Bedrock Geology of NTS 106B/04, Eastern Rackla Belt

David Moynihan[1]
Yukon Geological Survey, Whitehorse, YT

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ABSTRACT

The NTS 106B/04 map area straddles the upper reaches of the Stewart River in east-central Yukon. The area north of the Stewart River is underlain by Ediacaran clastic and carbonate continental slope deposits of the uppermost Windermere Supergroup, and by Ediacaran-Cambrian rocks of the Hyland Group (Selwyn basin). The area south of the Stewart River is dominated by the Cambrian Gull Lake Formation and Cambrian (-Silurian?) volcanic rocks of the Old Cabin Formation. The main structures in 106B/04 define an arcuate pattern; they are oriented NW-SE in most of the area, but are approximately E-W in the westernmost part of the map area. These structures include upright, gently-plunging folds and steeply-dipping, axial-planar cleavage. Folding was locally accompanied by thrusting. Late structures include a steeply-dipping sinistral fault that transects the central part of the map area and a number of NW-WNW-striking normal (± dextral) faults. Stratigraphic relationships suggest correlation of the upper Yusezyu, Algae, and Narchilla formations of the Hyland Group (Selwyn basin) with the upper Blueflower, Risky, and Ingta formations of the Windermere Supergroup (Ogilvie and Mackenzie platforms). Gold mineralization has recently been discovered in the Algae Formation, which has also been explored for Mississippi Valley-type lead-zinc-silver mineralization elsewhere in the area.

[1] *david.moynihan@gov.yk.ca*

INTRODUCTION

In 2010, the Yukon Geological Survey began a 1:50 000-scale bedrock mapping project focused on the northern margin of Selwyn basin in east-central Yukon (NTS 106D and 106C; Fig. 1). The project area covers a narrow region approximately parallel to the east-striking Dawson thrust, which marks the northern margin of Selwyn basin in this region. The area, which includes the headwaters of the Rackla and Nadaleen rivers, is informally known as the Rackla belt.

The Rackla belt contains numerous mineral occurrences (Fig. 2) and continues to attract exploration activity following recent discoveries of gold mineralization. Of particular interest is the recognition of sediment-hosted gold mineralization similar to that in the Carlin area of Nevada (Tucker *et al.*, 2013, Arehart *et al.*, 2013). With the exception of NTS 106D/01, which was mapped by Abbott (1990a,b), the only regional geological information available prior to 2010 was contained in 1:250 000 reconnaissance level maps (Green, 1972; Blusson, 1974). The YGS mapping program was established to document the regional stratigraphic and structural characteristics of this geological and metallogenic belt.

Following their work in the summer of 2012, Colpron *et al.* (2013) combined their mapping with all recent work (Abbott, 1990a,b; Chakungal and Bennett, 2011; Colpron, 2012a,b) and released a compilation map of most of the belt (5 contiguous 1:50 000 sheets) with a common legend (Figs. 1 and 2). In the summer of 2013, mapping was extended eastward to include NTS sheet 106B/04 (Figs. 2 and 3). This report describes the bedrock geology of this area and accompanies a new 1:50 000-scale open file map (Moynihan, 2014).

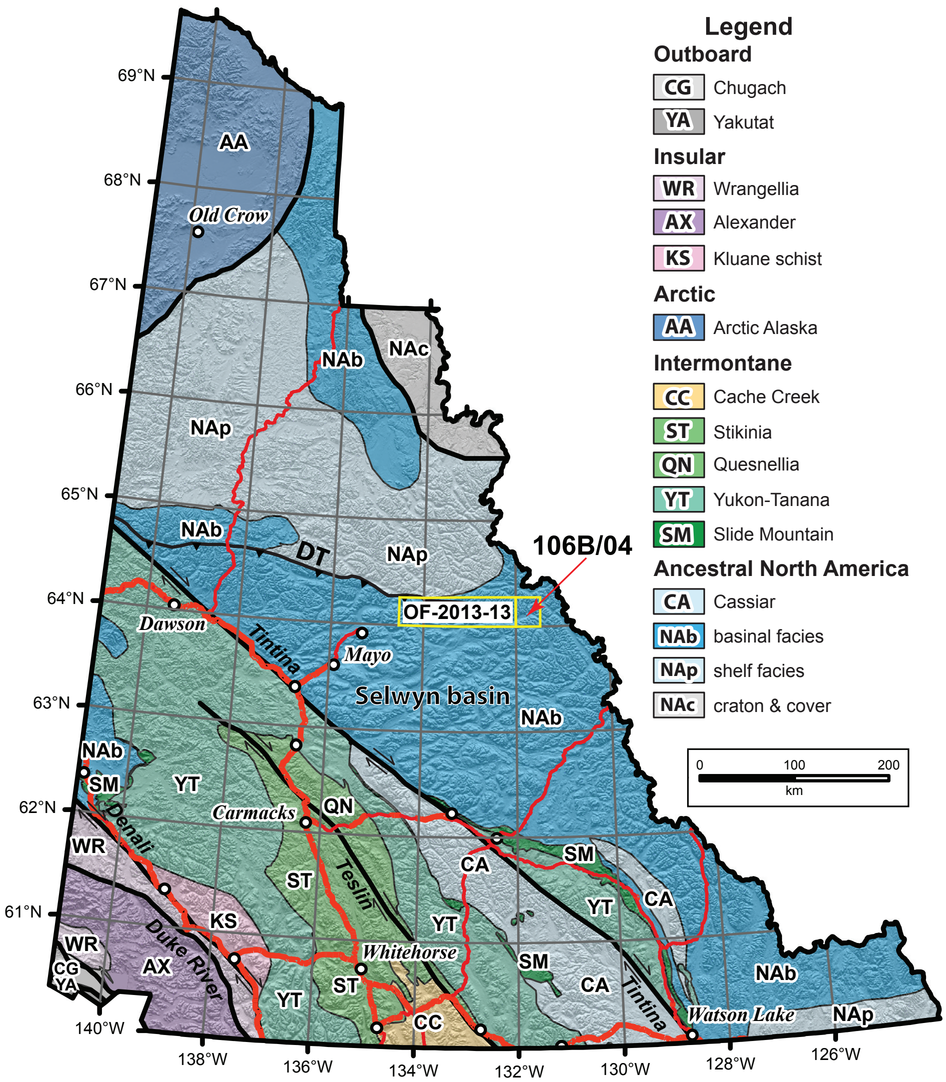


Figure 1. *Terrane map of Yukon, showing the location of the Rackla project area. The yellow boxes show the extent of the compilation map of Colpron et al. (2013) and the area mapped in 2013 (NTS 106B/04). DT = Dawson thrust.*

GEOLOGICAL BACKGROUND

The northern margin of Selwyn basin is marked by the Dawson thrust, which was active during Mesozoic (probably mid-Cretaceous) shortening associated with the Cordilleran orogeny. The Mesozoic thrust coincides with the location of an antecedent structure that influenced depositional/intrusion patterns over a number of intervals since the Neoproterozoic (Abbott, 1997).

In the western part of the Rackla belt the Dawson thrust juxtaposes Neoproterozoic-Cambrian rocks of the Selwyn basin (Hyland Group; Gordey and Anderson, 1993) against Proterozoic-Paleozoic shelf and

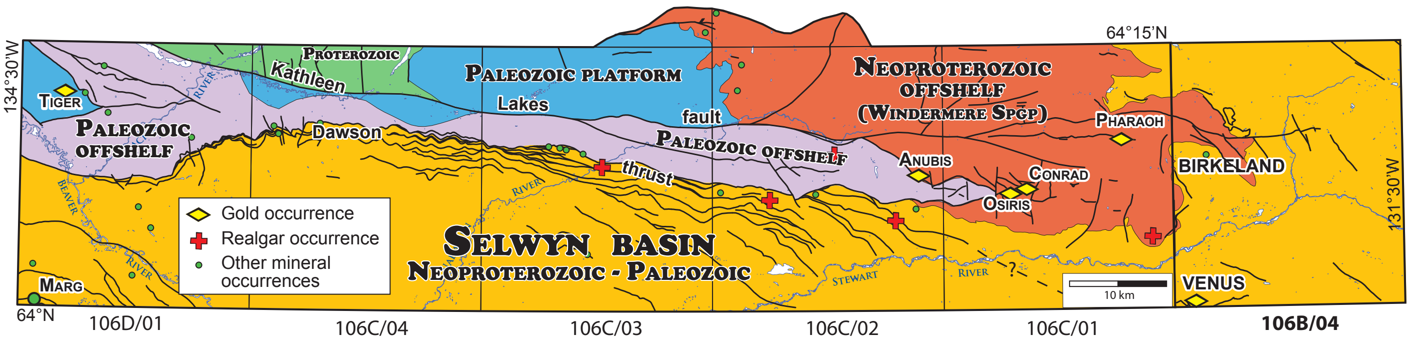


Figure 2*. Summary of facies domains, major structures, and mineral occurrences in the Rackla belt, after Colpron et al. (2013). The northern margin of Selwyn basin is marked by the Dawson thrust in the western and central Rackla belt; however, the fault dies out towards its eastern end of the Rackla belt.*

slope rocks of the Ogilvie platform (Fig. 2). The thrust is not a single structure but rather a highly imbricated zone with several closely-spaced thrust faults that strike east and dip at moderate angles to the south (Chakungal and Bennett, 2011; Colpron, 2012a,b).

Towards the eastern end of the belt the fault zone steepens, its strike changes to a SSE orientation, and the distances between splays of the fault increase (Fig. 2; Colpron *et al.*, 2013), implying a decrease in the amount of shortening across the zone. This diffuse fault zone projects into the NE corner of the Lansing area, where Roots (2003) mapped NE-verging thrusts and folds.

In the eastern Rackla belt, upper parts of the Hyland Group - represented by the carbonate Algae and mudstone-dominated Narchilla formations - occur within, and on either side of the diffuse fault zone. Whereas these formations are exposed throughout the area, the nature of the rocks they overlie varies. South of the Dawson thrust zone the Algae-Narchilla formations succeed coarse clastic rocks of the Yusezyu Formation (lower Hyland Group), whereas in the region to the north they form the upper part of a sequence dominated by fine clastic and carbonate rocks of the Windermere Supergroup. The information contained within this report illustrates the primary stratigraphic relationships between these contrasting sequences.

STRATIGRAPHY

WINDERMERE SUPERGROUP

The oldest units in the area, which are exposed north of the Stewart River, are correlated with the unnamed "upper group" of the Windermere Supergroup. The stratigraphy, sedimentology, and paleontology of these units have been documented extensively elsewhere in the Mackenzie and Wernecke mountains (Aitken, 1989; Narbonne and Aitken, 1995; Pyle *et al.* 2004; MacNaughton *et al.* 2000; Macdonald *et al.*, 2013). Colpron *et al.* (2013) provisionally correlated Neoproterozoic stratigraphy north of the Dawson thrust with the Windermere Supergroup, but did not use Windermere Supergroup formation names; instead, they divided the sequence into informal "assemblages". Correlation with the upper group of the Windermere Supergroup is substantiated by detailed lithostratigraphic, paleontological, and chemostratigraphic data collected by the author and J. Strauss during the summer of 2013, and formation names are used in this report. These data, and a discussion of their broader significance, are beyond the scope of the current article and will be presented elsewhere.

NADALEEN FORMATION

The oldest rocks in NTS 106B/04 belong to the upper part of a unit that is here informally termed the Nadaleen formation. This unit, which will be formally defined in the future, is correlative with the "June beds" of Macdonald *et al.* (2013), which were previously considered part of the Sheepbed Formation (Gabrielse *et al.*, 1973). The Nadaleen formation is equivalent to the "Nadaleen assemblage" of Colpron *et al.* (2013).

The Nadaleen formation comprises two members in the map area. The *lower member* consists of thickly-bedded quartz arenite and brown shale ("lower Nadaleen assemblage" of Colpron *et al.*, 2013). This is overlain by rhythmically-layered green to grey, thinly-bedded mudstone, siltstone, and sandstone of the *Stenbraten member*. Graded bedding is evident, sandstones layers are commonly cross-bedded, and some display sole marks, suggesting deposition by turbidity currents. The Stenbraten member was referred to as the "upper Nadaleen assemblage" by Colpron *et al.* (2013).

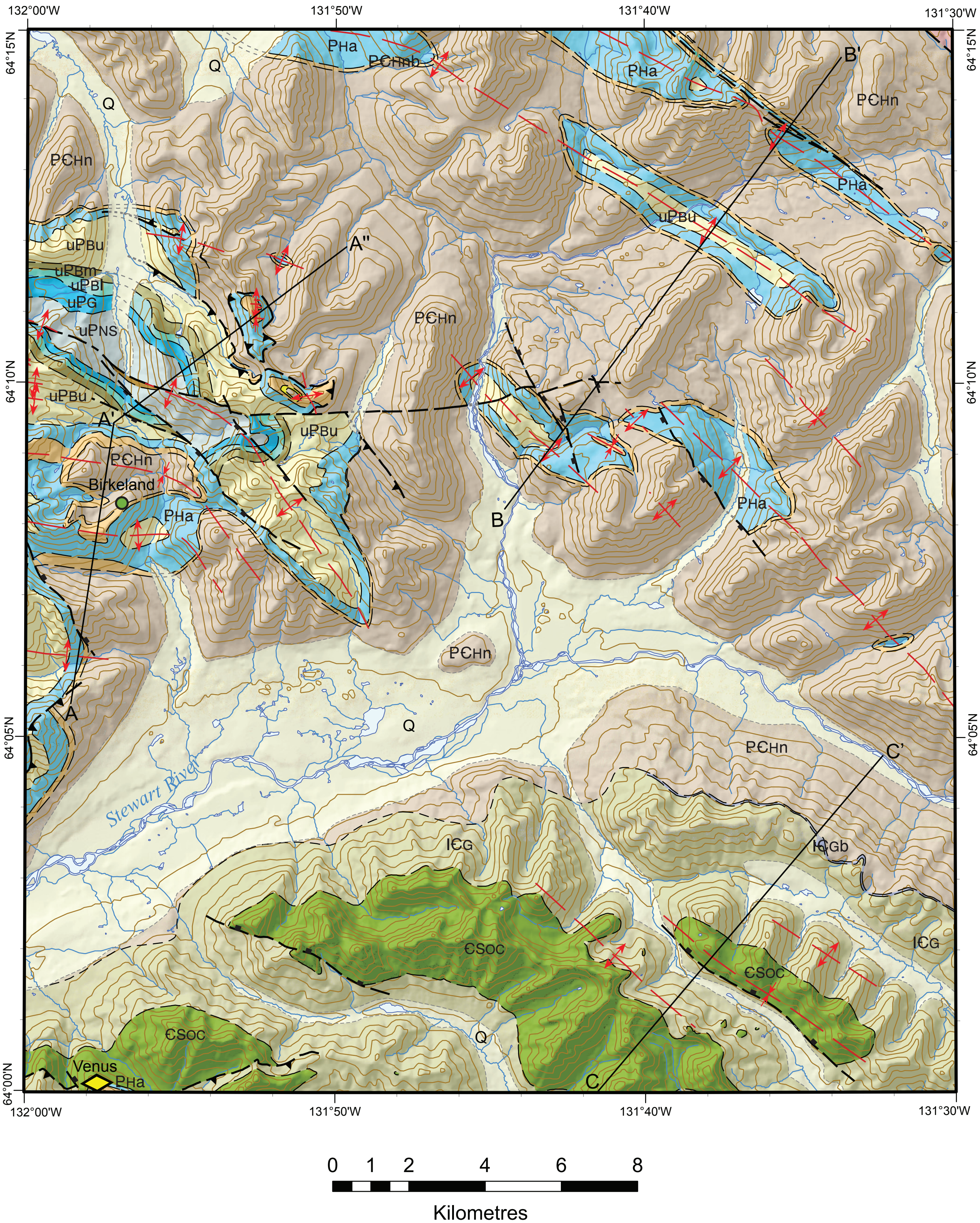


Figure 3. Preliminary geological map and cross sections of NTS 106B/04 at 1:150 000 scale.

QUATERNARY

Q — **QUATERNARY:** *unconsolidated alluvial, colluvial, fluvial and glacial deposits*

MIDDLE CAMBRIAN-SILURIAN

ЄSOc — **OLD CABIN FORMATION:** *mafic volcanic breccia and conglomerate, interbedded with argillite, siltstone and sandstone; minor diabase intrusions.*

LOWER TO MIDDLE CAMBRIAN

lЄs — **SEKWI FORMATION:** *thinly-bedded silty limestone*

lЄG — **GULL LAKE FORMATION:** *white, brown and orange-weathering, olive-green argillite, siltstone and fine sandstone; maroon, black and lime green shale; interbedded shale and quartz arenite; minor silty limestone and limestone-clast conglomerate*

lЄGb — **GULL LAKE FORMATION, BASAL MEMBER:** *boulder conglomerate with archaeocyathid-bearing limestone clasts; brown-weathering, green lithic sandstone and conglomerate, quartz arenite*

SYMBOLS

stratigraphic contact (approximate, covered)

fault (normal, thrust, sinistral movement not known)

fold axial trace (anticline, syncline)

gold occurrence

Zn/Pb occurrence

NEOPROTEROZOIC-CAMBRIAN HYLAND GROUP

EDIACARAN TO LOWER CAMBRIAN

PЄHnq — **NARCHILLA FORMATION:** *quartzite, quartz pebble conglomerate*

PЄHn — **NARCHILLA FORMATION:** *pale brown, green and maroon shale; well-cleaved, rhythmically-bedded mudstone and siltstone, locally bioturbated; white-weathering sandstone*

PЄHnb — **NARCHILLA FORMATION, BASAL MEMBER:** *limestone-clast conglomerate; quartz arenite and grit; limestone; calcareous siltstone/sandstone; green, brown and maroon shale*

NEOPROTEROZOIC (EDIACARAN)

PHa — **ALGAE FORMATION:** *dark grey, light grey and buff-coloured limestone and dolostone, variably dolomitized and variably silty/sandy; commonly graded and cross-bedded; minor grey and/or maroon shale; limestone pebble to cobble breccia and conglomerate; equivalent to Risky Formation of the Windermere Supergroup*

NEOPROTEROZOIC WINDERMERE SUPERGROUP

EDIACARAN

uPBu — **BLUEFLOWER FORMATION, UPPER MEMBER:** *brown-weathering, shale, siltstone and sandstone; pale grey-pink sandstone and grit; calcareous shale; limestone. Equivalent to Yusezyu Formation of the Hyland Group*

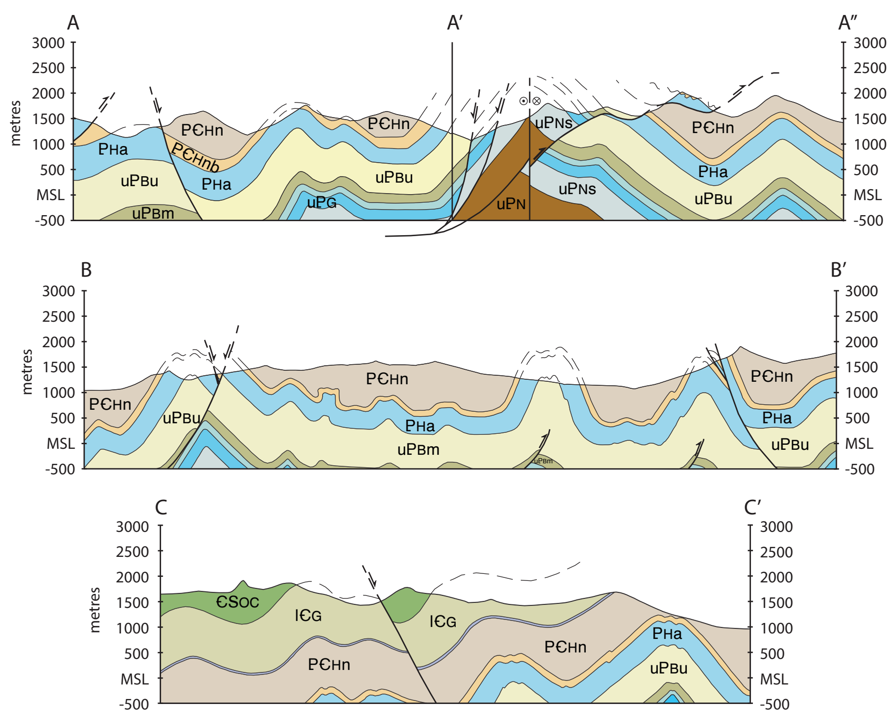
uPBm — **BLUEFLOWER FORMATION, MIDDLE MEMBER:** *green or grey, rhythmically-bedded mudstone, siltstone, and fine sandstone*

uPBl — **BLUEFLOWER FORMATION, LOWER MEMBER:** *buff, grey and pale yellow-weathering limestone interbedded with green shale. Limestone is planar and cross-bedded*

uPG — **GAMETRAIL FORMATION:** *grey, yellow and orange weathering dolostone, dolomitic siltstone/sandstone and limestone, commonly planar and/or cross laminated; calcareous shale and siltstone; maroon shale; carbonate-clast breccia and conglomerate*

uPNs — **NADALEEN FORMATION, STENBRATEN MEMBER:** *grey to greenish-brown rhythmically bedded fine-grained sandstone, siltstone, mudstone; maroon siltstone-mudstone*

uPN — **NADALEEN FORMATION, LOWER MEMBER:** *brownish-grey siltstone, mudstone, limestone; limestone conglomerate; rhythmically, thin to medium bedded mudstone and limestone; local pink-grey quartz sandstone and quartzite; calcareous grit and sandstone*



Gametrail Formation

The Gametrail Formation (Aitken, 1989) forms a distinctive resistant marker unit that is approximately 200 m thick. It comprises deep yellow-orange weathering, thin to thickly bedded dolomitic sandstone, siltstone and shale, grey or yellow ribbon-bedded limestone/dolostone, thin to medium-bedded silty limestone, and massive carbonate breccia. Silty limestone is typically planar and/or cross-bedded and exhibits sole structures indicative of deposition by turbidity currents. The top of the Gametrail Formation is marked by a boulder breccia consisting of large grey and orange limestone/dolostone clasts in a grey limestone matrix (Fig. 4a). In 106C/01, the formation contains a number of maroon shale intervals in a sequence that is generally paler coloured, with a higher proportion of grey limestone; these maroon intervals are not present in 106B/04. Colpron *et al.* (2013) referred to the Gametrail Formation as the "lower Stenbraten assemblage".

Blueflower Formation

The Blueflower Formation (Aitken, 1989) is here divided into three map units, termed the lower, middle, and upper members. The combined thickness of these units approaches 1 km. The Blueflower Formation was referred to as the "upper Stenbraten assemblage" by Colpron *et al.* (2013).

The *lower member* comprises approximately 100 m of medium-bedded silty limestone interbedded with green to grey mudstone (Fig. 4b). Silty limestone beds, interpreted as limestone turbidite deposits, are generally 2-20 cm thick, grey to pale yellow, and are typically planar and/or cross-bedded. They are interbedded with thin green to grey mudstone partings and layers <1 mm to several centimetres thick. On mountain slopes, the lower contact of the Blueflower Formation is marked by an obvious colour change, from pale tones of the lower member to the bright yellow/orange of the Gametrail Formation.

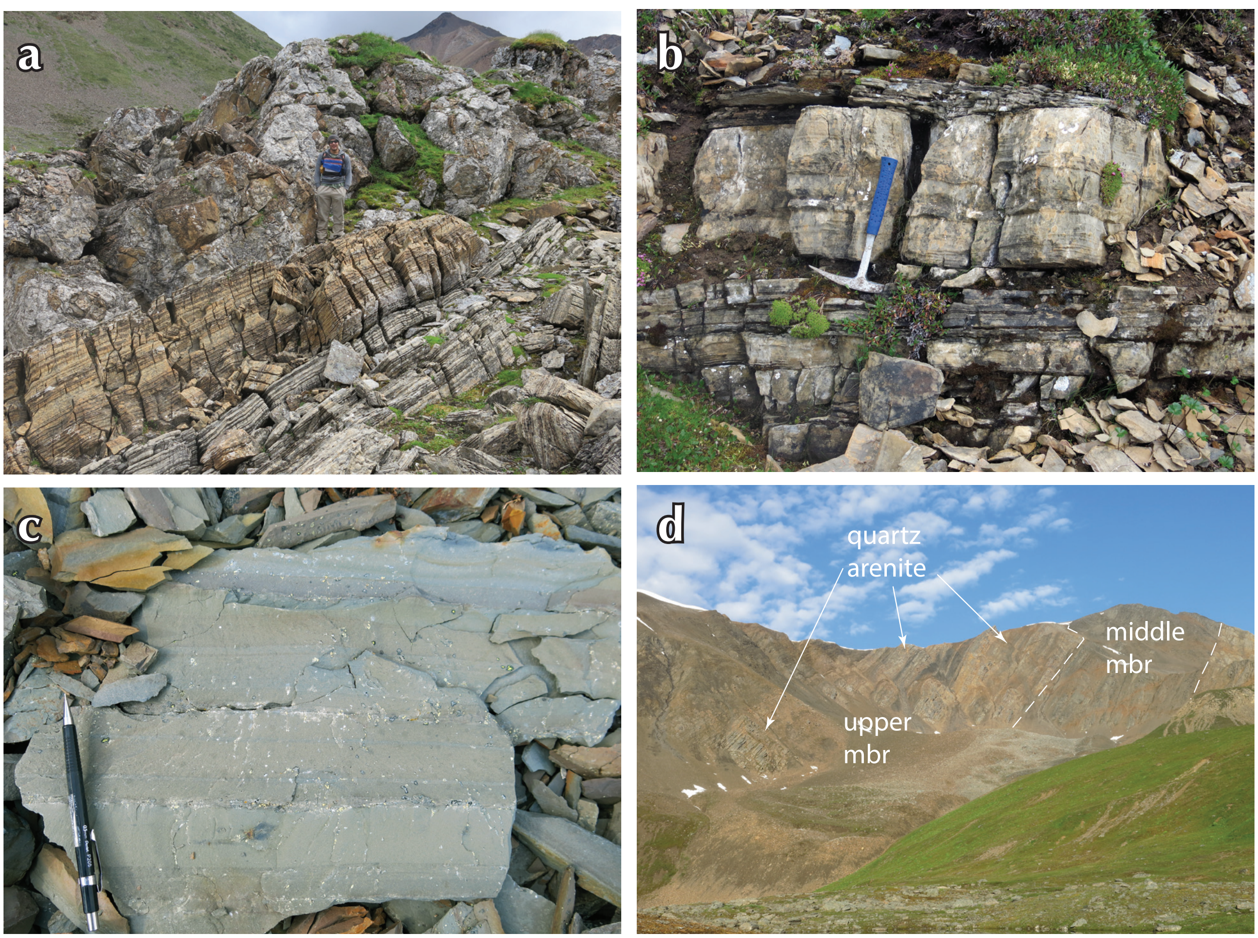


Figure 4. *(a) Ribbon-bedded limestone and dolostone overlain by carbonate-clast breccia; uppermost Gametrail Fm; (b) planar and cross-laminated limestone interbedded with grey-green mudstone; Blueflower Fm, lower mbr; (c) green mudstone and siltstone with graded bedding; Blueflower Fm, middle mbr; (d) view across steeply-dipping section of Blueflower Fm. The upper member contains thick, resistant intervals of quartz arenite and grit; relief is ~400 m.*

The *middle member* is approximately 200 m of olive green to grey, very thinly bedded mudstone, siltstone, and fine sandstone; graded bedding is common and the rocks are rhythmically-layered (Fig. 4c). The boundary between this and the underlying member is gradational. This member is similar to the Stenbraten member of the Nadaleen formation and is likewise interpreted to have been deposited by turbidity currents.

The *upper member* comprises a varied mixture of variably calcareous clastic rocks. It includes intervals of very thickly bedded quartz arenite/grit with abundant limonite spots, brown shale, black shale and sandstone, calcareous grit and conglomerate, silty/sandy limestone, and limy mudstone (Fig. 4d). The top of the unit comprises an interval of brown shale. This member has a total thickness of approximately 500 m. The rock types in the upper member are similar to those in the upper part of the Yusezyu Formation of the Hyland Group (Gordey and Anderson, 1993; Colpron, 2012a,b) south of the Dawson thrust.

In Windermere Supergroup sequences of the Mackenzie and Wernecke mountains, the Blueflower Formation is overlain by the Risky and Ingta formations, which are dominated by carbonate and green/maroon shale, respectively. Similar units overlie the Blueflower Formation in the Rackla area, but are referred to as the Algae and Narchilla formations of the Hyland Group (Selwyn basin; Fig. 3). Windermere Supergroup-Hyland Group stratigraphic nomenclature has evolved independently and clear relationships have not been reported elsewhere. The Risky-Ingta and Algae-Narchilla sequences are considered direct correlatives, but Hyland Group nomenclature is used here based on historical precedent, continuity with mapped sequences in the Selwyn basin, and proximity to the type section of one of the units (Algae Formation). Hyland Group-Windermere Supergroup stratigraphic relationships are discussed further in a later section.

HYLAND GROUP

ALGAE FORMATION

The Algae Formation (Cecile, 2000) consists of pale to dark grey, thinly to medium-bedded cliff-forming limestone and dolostone (Fig. 5a,b). Most of the rocks are limestone (micrite and grainstone, locally oolitic) and silty/sandy limestone, with minor intraclast floatstone/rudstones. Some shaly intervals are interbedded with grainstone near the top of the formation, and the formation also includes minor chert. The base of the formation includes a fetid interval that emits a strong sulphurous smell when walked over or hammered. Silty/sandy limestone is commonly cross-bedded, and in some cases display an upward transition from planar to cross-lamination within individual beds (Fig. 5c). This is interpreted to represent deposition by sediment gravity flows (Bouma B-C sequences). Dolomitized intervals have a coarse-grained, sugary texture, and are coloured white, beige, pink, and light grey. Zebra texture is locally developed. Dolomitization is most widespread and pervasive in the upper part of the formation (Fig. 5b). The Algae Formation is approximately 250-350 m thick in the area; at least part of this variation is due to the presence of an irregular erosional surface between it and the overlying Narchilla Formation.

CONTACT BETWEEN THE ALGAE AND NARCHILLA FORMATIONS

The contact between the Algae Formation and the Narchilla Formation is marked by an erosional surface of varying character. The contact zone commonly includes 1-5 m of clast-supported, brecciated limestone, and varying amounts of a brown sandy matrix (Fig. 5d). In places, this brecciated limestone can be traced downwards into intact bedded limestone with sand-filled cracks. Elsewhere, the brecciated limestone has been reworked and is in sharp contact with intact limestone. Relief on the erosional surface is visible in mountainside exposures in the western part of the area (Fig. 6). Here, the matrix to the limestone breccia is stained bright red. This red matrix is interpreted as a “Terra Rosa” (Merino and Banerjee, 2008) that developed during terrestrial weathering of the limestone.

NARCHILLA FORMATION

The Narchilla Formation (Gordey and Anderson, 1993) is dominated by fine-grained clastic rocks with a cumulative present-day (deformed) thickness of almost 1 km in 106B/04. In the Niddery Lake area, Cecile (2000) divided the formation into two members. The lower Senoah Member (~400 m thick) consists of grey-black, grey-blue, and minor mauve siltstone and shale, and some quartzite/grit and minor limestone, while the overlying Arrowhead Lake Member (~120 m) comprises maroon and lime green argillite and minor quartzite. The contact between the two members is described as “distinct and marked by a generally abrupt change from maroon, lime green or blue-grey argillite typical of the Arrowhead Lake Member, into more drab siltstone or coarser clastic rocks of the Senoah Member” (Cecile, 2000, p. 20). This subdivision, with its discrete colour-change, was not recognized in the map area; instead, a thin basal member is distinguished from the remainder of the formation.

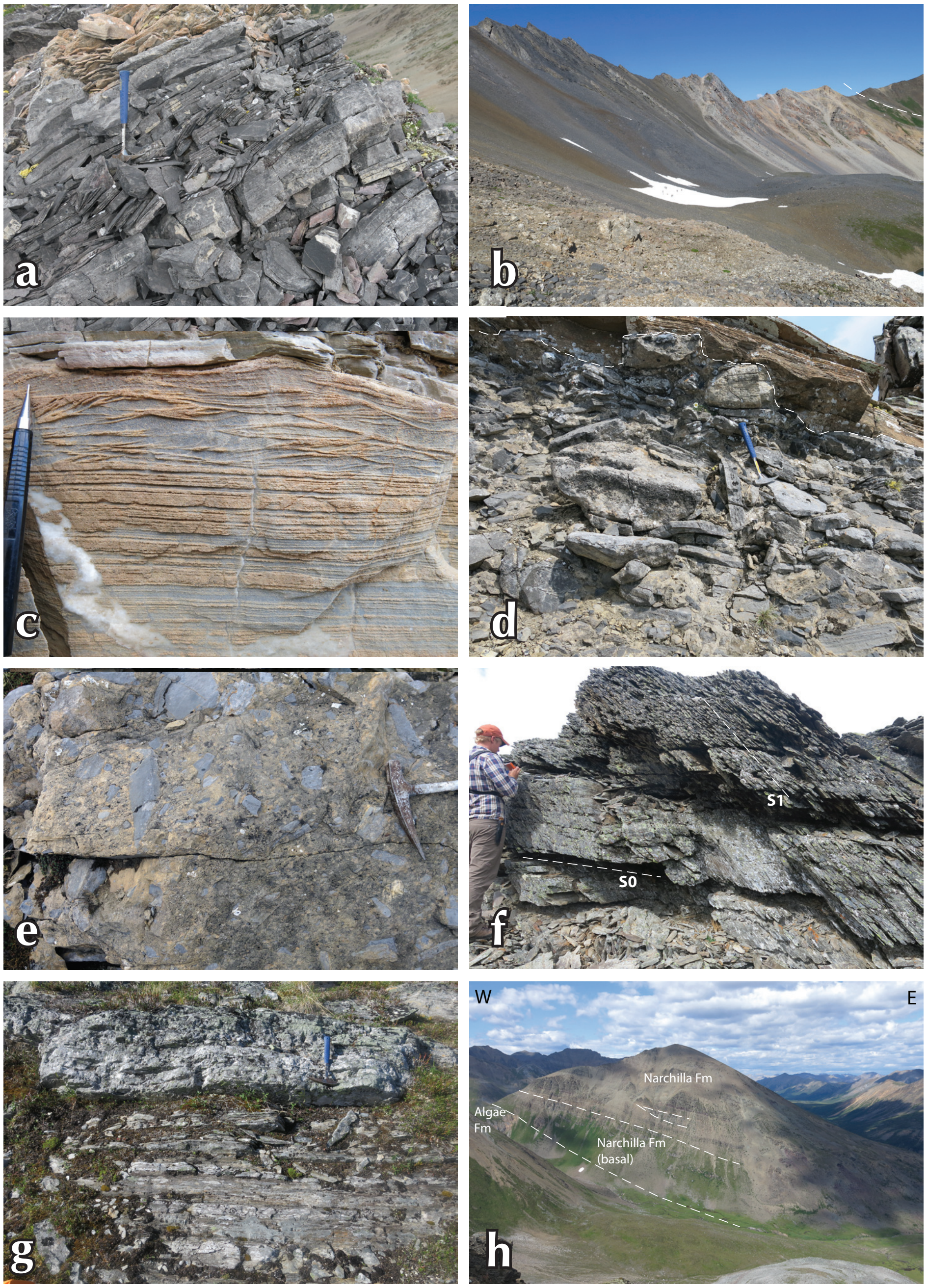


***Figure 5**. (a) Thinly-bedded grey limestone of Algae Fm. The buff-coloured layers at the top of the photograph are dolostone; (b) view across tilted section of Algae Fm. The upper part is pale grey as a result of dolomitization. The upper boundary with the Narchilla Fm is marked. Relief is ~200 m; (c) upward transition from planar to cross-bedding in sandy limestone of the Algae Fm; (d) limestone breccia at the top of the Algae Fm, overlain by pale brown sandstone (Narchilla Fm); (e) conglomerate at base of Narchilla Fm comprising grey limestone clasts in a brown, slightly calcareous sand/grit matrix; (f) high angle between bedding and cleavage in mudstone of the Narchilla Fm; (g) white-weathering sandstone beds ranging from 5-50 cm; sandstone beds display upwards transitions from planar to cross-lamination. Narchilla Fm; (h) lower part of the Narchilla Fm. Sandstone-rich basal member is overlain by maroon and green mudstone with some discontinuous sandstone intervals (wedge outlined in white). Relief is ~500 m.*

The *basal member* of the Narchilla Formation (~10 to 100 m) is highly variable in terms of lithology and thickness. Rock types include medium to thickly bedded quartz arenite, brown sandstone, conglomerate/breccia, green shale, thinly interbedded limestone and shale, medium to thickly-bedded limestone and silty limestone, calcareous sandstone, and grit. The most characteristic rock type is a brown-weathering conglomerate/breccia with a poorly-sorted sandstone or grit matrix and abundant clasts of grey limestone derived from the underlying Algae Fm (Fig. 5e). In areas that contain several conglomerate horizons, there is generally an upward increase in the matrix to clast ratio.

The remainder of the Narchilla Formation is dominated by thinly-bedded, well-cleaved mudstone (Fig. 5f), siltstone, and shale, with some sandstone-rich intervals. Mudstone and siltstone are very thinly bedded, and graded bedding is common. Thin, white-weathering sandstone layers are widely distributed and commonly cross-bedded (Fig. 5g). Rocks of the Narchilla Formation are bioturbated, and simple horizontal trace fossils are preserved on the base of sandy beds (Fig. 7a,b). Mudstones and siltstones are mostly pastel shades of beige and brown, but are also commonly lime green, mauve, or maroon (Fig. 5h). Green and mauve/maroon intervals are stratiform or patchy, and form particularly fine-grained shaly slopes. Colour variations within the Narchilla Fm are interpreted as a secondary characteristic rather than having any regional stratigraphic significance.

Figure 6. *Erosional unconformity between the Algae Fm and overlying Narchilla Fm. Note the irregular shape of the contact, which truncates bedding in the limestone, and the bright red colour (interpreted as 'Terra Rosa'). The cliff is approximately 300 m high.*

Sandstone-rich intervals contain abundant sandstone layers from 1 cm to 1 m thick. These beds typically weather white and contain abundant detrital white mica; orange limonite spots are also common on fresh surfaces. Sandstone typically displays a mixture of planar and cross-lamination, and flute casts are developed on the bottom of some beds, suggesting deposition by turbidity currents. A thick unit (~10 to 15 m) of quartzite and grit is present in some locations near the bottom of the main part of the formation.

CAMBRIAN-SILURIAN

GULL LAKE FORMATION

The Gull Lake Formation (Gordey and Anderson, 1993), which is exposed south of the Stewart River (Fig. 3), is dominated by fine-grained clastic rocks.

The thin *basal member* comprises a variable mix of limestone-clast conglomerate (Fig. 8a), lithic sandstone and grit, quartz arenite, and argillite. Lithic sandstone and granule-pebble conglomerate weathers orange, and is commonly green on fresh surfaces. It is poorly sorted and contains a mixture of subrounded quartz grains and lithic clasts. It is interfingered with a cobble to boulder matrix-supported conglomerate of variable thickness (2-10 m) that contains predominantly limestone clasts and, locally, with medium to thickly bedded white quartz arenite. Limestone clasts in the conglomerate are pale grey and mostly subrounded; some clasts contain archaeocyathids (Fig. 8b), and less commonly, oolites. Other clast types include blocky quartz arenite and dark sandstone. The conglomerate matrix consists of pale beige to brown, slightly calcareous sandstone with abundant granules of quartz and subangular to subrounded chert clasts.

Most of the Gull Lake Formation is dominated by argillite, siltstone, and fine sandstone. The argillite is typically olive green (Fig. 8c), very thinly bedded, and blocky. Beds are commonly graded and are extensively bioturbated by horizontal burrows (Fig. 7c). The argillite weathers brown, orange, or white in mountain exposures; where a white weathering rind is most intensely developed it has a porcelaneous character (Fig. 8d). Argillite is also coloured lime green, black, and red-maroon in places. Fine-grained clastic rocks of the Gull Lake Formation are extensively altered to a red-maroon colour near the southern margin of the map area (Fig. 8e).

The upper part of the formation includes a number of intervals, each tens of metres thick, characterized by rhythmic interbeds of sandstone and shale/argillite. Sandstone layers are white-grey, 2 to 40 cm thick, and display basal flute casts (Fig. 8f). Other minor rock types in this part of the section include rare silty limestone layers that display upward transitions from massive bedding to planar lamination to cross-lamination (Bouma A-C), and carbonate clast conglomerate. A small amount of black shale and blue chert are also present near the top of the formation.

A number of occurrences of the trace fossil *Oldhamia* were encountered in the upper part of the formation (Fig. 7d). As *Oldhamia* does not appear in the fossil record above Stage 5 of the Cambrian System (Herbosch and Verniers, 2011), this places a lower age limit on most of the Gull Lake Formation. An upper limit is imposed by the presence of archaeocyathid-bearing clasts at the base of the formation. As archaeocyathids are restricted to the interval covered by Stages 2-4, most, and possibly all of the formation was deposited during Stages 2 to 5 of the Cambrian (~528-506 Ma; Babcock and Peng, 2007).

In the Niddery Lake map area, Cecile (2000, p. 25) described the contact between the Arrowhead Member of the Narchilla Formation and the Gull Lake Formation as being “distinct and conformable and defined by a colour change”. In 106B/04, the formations cannot be distinguished based on their colour as each includes intervals of brown, maroon, and green shale/argillite.

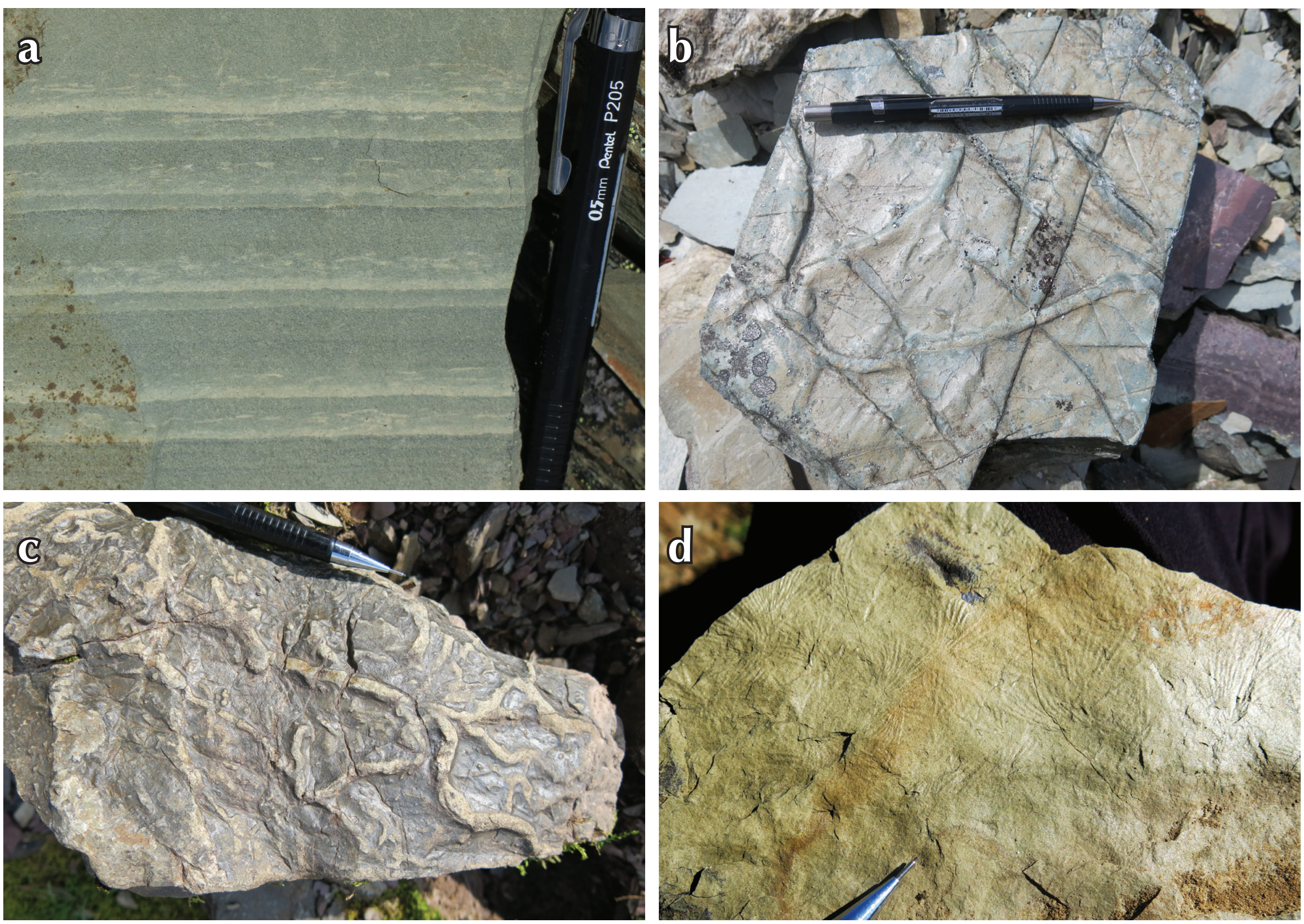


Figure 7. *(a) Pale green wispy lenses indicative of bioturbation of graded beds in rhythmically-layered mudstone-siltstone; Narchilla Fm; (b) casts of horizontal burrows on the base of a sandstone bed in green mudstone; Narchilla Fm; (c) cast of sinuous horizontal burrows on sandstone bed; Gull Lake Fm; (d) radiating traces of Oldhamia in green mudstone; Gull Lake Fm.*

Some of the rocks on the southern boundary of the map area that were included by Cecile (1998) in the Arrowhead Member of the Narchilla Formation are here assigned to Gull Lake Formation. The thickness of the Gull Lake Formation is comparable to that in its type area (~1 km) but exceeds that (~400 m) reported by Cecile (2000) in the Niddery Lake area.

OLD CABIN FORMATION

The Old Cabin Formation (Cecile, 2000) is dominated by green volcanic breccia and conglomerate composed of mafic volcanic clasts and matrix (Fig. 8g). The top of the Old Cabin Formation is not exposed in the area, but regionally it forms a separate unit above the Gull Lake Formation, or is intertongued with it (Cecile, 2000).

Clasts are typically lapilli to boulder size and sit in a matrix that is compositionally similar. Mafic clasts contain phenocrysts of black clinopyroxene and less commonly phlogopite in a fine-grained green matrix; some are also amygdaloidal. Locally, clasts are cemented together by coarsely crystalline, space-filling calcite, or more rarely, bluish opal/chalcedony. In addition to clasts of mafic volcanic rock, white to pale grey barren limestone clasts are common. These are generally 2 to 10 cm, but some clasts are up to 5 to 10 m in maximum dimension. Breccia and conglomerate are interbedded with thinly-bedded, orange, brown, or white-weathering siltstone and sandstone. Some sandstone beds are rich in clinopyroxene fragments. Breccia is generally massive, and locally form channelized bodies that are incised into finer grained layers. The base of the formation was drawn at the bottom of the first massive breccia layer overlying thinly-bedded siltstone and sandstone of the Gull Lake Formation. Thin units of siltstone and sandstone (Fig. 8h) are found throughout the Old Cabin Formation, but are most abundant in its lowest part. The formation also includes minor dolerite; a single small body, which probably represents a sub-volcanic feeder dike or sill, was encountered in the area.

While volcanic breccia and conglomerate are generally coloured green, maroon clasts are present in some places, and a small volume of the formation is maroon in its entirety. Some siltstone-sandstone sequences are also maroon or bright green. Locally, relatively unaltered green, coloured breccia can be traced laterally into maroon-red shaly material. This is not true shale but rather an alteration product of the mafic volcanic rocks. Areas that are altered in this manner locally define linear trends, suggesting fluids responsible for the alteration were channeled along steeply-dipping structures.

The Old Cabin Formation conformably overlies the Cambrian Gull Lake Formation, but there are no further age constraints in the map area. In its type area the Old Cabin Formation sits between Gull Lake Formation and the Silurian-Devonian Steel Formation of the Road River Group (Cecile, 2000). Elsewhere in the region, similar rocks are intercalated with Cambrian and Ordovician rocks, including the Gull Lake Formation. The Old Cabin Formation is one of a series of alkalic and potassic volcanic centres in the Selwyn basin that are associated with episodic lower Paleozoic rifting (Goodfellow *et al.*, 1995).

STRUCTURAL GEOLOGY

The mapped area forms part of the Selwyn fold belt, which developed during Jura-Cretaceous shortening associated with the Cordilleran orogeny (Gordey and Anderson, 1993). There are no plutonic rocks in the NTS 106B/04 map sheet area, but elsewhere in the region a lower limit on the age of deformation is provided by mid-Cretaceous plutons that overprint folds and faults (Cecile, 2000; Roots, 2003; Abbott, 2013). Structures are colour coded according to their relative age in Figure 9.

NW-SE TO E-W TRENDING FOLDS

The dominant structures in 106B/04 define an arcuate pattern; they are oriented NW-SE in most of the area, but are approximately E-W in the westernmost part of the map sheet area (major folds are coloured red in Fig. 9). These structures include folds at a range of scales and steeply-dipping axial-planar cleavage, which is variably developed.

Folds are typically upright, open to close, and plunge at shallow angles to the W-NW or E-SE (Figs. 3 and 10). Exceptions to this trend were observed in the hinge zones of major folds, where pelitic rocks are affected by tight, steeply-plunging folds, and in the vicinity of faults. Minor folds are best developed in strongly layered mudstone/siltstone-sandstone sequences, particularly those of the Narchilla Formation (Fig. 11a). Major folds generally have wavelengths of 2-3 km and amplitudes of approximately 500-750 m. These folds commonly have complex hinge zones characterized by abundant chevron and box folding of competent units (*e.g.*, carbonate of the Algae Formation; Fig. 11b-d). The axial traces of major folds are curved around the “strike-swing” in the west-central part of the map area (Fig. 11e).

A penetrative cleavage is developed in fine-grained clastic rocks (mudstone, siltstone) throughout the area, with the exception of argillite in parts of the Gull Lake Formation. In these rocks, a scaly, semi-penetrative cleavage is developed instead. Semi-penetrative foliation is also locally developed in impure carbonate units, but is largely absent from pure carbonate and quartz arenite.

SW-DIPPING THRUST FAULT

The oldest rocks in the area are exposed in the core of a large anticline in the western part of the area, the northeastern flank of which is cut by a SW-dipping thrust fault (coloured red in Fig. 9; Fig. 12a,b). The fault plane is affected by open folds, and intersection of the thrust with topography has produced a klippe of Algae Formation and lowermost Narchilla Formation (Fig. 12a). Offset on the fault, which reaches a maximum of ~1.5 km in its central part, diminishes rapidly along strike. Folding of the fault plane and truncation of the NE limb of the major anticline suggests there was temporal overlap between folding and thrusting.

Folds of the Algae Formation and lowermost Narchilla Formation in the hanging wall of the fault are tight chevrons and box folds (Fig. 12a). Fold axes trend E or W in the klippe, whereas folds in the hanging wall further south trend approximately NNW or SSE. The contact between the Algae Formation (hanging wall) and Narchilla Formation (footwall) is sharp, but there is a 5-15m thick zone below the contact characterised by highly disrupted bedding with abundant disarticulated blocks of quartzite; a crenulation cleavage is locally developed in pelitic rocks in this zone.

EAST-STRIKING THRUST FAULT IN THE SOUTH-WEST CORNER OF THE MAP AREA

An east-striking, north-verging fault extends into the SW corner of the map sheet area, where it separates Gull Lake Formation from underlying mafic volcaniclastic rocks of

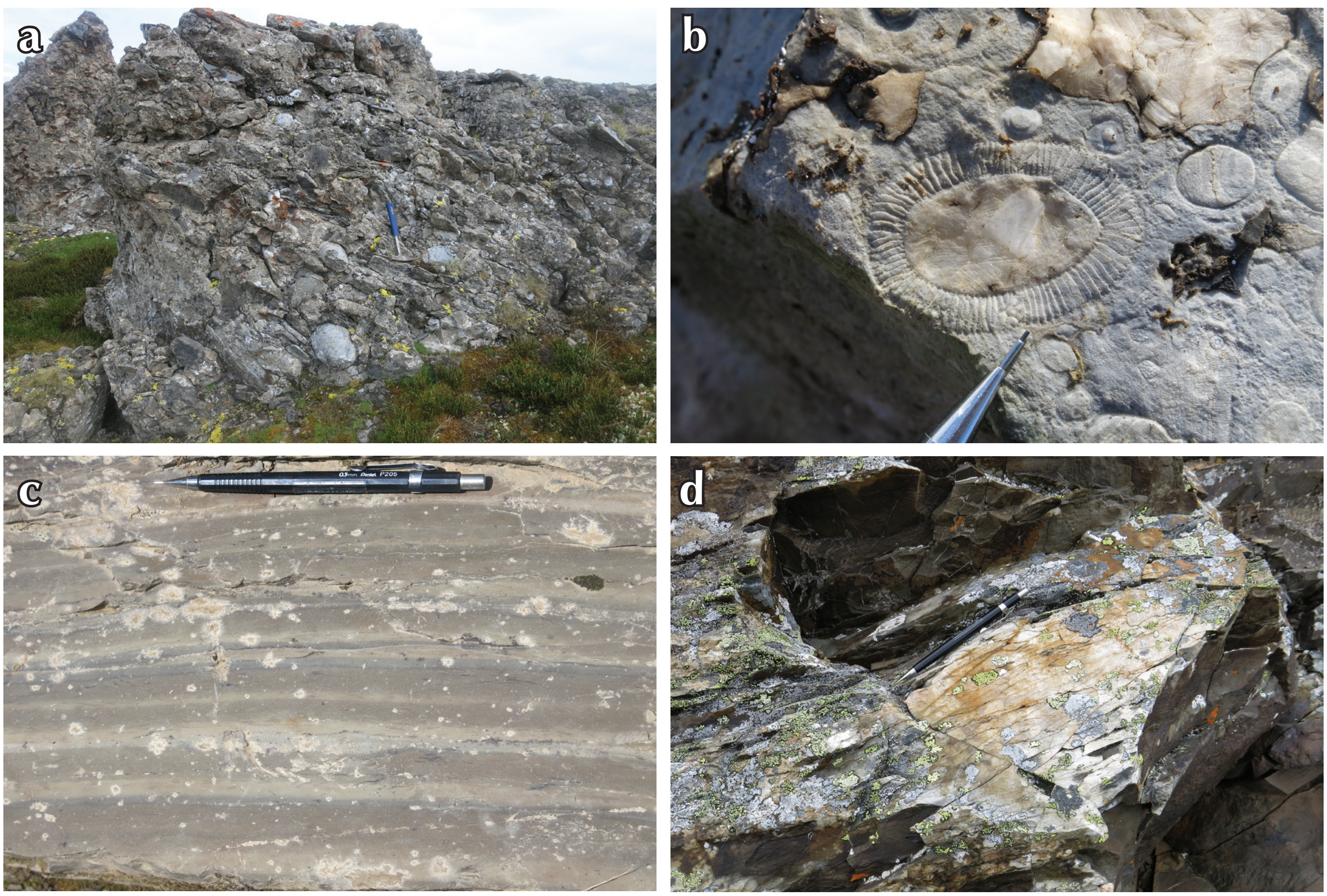


***Figure 8**. (a) Conglomerate containing abundant grey limestone clasts; Gull Lake Fm, basal mbr; (b) clasts in the conglomerate shown in (a) contain archaeocyathids; (c) graded bedding in green-brown argillite. Dark lenses indicate bioturbation; Gull Lake Fm; (d) white and orange weathering rind is typical of Gull Lake Fm argillite in mountain exposures;*

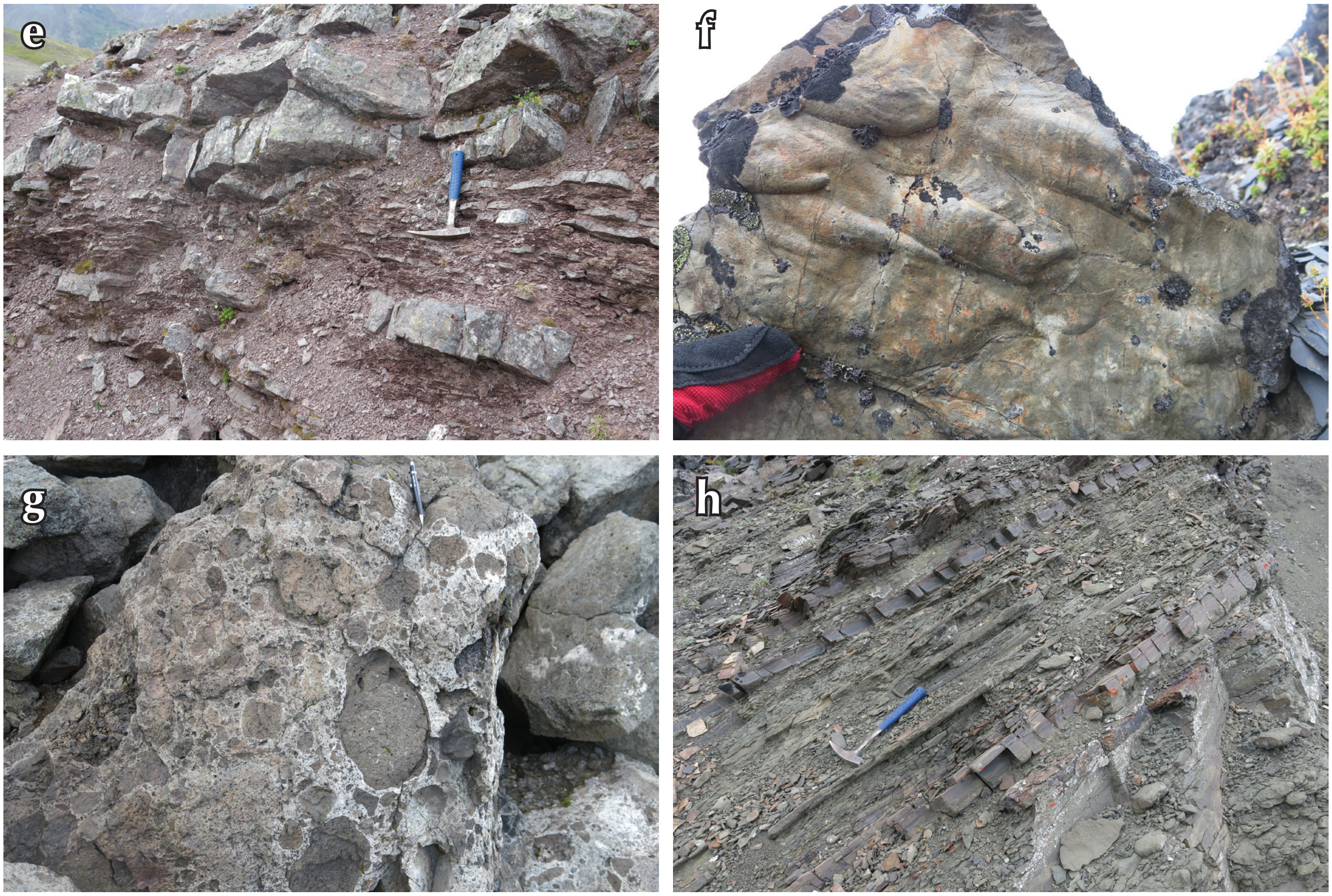


***Figure 8 con'd**. (e) white-grey sandstone beds interbedded with maroon shale; upper part of Gull Lake Fm; (f) Sole markings on the base of turbiditic sandstone beds; upper part of Gull Lake Fm; (g) breccia that comprises porphyritic mafic volcanic clasts in matrix composed of mafic volcanic detritus; Old Cabin Fm; (h) green, thinly-bedded siltstone and sandstone interbedded with mafic volcanic breccia/conglomerate; Old Cabin Fm.*

the Old Cabin Formation (coloured red in Fig. 9). Thrust-sense displacement of approximately 400 m is indicated by offset of the Gull Lake-Old Cabin formation contact close to the eastern limit of its mapped extent. Turbidite sequences of the Gull Lake Formation in the hanging wall of the fault are tightly folded and contain numerous small-scale faults.

The fault plane dips approximately 40° to the south and displays prominent ridges and grooves spaced at ~5 cm intervals that plunge approximately down the dip of the fault. Slickenlines with sub-horizontal or down-dip orientations are locally developed on polished fault surfaces. Overprinting relationships between the two sets of slickenlines were not observed, but as the down-dip grooves are the dominant structures it is likely the main phase of displacement was dip-slip, with some strike-slip reactivation.

NE-TRENDING FOLDS AND NW-VERGENT THRUST

Outcrop-scale upright, chevron folds (F2) whose axes plunge to the NE or SW are developed close to the western boundary of the map sheet area (Fig. 11f). Map-scale deflections that have NE or SW trending axes are also evident on the NE limb of the major antiform in the western part of the area. The axial planes of these folds are parallel to that of the strike-swing and are located in the vicinity of its hinge region. A NW-vergent thrust fault also formed on the western edge of the map area immediately north of the Stewart River (coloured green in Fig. 9).

EAST-STRIKING SINISTRAL FAULT

A steeply-dipping, east-striking fault extends approximately half-way across the central region of the map area (coloured blue in Fig. 9; Fig. 12c). This fault merges with, or is a splay of the Kathleen Lakes fault, a major structure that separates facies domains along the length of the Rackla belt (Fig. 2). In 106/C01, the fault has approximately 3 km of apparent sinistral offset. A slightly smaller offset (~2 km) of steeply-dipping stratigraphy is apparent in the western part of 106B/04, where it transects the major NW-SE to E-W-trending anticline. Displacement further decreases to the east, where the fault dies out. This fault is younger than the NW/W-trending folds and cleavage, and is unaffected by the strike-swing, but is offset by NW-trending faults.

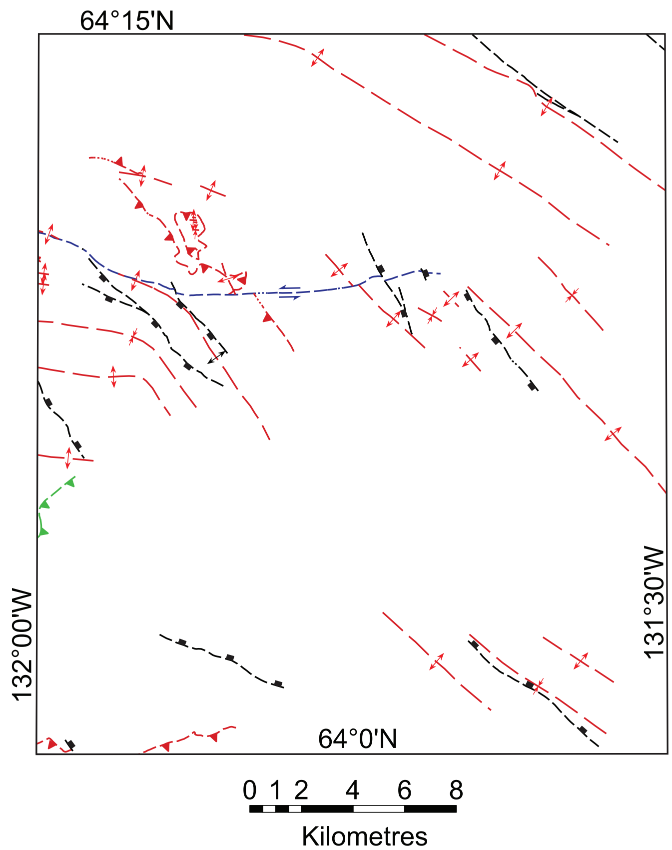


***Figure 9**. Map-scale structures in 106B/04. Early structures are shown in red. These are cut by an east-trending sinistral fault (blue), which is offset by the latest regional structures, NW to WNW- striking faults (black).*

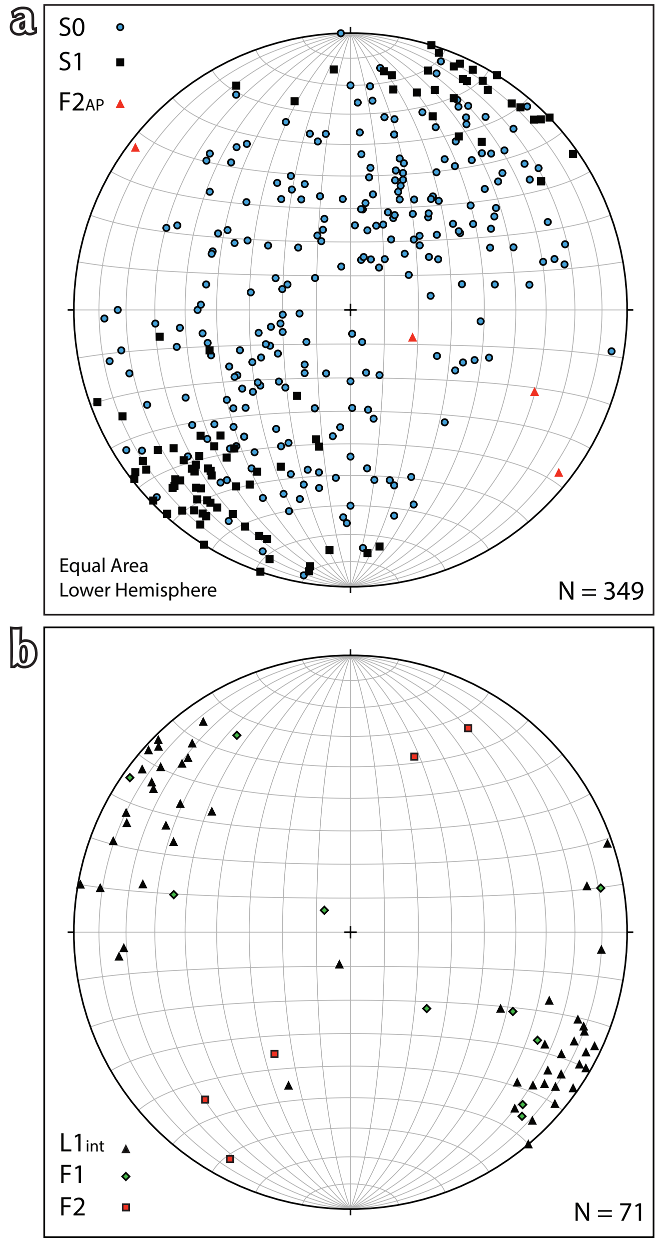


***Figure 10**. Equal area lower hemisphere stereographic projections of (a) planar and (b) linear structures in 106B/04. $F2_{AP}$=F2 axial plane; and $L1_{int}$=Intersection lineation.*

NW-STRIKING FAULTS

The youngest structures that affect the map pattern are steeply-dipping faults that strike NNW to WNW (Figs. 12d and 13; coloured black on Fig. 9). These faults, which occur throughout the area, have strike lengths of approximately 3-10 km. Where observed, areas adjacent to these faults are characterized by disrupted bedding and anomalous fold orientations; a fault-parallel foliation is also locally developed. Most of these faults have normal-sense offsets of hundres of metres (up to a maximum of approximately 1 km in the case of the fault illustrated in Fig. 13); however in some cases a component of dextral displacement is also required to account for the offset of markers. The sense of displacement on the steeply-dipping fault in the NE corner of the map is unclear (Fig. 12e); duplication of the Algae - Narchilla formation contact is compatible with thrusting, but could also be a result of strike-slip (dextral) faulting.

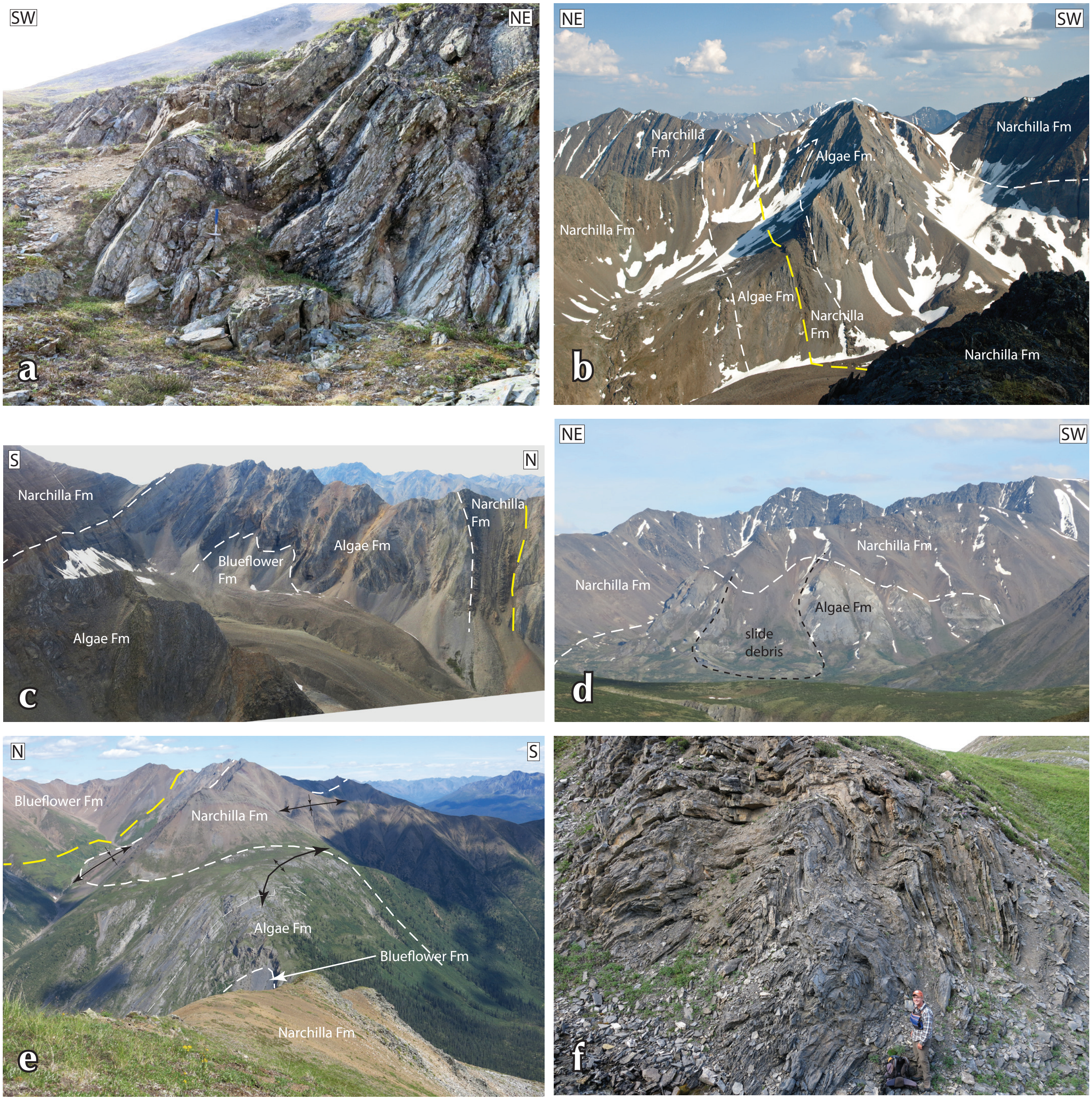


Figure 11. *(a) Minor upright folding of sandstone beds in the Narchilla Fm; (b) hinge region of large anticline in the NE corner of the map area. The Algae Fm on the NW limb is repeated across a steep fault; relief is ~400 m; (c) the same anticline as shown in b) viewed in the opposite direction from the air. Note the steep limbs and complex hinge zone with abundant chevron folding; relief is ~450 m; (d) anticline cored by Algae Fm in NE part of the area (west of the anticline shown in parts b,c). This anticline also has a folded hinge zone with sub-horizontal enveloping surface; relief is ~600 m; (e) anticline cored by Blueflower Fm and adjacent syncline in the western part of the area. Orientation of structures changes from E-W (foreground) to NW-SE (background); relief is ~950 m; (f) NE-plunging (F2) chevron folds in Algae Fm limestone.*

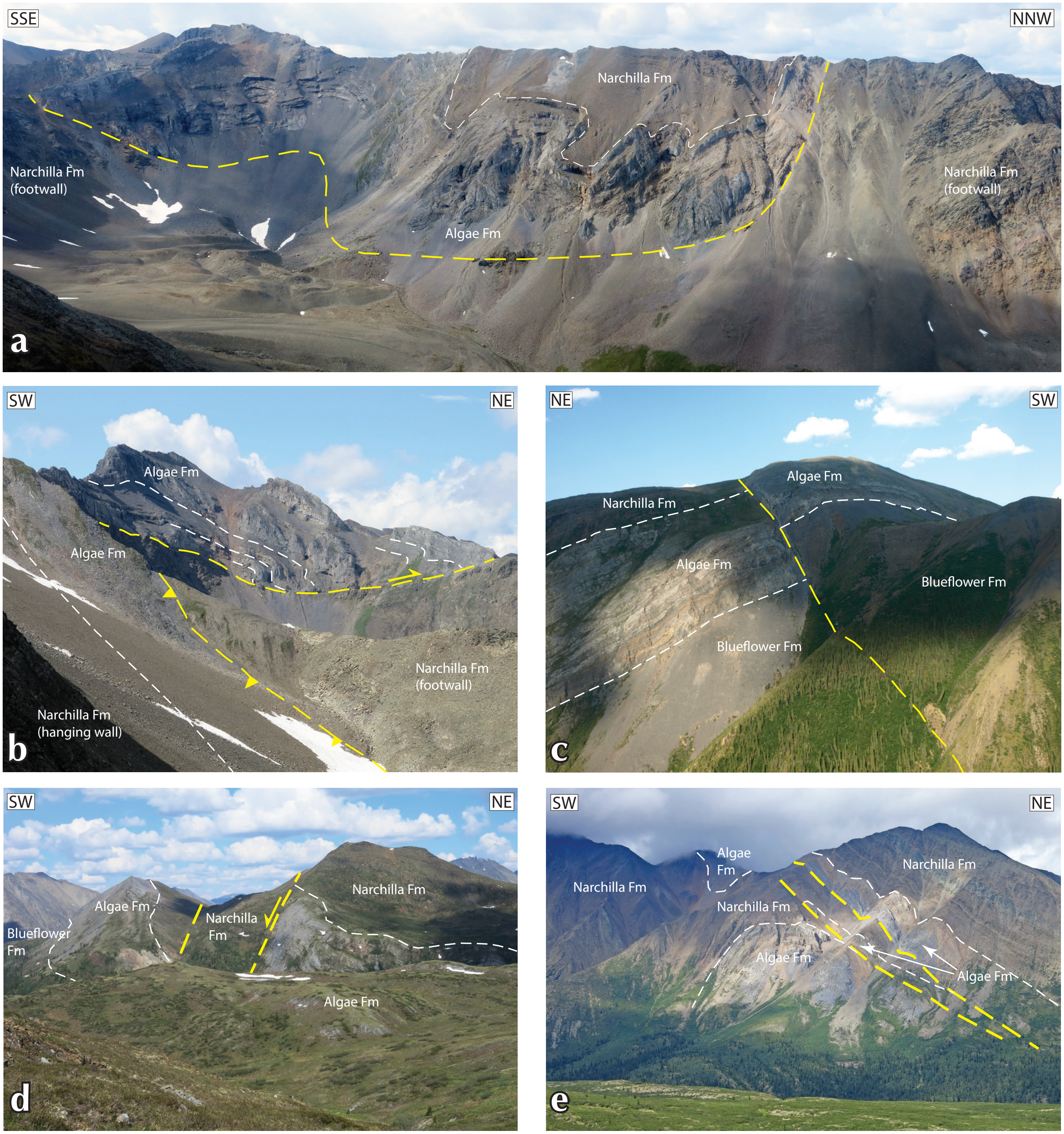


Figure 12. (a) Oblique view of the SW-dipping thrust fault in the western part of the area. The thrust (shown in yellow) is gently folded, but tighter folds are developed in the Algae and Narchilla formations in its immediate hanging wall; relief is ~400 m; (b) truncation of bedding in the Algae Fm along a sub-horizontal portion of the SW-dipping thrust fault; (c) offset of the Blueflower-Algae-Narchilla formation contacts by the east-striking, steeply-dipping fault in the centre of the map area. Displacement on the fault is small near its tip zone; relief is ~400 m; (d) Algae Fm offset by SE-striking normal fault in the central part of the area; relief is 300 m; (e) repetition of the Algae Fm-Narchilla Fm contact across steeply-dipping faults that truncate the flanks of the antiform in the NE corner of the area; relief is ~700 m.

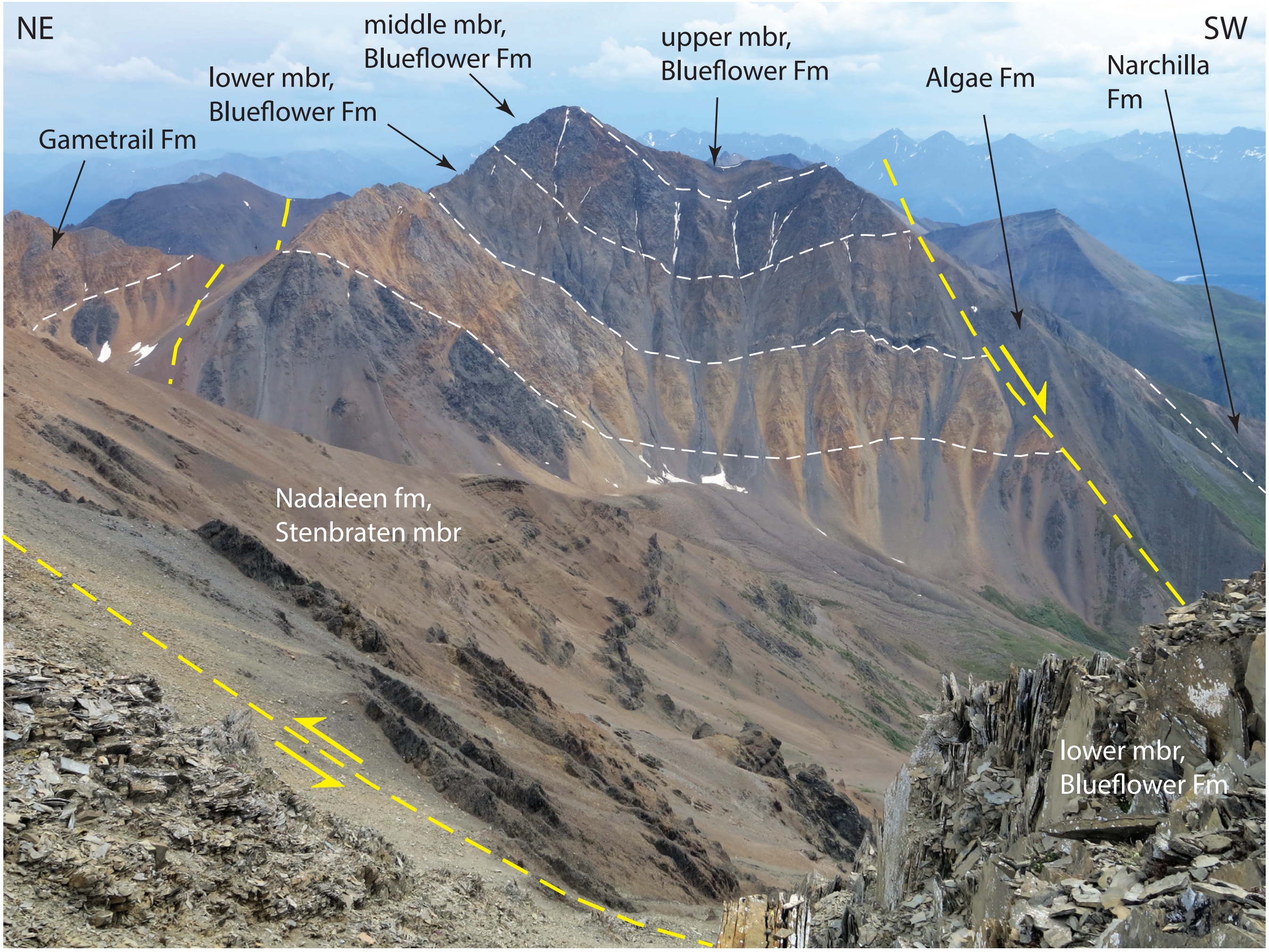


Figure 13. *Down-plunge view across the crestal region of the large antiform in the western part of the area. The antiform is cut by a SW-dipping normal fault that juxtaposes Algae Fm limestone against the Gametrail Fm, which forms a distinctive yellow-weathering layer. The sinistral fault that runs across the foreground offsets the axial plane and here juxtaposes the lower member of the Blueflower Fm against the oldest rocks that are exposed in the area (Nadaleen fm); relief is ~600 m.*

WEDGE-SHAPED PANEL OF ALGAE AND NARCHILLA FORMATIONS IN THE SW CORNER OF THE MAP AREA

The isolated, wedge-shaped panel of Algae and Narchilla formations in the SW-corner of the map area is in an anomalous structural position. The panel, which comprises the upper part of the Algae Formation and lowermost Narchilla Formation, dips gently south, and is truncated along its steeply-dipping southern boundary (Fig. 14). The gently-dipping base and the steeply-dipping southern boundary are in contact with mafic volcaniclastic rocks of the Old Cabin Formation, whereas the SW boundary is in contact with Gull Lake Formation across a NW-trending fault. The east-striking thrust runs ~350 m south of the Algae-Narchilla wedge, and is separated from it by a narrow belt of Old Cabin Formation.

The observed geometry could have been produced by out-of-sequence thrusting. In this interpretation, a low-angle thrust separating the Algae and Old Cabin formations is cut by a steeper fault that defines the southern boundary of the wedge; this fault is itself cut by, or is a splay of the east-striking thrust. A problem with this interpretation is that the low-angle “thrust” contact between Algae Formation and Old Cabin Formation is not exposed to the south, where it would be expected to intersect the surface. No north-verging thrust faults have been mapped in the area to the south (Cecile, 1998), where structures (folds, faults) are instead oriented NNW-SSE.

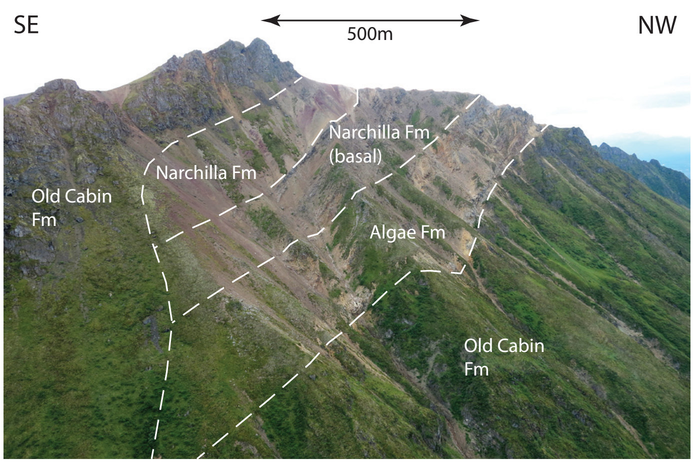


***Figure 14**. Aerial view of the small isolated panel of Algae Fm-Narchilla Fm in the SW part of the area. The Algae-Narchilla panel dips gently south and is truncated along a steeply-dipping surface at its southern end.*

An alternative interpretation is that the Algae Formation-Narchilla Formation wedge is an isolated block (an olistolith) that slid into its current position during deposition of the Old Cabin Formation. Although blocks of this magnitude were not observed elsewhere in the Old Cabin Formation, barren limestone clasts are common, and clasts up to 10 m in maximum dimension were observed.

MINERALIZATION

The map area lies to the east of recent discoveries of "Carlin-type" gold mineralization (Arehart *et al.*, 2013; Tucker *et al.*, 2013) by ATAC Resources (*www.atacresources.com*). Mineralization is structurally controlled and is hosted by arsenic-rich pyrite in calcareous rocks of widely varying age (Conrad zone – Ediacaran Nadaleen formation; Osiris zone – Ediacaran Gametrail Formation; Anubis zone – Devonian limestone).

Within the map area, gold mineralization has recently been discovered at the Venus zone in the SW part of the area (Anthill resources; *www.anthillresources.com*). Mineralization is located in the upper part of the Algae Formation, which is dolomitized and variably silicified. The Algae Formation in this area forms part of the isolated wedge-shaped panel discussed in the previous section.

Given the widespread presence of dolomitized limestone and its position close to the margin of the Selwyn basin, the area may also be prospective for Mississippi Valley-type mineralization. The Birkeland drilled prospect (originally staked as the Tom and Mom claims) was explored for Pb-Zn-Ag mineralization in the 1970's (Shearer, 1976). Mineralization is located in the upper part of the Algae Formation, where lead-zinc showings are associated with zebra dolomite.

DISCUSSION

STRATIGRAPHIC RELATIONSHIPS BETWEEN THE WINDERMERE SUPERGROUP AND HYLAND GROUP

The Algae and Narchilla formations were deposited throughout the eastern Rackla belt, but the nature of the rocks they overlie varies. North of the Dawson thrust they overlie the Blueflower Formation (Windermere Supergoup) whereas they succeed Yusezyu Formation (Hyland Group) in Selwyn basin (Fig. 15).

In NTS 106C/02 and the western part of 106C/01 (Colpron *et al.*, 2013), the Blueflower Formation is dominated by fine-grained clastic rocks and carbonate turbidites, with some carbonate-clast diamictites (debris-flow deposits). To the east, increasing amounts of quartz arenite and grit appear in its upper part, and in 106B/04, form a large proportion of an upper member that is lithologically comparable to the upper part of the Yusezyu Formation of the Hyland Group. These relationships imply equivalence of the Algae and Narchilla formations with the Risky and Ingta formations, and of the upper member of the Blueflower Formation with the Yusezyu Formation (Fig. 15). The upper Blueflower Formation-Yusezyu Formation comprises a clastic wedge that thickens into Selwyn basin, where it is estimated to have a stratigraphic thickness of approximately 3 km (Gordey and Anderson, 1993).

An erosional unconformity is developed between the Algae and Narchilla formations in the eastern Rackla belt and the Risky-Ingta formations on the Mackenzie and Ogilvie platforms. At the Algae Formation type section, located ~15 km south of the southern boundary of the map area, Cecile (2000) reported conglomerate with limestone clasts at the base of the Narchilla Formation but interpreted the contact to be conformable. It appears, therefore, that the Algae-Narchilla/Risky-Ingta unconformity passes basinward into a conformable surface.

FORMATION OF THE "STRIKE-SWING"

The dominant structures in the area define an arcuate trend, with a change in orientation from E-W around the western boundary of the map area (106B/04) to NW-SE in its remainder. The formation of this arcuate pattern is attributed to the position of the area in the "corner" between south and southwest-facing segments of the Selwyn basin margin (Fig. 1). The strike curvature is interpreted to have been acquired progressively as strata were shortened against the non-parallel basin margins. Continuity of major fold axes around the strike swing suggests that fold axes were originally approximately linear, as folds that initiated on either limb of the strike swing are unlikely to have propagated around a pre-existing bend. Tight folds in the hanging wall of the SW-dipping thrust trend ~E or W in the klippe and ~NNW or SSE in the region to its south. These folds exhibit a higher degree of obliquity across the axis of the strike swing than do regional-scale structures; this may reflect primary curvature arising from displacement gradients during thrusting. Although NE-trending structures around the hinge of the "strike-swing" ostensibly represent a second phase of deformation, these may have formed during the latter stages of the main deformation period as tightening of the strike swing gave rise to NW-SE-directed shortening around its hinge zone.

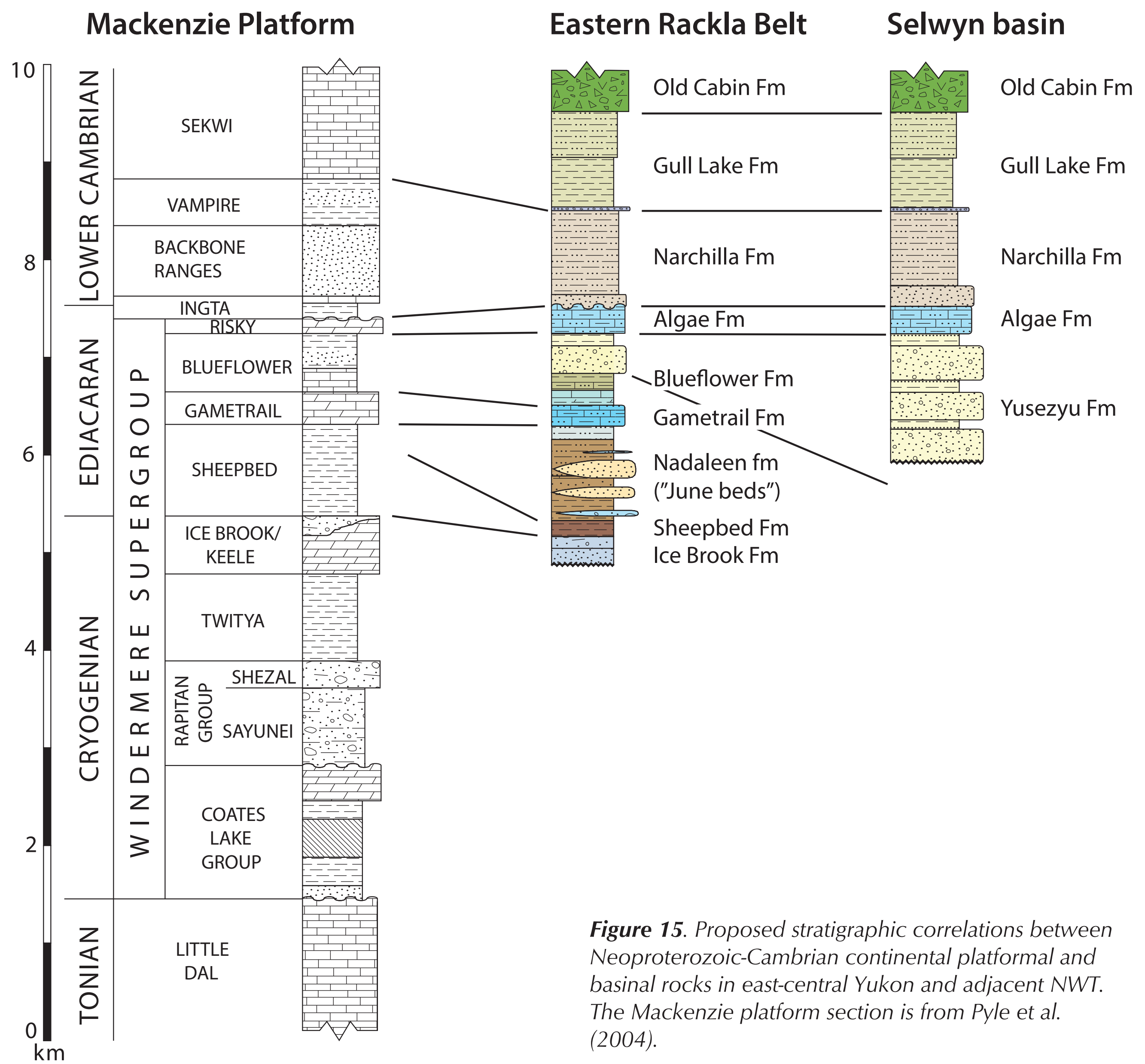


Figure 15*. Proposed stratigraphic correlations between Neoproterozoic-Cambrian continental platformal and basinal rocks in east-central Yukon and adjacent NWT. The Mackenzie platform section is from Pyle et al. (2004).*

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