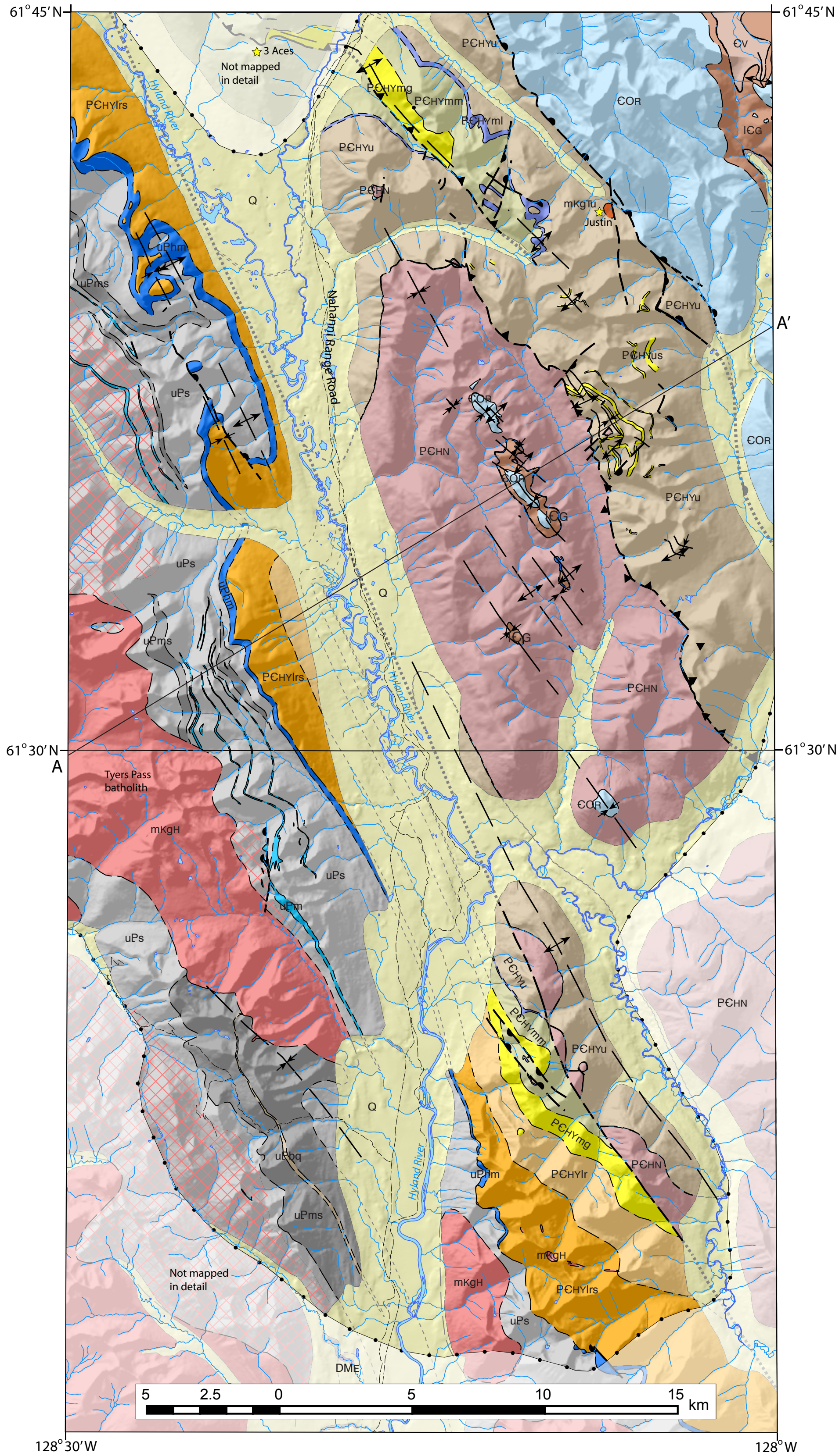


Figure 2. *Geological map and legend. The outline of the study area (105H/8 and 105H/9) is marked by a black box in Figure 1.*

PLUTONIC ROCKS

MID-CRETACEOUS

mKgTu — **TUNGSTEN SUITE:** *biotite granodiorite*

mKgH — **HYLAND SUITE:** *biotite +/- hornblende biotite granodiorite, quartz monzonite and quartz diorite*

SEDIMENTARY AND METASEDIMENTARY ROCKS

QUATERNARY

Q — **QUATERNARY**: *unconsolidated glacial, glaciofluvial and glaciolacustrine deposits; fluviatile silt, sand, and gravel, and local volcanic ash, in part with cover of soil and organic deposits*

UPPER DEVONIAN TO LOWER MISSISSIPPIAN

DME — **EARN GROUP:** *brown-weathering, brown and black shale, black and grey chert, quartzite, greywacke, chert-pebble conglomerate*

UPPER CAMBRIAN TO LOWER ORDOVICIAN

ЄOR — **RABBITKETTLE FORMATION:** *Thinly bedded and laminated cream, grey and buff-coloured argillacous limestone; thinly-bedded grey limestone.*

CAMBRIAN SERIES 2-3

lЄG — **GULL LAKE FORMATION, upper member:** *Rusty weathering, chocolate-brown weathering, dark brown to black shale; grey weathering, laminated, bioturbated mudstone-siltstone; thin-medium beds of limestone near base.*

lЄGb — **GULL LAKE FORMATION, basal member:** *Boulder conglomerate comprising grey limestone clasts in a siliciclastic, variably calcareous matrix; limestone; medium-thick bedded quartz arenite; minor greenschist*

NEOPROTEROZOIC-CAMBRIAN WINDERMERE SUPERGROUP

TERRENEUVIAN-CAMBRIAN SERIES 2

H Y L A N D G R O U P

PЄHN — **NARCHILLA FORMATION:** *green, maroon and grey, well-cleaved, rhythmically-bedded mudstone and siltstone and phyllite; upper part of formation is heavily bioturbated; white-weathering thin to medium-bedded, planar and*

ЄV — **VAMPIRE FORMATION:** *grey phyllite/mudstone-siltstone; medium- to thick-bedded sandstone; minor calcareous phyllite*

EDIACARAN

PЄHYul — **YUSEZYU FORMATION, UPPER, limestone:** *grey and buff, thin-bedded, planar and cross-laminated limestone; thin-bedded limestone and green shale; thin to medium-bedded grey limestone pebble conglomerate and breccia; bright yellow-orange to orange-brown dolostone; correlative with Algae and Risky formations elsewhere in Yukon and NWT.*

PЄHYus — **YUSEZYU FORMATION, UPPER, sandstone/conglomerate:** *pinkish-brown, white-grey weathering, limonitic, coarse sandstone, granule and pebble conglomerate; subordinate phyllite*

PЄHYu — **YUSEZYU FORMATION, UPPER (undivided):** *grey and pale green phyllite, sandstone, granule and pebble conglomerate; calcareous phyllite, siltstone and sandstone; silty and sandy limestone*

PЄHYml — **YUSEZYU FORMATION, MIDDLE, fetid limestone:** *thin, locally medium-bedded, medium to dark grey, generally fetid limestone; includes calcilutite, calcarenite and calcirudite; brownish-grey silty/sandy limestone*

PЄHYmm — **YUSEZYU FORMATION, MIDDLE, mixed unit:** *grey, maroon and green phyllite, sandstone, granule and pebble conglomerate (grit); grey limestone, silty/sandy limestone*

PЄHYmg — **YUSEZYU FORMATION, MIDDLE, 'grit':** *white or pale grey weathering, poorly sorted coarse sandstone, granule and pebble conglomerate; mostly quartz grains, with 10-15% milky-white feldspar grains in argillaceous/micaceous matrix.*

PЄHYlr — **YUSEZYU FORMATION, LOWER, recessive unit:** *grey, brown-weathering phyllite with subordinate thick to massive beds of coarse sandstone and granule-pebble conglomerate*

PЄHYlrs — **YUSEZYU FORMATION, LOWER, resistant unit:** *medium to thick bedded sandstone and granule conglomerate; brown-weathering grey phyllite; thin-bedded siltstone-fine sandstone; minor thin-bedded grey limestone*

SYMBOLS

geologic contacts (defined, approximate, inferred, covered)......

fault; movement not known (defined, approximate, inferred, covered)......

thrust fault (defined, approximate, inferred, covered)......

normal fault (defined, approximate, inferred, covered)......

anticline (upright, overturned)........................

syncline (upright, overturned)........................

Au mineralization...

cross-hatching indicates regions that comprise a mix of country rock and unit mKgH. In these regions, dikes, sills and other small bodies of mKgH form 25-75% of the rock.

uPHm — **"HYLAND MARBLE":** *pale grey to white weathering marble; calc-silicate schist; thin folia of metapelitic schist; locally abundant (structural?) intercalations of micaceous schist*

uPs — **HETEROLITHIC SCHIST:** *semi-pelitic schist, psammitic schist, metapelitic schist; marble; calc-silicate; quartzite*

uPm — **MARBLE:** *pale grey to white weathering, medium to dark grey marble*

uPbq — **"BANDED QUARTZITE":** *Laminated to thinly-bedded silica-rich rock with thin, dark, micaceous folia.*

uPms — **METAPELITIC SCHIST:** *rusty orange-brown weathering, medium to coarse-grained metapelitic and semi-pelitic schist; pasmmitic schist*

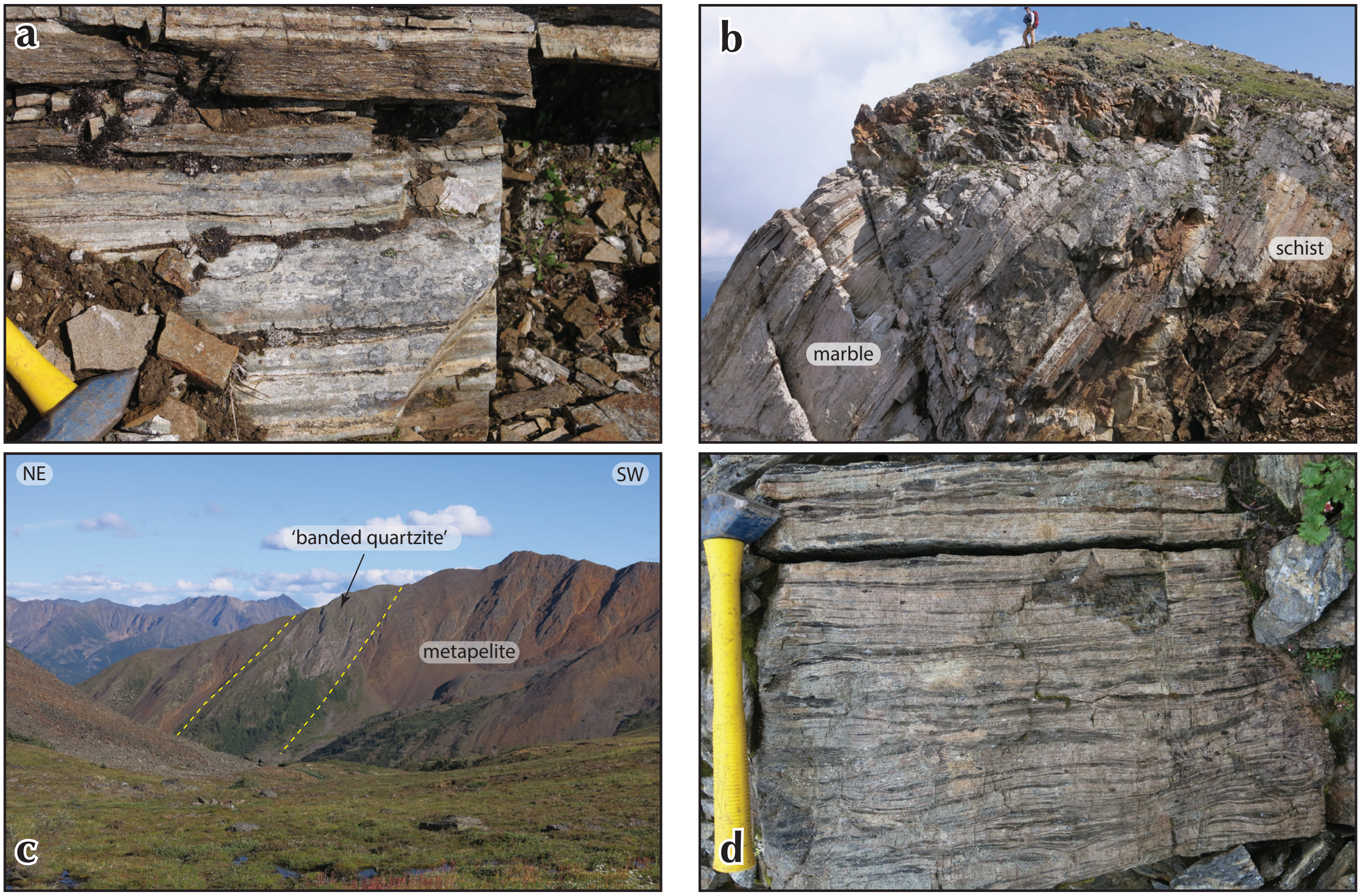


Figure 3. *(a) Interlayered quartz-rich and mica-rich schist of unit* uPs*. Hammer for scale. (b) Grey marble (~5 m thick) interlayered with rusty brown micaceous schist, unit* uPs*. Person for scale. (c) Rusty brown weathering metapelite (*uPms*), with grey-coloured band of 'banded quartzite' (*uPbq*) surrounded by rusty, orange-brown weathering metapelite. Relief on the photographed ridge is approximately 350 m. (d) 'Banded quartzite' (*uPbq*) unit forms a distinctive marker tens of metres thick in the west-central part of 105H/8. It comprises interlayered lamellae of grey, fine-grained quartzite and dark green-grey to black argillite. Numerous pinch and swell (boudinage) structures are visible. Hammer for scale.*

YUSEZYU FORMATION

LOWER YUSEZYU FORMATION

The lowest part of the Yusezyu Formation is a resistant unit (PЄHYlr) that is dominated by medium to thickly bedded, medium to coarse-grained, brown to cream weathering sandstone (Fig. 3f). In most of the unit, phyllite is subordinate and forms thin layers between sandstone beds. However, the sandstone: phyllite ratio is variable, and there are some thick intervals (tens of metres) composed exclusively of laminated phyllite. Phyllite in the lowest part of the unit is metamorphosed to cordierite-biotite spotted hornfels. The uppermost part of this unit also includes some thin (2-3 m) silty limestone layers. This unit forms resistant topography and the sandstone beds impart a ribbed appearance to hillsides underlain by these rocks (Fig. 3g).

The resistant unit is overlain by a recessive interval (PЄHYlrs) that forms brown shaly slopes. Phyllite is the dominant rock type, but there is also fine to medium-grained sandstone, and widely spaced intervals of thick to very thickly-bedded granule-pebble conglomerate ('grit') that forms pinnacles on ridge-tops.

MIDDLE YUSEZYU FORMATION

The lowest part of the middle Yusezyu Formation (PЄHYmg) comprises a thick sequence of pale grey to white weathering, medium to very thickly bedded coarse sandstone and granule-pebble conglomerate ('grit'). The conglomerate (Fig. 3h) is moderately sorted and is dominated by quartz grains, with 10-15% milky-weathering feldspar grains. Unlike elsewhere in the formation, grit is the dominant rock type and phyllitic interbeds are thin and volumetrically minor. Calcareous sandstone is locally also a constituent of this unit. The thick grit interval is overlain by a mixed sequence (PЄHYmm) including varicoloured phyllite (maroon, green, grey and blue-grey), thickly-bedded sandstone and granule conglomerate, medium-bedded sandstone, calcareous phyllite and thinly-bedded grey limestone. The top of this mixed unit is a thick sandstone-conglomerate interval, which is overlain by a distinctive fetid limestone marker horizon (PЄHYml; Fig. 3i). This limestone, which is approximately 30 m thick, is thin to medium bedded with internal planar laminations and less common cross-laminations. The weathered surfaces are mostly pale to medium grey and locally pale creamy brown. Freshly broken surfaces are dark grey and crystalline. Most of the rock is recrystallized grainstone, but some thin-medium limestone conglomerate layers are present. In some cases, the conglomerate layers contain distinctive bright orange or red shaley clasts. A notable feature of the limestone is the sulphurous smell emitted by much of the unit when it is walked over or hammered. This limestone may be equivalent to a "black, fine crystalline, thin(?)-bedded limestone" noted by Gordey and Anderson (1993, p. 41) in the Yusezyu Formation type section.

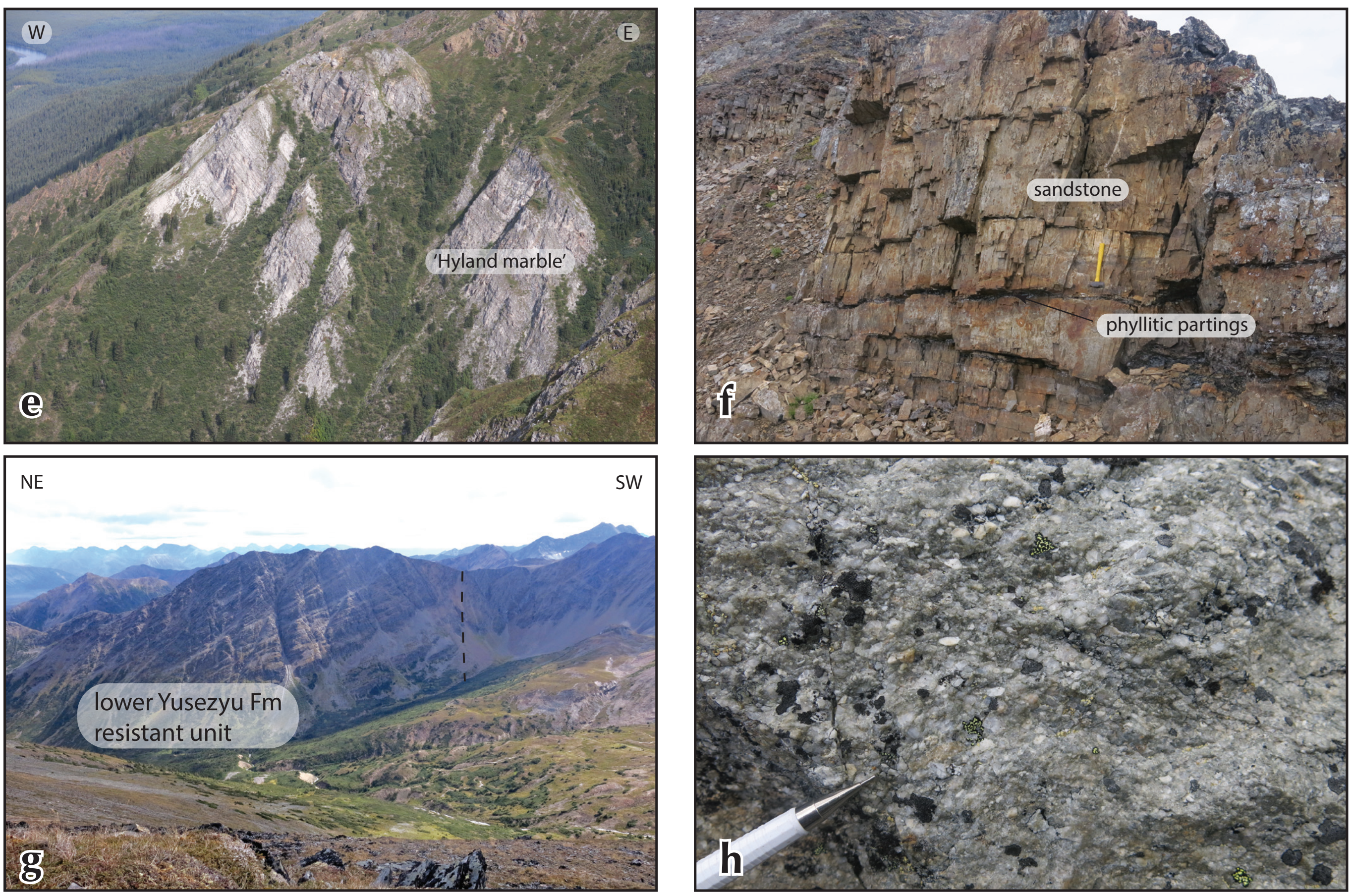


Figure 3 (continued). *(e) Pale grey weathering, marble band ('Hyland marble', uPHm) forms cliffs on the East side of the Hyland River in central 105H/8. It is approximately 75 m thick here. (f) Thickly bedded sandstone layers with thin phyllitic partings in the lower Yusezyu Fm, resistant unit that lies directly above the 'Hyland marble'. Hammer for scale. (g) Sandstones of the Lower Yusezyu Fm, resistant unit lends a ribbed appearance to this ridge in the eastern part of 105H/8. The elevation difference between the top of the ridge and the creek in the middle ground is approximately 550 metres. Dashed line marks the trace of a fault. (h) Granule-pebble conglomerate ('grit') of unit PЄHYmg. The clasts are mostly grey quartz, with prominent milky-white feldspar grains. Pencil for scale.*

UPPER YUSEZYU FORMATION

The upper part of the Yusezyu formation (PЄHYu) comprises a heterogeneous mix of variably calcareous, mostly fine-grained clastic rocks. The dominant rock type is well-cleaved, brown-weathering, medium grey, pale grey and pale green phyllite. Phyllite is thinly-bedded and laminated with graded bedding and ripple cross-lamination in silty layers; locally, the phyllite is calcareous (Fig. 3j). Other rocks types include thin to very thickly bedded sandstone and conglomerate, and thin to medium-bedded calcareous sandstone and silty-sandy limestone. Though most of this unit is relatively fine-grained, it also includes a number of resistant, thick to very thickly bedded intervals of coarse sandstone and pebble-granule conglomerate (PЄHYs). These intervals are generally 5-20 m thick and form excellent structural markers. Coarse sandstone and conglomerate layers are commonly graded and have erosive bases, some of which contain abundant rip-up clasts (Fig. 3k). The base of this unit is marked by one such layer of quartz (+subordinate feldspar) granule-pebble conglomerate.

A distinctive aspect of the upper part of the Yusezyu Formation is the presence of one or more layers (approximately 15-20 m thick) of olistostrome. This rock comprises clasts of massive orange weathering dolostone, up to 1 m diameter, in a green matrix (Fig. 3l). The matrix is a wacke composed of green shale with abundant poorly sorted, variably sized subangular to subrounded quartz grains.

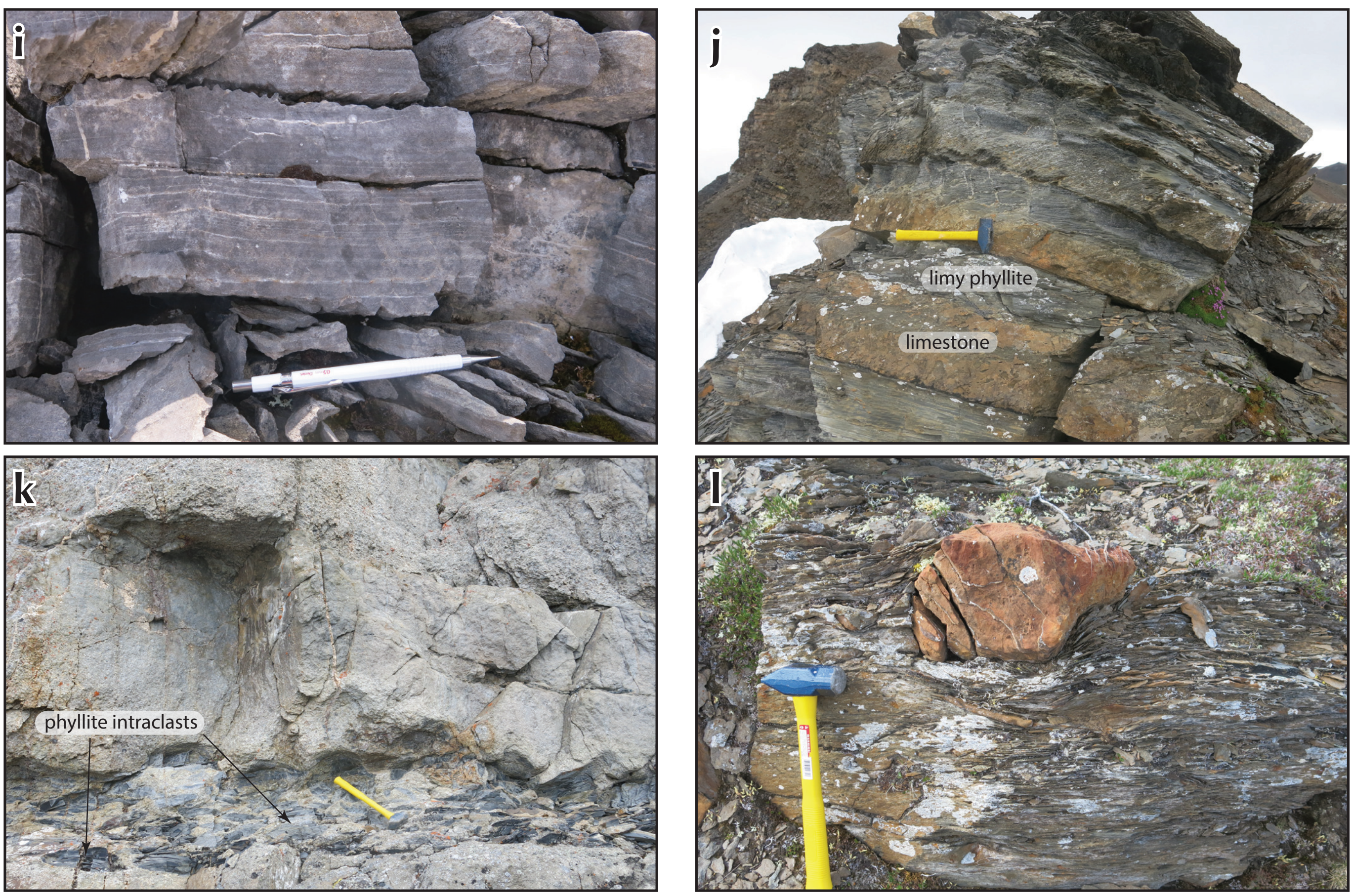


Figure 3 (continued). *(i) Grey, thinly bedded fetid grainstone of unit PЄHYml. This limestone forms a prominent marker horizon in the middle Yusezyu Formation on either side of the Hyland fault. Pencil for scale. (j) Medium to thin beds of limestone and limy phyllite in the upper part of the Yusezyu Fm. Much of the upper part of the formation comprises fine-grained, variably calcareous metasediments. Hammer for scale. (k) Thick beds of granule-pebble conglomerate ('grit') in the upper part of the Yusezyu Fm. The base of the lower bed contains abundant rip-up clasts, now converted to phyllite. (l) An olistostrome forms a distinctive marker in the upper part of the Yusezyu Formation. Orange dolostone clasts sit in a matrix of green wacke, which contains abundant subangular quartz grains. Hammer for scale.*

The limestone member (PЄHYul) that marks the top of the Yusezyu Formation is approximately 10-15 m thick. It includes thin-medium bedded grey limestone and thin to thick beds of calcirudite, each interbedded with cleaved laminated green mudstone (Fig. 3m). There are also thin beds of orange-weathering silty limestone with planar and ripple lamination (BC Bouma sequences) interbedded with green mudstone in the upper part of the member. The limestone member is gradational into the overlying Narchilla Formation and its top is defined as the uppermost limestone layer (Gordey and Anderson, 1993).

NARCHILLA FORMATION

The base of the Narchilla Formation consists of thinly bedded green shale and yellow-brown weathering, parallel laminated calcareous sandstone. These sandstone beds die out up-section over an interval of ~10-20 m. The remainder of the formation is dominated by laminated, graded, maroon, green and grey-green, well-cleaved mudstone (± siltstone) and shale (Fig. 3n). It also includes some sandstone beds and rare silty limestone layers. Sandstone forms thin to medium beds that weather white; they commonly show an upward progression in their internal structure, with massive bases overlain by intervals that display planar lamination, followed by cross-lamination; these progressions are interpreted as ABC Bouma sequences. The thickness of the Narchilla Formation is poorly constrained, but it is at least several hundreds of metres thick, and probably broadly similar to the thickness at its type section in the Little Nahanni River area to the north (750 m; Gordey and Anderson, 1993).

Parts of the Narchilla Fm that are bright maroon or green are friable and give rise to non-resistant shaly slopes made up of small rock fragments. Much of the upper part of the Formation, however, comprises relatively competent, bioturbated, pale green, olive green and green-grey, cleaved mudstone, which is more resistant than underlying shaly intervals and the overlying Gull Lake Formation. Roots *et al.* (1966) interpreted this variation as a stratigraphic transition and included the resistant rocks in what is now referred to as Vampire Formation (unit 3 of Roots *et al.*, 1966). As the basal Gull Lake Formation sits above both bright green/maroon friable rocks and duller, more competent rock, this would require an unconformity with significant relief beneath Gull Lake Formation. While such an unconformity may exist (see below), boundaries between colourful variegated shales and duller more competent rock are geometrically complex, and range from gradational to sharp, suggesting a secondary, non-stratigraphic control. Here, all of the rock between the top of the Yusezyu Formation and Gull Lake Formation is included in a single unit (Narchilla Formation) and patchy variation in the colour/competence is interpreted to reflect heterogeneous diagenesis/alteration of the rocks.

VAMPIRE FORMATION

The Early Cambrian Vampire Formation (Fritz, 1982) crops out in the northeast corner of the mapped area, in the hanging wall of the Sprogge fault. It is dominated by dark to steel grey phyllite, with lesser medium to very thick-bedded pale grey sandstone and rare thin calcareous phyllite layers. The phyllite forms compact outcrops that are more resistant than shale of the overlying Gull Lake Formation. In the region to the east of the mapped area, the Vampire Formation has a distinctive rusty reddish-brown weathering colour in the contact aureoles of mid-Cretaceous granitic plutons.

The Vampire Formation is considered to be a broadly coeval, palaeogeographically inboard equivalent to the Narchilla Formation (Gordey and Anderson, 1993; Martel *et al.*, 2011) and the two units are overlain by identical stratigraphy. Distinction between the formations can be difficult and in the Coal River area (95E), the position of the boundary is arbitrary (Pigage *et al.*, 2015). In the upper Hyland River area, the units can be distinguished on the basis that phyllite of the Vampire Formation is uniformly grey and less friable, and sandstone beds are thicker than in the Narchilla Formation. Colour differences may not be stratigraphically significant, however, and it is likely that the transition between the two formations is gradational.

GULL LAKE FORMATION

The basal member of the Gull Lake Formation (lЄGb) sharply overlies Narchilla and Vampire formations and varies from approximately 10 m to several tens of metres thick. The dominant rock type is grey limestone conglomerate, but non-conglomeratic pale grey limestone is common and laminated argillaceous limestone is also locally present. The conglomerate (Fig. 3o) is poorly sorted, with sub-angular to sub-rounded clasts of grey limestone in the pebble to boulder size range; in places clasts up to 1 m in diameter are present. The matrix to the conglomerate is variably calcareous, sandy, and generally weathers grey or yellow-orange. Much of the conglomerate is massive, but thick-bedded layers with a resistant, sand-rich matrix are common in the upper part. The top of the basal member is locally marked by a thick bed of grey, medium to coarse-grained sandstone.

Archaeocyathids were observed within grey limestone clasts at a single locality. These fossils are characteristic of the basal unit of Gull Lake Formation and indicate the unit is Cambrian Stage 2 or younger. The Gull Lake Formation was considered to be conformable with the underlying Narchilla Formation in the Little Nahanni River type area (Gordey and Anderson, 1993). However, the contact is unconformable in the Rackla area of east-central Yukon (Moynihan, 2016a) and an unconformity of this age is also widespread on the Yukon block (see discussion in Abbott, 1997).

The basal member of Gull Lake Formation is sharply overlain by the main/upper unit (lЄG). This contains a few 10-15cm thick beds of cream coloured laminated limestone near its base (lowermost 3 metres) but is otherwise composed of >200 m of dark argillite and phyllite. The lower portion of lЄG is dark grey to black, carbonaceous, laminated argillite with local spherical phosphate(?) nodules. The upper part of the unit is paler grey, laminated and commonly has a mottled appearance due to bioturbation. Rusty brown weathering of fracture surfaces is characteristic of the entire unit (Fig. 3n), and many rusty surfaces display an iridescent sheen. The argillite/phyllite is recessive and typically forms smooth, black to chocolate-brown coloured scree slopes; in places, however, the upper part of the formation weathers pale blue-grey.

The original thickness of the Gull Lake Formation is unknown as it is progressively cut out beneath an unconformity at the base of the Rabbitkettle.

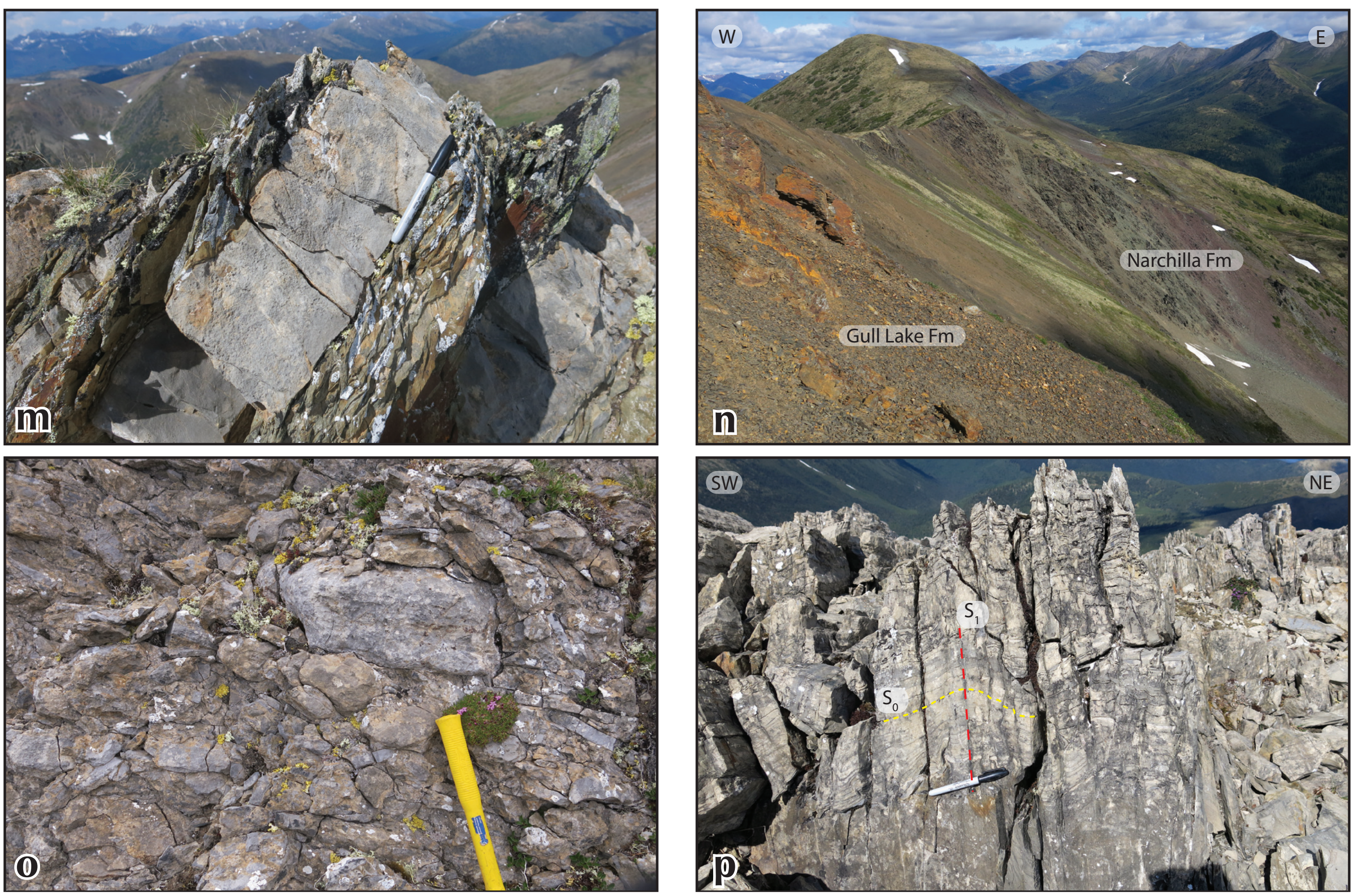


Figure 3 (continued). *(m) Interbedded grey limestone and green shale in the uppermost part of the Yusezyu Formation (limestone member, PЄHYul). This unit separates. (n) Rusty-weathering, brown shale of the Gull Lake Formation (foreground) overlies green and maroon mudstone of the Narchilla Formation. The distance from the photo site to the hilltop in the left side of the photo is approximately 1 km. (o) Limestone boulder conglomerate at the base of Gull Lake Formation. Rare archaeocyathids in limestone clasts indicate a maximum age of Cambrian series 2 for this unit. (p) Laminated argillaceous limestone of the Rabbitkettle Formation. Bedding (S_0) is disrupted across dark, graphite-rich, pressure-solution cleavage seams (S_1).*

RABBITKETTLE FORMATION

The Rabbitkettle Formation (ЄOR) comprises thin-bedded and laminated argillaceous limestone, with lamellae of limy argillite and lesser thin-bedded non-argillaceous fine-grained limestone (Fig 3p). Argillaceous limestone weathers cream, buff, grey and pale brown, whereas limestone layers weather pale grey. Limestone is locally replaced by sugary-textured, yellow to orange weathering dolostone. The Rabbitkettle Formation also contains numerous thin (tens of cm), altered mafic metavolcanic layers or dikes.

The Rabbitkettle Formation forms relatively vegetation-free, grey to yellow rubbly scree slopes. In some places the primary layering in the Rabbitkettle Formation is heavily disrupted across graphite-rich pressure solution cleavage planes. In these locations, discontinuous, lensoidal, secondary compositional layering is developed sub-parallel to cleavage.

The transition from underlying units to the Rabbitkettle is sharp and unconformable. The unconformable nature of its base is exemplified in east-central 105H/9, where the folded unconformity cuts down through the Gull Lake Formation (Fig. 7a).

Poorly preserved, non-age-diagnostic trilobite fragments were observed in one locality, but regionally the formation is Upper Cambrian-Lower Cambrian. Roots *et al.* (1966) indicate a number of fossil localities in this unit and assigned an age of Middle to Late Cambrian.

IGNEOUS ROCKS

The largest igneous body in the area is the Tyers Pass batholith, which forms part of the mid-Cretaceous Hyland Suite (mKgH). It is a northeast-dipping sheet-like body dominated by equigranular, medium grained biotite granodiorite and lesser hornblende-biotite granodiorite. Rocks are generally undeformed except near the base of the batholith, where it is locally weakly foliated. The batholith contains numerous screens of country rock and metasedimentary xenoliths are common. Xenocrysts of andalusite are also locally present. The boundary of the batholith is generally gradational, with abundant dikes in the adjacent country rock.

A dense network of dikes, similar in composition to the Tyers Creek batholith, affects large areas in the western part of the mapped area. These areas contain varying, sub-equal proportions of country rock and dike rock, and the dikes commonly coalesce to form numerous small plutons. The boundaries between these areas and those mapped as part of major batholiths are difficult to determine and, at least locally, arbitrary. Most dikes in this part of the area are equigranular and granodioritic, but quartz-feldspar porphyry dikes are also present, some of which weather pink.

Dikes and small intrusions are scattered throughout the area west of the upper Hyland fault. These include fine-grained green coloured dacitic (?) dikes. These are sub-equigranular, with some phenocrysts of hornblende and plagioclase in a fine-grained matrix. There are some small intrusions of medium-grained hornblende granodiorite, particularly in the Lower Yusezyu Formation east of the Hyland River (southern 105H/8). These are medium grained, commonly weather pink and are locally porphyritic.

Numerous felsic dikes intrude the Yusezyu Formation in the area around the Justin pluton, particularly to the south of the intrusion. These dikes contain mm-scale quartz phenocrysts in a white-weathering felsic matrix. One similar dike was observed in the Rabbitkettle Fm hanging wall of the Sprogge fault.

The northeastern part of 105H/9 also hosts numerous mafic dikes. These are dense, dark brown aphanitic, cpx-bearing vesicular rocks that commonly contain xenocrysts of spinel and a heterolithic suite of xenoliths. The dikes occupy brittle fracture sets and some show columnar jointing.

STRUCTURAL GEOLOGY

All (meta-) sedimentary rocks in the area are folded and penetratively deformed. The nature of the penetrative foliation ranges from phyllitic in eastern, low-grade parts of the area to schistose and gneissic in regions of higher metamorphic grade. Foliation dips to the northeast in most of the area, but there are large cross-strike differences in the orientation of folds and lineations, and the style of deformation. A cross-section (Fig. 4) illustrates some of this variation and the distribution of the six structural domains described below (Fig. 5). In broad terms, the area can be divided into three regions:

- A southwest-vergent fold and thrust belt in the northeast corner of the mapped area (domains 1-3). Folds in this area mostly trend NW (domains 1 and 2).

- A central region characterized by upright, NW-trending folds (domain 4)
- A highly deformed region in the southwest, characterized by tight-isoclinal folding, in which folds and stretching lineations trend at a high angle to strike (domains 5 and 6).

DOMAIN 1

Domain 1 includes rocks belonging to the Vampire, Gull Lake and Rabbitkettle formations in the northeast corner of 105H/9. The foliation (S_1) dips northeast at steep to moderate angles and is axial planar to open-close folds and has axes that mostly plunge at shallow angles to the northwest or southeast (Fig. 6a). Folds (F_1) are upright but mostly asymmetric, with relatively steep and short southwest-dipping limbs (Fig. 7a). There is large relief and good exposure in this area but the relative homogeneity of the Rabbitkettle Formation means that large-scale folds are not prominent.

SPROGGE FAULT

The boundary between domains 1 and 2 (and locally also the domain 1-3 boundary; Fig. 5) is marked by a northeast-dipping fault, or series of faults that separates Yusezyu Formation from Rabbitkettle Formation. This is interpreted as a northeast-side-down normal fault/fault zone.

For much of its length, the Yusezyu Fm-Rabbitkettle Fm boundary is marked by a simple fault/fault zone (here termed the Sprogge fault) that dips moderately steeply towards the northeast. The geometry is more complex, however, in the area southeast of the Justin pluton. On the ridge immediately south of the pluton (1.5 km to the southeast of its centre), the Yusezyu Fm-Rabbitkettle Fm boundary is marked by a steep normal fault (Kangas fault; Fig. 5) that is interpreted to offset the Sprogge fault (Fig. 7b). Rocks to the west of the Kangas fault are

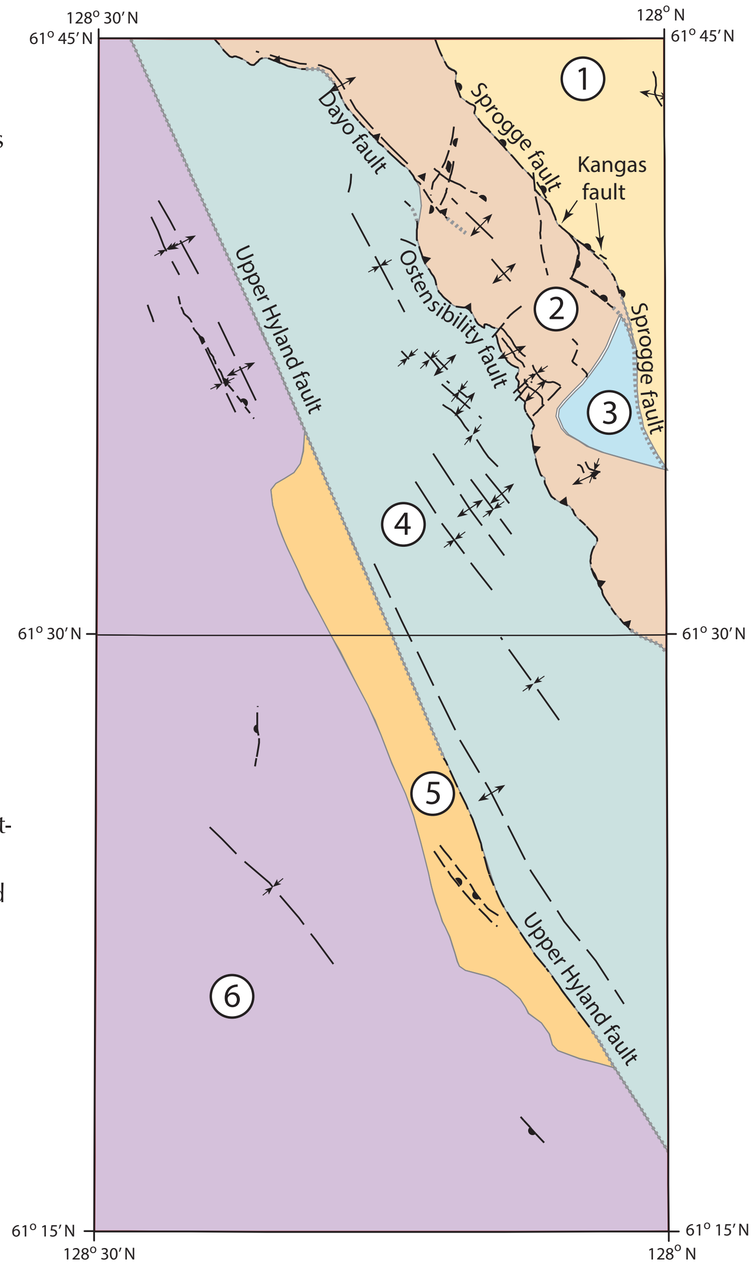


Figure 5. *Structural domains 1-6 and major faults referred to in the text. Symbols as in Figure 2.*

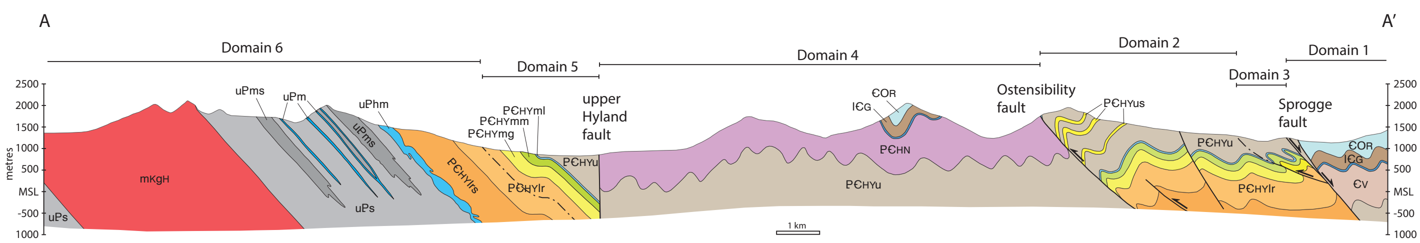


Figure 4. *Cross section across line A-A′; see Figure 2 for location of section line and legend.*

hornfelsed and host numerous small granitic intrusions, whereas dikes/sills are absent from rocks on its east side. This demonstrates post-mid-Cretaceous motion on the Kangas fault. Further south (~4 km to the south-southeast), a northeast-dipping sliver of basal Gull Lake Fm (limestone conglomerate and minor greenschist) is structurally intercalated between two panels of upper Yusezyu Fm

The Sprogge fault extends southeast into the Flat River area (95E, Gabrielse *et al.*, 1973), and continues northweast into the Little Hyland River valley, where it separates Yusezyu Formation (west side) from Vampire Formation (east side). Further up the valley to the northwest, hills to the west of the valley are underlain by Narchilla Fm, and it is not clear whether the fault continues the length of the valley or whether the Narchilla Fm-Vampire Fm contact is depositional.

Hart and Lewis (2006) interpreted the Sprogge Creek fault as a continuation of the March fault (Gordey and Anderson, 1993), a southwest-dipping thrust fault in the Little Nahanni River area that marks the northeastern limit of the Gull Lake Formation. However, this interpretation is subject to uncertainty, as there may not be physical continuity between the structures, they dip in opposite directions and there is Gull Lake Formation on either side of the Sprogge fault. Hart and Lewis (2006) further postulated that the March fault/Sprogge fault continues south into the Coal River area (95D) and continues along a magnetic anomaly that is coincident with the northern part of the Acland fault (Pigage *et al.*, 2015). As noted below, the Acland fault is more likely continuous with the Upper Hyland fault.

DOMAIN 2

Domain 2 is bounded by the Sprogge fault on the east and by two northeast-dipping faults in the west; the Ostensibility and Dayo faults.

The Ostensibility fault is a northeast-dipping reverse fault which marks the boundary between the Yusezyu Formation and the Narchilla Formation in the eastern part of 105H/9. Rocks adjacent to the fault are strongly foliated and compositionally banded. The location of the fault commonly coincides with discontinuous lenses of overturned limestone or brecciated orange-brown, sugary-textured dolostone. These rocks are interpreted as variably altered limestone from the uppermost part of the Yusezyu Fm (PƐHYul). The Dayo fault is north of and sub-parallel to the Ostensibility fault (parallel to Dayo Creek). It is a steeply-dipping fault that juxtaposes the grit member of the middle Yusezyu Formation (PƐHYmg) against the upper Yusezyu Formation. The fault is interpreted as a continuation of a thrust fault north of the 3 Aces (formerly 3Ace) prospect that also carries PƐHYmg in its hanging wall.

Foliation in Domain 2 dips at moderate to shallow angles to the northeast (Fig. 7c), and is axial planar to open-close folds that trend northwest (Fig. 6b). The axes of these folds generally plunge at shallow angles. Folds are asymmetric (Fig. 7d,e) and overturned to the southwest, adjacent to the Ostensibility Creek fault (Fig. 7f). Some fold trains are well defined by prominent sandstone/grit layers in the upper Yusezyu Formation (PƐHYu) and can be traced for several km along strike.

DOMAIN 3

This domain also lies within the corridor between the Sprogge Creek and Ostensibility Creek faults (Fig. 5). Foliation dips at shallow to moderate angles to the northeast, as in domain 2, but is instead axial planar to folds that plunge towards the north and northeast, approximately down the dip of the foliation (Fig. 6c). These folds are tight and commonly disharmonic, and layers that define folds are highly discontinuous; this lends a chaotic appearance to exposure viewed approximately down plunge.

The folds in this domain are interpreted to have been tightened and rotated towards their down-dip orientation during progressive deformation. Kinematic study is required to determine whether fold tightening was accompanied by thrust or normal sense shearing during foliation development; however, the fact that this zone appears to form a wedge within domain 2 suggests that it is a thrust-sense shear zone associated with the southwest-vergent deformation that characterizes domains 1 and 2.

Although the Selwyn fold and thrust belt generally verges towards the foreland (to the northeast/east), southwest-vergent deformation was also noted in the southern part of the Little Nahanni River area (Gordey and Anderson, 1993), and it is possible that it forms an extensive belt in SE Yukon.

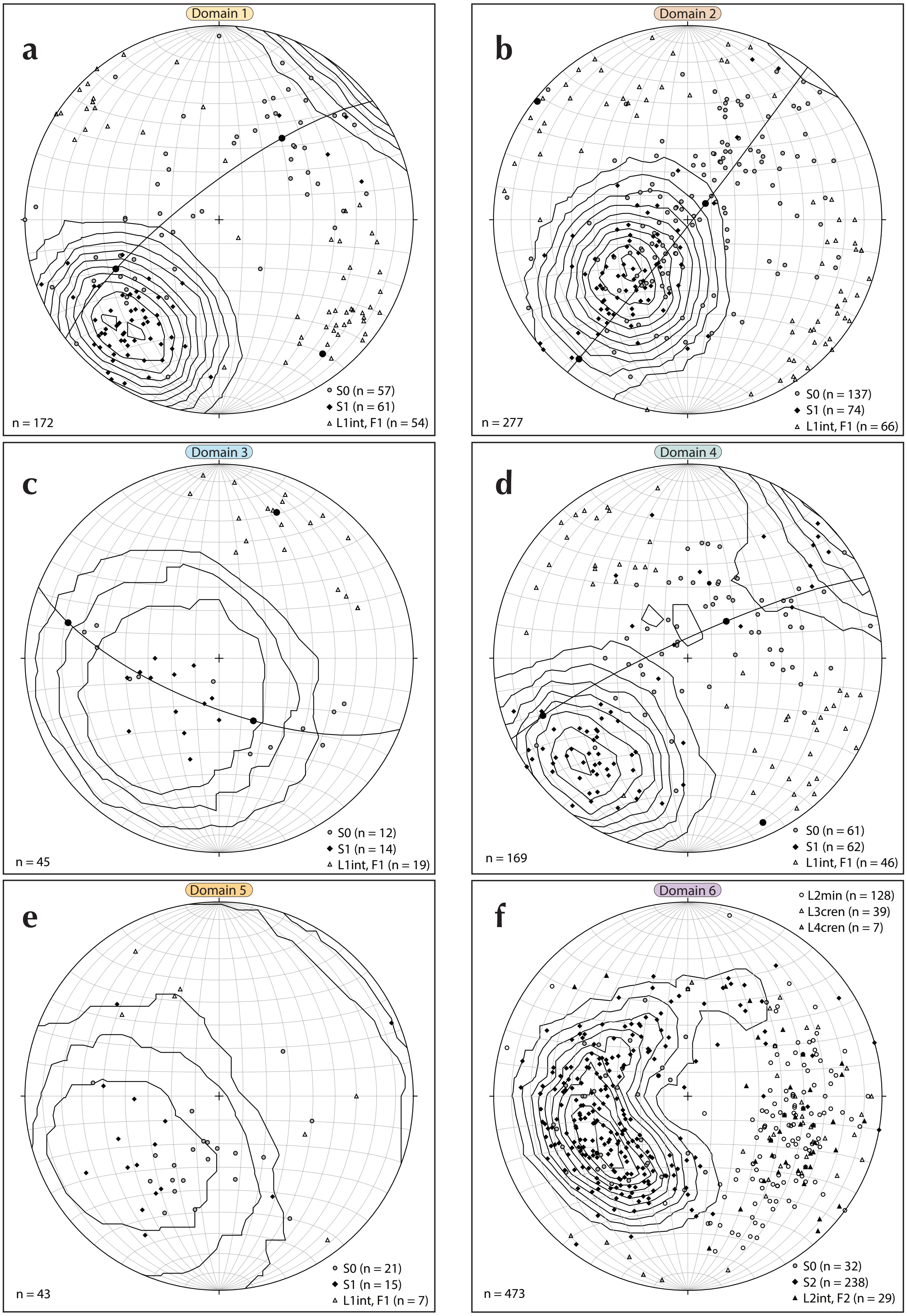


Figure 6. *Equal area, lower hemisphere projections showing the orientation of structures in each of the six structural domains. The dominant foliation in each domain (S_1, S_2) is contoured using the Kamb (1959) method, with contour intervals of 2σ.*

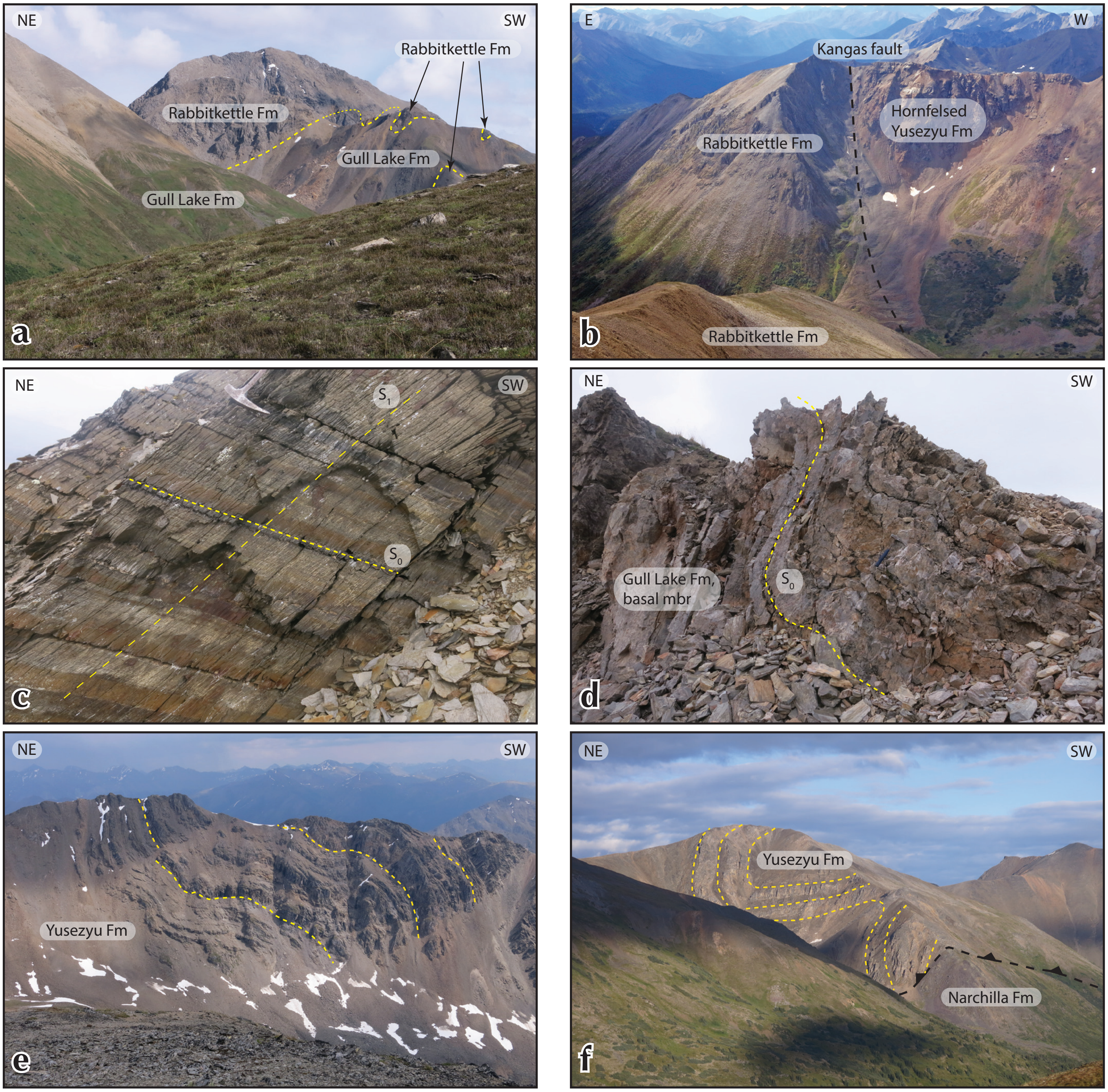


Figure 7. *(a) Folded contact between Gull Lake Fm and Rabbitkettle Fm on the eastern margin of 105H/9 (domain 1). Cleavage dips northeast and folds are asymmetric, with shorter, steeper southwest-dipping limbs. Elevation difference between the viewpoint and the highest mountaintop is approximately 650 m. (b) Fault contact between Rabbitkettle Fm and hornfelsed Yusezyu Fm approximately 2 km southeast of the Justin pluton in eastern 105H/9 (boundary between domains 1 and 2). The fault dips steeply and is interpreted to cut a lower-angle normal fault that marks the boundary between these formations in much of the northeastern part of the area. Relief between the valley bottom and ridge top is approximately 550 m. (c) Well-developed cleavage in brown-weathering, grey phyllite of the upper Yusezyu Formation (domain 2). Hammer for scale. (d) Southwest-verging folds in limestone conglomerate of the basal Gull Lake Formation. Gull Lake formation is tectonically intercalated with Yusezyu Formation at this location in the northeast part of 105H/9. Hammer for scale. (e) Large folds in the upper Yusezyu Formation, domain 2. Cleavage is axial planar to these folds and dips northeast moderately steeply. The cliff/steep slope facing the viewpoint is approximately 300 m high. (f) Overturned, southwest-verging folds in the immediate hanging wall of the Ostensibility thrust. The folds are outlined by two thick grit units in the upper Yusezyu Formation, which is thrust over the Narchilla Formation. The limestone member of the uppermost Yusezyu Fm is locally preserved along this contact. Visible relief is ~650 m.*

DOMAIN 4

Domain 4 includes a large region in the centre of the mapped area between the Ostensibility/Dayo faults and the Upper Hyland fault (Fig. 5). This area is mostly underlain by frost-heaved Narchilla Formation; topography is relatively subdued and except where Gull Lake and Rabbitkettle formations are exposed in the cores of synclines, large-scale fold geometries are difficult to discern. Foliation generally dips moderately to steeply northeast and locally steeply to the southwest (Fig. 6d). Folds are upright (Fig. 7g), open-close and have axes that plunge at shallow angles to the northwest or southeast. The structure is similar to that in domain 2, but in general folds are more symmetrical and the foliation dips more steeply.

UPPER HYLAND FAULT

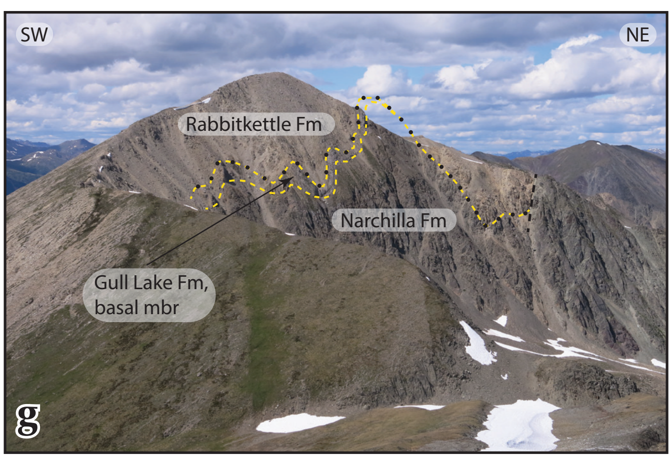
A steeply-dipping, northwest-striking fault in the eastern part of 105H/8 juxtaposes oppositely dipping panels of Hyland Group. Southwest of the fault, rocks generally dip towards the northeast, and stratigraphy is truncated at a low angle by the fault. As the sequence strikes slightly counter-clockwise of the fault trace, progressively deeper levels are truncated towards the southeast. Northeast of the fault, rocks of the uppermost Hyland Group (upper Yusezyu and Narchilla formations) dip southwest towards the fault. Northeast of the fault, metamorphic grade in mudstones of the Narchilla Formation is very low, whereas rocks with similar protolith to the southwest are coarser-grained phyllites with rare biotite crystals in lower parts of the Yusezyu Formation.

To the southeast, the fault runs into a broad valley that separates Yusezyu Formation (west side) from Rabbitkettle Formation (east side). This boundary is probably a continuation of the fault, which is along strike from, and possibly continuous with, the Acland fault, a major structure in Coal River map sheet (105D) that Pigage *et al.* (2011) interpreted as a thrust.

To the northwest, the fault projects into the upper Hyland River valley, where it is interpreted to coincide with the eastern margin of a region of high magnetic susceptibility (Fig. 8). As the broad river valley is filled with Quaternary sediment and the Yusezyu Formation undivided on current maps, the northwestern extent of this fault is unknown. Although speculative, the convergence of magnetic lineaments and possible truncation of the east end of the Shannon pluton suggests the fault may extend northwest into the Little Nahanni River map area (105I; Fig. 8). The movement history of the fault is unknown, but its steep dip, linear trace and long strike-length are suggestive of strike-slip displacement.

DOMAIN 5

Domain 5 includes rocks of the middle and upper Yusezyu Fm that are located immediately west of the Upper Hyland fault. The stratigraphic sequence dips northeast, as does foliation (S_1), which is axial planar to folds that trend northwest or southeast (Fig. 6e). The structural style is similar to that in domain 4.



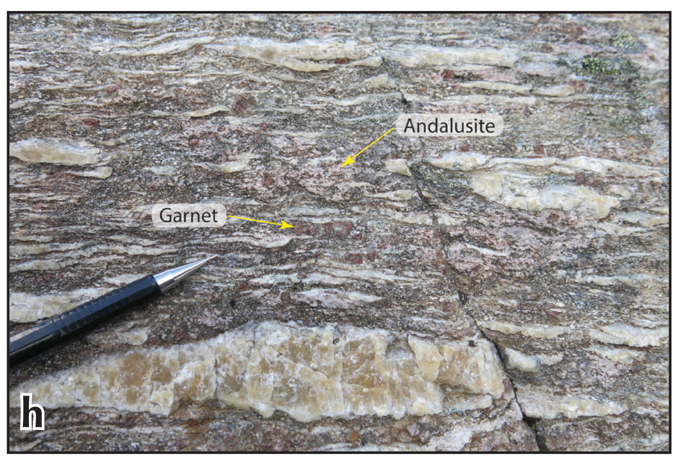


Figure 7 (continued). *(g) Upright folds in the east-central part of 105H/9 (domain 4). The basal member (limestone conglomerate) of the Gull Lake Fm is cut out beneath the folded, sub-Rabbitkettle unconformity (unconformity indicated with dots). The elevation difference between the saddle in the foreground and the peak is approximately 160 m.*
(h) Schistosity in Andalusite-zone schist in the western part of 105H/9. Partly preserved crenulations indicate this schistosity (S_2) overprints an earlier planar fabric (S_1). Pencil for scale.

DOMAIN 6

Domain 6 includes most of the rocks on the west side of the upper Hyland River fault, including all of the amphibolite-facies rocks that fringe the Billings and Anderson batholiths. Whereas a single foliation is discernable in other domains, evidence that the main schistosity (S_2) overprints an earlier cleavage (S_1) is commonly preserved in thin section in domain 6. Further investigation of age relationships is required to reach a definitive conclusion, but this observation suggests that structures in domains 1-5, including the southwest-vergent folds and thrusts, pre-date the amphibolite-facies, penetrative deformation recorded in domain 6.

The foliation (S_2; Fig. 7h) generally dips northeast at shallow-moderate angles (Fig. 6f). Compositional layering is invariably parallel to the dominant schistosity, which is axial-planar to tight-isoclinal folds (Fig. 7i,j,k,l). Fold axes, intersection lineations, mineral lineations (Fig. 7m) and elongation lineations generally trend east-southeast, and pitch steeply on the foliation plane, perpendicular to boudin necks (Fig. 7n). Crenulations of S_2 with axes parallel to the mineral lineation are common throughout (F_3; Fig. 7o), and a later set of crenulations, at a high angle to the first, is locally developed east of the Hyland River (F_4). When viewed perpendicular to the lineation, structures are not obviously asymmetric and further kinematic study is required to establish whether penetrative deformation and east-southeast to west-northwest stretching in this area was accompanied by top to the east (normal sense) shearing, top to the west (thrust-sense) shearing, or neither.

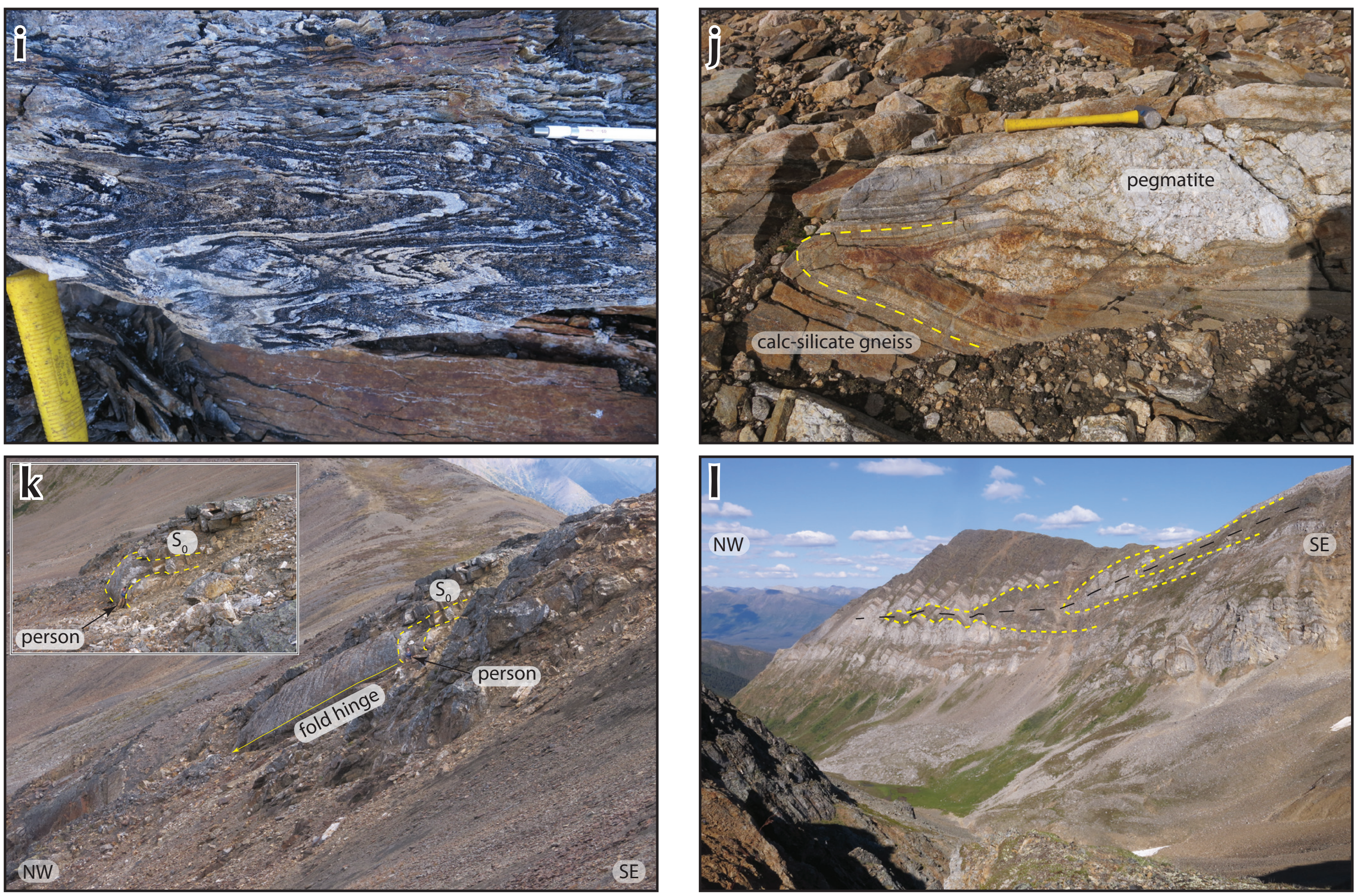


Figure 7 (continued). *(i) Tight similar folds in calc-silicate of unit* uPm*. Pencil for scale. (j)Tight folds in calc-silicate gneiss of unit* uPs*. The pegmatite cross-cuts layering but is itself deformed, suggesting it was intruded during deformation. (k) Tight to isoclinal fold of thick sandstone beds in low grade rocks of the Lower Yusezyu Formation, recessive unit. The large photo is an oblique view of the fold, whereas the inset photo shows the view looking down the plunge, towards the northeast. This is near the upper boundary of domain 6. Person for scale. (l) Isoclinal folds of marble and micaceous schist (units* uPm *and* uPs*, domain 6). The folds plunge towards the northeast, in the approximate dip-direction of the axial-planar foliation (S_2). The elevation difference between the valley bottom and the ridge top is approximately 400 metres.*

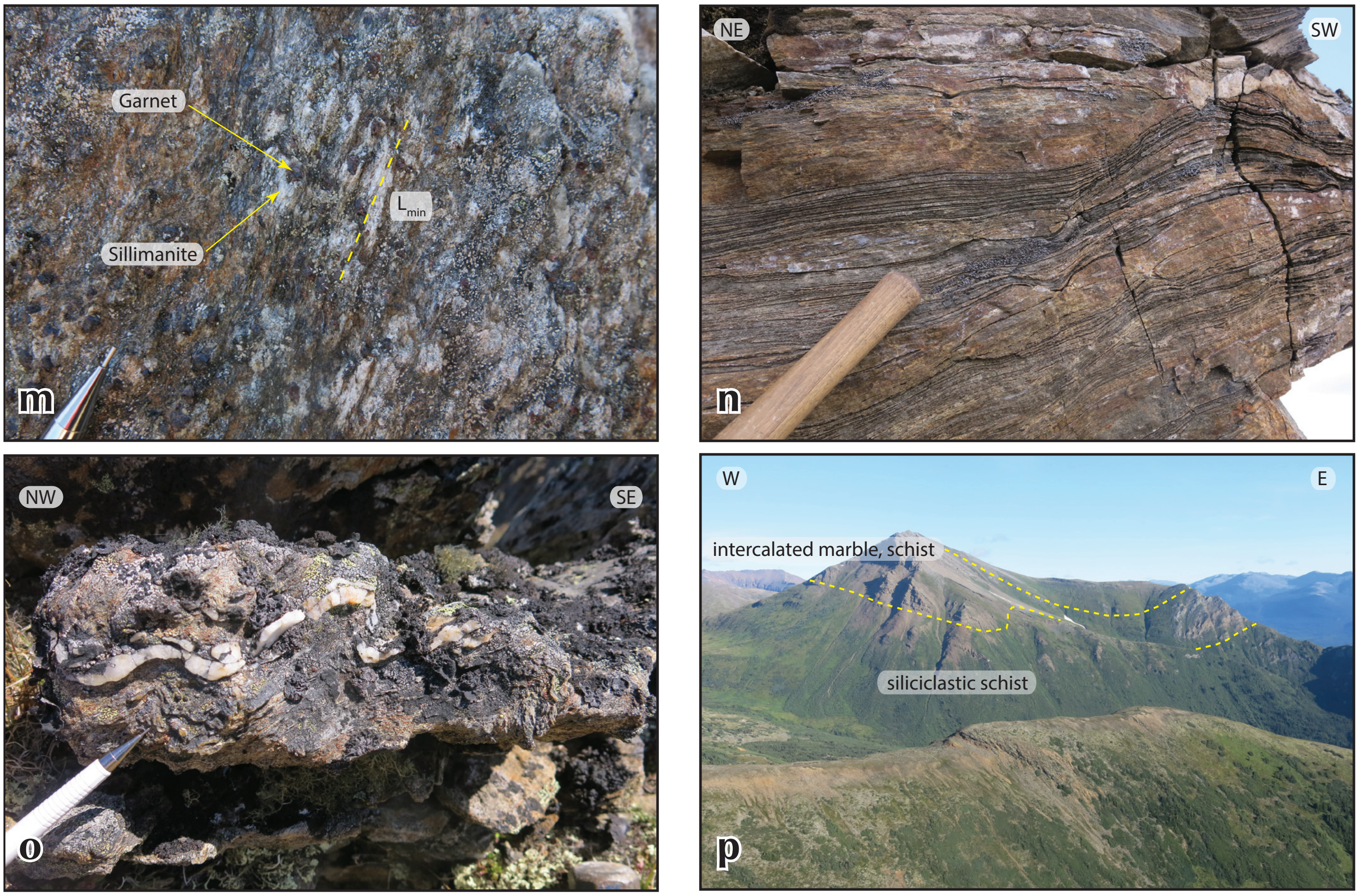


Figure 7 (continued). *(m) Mineral lineation defined by sillimanite crystals around garnet porphyroblasts. Pencil tip for scale. (n) Crenulations and small-scale folds of S_2 and quartz veins. Crenulations in domain 6 pitch steeply, and are generally coaxial with mineral lineations. Pencil for scale. (o) Boudinage structures in calc-silicate schist (*uPm*, domain 6). Boudin necks have gentle plunges, and are perpendicular to fold axes, mineral lineations and crenulations of the foliation (S_2). (p) The dominant foliation in domain 6 is overprinted by some open folds with axes that trend northwest. Elevation from valley bottom (left middle ground) to peak is approximately 550 m.*

The boundary between domains 5 and 6 lies within the unit PЄHYlr, and is evidenced by a change in the orientation of folds/intersection lineations from approximately strike-parallel (domain 5) to steeply pitching (domain 6).

The S_2 foliation and associated structures are folded around late, upright open folds with axes that plunge shallowly to the northwest or southeast (Fig. 7p).

MINERALIZATION

The Upper Hyland River area hosts intrusion-related gold and W-Mo-Cu ± Pb skarn prospects, as well as gold mineralization that has no obvious connection to igneous activity (Hart and Lewis, 2006). Recent exploration activity has been focused in the northeast part of the mapped area where there is intrusion-related Au-W mineralization around the Justin pluton (Higgs, 2009), and coarse, vein-hosted gold mineralization at 3 Aces (Schulze, 2010). 3 Aces is one of a number of gold occurrences hosted in the Yusezyu Formation east of the Hyland River to which Hart and Lewis (2006) ascribed a non-magmatic origin. They proposed that gold mineralization in this belt was related to metamorphic fluids that were generated in response to regional deformation and prograde metamorphism. However, as discussed above, there is uncertainty over the southeastern extent of the March fault, and its postulated extension – the Sprogge fault - appears to be a younger feature, which truncates structures that developed during low grade regional metamorphism.

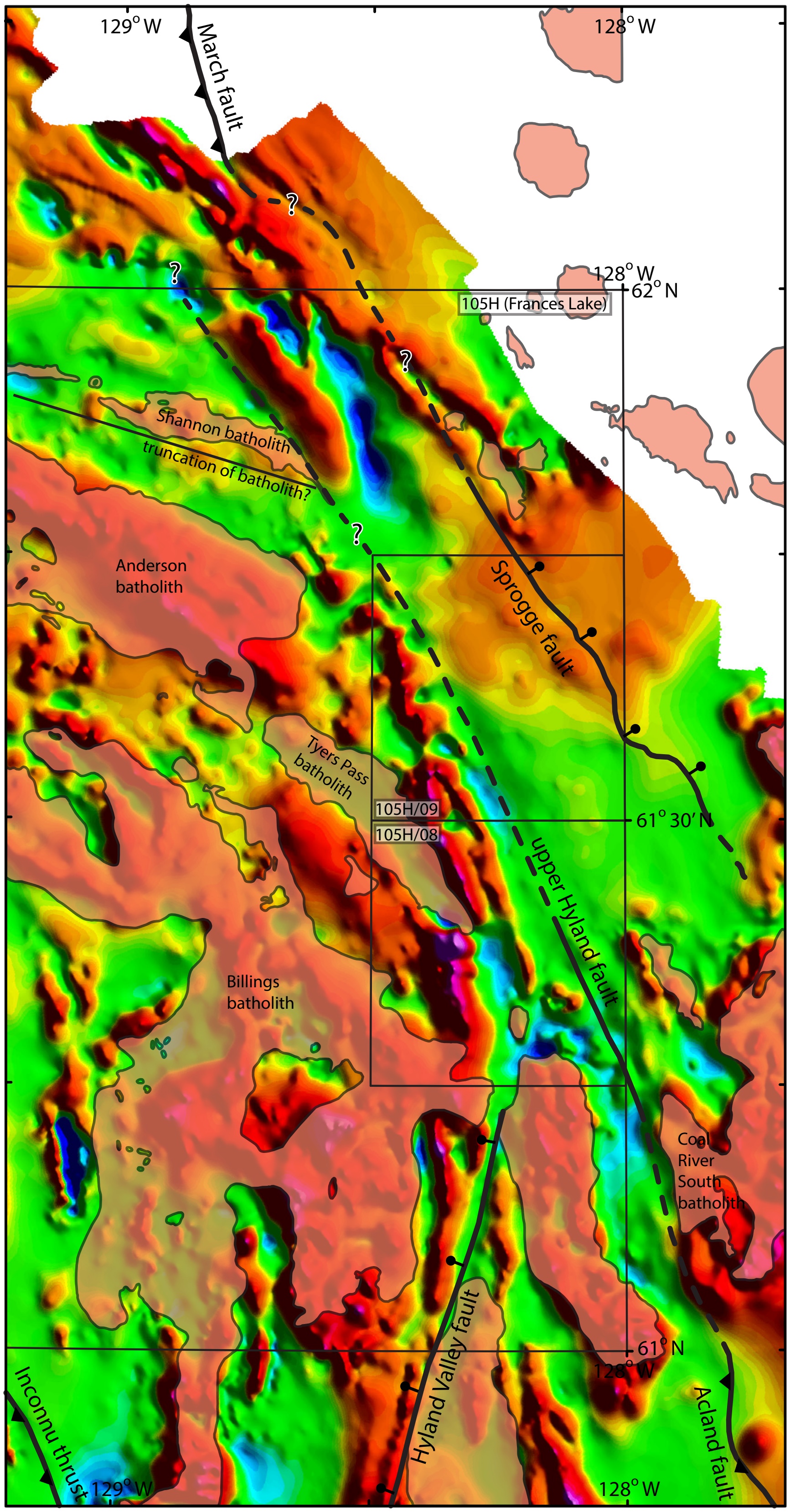


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Figure 8. *Total field aeromagnetic data from part of southeast Yukon, and postulated traces of major faults in the eastern part of the Frances Lake map area (105H). Plutonic rocks are indicated with a red semi-transparent overlay.*

REFERENCES

Abbott, J.G., 1997. Geology of the Upper Hart River area, eastern Ogilvie Mountains, Yukon Territory (116A/10, 116A/11). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 9, 92p.

Colpron, M., Moynihan, D., Israel, S. and Abbott, G., 2013. Geological map of the Rackla belt, east-central Yukon (NTS 106C/1-4, 106D/1). Yukon Geological Survey, Open File 2013-13, 1:50 000 scale, 5 maps and legend.

Cecile, M.P., 2000. Geology of the Northeastern Niddery Lake map area, east-central Yukon and adjacent Northwest Territories. Geological Survey of Canada, Bulletin 533, 120 p.

Fritz, W.H., 1982. Vampire Formation, and new Upper Precambrian(?)/Lower Cambrian Formation, Mackenzie Mountains, Yukon and Northwest Territories. *In:* Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 83-92.

Gabrielse, H., Blusson, S.L. and Roddick, J.A., 1973. Geology of Flat River, Glacier Lake and Wrigley Lake map areas, District of Mackenzie and Yukon Territory. Geological Survey of Canada, Memoir 366, 421 p.

Gordey, S.P. and Anderson, R.G., 1993. Evolution of the Cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428, 214 p.

Hart, C.J.R. and Lewis, L.L., 2006. Gold mineralisation in the upper Hyland River area: A non-magmatic origin. *In:* Yukon Exploration and Geology 2005, D.S. Emond, G.D. Bradshaw, L.L. Lewis and L.H. Weston (eds.), Yukon Geological Survey, p. 109-125.

Higgs, A., 2009. Geological and geochemical report for the Sprogge (Justin) property, Watson Lake mining district, southeastern Yukon territory, 105H/09. Energy, Mines and Resources, Government of Yukon, Assessment Report 095153.

Kamb, W.B., 1959, Ice petrofabric observations from Blue Glacier, Washington, in relation to theory and experiment. Journal of Geophysical Research, vol. 64, p. 1891-1909.

MacLeod, W.A., 1982. Cal 81-144 mining claims, Watson Lake mining district, 105H/08W. Energy, Mines and Resources, Government of Yukon, Assessment Report 090867.

Martel, E., Turner, E.C. and Fisher, B.J. (eds.), 2011. Geology of the central Mackenzie Mountains of the northern Canadian Cordillera, Sekwi Mountain (105P), Mount Eduni (106A), and northwestern Wrigley Lake (95M) map area, Northwest Territories. NWT special Volume 1, NWT Geoscience Office, 423 p.

Moynihan, D.P., 2013. A preliminary assessment of low pressure, amphibolite-facies metamorphism in the upper Hyland River area (NTS 105H), southeast Yukon. *In:* Yukon Exploration and Geology 2012, K.E. MacFarlane, M.G. Nordling, and P.J. Sack (eds.), Yukon Geological Survey, p. 99-114.

Moynihan, D., 2016a. Bedrock geology compilation of the eastern Rackla belt, NTS 105N/15, 105N/16, 105O/13, 106B/4, 106C/1, 106C/2, east-central Yukon. Yukon Geological Survey, Open File 2016-2, 1:75 000 scale.

Moynihan, D., 2016b. Bedrock geology of parts of NTS 105H/8 and 105H/9, upper Hyland River area, southeast Yukon. Yukon Geological Survey, Open File, 1:50 000 scale, in prep.

Pigage, L.C., Roots, C.F. and Abbott, J.G., 2015. Regional bedrock geology for Coal River map area (NTS 95D), southeast Yukon. Yukon Geological Survey, Bulletin 17, 155 p.

Rasmussen, K., 2013. The timing, composition and petrogenesis of syn- to post-accretionary magmatism in the northern Cordilleran miogeocline, Eastern Yukon and southwestern Northwest Territories. Unpublished PhD thesis, University of British Columbia, Vancouver, Canada, 788 pages.

Roots, E.F., Green, L.H., Roddick, J.A. and Blusson, S.L., 1966. Geology, Frances Lake, Yukon territory and district of Mackenzie. Geological Survey of Canada, preliminary map 6-1966. 1:253 440 scale.

Ross, G.M., 1991. Tectonic setting of the Windermere Supergroup revisited. Geology, vol. 19, p.1125-1128.

Schulze, C.M., 2010. YMIP report on the phase 1 2010 geological and geochemical surveys on the 3Ace property, southeast Yukon, 73 pages. YEIP 2010-118.