Stratigraphic affinity of late Neoproterozoic limestone in the vicinity of Tillei and McPherson lakes, 105H/13, 14, southeastern Yukon

D. Moynihan
Yukon Geological Survey

Moynihan, D., 2018. Stratigraphic affinity of late Neoproterozoic limestone in the vicinity of Tillei and McPherson lakes, 105H/13,14, southeastern Yukon. *In:* Yukon Exploration and Geology 2017, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 129-137.

ABSTRACT

The area around Tillei and McPherson lakes includes extensive exposure of a relatively thick, late Neoproterozoic limestone. The limestone is lithologically similar to the Espee Formation of the Ingenika Group, but is in geological continuity with the Hyland Group. The Hyland and Ingenika groups are age-equivalent sequences that were in close proximity before they were separated by Cenozoic dextral displacement on the Tintina fault. The area may therefore contain evidence for stratigraphic linkages between the two groups. The limestone is interpreted to have been deposited in a high-standing region outboard of the Hyland Group type-area. Further work is required to determine the extent to which late Neoproterozoic paleobathymetry aligns with Paleozoic platform/basin margins.

* *david.moynihan@gov.yk.ca*

INTRODUCTION

The oldest rocks exposed in the core of the Selwyn-Mackenzie fold belt (Gordey and Anderson, 1993; Fig. 1) belong to the Windermere Supergroup (Ross, 1991). This supergroup comprises Cryogenian-Terreneuvian rocks that were deposited during episodes of rifting that led to formation of the western Laurentian ancestral margin. The most extensive exposures of the Windermere Supergroup in southern Yukon are mostly Ediacaran-Terreneuvian rocks of the Hyland (Gordey and Anderson, 1993) and Ingenika groups (Mansy and Gabrielse, 1978; Fig. 1). These groups are restricted to opposite sides of the Tintina fault, but were in close proximity to one another prior to >430 km of dextral displacement during the Cenozoic (Gabrielse *et al.*, 2006).

Correlation between the two groups is hampered by a scarcity of fossils and volcanic rocks, but there are clear lithological similarities (Fig. 2), in particular the presence of a late Neoproterozoic limestone that separates mostly coarse clastic rocks from overlying varicoloured mudstone/siltstone. Limestone and dolostone comprise a relatively small part of the Hyland and Ingenika groups, but calcareous units form useful marker horizons that facilitate stratigraphic subdivision of the groups and recognition of the structural geometry.

The Hyland and Ingenika groups are overlain by contrasting Paleozoic sequences. The Ingenika Group underlies Paleozoic rocks of the Cassiar platform (Fritz *et al.*, 1991), while the Hyland Group was succeeded by deeper marine strata of the Selwyn basin (Gordey and Anderson, 1993; Fig. 1). Dextral displacement on the Tintina fault separated most of the Cassiar platform from its northernmost part. Its inferred northern extension, now located east of the Tintina fault, is called the McEvoy platform, and includes many of the same distinctive Paleozoic rocks as the main part of the Cassiar platform. Although Paleozoic rocks of the Cassiar platform have been identified on either side of the Tintina fault, the same is not true of the Ingenika Group.

Unresolved questions therefore include the following:

1. What is the extent of similarities/differences between the Hyland and Ingenika groups, and
2. If they are as similar as they appear to be, when did their depositional histories diverge?

Relatively thick Neoproterozoic limestone/dolostone in the region around Tillei and McPherson lakes (Figs. 3 and 4a) was first recognized by Roots *et al.* (1966), and the area was revisited during the summer of 2017 as part of an ongoing bedrock mapping project in the Hyland region of southeastern Yukon. The area is interesting because it includes the westernmost exposures of the Hyland Group in southeastern Yukon, and also lies in close proximity to Paleozoic rocks of the McEvoy platform. The area may therefore shed light on the relationship between upper parts of the Hyland and Ingenika groups. This paper provides a description of the limestone and adjacent units, outlines the stratigraphic position of the limestone, and discusses its implications for regional correlations.

REGIONAL STRATIGRAPHY

HYLAND GROUP

The Hyland Group, which was defined in the Little Nahanni River area (NTS 105I), comprises the Yusezyu Formation and the overlying Narchilla Formation (Gordey and Anderson, 1993; Fig. 2). The Yusezyu Formation is dominated by sandstone, conglomerate ('grit') and shale, with minor calcareous horizons, while the Narchilla Formation is mostly variably coloured (grey, black, green and maroon) mudstone with lesser sandstone. A discontinuous, <15 m-thick limestone (limestone member of Yusezyu Formation; Gordey and Anderson, 1993) typically marks the boundary between the two formations, and is stratigraphically equivalent to thicker limestone/dolostone of the Algae formation in the Niddery Lake area (NTS 105O; Cecile, 2000) and the Risky Formation of the Mackenzie and Ogilvie Mountains (Turner *et al.*, 2011). Moynihan (2016, 2017) recognized the presence of prominent limestone/marble horizons at deeper levels in the Yusezyu Formation in the upper Hyland area (NTS 105H), including distinctive fetid limestone, and a stratigraphically lower marble/calc-silicate layer up to 60 m thick (Hyland marble of Moynihan, 2016; Fig. 2). There are few age constraints on the Hyland Group but based on trace fossils, the Precambrian-Cambrian boundary is low within the Narchilla Formation (Hofmann *et al.*, 1994).

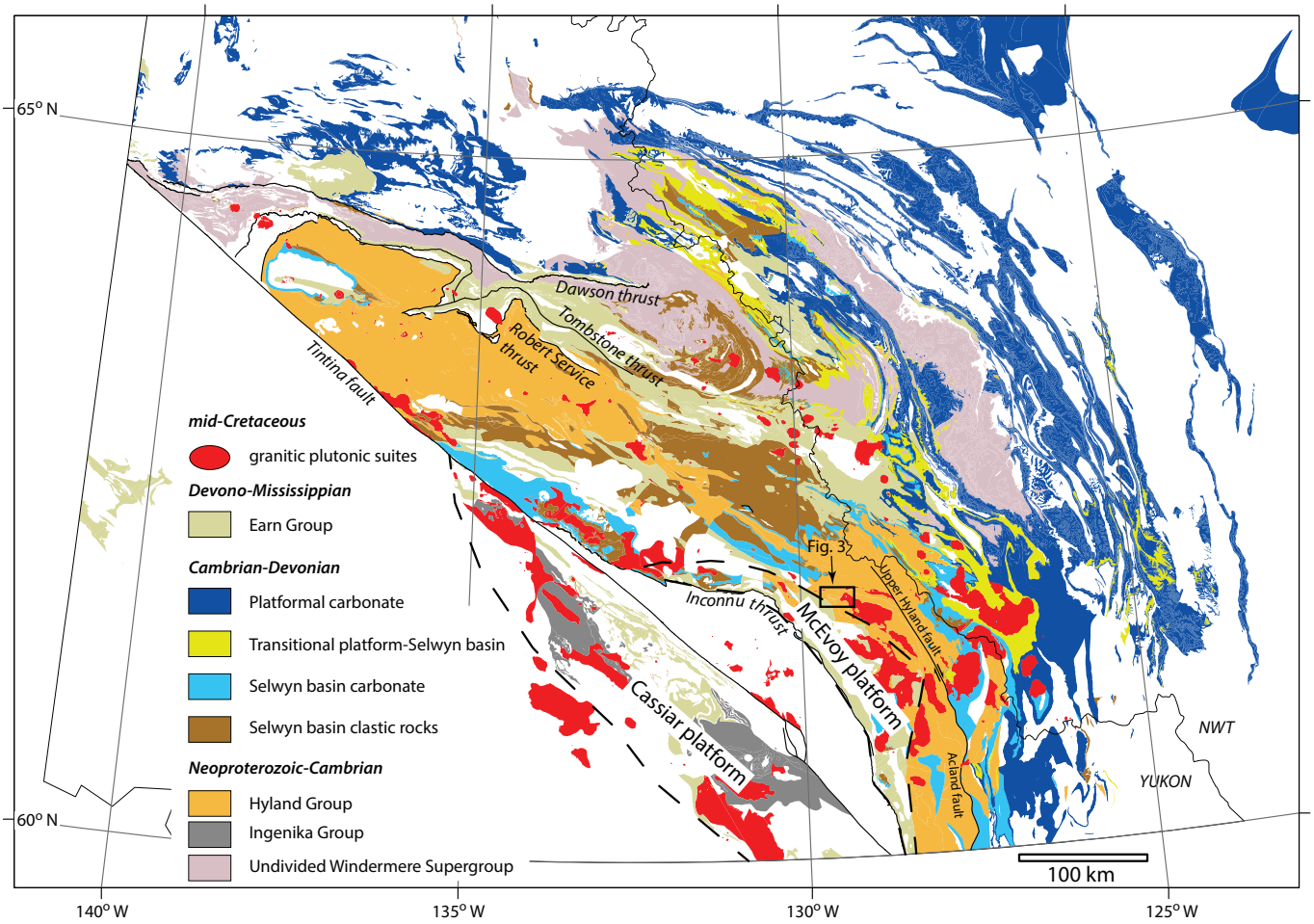

Figure 1. *Neoproterozoic – lower Paleozoic rocks within the arcuate Selwyn-Mackenzie fold and thrust belt, in Yukon and NWT (Colpron et al., 2016). The Hyland Group crops out extensively in the core of the fold belt east of the Tintina fault. Rocks of the same age west of the Tintina fault belong to the Ingenika Group. Prior to Cenozoic dextral displacement on the Tintina fault, the Hyland and Ingenika groups were continuous with one another.*

INGENIKA GROUP

The oldest part of the Ingenika Group (Mansy and Gabrielse, 1978) is the Swannell Formation, which comprises resistant sandstone/conglomerate and shale. This is overlain by the less resistant, generally finer-grained Tsaysdiz Formation, followed by the Espee Formation – a thick cliff-forming cryptograined limestone-dolostone unit that is characterized by abundant pisoliths/oolites and ferrodolomite nodules in its type area (Mansy and Gabrielse, 1978). The youngest part of the Ingenika Group is represented by the Stelkuz Formation, which includes varicoloured, typically green and maroon shale, with lesser limestone and sandstone.

STRATIGRAPHY OF THE TILLEI AND MCPHERSON LAKES AREA

Neoproterozoic-Cambrian rocks, including the thick limestone-dolostone exposures in the area (Fig. 3) were assigned to the Hyland Group by Gordey and Makepeace (2001). Deepest stratigraphic levels are exposed in the eastern part of the area illustrated in Figure 3, where they form the core of an overturned antiform. These rocks, which correlate with parts of the middle/lower Yusezyu Formation (as defined in Moynihan, 2017) are dominated by medium to thick-bedded sandstone and grit, interlayered with brown-weathering mudstone/phyllite. They form relatively resistant topography, and sandstone-rich sections impart a ribbed appearance to hillslopes. These rocks are overlain by a distinctive fetid

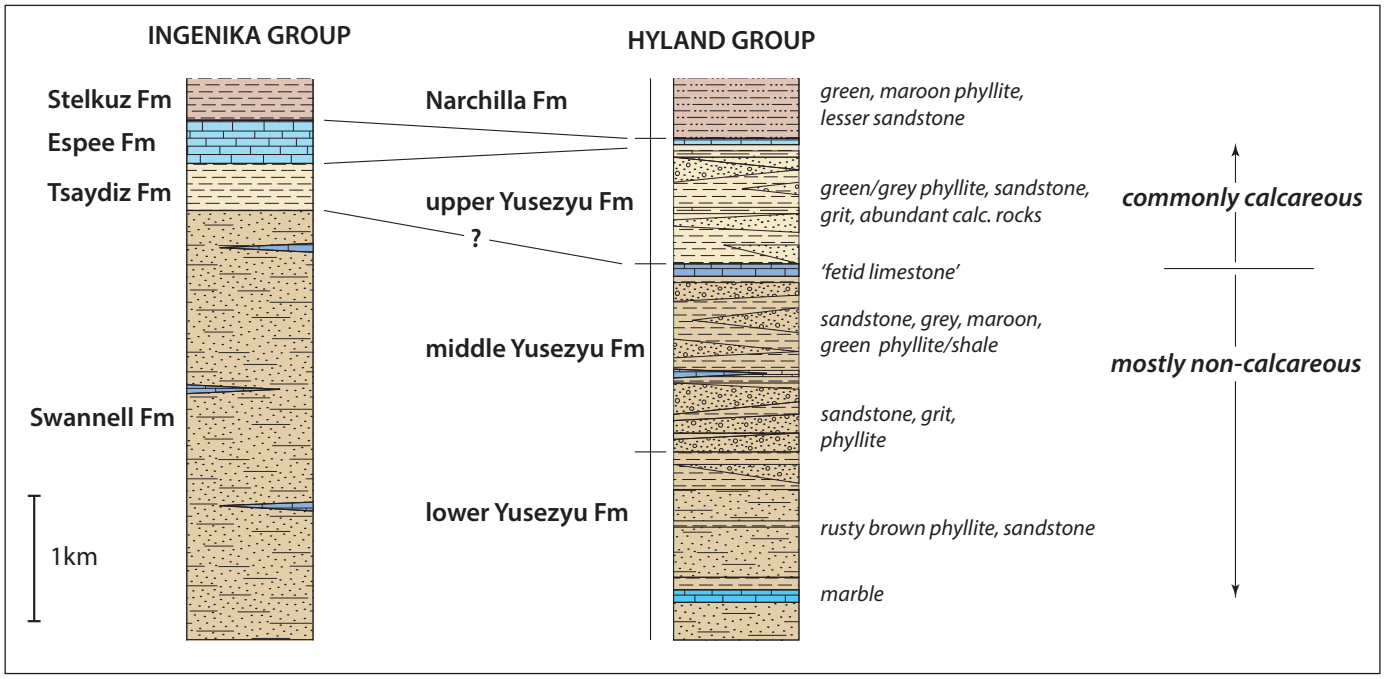

Figure 2. *Generalized stratigraphy of the Hyland and Ingenika groups; information from Mansy and Gabrielse (1978) and Moynihan (2017).*

limestone (*see* Moynihan 2017), followed by the upper part of the Yusezyu Formation, which includes sandstone, conglomerate, minor limestone and abundant mudstone/phyllite, including a thick interval of green (locally maroon) mudstone/phyllite above the fetid limestone.

The latest Neoproterozoic limestone-dolostone is a resistant (cliff-forming) unit that is dominated by pure, pale grey weathering, pale to medium grey limestone (Fig. 4b,c). The limestone is mostly blocky and forms coarse talus with irregular-shaped blocks generally >5 cm in diameter. Creamy-brown dolomite nodules (ferrodolomite?; generally ~2-4 mm in diameter; Fig. 4c) are common throughout the limestone, and locally form clusters. Bedding is rarely discernible, but banding is common in regions of higher metamorphic grade/strain. In these areas, tectonic foliation wraps dolomite nodules and clusters, giving rise to a streaky, marbled appearance; locally ferrodolomite clusters form porphyroclasts in a matrix of recrystallized calcite marble.

East of Tillei Lake, there is a large region of brecciated dolostone adjacent to a N-S striking late normal fault. Elsewhere, between Tillei and McPherson Lakes, dolostone is commonly developed in the upper part of the unit. The dolostone is a cream to creamy-brown colour with sucrosic texture and local rust-stained sections (Fig. 4d). Space-filling sparry calcite is common and zebra dolostone is locally developed.

The upper contact of the limestone unit was observed in two areas. East of Tillei Lake, where it is isoclinally infolded with the overlying phyllite (Fig. 4e), the contact between the limestone and overlying fine clastic unit consists of a zone, 1-5 m thick comprising clasts, pods and lenses of limestone in a green phyllite matrix (Fig. 4f). Lenses are up to 1 m thick and are composed exclusively of tightly packed pisoids/ooids (Fig. 4g). Limestone ooids/pisoids weather grey while dolomitized equivalents are orange-brown. In the north of the area, a pisolitic layer was not observed at the contact, but there is a 3-5 m thick interval within the overlying shale (Fig. 4h) that consists of abundant limestone pods and lenses within green phyllite (Fig. 4i).

The thickness of the limestone is difficult to estimate due to the effects of folding; nevertheless it is clear that there is significant variation in its thickness. In the northernmost part of the study area the limestone is approximately 10 to 30 m thick, while between Tillei and McPherson lakes it may exceed 100 m in true (stratigraphic) thickness.

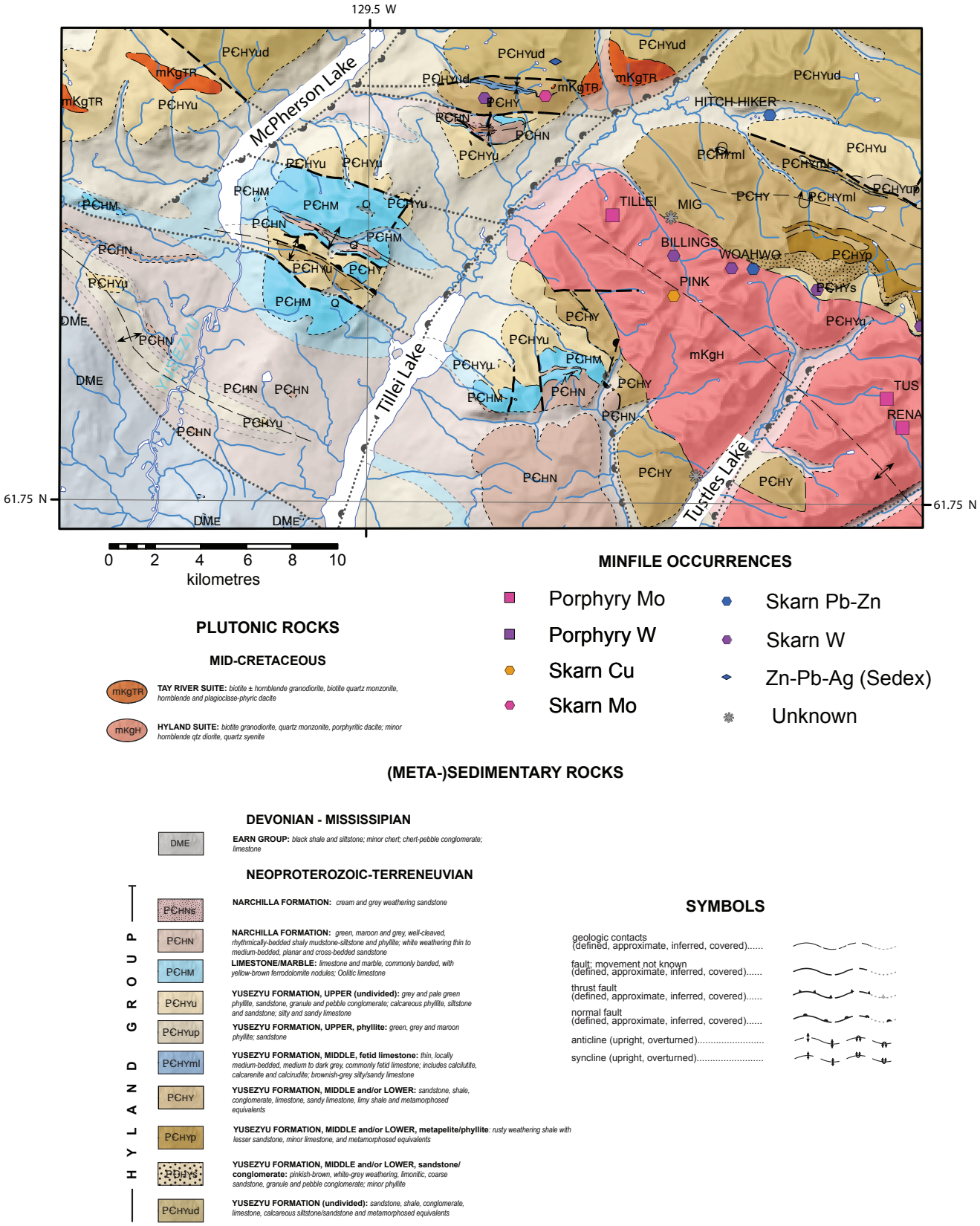

Figure 3. *Geological map of the study area, showing extensive exposure of late Neoproterozoic limestone in the region around Tillei and McPherson lakes, SE Yukon (NTS 105H/13, 14). SEDEX=sedimentary exhalative.*

DISCUSSION

DEPOSITIONAL ENVIRONMENT

The limestone in the study area is homogeneous and clean, devoid of siliciclastic rocks or structures indicative of deep marine deposition. The only macroscopically visible textures preserved in the limestone are the dense ooids/pisoliths that form layers, pods and lenses at, or near, the base of the overlying shale; these layers are interpreted to have formed in a platformal environment before being reworked into overlying shale. While sedimentological interpretation of the limestone is inhibited by the level of deformation/recrystallization, it is reasonable to infer that the clean, homogeneous, relatively thick limestone unit was deposited in a shallow marine environment.

STRATIGRAPHIC CORRELATIONS

The limestone around Tillei and McPherson lakes is in the same stratigraphic position as the limestone member at the top of the Yusezyu Formation, but differs in its character and depositional environment. The upper limestone member of the Yusezyu Formation in the Hyland River and Little Nahanni River region (Gordey and Anderson, 1993) includes interbedded shale and limestone conglomerate, and exhibits sedimentary structures indicative of deposition by turbidity currents below wave base. Lithologically, the limestone in the Tillei and McPherson lakes area has more in common with the Espee Formation, including the ubiquitous presence of distinctive cream-brown ferrodolomite nodules and oolitic/pisolitic limestone.

Given the continuity of Neoproterozoic-early Cambrian rocks in the area with the type area of the Hyland Group, and similarities with the Espee Formation, the study area appears to represent a link between the Hyland and Ingenika groups. Rocks underlying the limestone are similar to those of the Swannell and Tsaydiz formations, just as overlying rocks resemble the Stelkuz Formation. Distinction between the Hyland and Ingenika groups in this area may therefore be a question of nomenclature rather than substance. The fetid limestone marker unit extends throughout the study area and is a distinctive part of the Hyland Group; the linkages proposed here could be confirmed if this marker unit were to be recognized elsewhere in the Ingenika Group.

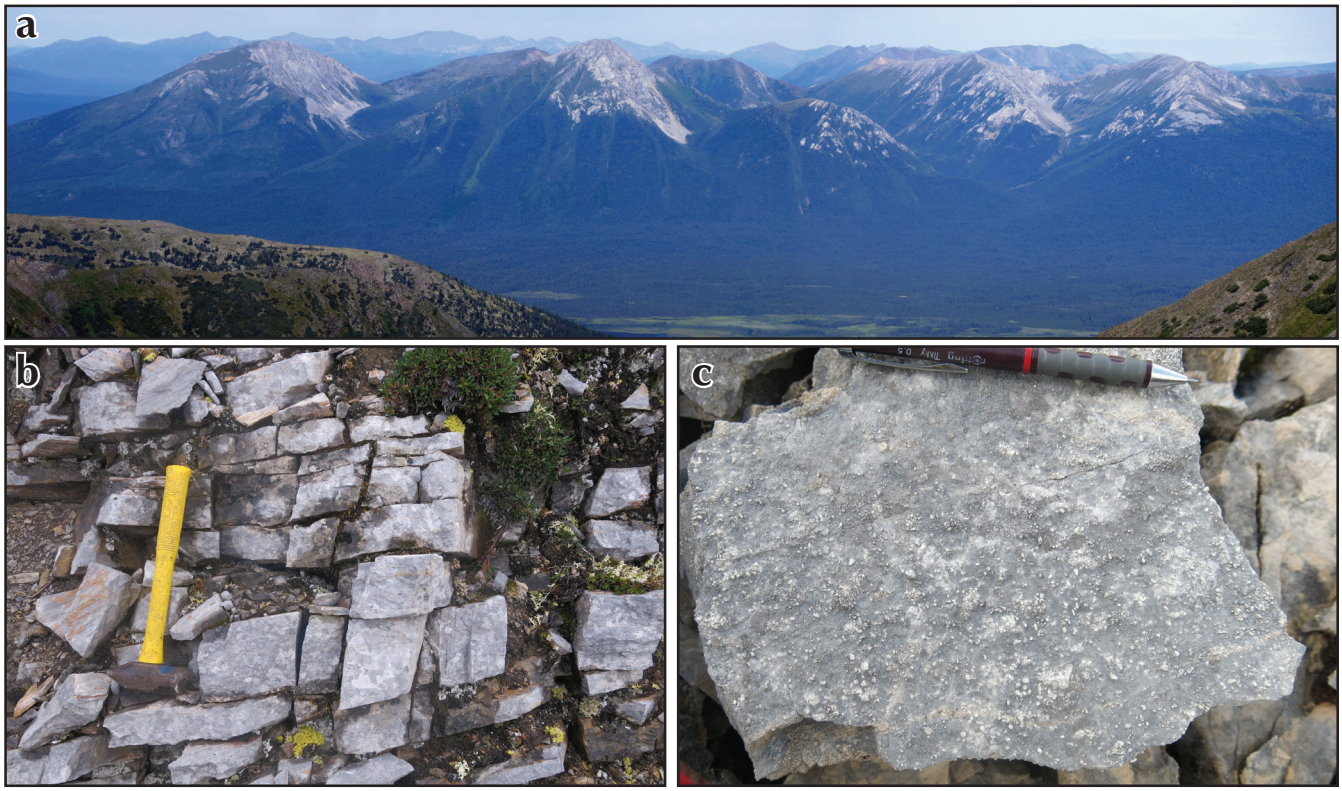

Figure 4. *Field photographs:* ***(a)*** *panorama looking NW across Tillei Lake towards exposures of cliff-forming, late Neoproterozoic limestone; relief is approximately 1000 m;* ***(b)*** *faint lamination visible in blocky, medium grey weathering limestone; hammer for scale;* ***(c)*** *dolomite nodules weather out from the surface of grey limestone. Nodules are commonly creamy-brown on broken surfaces; pencil for scale;* **continued on next page.**

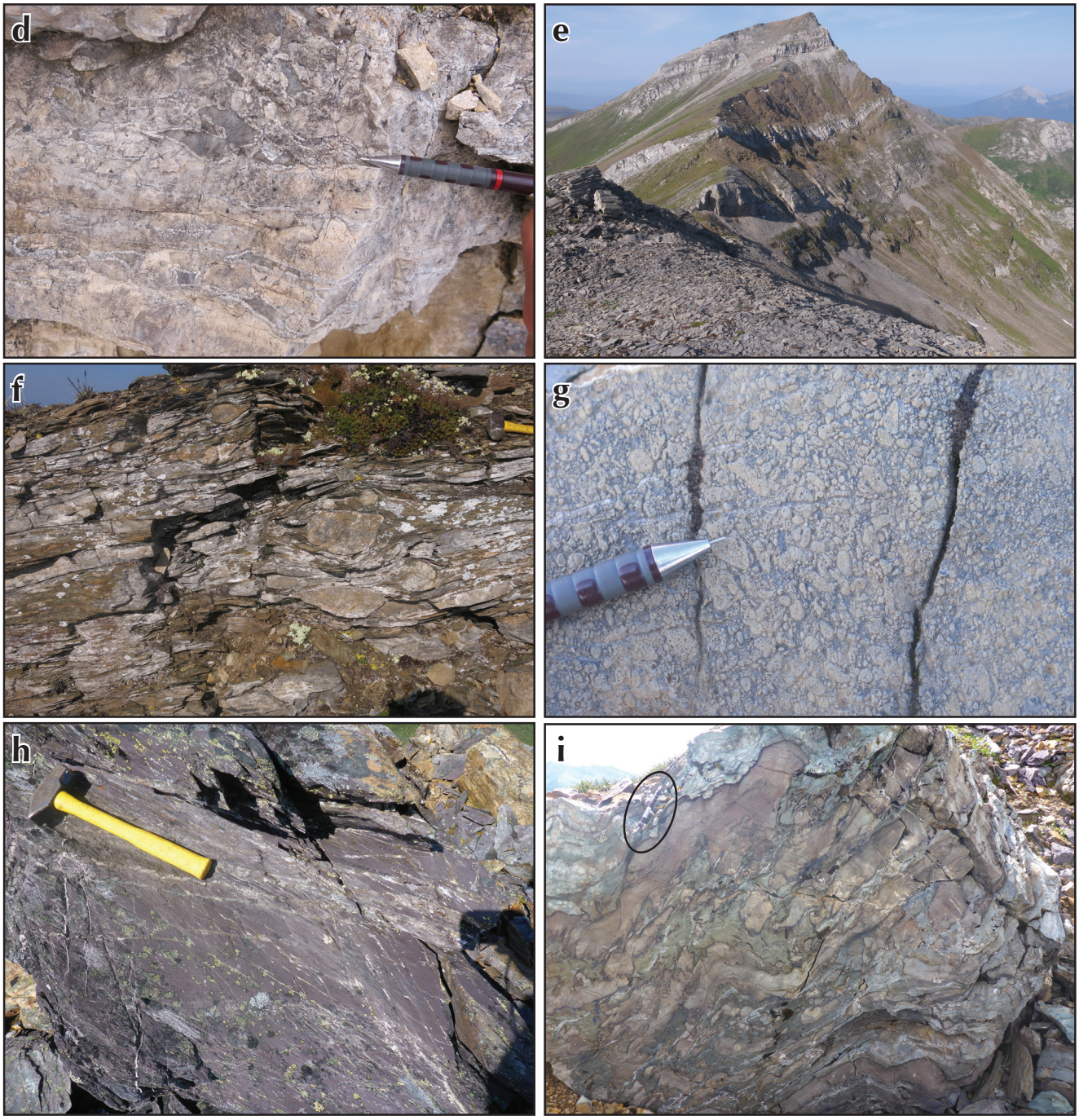

Fig. 4 continued - (d) *sparry calcite-filled vugs in cream-coloured, sugary-textured dolostone; pencil for scale;* ***(e)*** *isoclinally folded upper contact between limestone and stratigraphically overlying shale; SE of Tillei Lake; relief is approximately 300 m;* ***(f)*** *pods and lenses of pisolitic limestone in matrix of green shale. This layer marks the transition between the limestone and overlying shale-dominated unit. Hammer in upper right for scale;* ***(g)*** *densely-packed, concentrically zoned ooliths and pisoliths at the top of the late Neoproterozoic limestone unit; pencil for scale;* ***(h)*** *cleaved, maroon mudstone and siltstone; hammer for scale; and* ***(i)*** *limestone lenses and pods in a green mudstone matrix; pencil for scale (circled).*

REGIONAL VARIATION IN THE THICKNESS AND CHARACTER OF THE LATE NEOPROTEROZOIC LIMESTONE

There is considerable variations in the thickness and character of the late Neoproterozoic limestone throughout eastern Yukon. Although thin to non-existent in the type area of the Hyland Group (Gordey and Anderson, 1993), and thin (<15 m) east of the Hyland River (Moynihan, 2016), it is thicker in the study area, and in parts of the Sheldon Lake-Tay River area (NTS 105J, K; Gordey, 2013). Thick-bedded, fine-crystalline limestone is up to 250 m thick between the South Macmillan and Ridell rivers, while planar and cross-laminated limestone, interbedded with maroon and green shale is 40-50 m thick near Dragon Lake (Gordey, 2013). In the Niddery Lake (NTS 105O; Cecile, 2000) and Nadaleen River areas (NTS 106C; Moynihan, 2014), the equivalent limestone – the Algae Formation – is more than 400 m thick in places.

Further work, including detailed facies analysis is required to interpret the implications of variations in thickness and rock types for paleogeography; however, a reasonable interpretation of available information is that, rather than a simple SW-deepening basin (*c.f.*, Gordey and Anderson, 1993), there was heterogeneous bathymetry in eastern Yukon during the latest Neoproterozoic. The type area of the Hyland Group likely occupied a paleogeographic low, while the current study area, along with the Ingenika Group and parts of the Sheldon Lake-Tay River area were deposited in a higher-standing regions. The extent to which latest Neoproterozoic bathymetry aligns with the depositional environments that developed during the Paleozoic (*i.e.*, Selwyn basin and Cassiar/McEvoy platform) remains to be determined.

CONCLUSIONS

Late Neoproterozoic limestone/dolostone in the region around McPherson and Tillei lakes is stratigraphically equivalent to the upper limestone member of the Yusezyu Formation (Hyland Group), and the Espee Formation of the Ingenika Group. The limestone is interpreted to have been deposited in a shallow water environment on a high-standing region outboard of the Hyland Group type-area. The study area provides evidence for correlations between the Ingenika and Hyland groups of the Windermere Supergroup.

AKNOWLEDGEMENTS

Thanks to Jessie Thomson-Gladish for assistance during the 2017 field season. Thanks also to Golden Predator Ltd. for providing logistical support, and to Maurice Colpron for reviewing an earlier version of the manuscript.

REFERENCES

Cecile, M.P., 2000. Geology of the northeastern Niddery Lake map area, east-central Yukon and adjacent Northwest Territories. Geological Survey of Canada, Bulletin 553, 120 p.

Colpron, M, Israel, S., Murphy, D., Pigage, L. and Moynihan, D., 2016. Yukon bedrock geology map. Yukon Geological Survey, Open File 2016-1, scale 1:1 000 000.

Gabrielse, H., Murphy, D.C. and Mortensen, J.K., 2006, Cretaceous and Cenozoic dextral orogeny-parallel displacements, magmatism, and paleogeography, north-central Canadian Cordillera. *In:* Paleogeography of the North American Cordillera: Evidence for and against large-scale displacements, J.W. Haggart, R.J. Enkin and J.W.H. Monger (eds.). Geological Association of Canada, Special Paper 46, p. 255-276.

Fritz, W.H., Cecile, M.P., Norford, B.S., Morrow, D. and Geldsetzer, H.H., 1991. Cambrian to Middle Devonian assemblages. *In:* Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath (eds.). Geological Survey of Canada, Geology of Canada, no. 4, p. 151-218.

Gordey, S. P and Makepeace, A.J., 2001. Bedrock Geology, Yukon Territory. Yukon Geological Survey, Open File 2001-1; *also Geological Survey of Canada, Open File 3754*, scale 1: 1 000 000

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

Gordey, S.P., 2013. Evolution of the Selwyn basin region, Sheldon Lake and Tay River map areas, central Yukon. Geological Survey of Canada, Bulletin 599, 176 p.

Hofmann, H.J., Cecile, M.P. and Lane, L.S., 1994. New occurrences of Oldhamia and other trace fossils in the Cambrian of the Yukon and Ellesmere Island, Arctic Canada. Canadian Journal of Earth Sciences, vol. 31, p. 767-782.

Mansy, J.L. and Gabrielse, H., 1978. Stratigraphy, terminology and correlation of Upper Proterozoic rocks in Omineca and Cassiar Mountains, north-central British Columbia. Geological Survey of Canada, Paper 77-19, 17 p.

Moynihan, D., 2014. Bedrock Geology of NTS 106B/04, Eastern Rackla Belt. *In:* Yukon Exploration and Geology 2013, K.E. MacFarlane, M.G. Nordling and P.J. Sack (eds.), Yukon Geological Survey, p. 147-167.

Moynihan, D., 2016. Stratigraphy and structural geology of the upper Hyland River area (parts of 105H/8, 105H/9), southeast Yukon. *In:* Exploration and Geology 2015, K.E. MacFarlane and M.G. Nordling (eds.), Yukon Geological Survey, p. 187-206.

Moynihan, D., 2017. 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). *In:* Yukon Exploration and Geology 2016, K.E. MacFarlane and L.H. Weston (eds.), Yukon Geological Survey, p. 163-180.

Roots, E.F., Roddick, J.A. and Blusson, S.L., 1966. Geology, Frances Lake, Yukon Territory and District of Mackenzie. Geological Survey of Xanada, Preliminary Map 6-1966, scale 1:250000.

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

Turner, E.C., Roots, C.F., MacNaughton, R.B., Long, D.G.F., Fischer, B.J., Gordey, S.P., Martel, E. and Pope, M.C., 2011. Chapter 3. Stratigraphy. *In:* Geology of the central Mackenzie Mountains of the Northern Canadian Cordillera, Sekwi Mountain (105P), Mount Eduni (106A), and northwestern Wrigley Lake (95M) map areas, Northwest Territories, E. Martel, E.C. Turner and B.J. Fischer (eds). NWT Geoscience Office, NWT Special Volume 1, 423 p.