# Progress report on geological mapping in the upper Hyland River region of southeastern Yukon (parts of NTS 105H/08,09,10,15,16 and 105I/02)

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## ABSTRACT

Most of the upper Hyland River area of southeastern Yukon is underlain by Neoproterozoic to Cambrian rocks of the Hyland Group. Excellent exposure allows for identification of new stratigraphic subdivisions within the Hyland Group, in addition to those previously recognized in its type area to the north. A steeply dipping fault zone, comprising several subparallel splays (the Upper Hyland fault) is coincident with the upper reaches of the Hyland River. The Upper Hyland fault is continuous with the northern part of the Acland fault in Coal River area (NTS 95D) and likely accommodated tens of kilometres of dextral offset. Displacement took place during or after emplacement of the Shannon pluton (97 ± 2 Ma), which is penetratively deformed adjacent to the fault zone. Dextral faulting followed widespread Early Cretaceous (pre-107 Ma) penetrative deformation and greenschist to upper amphibolite facies metamorphism.

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## INTRODUCTION

Preliminary 1:50 000-scale mapping of parts of the upper Hyland River area (NTS 105H/09 and 08) was carried out in 2014/2015 (Moynihan, 2016a) and further work in 2016 extended the mapped region to the northwest (parts of NTS 105H/10,15,16 and 105I/02). The total area mapped between 2014 and 2016 includes ~1985 km$^2$ in a swath approximately 70 km long and 20 to 25 km wide (Fig. 1). This report includes a summary of the bedrock geology and accompanies the recent release of a 1:50 000-scale map (Moynihan, 2016b). The stratigraphic divisions described in Moynihan (2016a) are generally applicable to the entire area, but local revisions have been made to the map, where stratigraphic assignment and nomenclature has been refined. A simplified map and cross sections at a scale of 1:250 000 is included in this report (Appendix A), however more detailed information is contained in the 1:50 000-scale map (Moynihan, 2016b).

## LOCATION AND GEOLOGICAL SETTING

The map area straddles the Hyland River in southeastern Yukon (Fig. 1; Appendix A). It is bisected along half of its length by the Nahanni Range Road (Highway 10), which connects the Robert Campbell Highway with the townsite of Tungsten, Northwest Territories. The terrain is mountainous, and bedrock exposure is generally plentiful; however, most of the valley bottoms and lower slopes are underlain by thick deposits of Quaternary sediment.

The region surrounding the study area (Fig. 1) is dominated by Neoproterozoic to Early Cambrian clastic and carbonate rocks of the Hyland Group (Windermere Supergroup), minor Lower Palaeozoic strata, and abundant Cretaceous intrusive bodies. The Lower Palaeozoic strata were deposited close to the shelf-slope boundary of Selwyn basin, an embayment in the Lower Palaeozoic Laurentian continental margin. The sedimentary rocks

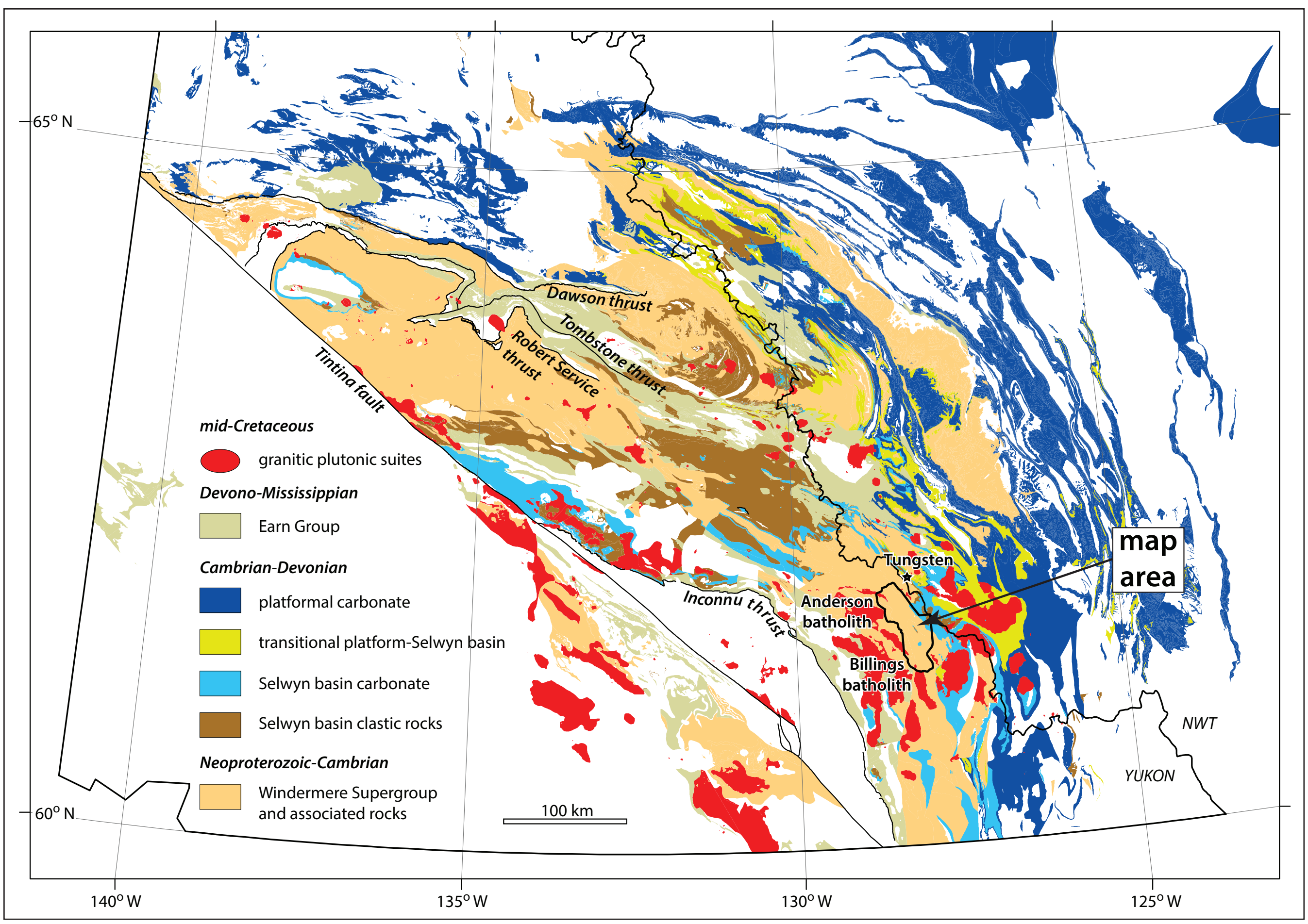


***Figure 1.*** *Geological map of the Selwyn fold-and-thrust belt. The study area is located in southeastern Yukon, close to the position of the margin of Selwyn basin during the Lower Paleozoic.*

were deformed and metamorphosed under greenschist to amphibolite-facies conditions during the Cordilleran orogeny, which also led to the intrusion of abundant granitic rocks.

A fault with large displacement, herein termed the Upper Hyland fault (UHF), is coincident with the Hyland River valley along much of the length of the mapped area (Moynihan, 2016a; this work). Rocks on the east side of the fault record a single episode of penetrative deformation and greenschist facies metamorphism, whereas much of the area to the west underwent polyphase deformation at a higher metamorphic grade. As a result, rocks on the eastern side of the fault can be readily correlated with well-known regional units, but the stratigraphic affinity of rocks west of the fault is less certain.

## STRATIGRAPHY

### WINDERMERE SUPERGROUP, WEST OF THE HYLAND RIVER

The rocks west of the Hyland River are mostly brown-weathering micaceous schists with lesser marble and calc-silicate. Owing to the generally higher metamorphic grade and polyphase penetrative deformation, way-up indicators are largely absent, the thickness of units is highly variable, and many useful markers, particularly marble layers, are discontinuous. Interpretation of the stratigraphy (Fig. 2) is based on the distribution of units, dip directions, and regional stratigraphic information.

Most of the area is underlain by brown, generally semipelitic to psammitic micaceous schist (unit uPs). The schist displays compositional layering at a centimetre to metre scale and includes layers and thicker intervals of metapelite, quartzite, marble and calc-silicate. Marble layers are pale to medium grey and are homogeneous to banded; they are generally decimetres to metres thick, but some are up to tens of metres thick and have been mapped as a separate unit (uPm). Additionally there are some thicker intervals, tens to hundreds of metres thick or more, that are dominated by metapelitic schist with lesser metasemipelite (unit uPmps).

Marble layers are relatively common within unit uPs, but marble and calc-silicate is generally absent from metapelite-dominated units (uPmps). An exception to this is a layer of siliceous, finely banded calc-silicate (unit uPcs) that is contained within metapelite close to the stratigraphically and structurally deepest level of the mapped area (western part of NTS 105H/08). This is the lowest distinct stratigraphic marker in the study area, but is only ~30 m thick and may not be traceable regionally.

Unit uPmsr is a thick (80-100 m), interlayered grey marble and metapelitic/semipelitic schist which is the most continuous, and stratigraphically lowest of the mapped marker horizons. The unit has a banded appearance, and owing to the high proportion of relatively pure marble (~50 - 70%), is a resistant, cliff-forming unit. Individual marble/schist layers are metres to tens of metres thick but thin folia of schist are also developed within marble-dominated sections. Unit uPmsr is overlain by a recessive interval of metapelite/dark shale (unit uPmps), which is separated from overlying, more resistant quartz-rich schists (unit uPs) by a thin (2 to 5 m), light-coloured marble band unit (uPm; Fig 2).

A second band of mixed calcareous and metaclastic rocks forms another marker horizon at a higher structural/stratigraphic level (unit uPms; Figs. 2 and Fig. 3a). The overall character of this interval is less resistant than unit uPmsr as the marble bands are generally thinner (typically 5 m thick or less). The rock types in this unit include dark grey, sooty marble; pale grey or beige marble; calc-schist; rusty-weathering, dark grey/black siliceous schist; quartzite; micaceous quartzite; psammite; and semipelite. The dark siliceous schist and some marble layers are commonly distinctly sulphide rich (Fig. 3b). The same is true of very rusty schist that occurs within unit uPs just above the contact with unit uPms.

As most of the area underlain by unit uPs was metamorphosed under amphibolite-facies conditions, rocks of metapelitic and semipelitic composition are generally represented by biotite ± staurolite ± andalusite ± sillimanite ± garnet schists. North of Shannon Creek however, there is a small area of low metamorphic grade where unit uPs includes extensive exposures of green phyllite, similar to parts of the Yusezyu Formation on the east side of the Hyland River. Further work is required to determine the stratigraphic relationships between ostensibly older rocks west of the Hyland River and those at higher structural/stratigraphic levels which are contiguous with the type Hyland Group (*see* discussion below).

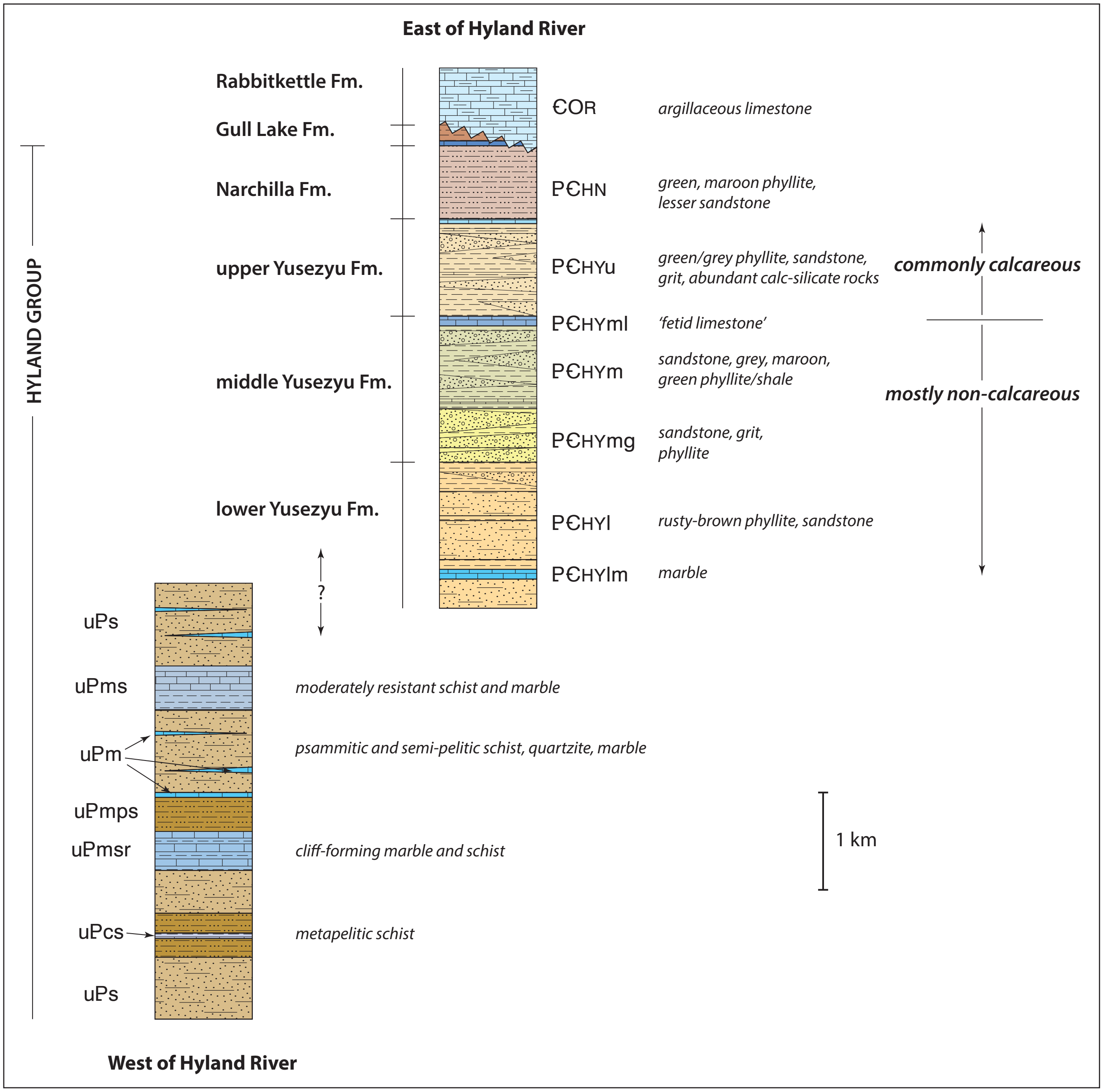


***Figure 2.*** *Stratigraphy of the upper Hyland River area. The stratigraphic relationship between rocks on either side of the Hyland River requires further study, as discussed in the text.*

## YUSEZYU FORMATION, HYLAND GROUP (EAST OF HYLAND RIVER)

The Yusezyu Formation is undivided in its type area (NTS 105I; Gordey and Anderson, 1993), and its base is undefined. Several stratigraphic subdivisions are recognizable throughout the upper Hyland River map area (Fig. 2). Although the formation is dominated by non-diagnostic rock types, it includes some distinctive units such as a 'fetid limestone' (unit ЄPHYml), olistostrome with a green wacke matrix (a constituent of unit ЄPHYu), and thick intervals of quartz-feldspar pebble conglomerate (unit ЄPHYmg). The upper part of the formation contains abundant calcareous rocks, but these are a minor constituent below the level of unit ЄPHYml.

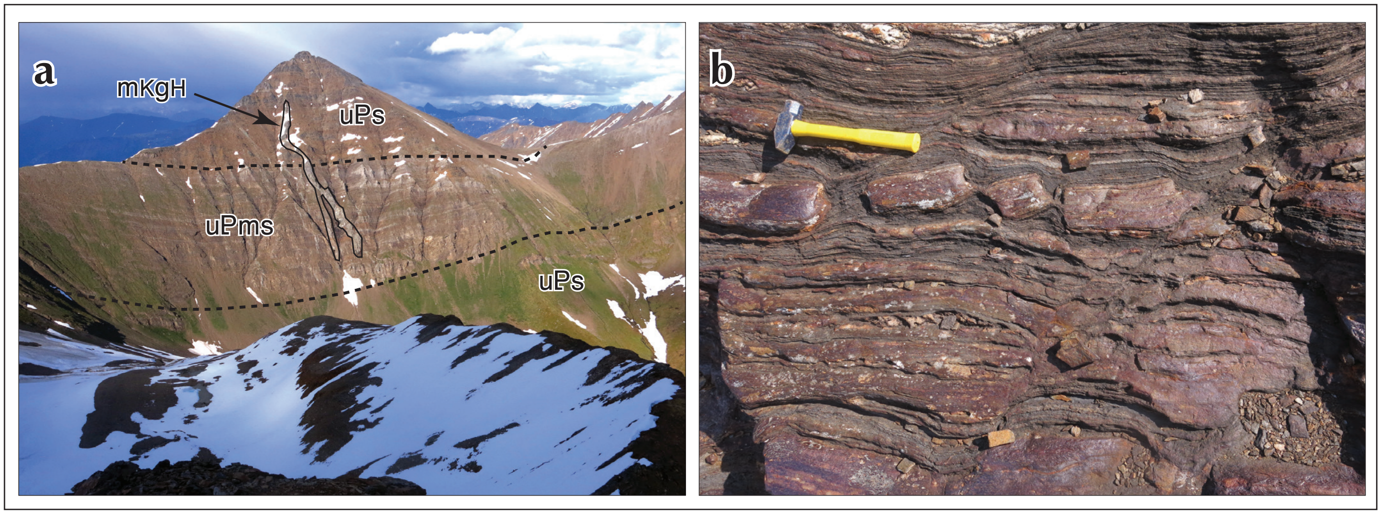


***Figure 3. (a)*** *Mixed marble and schist band (unit uPms), cut by undeformed dike of biotite-plagioclase porphyry (unit mKgH). Approximately 500 m of relief is visible.* ***(b)*** *Boudinaged, sulphide-rich schist and marble layers in unit uPS.*

### *Lower Yusezyu Formation (*ⱣЄHYl*)*

The oldest unit that exhibits stratigraphic continuity with the type Yusezyu Formation (characterized by Gordey and Anderson, 1993) is a thick package of rusty-brown to chocolate brown-weathering grey phyllite, sandstone, quartz-feldspar pebble conglomerate ('grit'), and rare limestone. Moynihan (2016a) separated a lower, sandstone-dominated interval (unit ⱣЄHYlrs) from an overlying phyllite-dominated unit (ⱣЄHYlr) in NTS 105H/08, but this contrast was not discerned in the northern part of the study area (*i.e.*, eastern part of NTS 105H/15), where the unit (undivided ⱣЄHYl) is exposed in the core of a large anticline (Fig. 4a).

In the southern part of NTS 105H/08, a thick marble/calc-silicate package underlies approximately 1500 m (current thickness) of unit ⱣЄHYl. The rocks underneath the marble unit are similar to those overlying it, but are also lithologically comparable with parts of unit uⱣs. This section may record the stratigraphic transition from unit uⱣs upwards into unit ⱣЄHYl and if so, this marble represents an ideal marker with which to separate the Yusezyu Formation from older rocks. Alternatively, there may be additional stratigraphy, not exposed in the map area, between units uⱣs and ⱣЄHYl. Resolution of this issue will require further mapping in the northern parts of NTS 105H/14 and 15, where stratigraphic relationships between unts uⱣs and ⱣЄHYl are most likely preserved.

### *Middle Yusezyu Formation (*ⱣЄHYm*)*

While the lower part of the Yusezyu Formation is relatively monotonous, the middle part of the formation is divisible into three map units. The lowest of these is a ~500 m-thick interval dominated by pale grey to white coarse sandstone and quartz-feldspar pebble conglomerate (unit ⱣЄHYmg). Sandstone and conglomerate beds are tens of centimetres to metres thick and are interlayered with variable proportions of grey phyllite. Calcareous grit is a local constituent, as are rare, thin limestone beds. This unit also locally includes intervals of brown-weathering, thin-bedded siltstone and sandstone with graded bedding. Unit ⱣЄHYmg forms relatively resistant rubbly slopes and cliffs. The loose rubble typically has a cream-beige hue but cliffs often appear dark due to extensive black lichen cover.

Unit ⱣЄHYmg is overlain by an interval (~1 km) that also contains abundant, thick to very thick, graded to massive, coarser sandstone-grit beds, but has a higher proportion of interlayered phyllite (unit ⱣЄHYm). The phyllite is mostly grey but is locally maroon or green. Some sandstone beds are calcareous and there is also minor limestone.

In the northern part of the map area (eastern part of NTS 105H/15 and western part 105H/16; Appendix A), unit ⱣЄHYm includes a number of distinctive rock types at approximately the same stratigraphic level. This includes up to a few tens of metres of green lithic siltstone-sandstone and a variety of dolomitic rock types (unit ⱣЄHYmd). The green lithic siltstone-sandstone is thin to medium bedded with graded and cross-laminated beds. Thin-bedded, yellow-orange dolostone is discontinuous and typically only a few metres thick. Locally it includes bright green sheet silicate minerals in a sugary dolomite matrix. Locally, interbedding of dolostone and green siltstone-sandstone gives rise to very brightly coloured rocks with a striped yellow-green appearance. Thin-bedded, yellow-orange dolostone locally grades into non-calcareous phyllite, suggesting a secondary origin for at least some of the dolostone. Matrix to clast-supported, yellow or orange-brown pebble to boulder conglomerate also forms part of unit PЄHYmd; the matrix of the conglomerate is dolomitic and clasts (up to 1.5 m in diameter) include quartz arenite and grey, extensively dolomitized limestone. Some partly dolomitized clasts have a relatively resistant dolomitic outer layer with a recessive limestone core.

The most prominent marker horizon in the Yusezyu Formation (unit PЄHYml) is a grey to blue-grey, thin to medium-bedded limestone ('fetid limestone') that ranges from 5 to 30 m in thickness and forms outcrops and talus slopes with a distinctive colour and lustre (Fig. 4b). The limestone is pale to medium (blue-) grey on weathered surfaces, and has medium to dark grey, crystalline fresh surfaces. The unit includes calcisiltite, calcarenite, calcirudite with bright ochre and red shale chips, and brown-weathering calcareous siltstone/sandstone. A thin layer of orange-weathering calcareous grit locally forms the top of the unit. A distinctive characteristic of unit PЄHYml is the sulphurous smell emitted by parts of the formation upon hammering or when walking over talus.

### *Upper Yusezyu Formation (PЄHYu)*

The upper part of the Yusezyu Formation comprises approximately 1 km of mixed clastic and carbonate rocks including the following: 1) thick packages (tens to hundreds of metres) of brown-weathering grey phyllite, green phyllite, and locally maroon phyllite; 2) intervals dominated by thick-bedded to massive, medium to coarse-grained sandstone and quartz-feldspar pebble conglomerate ('grit'), with minor phyllite between coarser-grained beds (prominent sandstone/grit layers were individually recorded as unit PЄHYus); 3) calcareous phyllite; 4) calcareous sandstone and conglomerate; and 5) green phyllitic wacke and conglomerate with boulder-sized clasts of orange dolostone.

In the northern part of the study area, west of the Hyland River, the 'fetid limestone' is overlain by ~200 m of relatively homogeneous green phyllite (unit PЄHYup), and coarse clastic rocks are restricted to stratigraphically higher levels of unit PЄHYu. Elsewhere, sandstone and conglomerate beds are found throughout the upper part of the Yusezyu Formation and green phyllite is not recorded as a separate map unit.

The top of the Yusezyu Formation is marked by an ~1 to 15 m-thick limestone unit (PЄHYul). This includes thin to medium-bedded, grey to buff-coloured limestone, interbedded limestone and green shale, and grey-buff calcirudite (*see* Moynihan, 2016a).

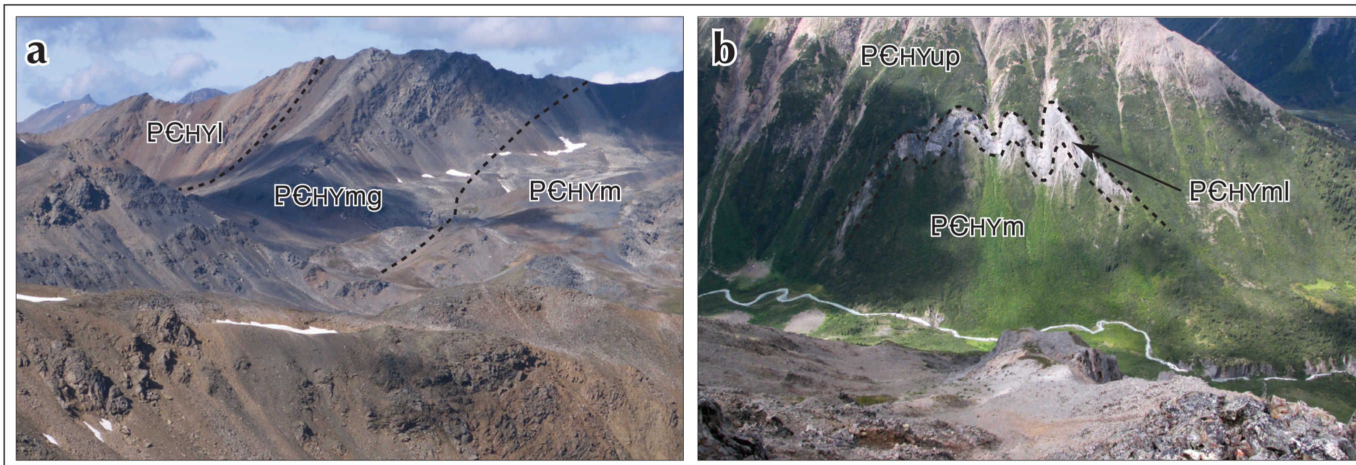


***Figure 4. (a)** Overturned section of the lower parts of the Yusezyu Formation in the northernmost part of the map area. The ridge crest is approximately 600 m above the valley floor. **(b)** Prominent 'fetid limestone' marker unit of the middle Yusezyu Formation deformed into an upright antiform; located in structural domain 3. The visible relief on this slope is approximately 400 m.*

### *Narchilla Formation (PЄHN)*

The Yusezyu Formation is gradationally overlain by mostly fine-grained clastic rocks of the Narchilla Formation, which outcrops in the northeastern corner of the 2016 map area. The proportion of grey limestone (unit PCHYul) diminishes up section and the lowest part of the Narchilla Formation locally comprises 5-20 m of green phyllite and yellow-brown-weathering calcareous sandstone. The remainder of the Narchilla Formation is dominated by variegated grey, green, maroon, mauve and creamy-brown phyllite or shale with sparsely distributed medium to thick-bedded, white-weathering sandstone and rare thin beds of limestone. Creamy brown to yellow-brown-weathering sections are relatively resistant and appear to resemble parts of the age-equivalent Vampire Formation east of the Nahanni Range Road.

### *Gull Lake Formation (lЄG)*

A small area of Gull Lake Formation crops out in the core of an overturned syncline in the northeastern part of the study area. The basal unit is ~3-4 m of conglomerate composed of grey limestone clasts in a grey to yellow-weathering sandy matrix (unit lЄGb). Deformation of the clasts gives the rock a wavy, nodular appearance. This rock is stratigraphically overlain by rusty-weathering, blocky and splintery, finely laminated grey argillite with minor planar-laminated, medium grey limestone. The argillite forms dark grey and paler blue-grey talus. Further information on the Gull Lake Formation and other Paleozoic rocks of this area is included in Roots *et al.* (1966) and Moynihan (2016a).

## IGNEOUS ROCKS

Most igneous rocks in the area were intruded in the middle part of the Cretaceous, during an extended period of voluminous magmatism in the northern Cordillera. Several magmatic suites have been recognized on the basis of age, composition and isotopic character, three of which are represented in the mapped area (Heffernan, 2004; Rasmussen, 2013).

### HYLAND SUITE

The Hyland suite, which was intruded *ca.* 107-105 Ma, includes large intrusions in the central part of NTS 105H such as the Billings and Anderson batholiths. These laccolithic bodies are mostly medium-grained, biotite granodiorite and monzogranite. They are generally undeformed but parts of their margins are foliated. In the map area, the Hyland suite is represented by parts of the Anderson and Tyers Pass batholiths, and by numerous smaller bodies, all of which are on the west side of the Upper Hyland fault. Smaller bodies include uncommon hornblende diorite and hornblende-biotite granodiorite, and locally abundant dikes and sills of equigranular biotite granodiorite and biotite-plagioclase ± quartz-eye porphyry. In places, the boundaries of the plutons are gradational, and are surrounded by large areas with abundant dikes and sills that make up 30-80% of the rock.

### TAY RIVER SUITE

Medium to coarse-grained, biotite ± hornblende granodiorite and monzonite intrusions of the younger Tay River suite (100-96 Ma) lie inboard (north and east) of the Hyland suite. Members of this suite include the curvilinear Shannon pluton (Fig. 5), which crops out in the northern part of the map area, and small intrusions of hornblende-biotite granodiorite in the southeastern part of the area (east of the Hyland River but west of the Upper Hyland fault). Rocks of the Tay River suite are mostly undeformed, but the eastern part of the Shannon pluton is penetratively foliated and lineated. Small, hornblende-bearing dikes elsewhere in the map area may also form part of the Tay River suite. Greenish-grey, fine-grained, equigranular to sub-porphyritic hornblende-biotite dacite dikes are widely distributed west of the Upper Hyland fault, and there are some cream-weathering, weakly foliated, quartz-amygdaloidal, hornblende-phyric, dacitic dikes immediately northeast of the Shannon pluton. The area east of the Shannon pluton, on the east side of the Hyland valley, also hosts a number of small, texturally variable hornblende-bearing dikes. These range from fine-grained, quartz-amygdaloidal dacite, to medium-grained hornblende granodiorite/diorite.

### TUNGSTEN SUITE

The Tungsten suite overlaps in age with the Tay River suite and includes the Justin pluton, a small, equidimensional body that is exposed close to the Little Hyland fault in the northeastern corner of NTS 105H/09. The pluton is biotite granodiorite, and hosts sheeted vein and skarn Au mineralization. The area south and west of the pluton also includes numerous dikes of similar composition, and one such dike was also encountered in the Rabbitkettle Formation east of the Little Hyland fault.

### CENOZOIC IGNEOUS ROCKS

The youngest igneous rocks in the area (Cenozoic?) are a series of basaltic dikes that occur on both sides of the Upper Hyland fault at roughly the same latitude as the 3-Aces prospect (Appendix A); they are also common in the northeastern corner of NTS 105H/09. These dikes weather dark chocolate brown, are fine grained, and are predominantly composed of clinopyroxene and plagioclase. The basalt is amygdaloidal or vesicular, commonly columnar jointed, and locally hosts megacrysts of spinel and xenoliths of spinel lherzolite and granulite-facies felsic gneiss (Colin Padget, pers. comm).

## DEFORMATION AND METAMORPHISM

Rocks in the study area have varied Mesozoic deformational and metamorphic histories. Much of the eastern part of the map area underwent a single main phase of deformation at low metamorphic grade, whereas the southwestern part of the map area underwent amphibolite facies polyphase deformation. Most of the penetrative deformation and metamorphism took place prior to intrusion of the *ca.* 107 Ma Hyland suite; however, additional faulting and local penetrative deformation took place after intrusion of the Shannon pluton (Tay River suite), which formed *ca.* 97 Ma. The intrusive rocks act as structural markers that help distinguish between Early Cretaceous deformation (referred to herein as the 'Hyland phase'), and the more localized Late Cretaceous deformation and metamorphism (the 'Shannon phase').

Moynihan (2016a) documented the presence of a steeply dipping, northwest-striking fault that bisects the area, and mapping during 2016 has provided additional information on the trace and character of this fault zone (Fig. 6). The fault, referred to as the Upper Hyland fault, is interpreted to include several subparallel strands that form an anastomosing array centred on the upper Hyland river valley. Individual faults include: the Shannon fault (Fig. 7), which truncates the Shannon pluton; the main Upper Hyland fault, which is inferred to occupy the Hyland River valley, except in the eastern part of NTS 105H/08, where it crosses a number of ridges; and a number of north to northeast-trending faults east of the Hyland River. The fault array is interpreted to record dextral strike-slip displacement, as discussed in a later section. The deformation and metamorphism of the area is described below in terms of six structural domains, most of which are partly bounded by one or more strands of this fault zone (Fig. 6).


***Figure 5.*** *Northeastern boundary of the Shannon pluton with rusty-brown schist of unit* uPs*. Visible relief is approximately 650 m.*

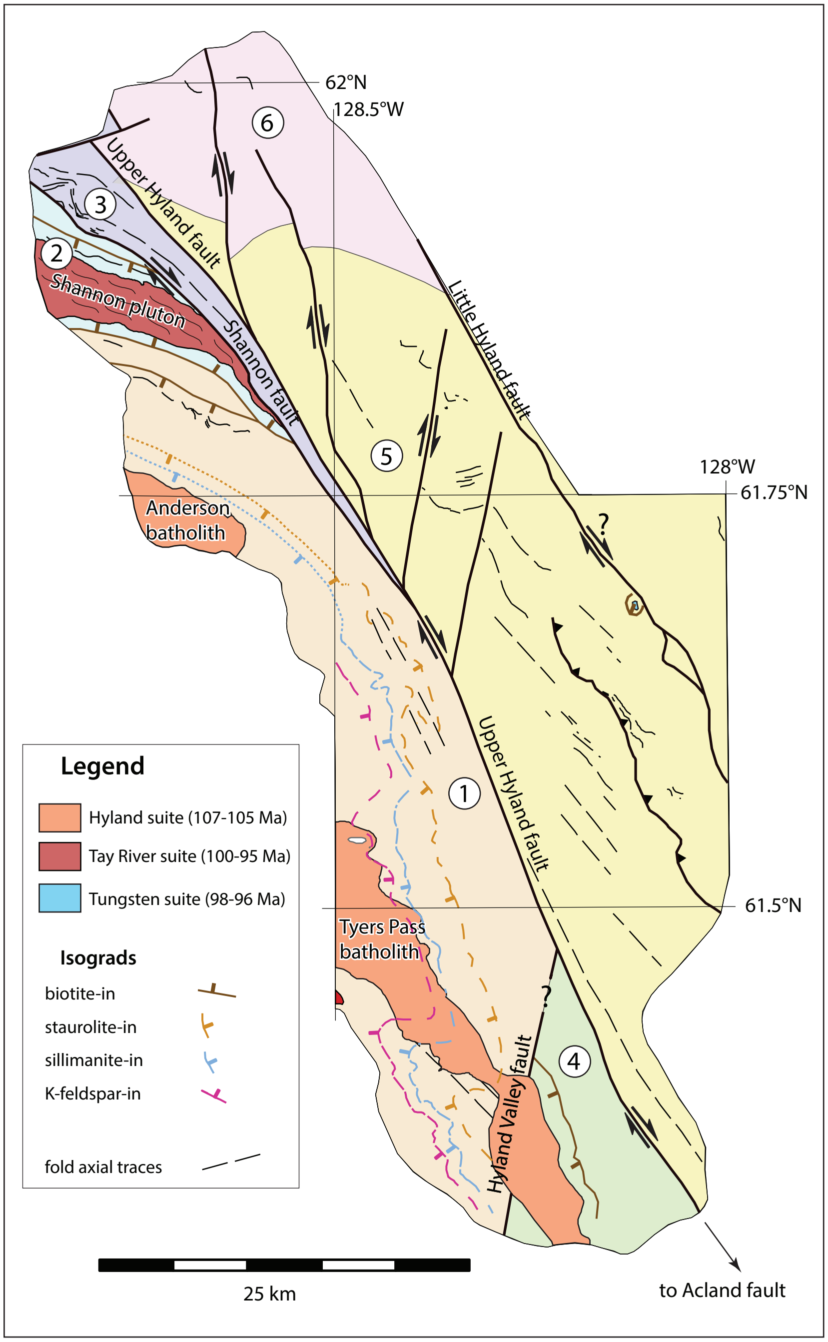


***Figure 6.*** *Structural domains (numbered circles), intrusions and major faults in the upper Hyland River area. Fold axial traces and the preliminary location of the biotite, staurolite, sillimanite and K-feldspar isograds are also shown. See text for details.*

## WEST OF THE UPPER HYLAND FAULT (UHF)

### *Domain 1 (Hyland phase deformation and metamorphism)*

This domain includes the area west of the Hyland River, except for the region surrounding, and northeast of, the Shannon pluton (Fig. 6). In most of this domain, the dominant penetrative foliation ($S_{nH}$) dips gently to moderately steeply to the northeast or east-northeast. An arcuate trend is defined by a systematic change in the dip direction from northeast in the northern part of the map area to east-northeast in the southern part. The foliation is axial planar to tight to isoclinal folds ($F_{nH}$) whose hinges are rarely seen except in cliff faces and the steep sides of northeast-trending valleys. As a result of the tight, isoclinal folding, compositional layering is generally parallel or subparallel to $S_{nH}$. This schistosity is dominant throughout the domain, but evidence for an earlier foliation ($S_{n-1H}$) is locally preserved in the hinges of folds ($F_{nH}$). Mineral lineations are parallel to the axes of these folds, and boudin necks are perpendicular. Crenulations that overprint $S_{nH}$ and are collinear with fold axes are locally common. Fold axes, lineations and crenulations ($F_{n+1H}$) generally plunge shallowly in the northern part of this domain, but are more variable in the southern part, where $D_{nH}$ structures are overprinted by map-scale, open, upright folds ($F_{n+2H}$) that trend approximately to the northwest.

Deformation ($D_{nH}$) was accompanied by greenschist to upper amphibolite facies metamorphism, which is recorded by synkinematic growth of biotite, staurolite, sillimanite and K-feldspar in rocks of metapelitic composition, and by late to post-kinematic growth of andalusite and cordierite. Garnet is also locally developed, but is only common in the sillimanite and sillimanite+K-feldspar zones. An increase in metamorphic grade towards the southwest is indicated by the distribution of the synkinematic staurolite, sillimanite and sillimanite+K-feldspar zones (Fig. 6). Boundaries between these zones are subparallel to the dominant foliation and are folded by the late upright folds ($F_{n+2H}$). Andalusite and cordierite are widely distributed throughout domain 1, but their occurrence is less systematic than that of staurolite, sillimanite and K-feldspar.

Hyland suite intrusions crosscut: 1) the ‘Hyland phase’ foliation ($S_{nH}$), 2) isograds of synkinematic minerals (staurolite, sillimanite, k-feldspar), and 3) late map-scale folds ($F_{n+2}$) that overprint both the foliation ($S_{nH}$) and isograds; therefore all the major structures in the area are early Cretaceous or older (pre-107 Ma). Hyland suite intrusions such as the Tyers and Anderson batholiths are not generally deformed, but are locally foliated parallel to $S_{nH}$ on their margins.

### *Domain 2 (superimposed Hyland phase and Shannon phase deformation/metamorphism)*

This domain includes an area to the west of the Shannon fault, on either side of the Shannon pluton (Fig. 6). It includes the pluton and its contact metamorphic aureole. As the pluton is approached from the southwest, the orientation of the dominant foliation changes progressively from northeast-dipping in domain 1 ($S_{nH}$), to steeply dipping in, and adjacent to the pluton ($S_{nS}$; domain 2). The country rock and the intrusion are both affected by this foliation ($S_{nS}$), which is parallel to the long axis of the pluton. The foliation ($S_{nS}$) is axial planar to upright, close to isoclinal, centimetre to map-scale crenulations and folds ($F_{nS}$) northeast of the pluton. These folds overprint $S_{nH}$, and $L_{nH}$ is folded around their axes. Similar overprinting is locally developed on the southwest side of the pluton, but in at least parts of the area, it appears that $S_{nH}$ was deflected into parallelism with the Shannon pluton during later deformation without being folded.

Mineral lineations in the pluton and its deformed carapace are subhorizontal, and systematic arrays of shear bands (C′ fabrics of Berthe *et al*. 1979) indicate a component of dextral shearing during its deformation (Fig. 8). The foliation is most penetrative, and the shear bands most pervasively developed near the northeast margin of the intrusion. Dextral strike-slip deformation is also suggested by a change in the orientation of the foliation/long axis of the pluton from west-northwest-striking, to northwest-striking near the Shannon fault.

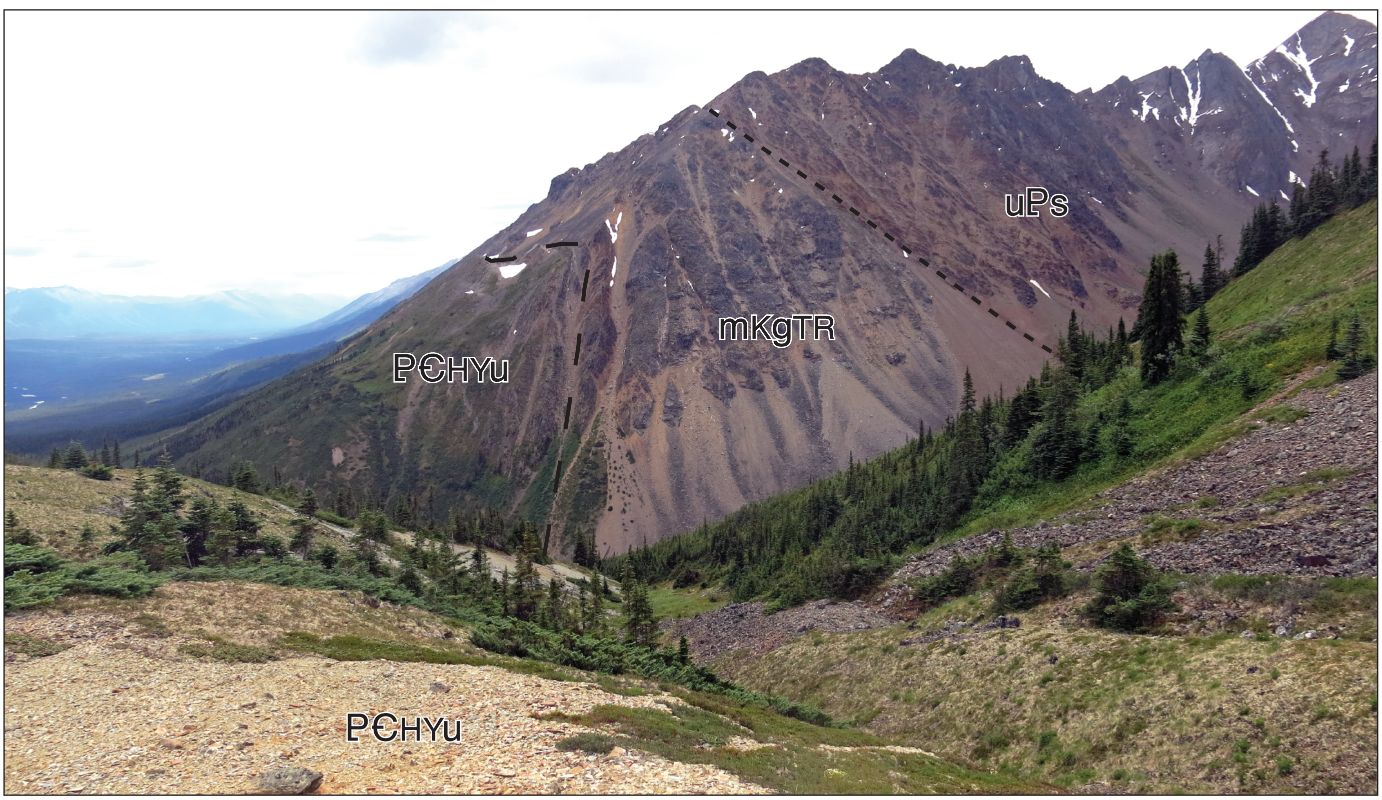


***Figure 7.*** *Exposure of the Shannon fault flanking the Hyland River valley. The fault juxtaposes rocks of the Shannon pluton against upper Yusezyu Formation, and is marked by a bright white, clay-rich band 2 to 3 m thick. Relief is approximately 600 m.*

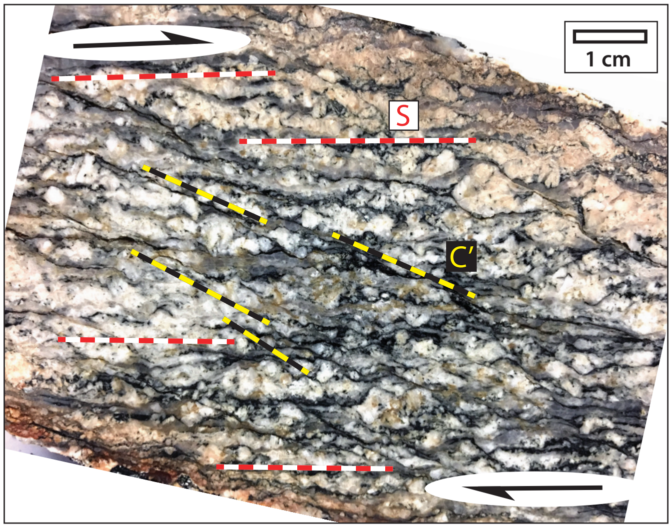


***Figure 8.*** *Cut slab of deformed granodiorite from the Shannon pluton. Shear bands (C′) that cut obliquely across the plane of flattening (S) indicate dextral shearing.*

A kinematic relationship between dextral shearing in and around the Shannon pluton and motion on the Shannon fault is suggested by: 1) the absence of a penetrative foliation in the western part of the Shannon pluton, and 2) the progressive decrease in the angle between $S_{nS}$ and the Shannon fault with increasing proximity to the fault.

The presence of biotite, andalusite and cordierite in metapelitic rocks defines the contact metamorphic aureole of the Shannon pluton. There is a narrow region of greenschist-facies rocks between the Hyland phase biotite isograd to the southwest, and the contact aureole of the Shannon pluton. This Early Cretaceous (Hyland phase), low-grade metamorphism is interpreted as the regionally extensive background upon which Shannon phase deformation and metamorphism was superimposed.

The Shannon phase of deformation and metamorphism is Late Cretaceous or younger as the Shannon pluton was intruded at 97 ± 2 Ma (Heffernan, 2004). The development of a penetrative foliation in the immediate vicinity of the pluton, but not elsewhere, suggests that deformation and intrusion may have been at least partly synchronous. This possibility may also be supported by the presence of weakly deformed dikes that crosscut the penetrative foliation immediately northeast of the pluton. The dikes are compositionally similar to the intrusion, and if genetically related, may record the waning stages of magmatism during the latest part of this phase of deformation.

### *Domain 3*

This domain includes the wedge-shaped area east of the Shannon fault and west of the inferred trace of the Upper Hyland fault (UHF; Fig. 6). The rocks are deformed into a series of close to tight upright folds with shallowly plunging hinges. The axial planes and phyllitic cleavage dip northeast or southwest. Locally, this main fold train refolds earlier isoclines defined by sandstone beds in the upper Yusezyu Formation. There are no local constraints on the age of deformation in this domain, but it predates the Upper Hyland fault zone and is interpreted to be Early Cretaceous. The metamorphic grade is low (chlorite zone, greenschist facies).

### *Domain 4*

This domain comprises the northeast-dipping panel in southern NTS 105H/08 that occurs east of the Hyland River but west of the Upper Hyland fault (UHF).

At the lower levels of this panel, the dominant foliation ($S_{nH}$?) is axial-planar to isoclinal folds, which pitch steeply down $S_n$. At higher levels, folds trend northwest, as is observed elsewhere east of the Hyland River. This domain may record a continuous transition from lower to higher structural levels, and if so, may indicate contemporaneity of $S_{nH}$ with the phyllitic foliation ($S_n$) at higher structural levels. Rocks in this domain were deformed at low grade (chlorite zone, greenschist facies), except in the aureole of the southeastern extension of the Tyers Pass batholith, where they contain biotite, cordierite and andalusite.

There is a change in structural and stratigraphic level across the Hyland River valley in the southern part of NTS 105H/08. Rocks on the northwest side of the valley (domain 1) belong to the deepest exposed parts of the Windermere Supergroup and underwent regional amphibolite-facies metamorphism, whereas rocks on the southeast side belong to the Yusezyu Formation and, with the exception of the contact aureole, are lower grade. This difference can be attributed to the Hyland Valley fault (HVF), which projects along the valley floor from the southwest and may extend as far as the Upper Hyland fault. If so, truncation provides evidence of their relative ages. The Tyers Pass batholith is believed to cross the Hyland River valley, and therefore the HVF, if continuous, may predate its intrusion *ca.* 107 Ma. These relationships are uncertain as there is little exposure of bedrock in the Hyland River valley.

## EAST OF THE UPPER HYLAND FAULT

### *Domain 5*

Rocks east of the Hyland River were deformed under low grade (chlorite zone, greenschist facies) conditions, except adjacent to the Justin pluton, where cordierite + biotite assemblages are developed. A phyllitic foliation is developed parallel to the axial planes of close to tight folds; this is generally the sole tectonic foliation developed in the rocks, and is only locally overprinted by crinkles and open folds.

In most of this domain, the phyllitic cleavage and axial planes of the folds dip northeast and folds are asymmetric (southwest-verging), with steep limbs that are locally overturned. Southwest-verging thrusts are also locally developed in this area, including a fault with a strike length of over 20 km in the eastern part of NTS 105H/09. Folds generally plunge at shallow angles to the northwest or southeast, but have steeper plunges in some eastern parts of the domain (*see* Moynihan 2016a).

### *Domain 6*

Folds in the northeastern corner of the map area also plunge at shallow angles to the northwest or southeast, but the axial-planar phyllitic cleavage dips southwest and the sense of fold asymmetry is reversed (northeast vergence). The boundary between the northwest and southeast-vergent regions is a diffuse zone that marks the axis of a structural fan. This axis is oblique to the overall trend of the belt and continues into the Little Hyland valley, where it is probably truncated by the Little Hyland fault (Fig. 6).The metamorphic grade is low throughout (*i.e.*, chlorite zone, greenschist facies).

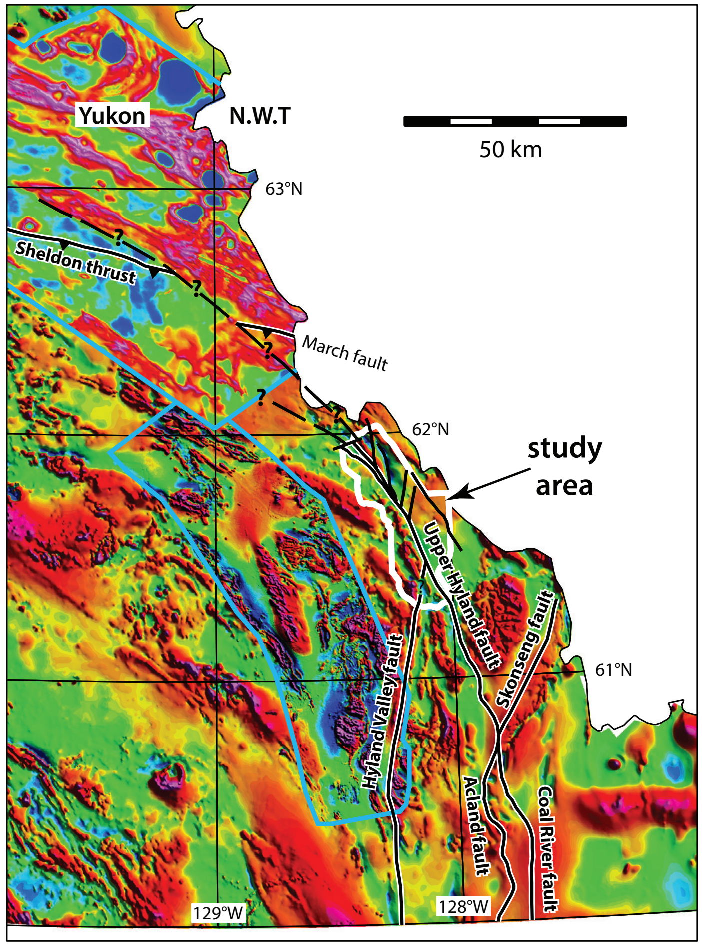


***Figure 9.*** *Regional geophysical data and mapped or postulated major faults in southeastern Yukon. The geophysical data shown is regional total field aeromagnetic data (Miles et al., 2015; Kiss and Boulanger, 2016), except in the northern part of the figure, where conductivity data from a ZTEM survey is displayed (Condor Geophysics, 2013). Blue outlines delineate the boundaries between different geophysical datasets. See text for discussion.*

# DISCUSSION

## REGIONAL EXTENT OF THE UPPER HYLAND FAULT (UHF)

The Upper Hyland fault is continuous with a structure named the Acland fault in the northern part of the Coal River area (NTS 95D; Fig. 9). Pigage *et al.* (2011) interpreted the Acland fault to extend into British Columbia, giving the combined Upper Hyland-Acland faults a strike length of at least 250 km. As currently interpreted, the southern part of the Acland fault is plugged by the Gabe pluton in the central Coal River area (NTS 95D; Pigage *et al.*, 2015). The Gabe pluton was intruded at 97.83 ± 0.22 Ma (Pigage *et al.*, 2015), which overlaps the age of the Shannon pluton (97 ± 2 Ma; Heffernan, 2004). If the current interpretation of the geology is correct, this restricts the window for motion on the fault to a short time interval (under 0.5 Ma). The distance between the Shannon pluton and the Gabe pluton may allow for some variation in the age of motion on the southern Acland and Upper Hyland faults prior to their linkage; nevertheless, the date of the Shannon pluton requires refinement, and more precise geochronology may rule out continuity of the Upper Hyland and southern Acland faults. As there is poor bedrock exposure in the area, it is possible the Acland fault is not plugged by the Gabe pluton but rather passes beside it.

Another possibility is that the Acland fault is not a continuous structure (as interpreted by Pigage *et al.*, 2011) but rather that the northern part of the Acland fault is continuous with the Coal River fault. The trace of the Coal River fault is less irregular than that of the southern part of the Acland fault and is closer to parallelism with the UHF (Fig. 9). The Coal River fault marks the western boundary of Palaeozoic platformal rocks in southeastern Yukon and also extends south into British Columbia. Further mapping and geochronology is required to resolve the details, but it is likely that one of these previously mapped structures (Acland or Coal River faults) represents the southern extension of the Upper Hyland fault.

The northern continuation of the Upper Hyland Fault is less clear, as it projects towards a region in which few significant structures have been recognized. Gordey and Anderson (1993) documented the presence of several fault strands along-trend to the northwest, and the UHF may form a continuous structure linking these. If so, the northwest continuation of the UHF projects towards, and may extend along, the southwestern margin of a prominent linear conductivity high in the northeastern part of the Sheldon Lake area (105J; Fig. 9). Extension into this region would increase the minimum strike length of the fault system by a further 190 to ~440 km. The margin of the aforementioned conductivity linear does not coincide with a known fault, and is oblique to both the Sheldon thrust and the March fault. Martel (2015) suggested that the Sheldon thrust is continuous with the March fault. A modified version of this suggestion is that the March fault and Sheldon thrust were once continuous, but were separated by ~50 km dextral offset on the northwestern continuation of the UHF. This is less than the apparent offset of the Tay River suite intrusions (*see* below), but variation in displacement can be accounted for by motion on other strands of the fault zone, including the Shannon fault, and possibly the Little Hyland fault. An alternative possibility is that the Shannon fault accommodates most displacement of the Upper Hyland fault system to the north, and if so, the central strand may not extend as far beyond the northern limit of the map area.

These suggestions are necessarily speculative, but whatever its full extent and displacement profile, the Upper Hyland fault (with along-strike continuations) is the longest structure recognized in the southeastern Selwyn fold-and-thrust belt and is likely to account for significant displacement.

## DISPLACEMENT ESTIMATES FOR THE UPPER HYLAND FAULT

The array of steep faults that occupies the northeastern part of the map area (Fig. 6) is interpreted as a composite dextral strike-slip fault system, and motion may have coincided with intrusion of the Shannon pluton *ca.* 97 Ma. Dextral offset on the Shannon fault is indicated by the rotation of $S_{nS}$ towards parallelism with the fault, as discussed above. The magnitude of displacement on this strand is unknown, but lack of exposure of the offset part of the pluton on the east side of the fault requires at least ~15 km offset, and it could be significantly more. Other strands also show apparent dextral offsets, though the true movement direction of the faults is less certain. The northernmost, north-trending strand of the fault zone has an apparent dextral offset of southwest-dipping overturned layers by ~3.5 km, while another strand directly to the south displays apparent dextral offset of the hinge zone of an antiform by >5 km. The east to northeast-trending fault north of the 3 Aces prospect has an apparent dextral offset of 1.5 to 2 km, and the subparallel fault to the south of this strand may have a similar, lower magnitude apparent offset. The true extent and movement direction of the Little Hyland fault is uncertain, but it has a moderate to steep dip and may also accommodate dextral strike-slip offset. Given the strike length of the fault zone, and these tentative estimates for displacement on lesser strands, the cumulative offset of the Upper Hyland fault system is therefore likely to measure in the tens of kilometres.

The Shannon pluton is part of the Tay River suite, which was intruded inboard (northeast) of the Hyland suite from 98 to 95 Ma. The Shannon pluton is truncated by the Shannon fault, and the nearest Tay River suite intrusion on the east side of the fault zone is ~75 km to the south-southeast (Coal River South batholith; Fig. 10). Tens of kilometres of dextral offset on the Upper Hyland fault can account for the absence of Tay River suite intrusions in the northeast part of NTS 105H. Restoration of ~80 km of cumulative dextral motion on the Upper Hyland fault has the effect of producing continuity of the Hyland Valley fault (HVF) with the Skonseng fault. The Skonseng and Hyland Valley faults have a similar orientation, which is anomalous with respect to the regional structural grain. Continuity of these structures following restoration may be fortuitous, but apparent offset of the Tay River suite provides a plausible working estimate for displacement on the fault zone.

The main body of the Coal River South batholith is approximately the same age as the Shannon pluton (96-97 Ma; *see* compilation in Rasmussen, 2013); however, the aeromagnetic response of the Shannon pluton is muted, whereas the Coal River South batholith exhibits a positive magnetic anomaly. The Coal River South batholith and the Shannon pluton cannot therefore be matched directly; however, an ancillary intrusion that also belongs to the Tay River suite – the Caesar Lakes pluton (Fig. 10), was intruded at 97.1 Ma (Heffernan, 2004), and has a similar magnetic response as the Shannon pluton. The southwestern corner of the Coal River South batholith may also include a region with low aeromagnetic response that is directly east of the Upper Hyland fault. Evidently, there is variation in the magnetic character of different parts of the intrusive suite. The Coal River South batholith intruded Cambro-Ordovician rocks of the Rabbitkettle Formation and probably represents a higher structural level compared to the Shannon pluton, which intrudes the Windermere Supergroup; this difference may reflect a component of vertical movement on the UHF.

## MINERALIZATION

The mapped area is close to the Tungsten mine site, and the region west of the Hyland River contains numerous tungsten-skarn and vein/manto-type occurrences (e.g., MacLeod, 1982). These latter occurrences are related to intrusion of granitic rocks of the Hyland suite, and new information on the position and extent of calcareous units may help to define regions of enhanced prospectivity for tungsten-skarn mineralization.

More recent exploration has focused on the potential for gold mineralization within the corridor between the Upper Hyland fault and the Little Hyland fault. This includes intrusion-related gold mineralization associated with the Justin pluton and associated dikes (Higgs, 2009), and non-magmatic, vein-hosted gold mineralization in the Yusezyu Formation at the 3-Aces prospect (Schulze, 2010) and further to the northwest (Hart and Lewis, 2006).

The potential significance of the Upper Hyland fault for mineral prospectivity in the region is two-fold. Given the apparent temporal overlap of the Shannon fault with intrusions of the Tay River suite, there may be potential for structurally controlled, intrusion-related mineralization associated with igneous rocks of this age (Tungsten or Tay River suites). Second, mineralizing systems that

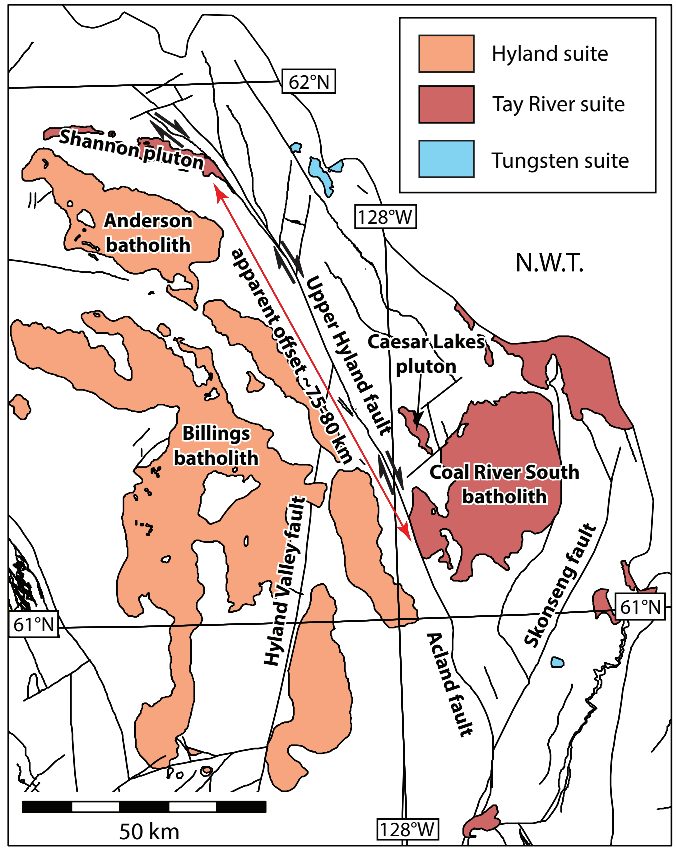


***Figure 10.*** *Major faults and intrusions documented in the eastern part of NTS 105H and adjacent areas. Dextral displacement of ~75 to 80 km is suggested by an apparent offset of Tay River suite intrusions across the Upper Hyland fault. N.W.T. = Northwest Territories.*

predate the Upper Hyland fault may have been truncated and offset. The belt that contains non-magmatic gold occurrences is immediately east of the Upper Hyland fault, and offset rocks that were formerly in close proximity are now likely to be located to the northwest. Therefore, there may be potential for further discoveries of non-magmatic gold mineralization on the west side of the Upper Hyland fault.

Hart and Lewis (2006) speculated on the presence of a major structure that played a role in the localization of non-magmatic gold mineralization. They suggested continuity of the March fault from its well-documented position in the Northwest Territories (Gordey and Anderson, 1993), southward along the Little Hyland River, to join with the structure that is now known as the Acland fault. This interpretation, which was based primarily on regional geophysics before detailed geological maps of the area existed, is incompatible with the results of new mapping. The March fault does not extend into the map area and does not join with the Acland fault; instead it dies out farther north. Rather than crossing the Coal River South batholith as hypothesized by Hart and Lewis (2006), the Acland fault forms the southwest boundary of the batholith and continues to the northwest, where it joins the Upper Hyland fault.

## CONCLUSION

The stratigraphy of the oldest known parts of the Hyland Group has been established; newly defined, informal stratigraphic subdivisions can be traced throughout the map area. Proterozoic to Palaeozoic rocks were affected by Early Cretaceous penetrative deformation and greenschist to amphibolite-facies metamorphism. Deformation ceased prior to intrusion of the 107 Ma Hyland suite, but there was further localized penetrative deformation adjacent to the 97 ± 2 Ma Shannon pluton. The Upper Hyland fault, whose trace is parallel to the headwaters of the Hyland River, comprises a number of anastomosing, subparallel splays that juxtapose varying parts of the Hyland Group. The fault likely accommodated tens of kilometres of dextral strike-slip displacement during, and/or after emplacement of the Shannon pluton.

## ACKNOWLEDGEMENTS

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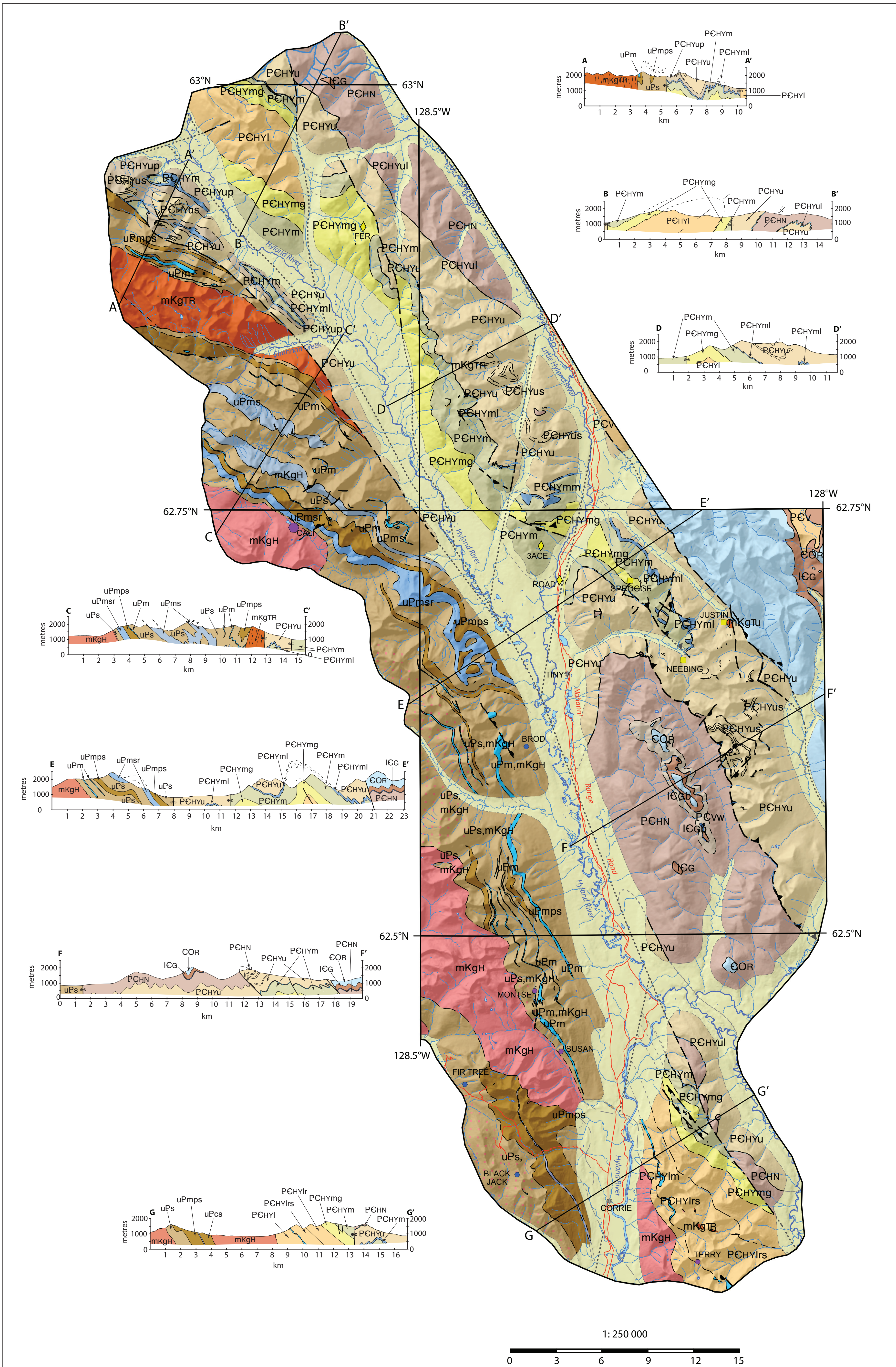
***Appendix A.*** *Simplified geological map and cross sections at 1:250 000 scale; elevation for cross sections is in metres above sea level (a.s.l.). For more details, see the 1:50 000-scale open file map (Moynihan, 2016b).*



# LEGEND

## PLUTONIC ROCKS

### MID-CRETACEOUS

mKgTu — **TUNGSTEN SUITE:** *biotite granodiorite, biotite quartz monzonite*

mKgTR — **TAY RIVER SUITE:** *biotite ± hornblende granodiorite, biotite quartz monzonite, hornblende and plagioclase-phyric dacite*

mKgH — **HYLAND SUITE:** *biotite granodiorite, quartz monzonite, porphyritic dacite; minor hornblende quartz diorite, quartz syenite*

## 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 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 to 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 to thick-bedded quartz arenite; minor greenschist*

### TERRENEUVIAN-CAMBRIAN SERIES 2

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

PЄVw — **VAMPIRE FORMATION, western facies:** *green and grey phyllite/mudstone-siltstone; minor sandstone; commonly heavily bioturbated; local maroon mudstone-siltstone; more resistant than PЄHN*

### NEOPROTEROZOIC-CAMBRIAN WINDERMERE SUPERGROUP

HYLAND GROUP

PЄHN — **NARCHILLA FORMATION:** *green, maroon and grey, well-cleaved, rhythmically bedded shaly mudstone-siltstone and phyllite; white-weathering, thin to medium-bedded, planar and cross-bedded sandstone*

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*

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

PЄHYup — **YUSEZYU FORMATION, UPPER, phyllite:** *green phyllite*

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

PЄHYm — **YUSEZYU FORMATION, MIDDLE, mixed unit:** *grey, purple and green phyllite, sandstone, granule and pebble conglomerate (grit); grey limestone, silty/sandy limestone; local green, plagioclase-rich wacke*

PЄHYmd — **YUSEZYU FORMATION, MIDDLE, mixed unit, dolostone:** *yellow-orange dolostone, silty and sandy dolostone, pebble to boulder conglomerate with dolomitic matrix*

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*

PЄHYl — **YUSEZYU FORMATION, LOWER (undivided):** *grey, rusty brown-weathering phyllite, sandstone, granule-pebble conglomerate*

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

PЄHYlm — **YUSEZYU FORMATION, LOWER, marble:** *pale grey to white-weathering, medium to dark grey marble, calc-silicate*

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

## METAMORPHIC ROCKS WEST OF THE HYLAND RIVER

### NEOPROTEROZOIC TO CAMBRIAN WINDERMERE SUPERGROUP

**(MOSTLY OLDER THAN PЄHY, BUT MAY BE PARTLY EQUIVALENT)**

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

uPmsr — **MARBLE-SCHIST (resistant):** *rusty orange-brown-weathering, medium to coarse-grained metapelitic and semi-pelitic schist; psammitic schist*

uPcs — **CALC-SILICATE:** *banded, laminated to thin-bedded, siliceous calc-silicate with thin, dark, micaceous folia*

uPmps — **METAPELITIC SCHIST:** *rusty orange-brown-weathering, medium to coarse-grained metapelitic and semi-pelitic schist; psammitic schist; green phyllite in regions of low metamorphic grade*

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

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

*Stippling 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.*

## 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)......

strike-slip fault (dextral) (defined, approximate, inferred, covered)......

strike-slip movement direction (cross section) (dextral)........ ⊕ ⊙

## MINFILE OCCURRENCES

- plutonic-related Au
- skarn Pb-Zn
- skarn W
- vein Au-quartz
- unknown