Neoproterozoic-(?)Cambrian lithostratigraphy, northeast Sekwi Mountain map area, Mackenzie Mountains, Northwest Territories: new data from measured sections

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Abstract: Three overlapping stratigraphic sections measured through previously undivided Neoproterozoic-Cambrian strata near Godlin River, northeast Sekwi Mountain map area (NTS 105 P) Northwest Territories, permit the succession to be subdivided in terms of established formations. Strata in the upper Sheepbed Formation record gradational, upward transition from deep-marine mudrock into shallow-marine sandstone and siltstone. The overlying Gametrail Formation (100 m) is gradationally based, dominated by shallow-marine dolostone, and resembles other platformal expressions of this unit. It is overlain erosionally by the Backbone Ranges Formation, which comprises a sandstone-dominated lower member (70 m), a middle member of thin-bedded carbonate (125 m), and a sandstone-dominated upper member (not measured). Contacts between members are poorly exposed, but apparently abrupt. The members correspond well with those in the formation's type section in NTS 95 L. Southwestward correlation of these formations to their probable distal equivalents is controversial and remains challenging.

Résumé : Dans des strates jusqu'alors non divisées du Néoprotérozoïque-Cambrien près de la rivière Godlin, dans la partie nord-est de la région cartographique de Sekwi Mountain (SNRC 105P), dans les Territoires du Nord-Ouest, trois coupes stratigraphiques se recouvrant en partie ont été mesurées et permettent de subdiviser la succession stratigraphique en fonction de formations déjà établies. Les strates de la partie supérieure de la Formation de Sheepbed témoignent d'une transition progressive, du bas vers le haut, depuis du mudrock de milieu marin profond à du grès et du siltstone de milieu marin peu profond. La base de la Formation de Gametrail (100 m) sus-jacente est marquée par un passage progressif à une succession de dolomie de milieu marin peu profond, laquelle s'apparente à d'autres manifestations de plate-forme de cette unité. La Formation de Gametrail est surmontée en contact d'érosion par la Formation de Backbone Ranges, qui se compose d'un membre inférieur (70 m) à prédominance gréseuse, d'un membre intermédiaire (125 m) formé de minces lits de roches carbonatées, ainsi que d'un membre supérieur (d'épaisseur non mesurée) à prédominance gréseuse. Les contacts entre les membres sont mal exposés mais apparemment francs. Les membres montrent une bonne correspondance avec ceux du stratotype situé dans la région cartographique 95L du SNRC. La mise en corrélation de ces formations avec leurs équivalents probables de milieu distal en direction du sud-ouest est sujette à controverse et reste complexe à établir.

INTRODUCTION

The Backbone Ranges Formation (Gabrielse et al., 1973) is a widely distributed (?)Neoproterozoic-Cambrian unit in the Mackenzie Mountains, Northwest Territories (Fig. 1), but its detailed correlation is problematic. In some areas, the Backbone Ranges Formation is the basal unit of the Sauk Sequence (Aitken, 1989; MacNaughton et al., 2000). Elsewhere, it may lie upsection from (MacNaughton et al., 1997) or span (Fritz et al., 1991) the probable base of the Sauk Sequence. Although the Backbone Ranges Formation has been considered to be a basal Paleozoic unit (e.g. Aitken, 1989), part of its type section may correlate with Neoproterozoic (Ediacaran) strata of the upper Windermere Supergroup (Fritz, 1982; Fritz et al., 1991).

To help resolve these difficulties, the authors present three overlapping measured sections that comprise a composite section through Neoproterozoic-Cambrian strata exposed near Godlin River, in northeast Sekwi Mountain map area (NTS 105 P). Blusson (1972) assigned Neoproterozoic-Cambrian strata in this area to his map unit 12, a sandstone-dominated unit of formation rank. Data presented in this paper subdivide this interval, update its stratigraphic nomenclature, and help to clarify Neoproterozoic-Cambrian lithostratigraphic correlations in aid of new geological mapping. An improved stratigraphic framework will improve the efficiency of exploration for stratiform and stratabound mineral occurrences in upper Ediacaran and Lower Cambrian strata of the Mackenzie Mountains and adjacent Wernecke Mountains (e.g. Osborne et al., 1986; Aitken, 1989; Dewing et al., 2006).

REGIONAL TECTONO-STRATIGRAPHIC CONTEXT

Latest Proterozoic (Cryogenian and Ediacaran) sedimentation in the Mackenzie Mountains is recorded by the Windermere Supergroup. The Windermere Supergroup is dominated by siliciclastic and carbonate units, with minor evaporite and volcanic strata. It was deposited along the length of the present-day western margin of Laurentia and, in Canada, is exposed in southeastern British Columbia (Kootenay Mountains), southwestern Northwest Territories (Mackenzie Mountains), and eastern Yukon (Wernecke Mountains). Its shelf-to-basin character is documented in widely separated localities (Aitken, 1989, 1991; Ross, 1991). Initial deposits, including thick diamictite and local tholeiitic volcanic rocks, occupy rift-fill subbasins that likely were fault controlled. Extension episode(s) inferred from the Windermere Supergroup ended at least 1 Ga of relative tectonic stability on the Laurentian western margin that is recorded by thick, regionally extensive siliciclastic and carbonate deposits of the underlying, informal Mackenzie Mountains supergroup (Rainbird et al., 1996). Younger units deposited after rifting comprise several siliciclastic-to-carbonate "grand cycles" and record the early history of a passive margin that lasted up to 250 ma (*see* Aitken, 1989; Narbonne and Aitken, 1995; James et al., 2001).

Following deposition of the Windermere Supergroup, renewed thermal subsidence established a miogeocline along the western margin of Laurentia (Armin and Mayer, 1983; Bond et al., 1985). This may have begun as early as 600 Ma (Ross, 1991) and lasted until about 350 Ma. Lower Cambrian strata of the Mackenzie Mountains are part of this miogeoclinal succession. Bond and Kominz (1984) and Devlin and Bond (1988) recognized that, in addition to the rifting event that coincided with the onset of Windermere Supergroup deposition, a latest Proterozoic–Early Cambrian extensional event was required to drive ongoing subsidence. Erosional events recognized around the Neoproterozoic-Cambrian boundary in the Mackenzie Mountains may allude to this second extensional episode (Fritz, 1982; MacNaughton et al., 2000). In the Mackenzie Mountains, Neoproterozoic and Cambrian units were uplifted, folded, and thrust northward and eastward during Mesozoic (Laramide) and later deformation.

CORRELATION OF THE BACKBONE RANGES FORMATION

In the Mackenzie Mountains, Neoproterozoic-Cambrian lithostratigraphy is particularly robust in three areas (Fig. l, 2): the type area of the Sheepbed and Backbone Ranges formations on the headwaters of Sheepbed Creek in central Glacier Lake map area (NTS 95 L); the June Lake region of central Sekwi Mountain map area (NTS 105 P);and the Sekwi Brook region of southeastern Sekwi Mountain map area (NTS 105 P). Detailed correlation between these well documented regions remains problematic and comparable stratigraphic documentation is unavailable for many areas in the Mackenzie Mountains. Godlin River area is one such poorly documented region.

In its type section (hereafter referred to as Sheepbed Creek section), the Backbone Ranges Formation lies upon the dark-weathering, siltstone-dominated Sheepbed Formation (Gabrielse et al., 1973), a unit of confirmed Ediacaran age (Narbonne and Aitken, 1990), and is unconformably overlain by the Middle Cambrian Avalanche Formation (Fritz, 1982). The type section has a sandstone-dominated lower member, a middle member of thin-bedded carbonate, and a sandstone-dominated upper member (Gabrielse et al., 1973). This tripartite organization has been mapped several hundred kilometres to the north and northwest (Gabrielse et al., 1973; Aitken, 1989). The upper member is at least partly Early Cambrian (Gabrielse et al., 1973; Fritz, 1982), but the position of the Ediacaran-Cambrian boundary is poorly constrained.

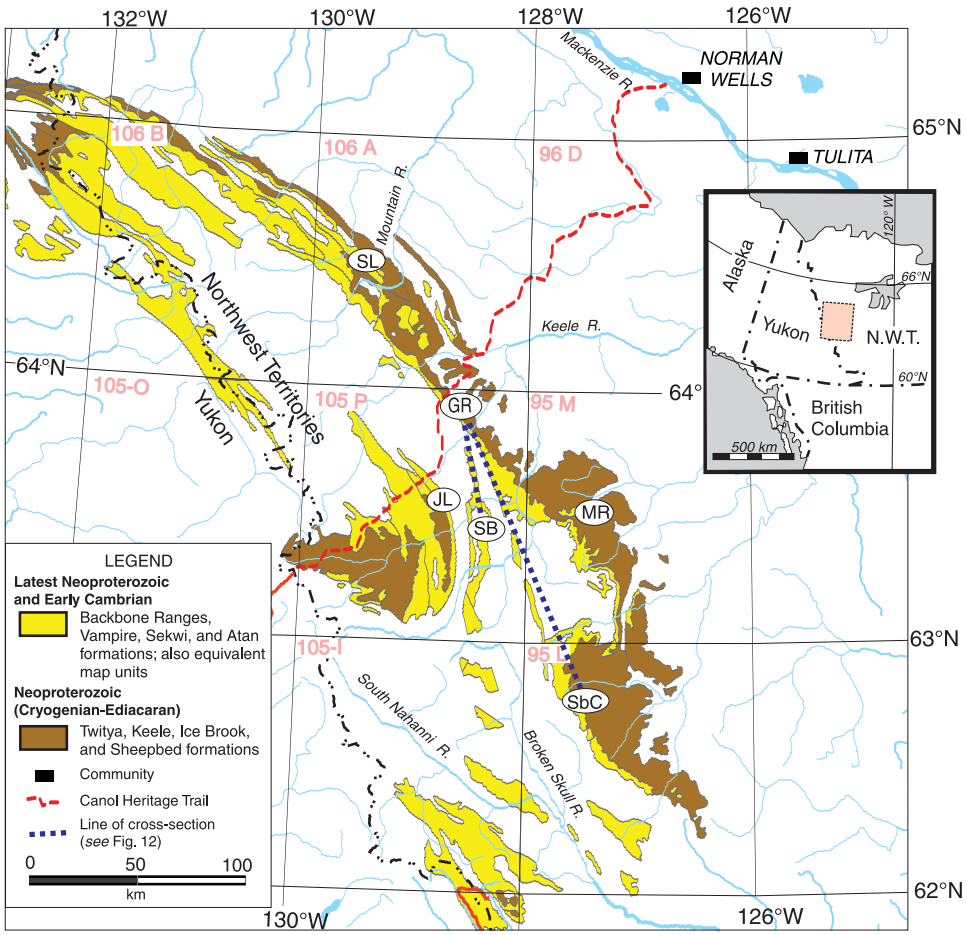

Figure 1. Distribution of Neoproterozoic to Cambrian regional units in the Mackenzie Mountains. Locations of sections mentioned in text: SbC: Sheepbed Creek (type section, Backbone Ranges and Sheepbed formations; Gabrielse et al. (1973)); MR = Moosehorn River (reference section, Gametrail Formation; Aitken (1989)); JL = June Lake (type section, Ingta Formation; Aitken (1989)); SB = Sekwi Brook (type sections, Gametrail, Blueflower, and Risky formations; Aitken (1989)); GR = Godlin River (this paper); SL = Shale Lake (also known as 'Palmer Lake') (reference locality, platformal Gametrail Formation; Aitken (1989)).

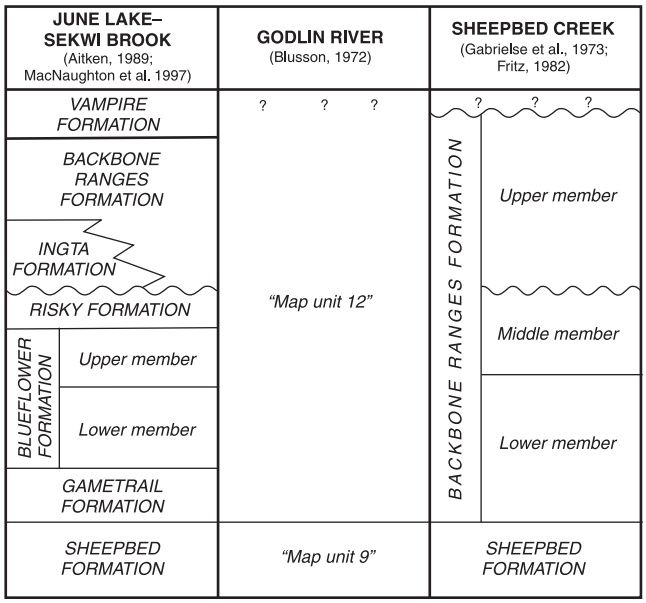

Figure 2. Lithostratigraphic divisions of Neoproterozoic-Cambrian strata in the Mackenzie Mountains. Sheepbed Creek is type area of Backbone Ranges and Sheepbed formations (Gabrielse et al., 1973). Godlin River exposure is the focus of this report. In the June Lake–Sekwi Brook column, base of the Cambrian is in the upper part of Ingta Formation (MacNaughton and Narbonne, 1999) and lowest *Fallotaspis* Zone trilobites are in uppermost beds of Vampire Formation (e.g. Fritz, 1979, 1982). The base of the Cambrian is not well constrained at Godlin River or Sheepbed Creek.

At June Lake and Sekwi Brook, by contrast, the Sheepbed Formation is overlain by five or six named formations (Fig. 2). Carbonate units and siliciclastic mudrocks are more prevalent in these formations. The depositional setting of these strata is more distal overall than correlative strata at Sheepbed Creek and includes units of slope origin (Aitken, 1989; Dalrymple and Narbonne, 1996; MacNaughton et al., 1997, 2000). The Gametrail, Blueflower, and Risky formations (Fig. 2) are of Ediacaran age and belong to the Windermere Supergroup (Narbonne and Aitken, 1990, 1995). A major karst surface atop the Risky Formation probably marks the base of the Sauk Sequence (Narbonne and Aitken, 1995; MacNaughton et al., 2000). An overlying siliciclastic succession (Ingta, Backbone Ranges *sensu lato*, and Vampire formations) encompasses a well constrained Ediacaran-Cambrian boundary within the Ingta Formation (MacNaughton and Narbonne, 1999) and is overlain conformably by the trilobite-bearing Lower Cambrian Sekwi Formation (Fritz, 1979; Fritz et al., 1991).

At least three distinct schemes for correlating the Sheepbed Creek, Sekwi Brook, and June Lake successions have been published. Aitken (1984, 1989) correlated the Ingta to Vampire formation succession at June Lake and Sekwi Brook with the entirety of the Backbone Ranges Formation at Sheepbed Creek (*see also* Narbonne and Aitken, 1995). Alternatively, the middle member of the Backbone Ranges Formation (at Sheepbed Creek) has been equated with the Risky Formation (Fritz, 1982), implying that the Ingta to Vampire formation succession correlates only with the upper member of the Backbone Ranges Formation (Fritz, 1982; Fritz et al., 1991). A third view (MacNaughton et al., 1999) was that the Gametrail Formation might be equivalent to the middle member of the Backbone Ranges Formation, based on apparent lithological similarities.

These difficulties are exacerbated by regional variations in Blusson's (1972) map unit 12, which varies in lithology across map area NTS 105 P (Blusson, 1972, Fritz et al., 1983) and has diachronous upper and lower contacts (Blusson, 1972; Gabrielse et al., 1973). Other map units described by Blusson (1972) have proven more straightforward to correlate: map unit 9 corresponds to the Sheepbed Formation (Aitken, 1989); map unit 11 was named the Risky Formation by Aitken (1989); and map unit 13 is considered to be a tongue of the Vampire Formation (Fritz, 1982; MacNaughton et al., 1997).

MEASURED SECTIONS

Three overlapping sections were measured in the studied interval. They lie along 15 km of depositional strike on the northeast-facing flank of a long, castellated ridge (Fig. 3) that extends from Godlin River southeast to Ekwi River. Summaries are presented here; full descriptions will be archived in the Digital Atlas for Sekwi Mountain Project, Northwest Territories Geoscience Office. Detailed section co-ordinates are given in the Appendix. Thickness terms used for bedding follow Ingram (1954).

Section MWB0702

Description

Section MWB07-02 (Fig. 4) encompasses the uppermost 190.1 m of the Sheepbed Formation and the basal 77.4 m of the overlying Gametrail Formation. Beneath the base of the section, the Sheepbed Formation comprises poorly exposed, monotonously dark grey-brown-weathering shale and siltstone.

The basal part of the section (intervals 1–3) is in dark-weathering, laminated siltstone and shale with sporadic thin beds of very fine-grained sandstone (Fig. 5a). Sandstone beds have sharp bases and display an internal, normal-graded succession from parallel lamination upward into current-ripple crosslamination, with or without a basal massive interval. Soft-sediment deformation is also present.

Figure 3. Southeastward view of Sheepbed to Backbone Ranges formations, 2 km southeast of Godlin River at 63°54′N. Measured section MWB07-02 (labelled) follows an arête through upper part of Sheepbed Formation up to the prominent light grey band of Gametrail Formation. Sheepbed Formation continues downsection through dark-weathering strata in foreground; base of Sheepbed Formation is not visible in the photograph. The tripartite Backbone Ranges Formation forms the ridge crest (*see* labels at right).

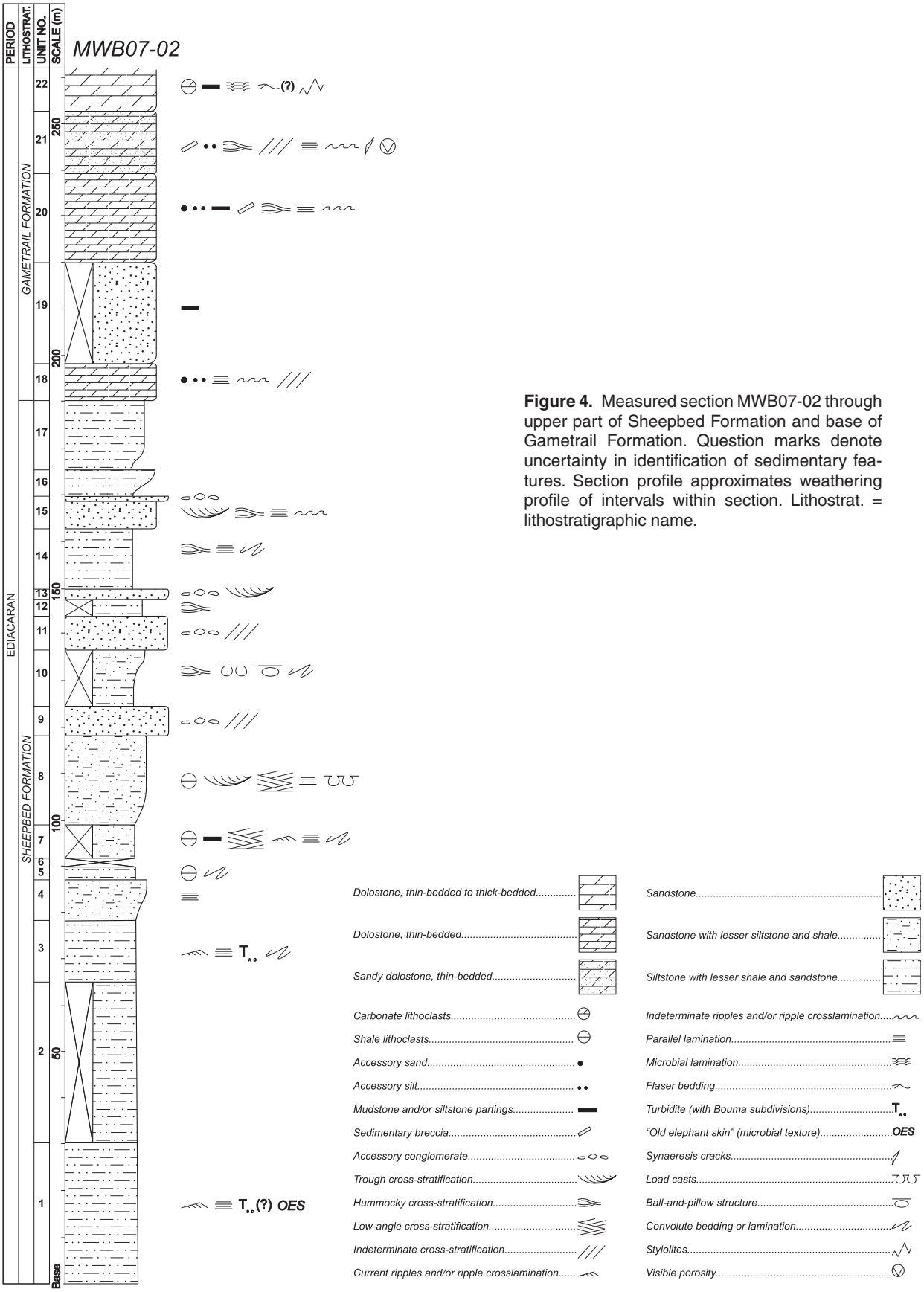

Figure 4. Measured section MWB07-02 through upper part of Sheepbed Formation and base of Gametrail Formation. Question marks denote uncertainty in identification of sedimentary features. Section profile approximates weathering profile of intervals within section. Lithostrat. = lithostratigraphic name.

Intervals 4–17 constitute at least seven upward-coarsening packages (Fig. 5b) that range from a few metres to several tens of metres in thickness. At its base, each package consists of recessive-weathering, interbedded siltstone and sandstone, passing upsection into semiresistant to resistant sandstone with siltstone interbeds. Sandstone in the upper part of each package is up to very coarse grained and contains low-angle cross-stratification (including hummocky cross-stratification), high-angle crossbedding (including trough crossbeds), and soft-sediment deformation. Several packages are capped by quartz-granule conglomerate with high-angle crossbedding.

The balance of section MWB07-02 records a gradational transition from siliciclastic to carbonate-dominated sedimentation. The base of the Gametrail Formation is marked at the lowest dolostone to sandy dolostone bed (interval 18), but the transition is nearly 50 m thick. The transition interval (intervals 18–20) contains varying amounts of sandstone, dolomitic sandstone, dolostone, carbonate breccia, and siltstone. Physical sedimentary structures include hummocky cross-stratification, ripple cross-lamination, parallel-lamination, and high-angle crossbedding. Carbonate strata above the transition interval are pale grey-weathering, locally sandy, particulate dolostone with abundant physical sedimentary structures, including hummocky cross-stratification, parallel lamination, and indeterminate crossbedding. Above interval 22, the Gametrail Formation forms a precipitous cliff.

No fossils were observed in section MWB07-02.

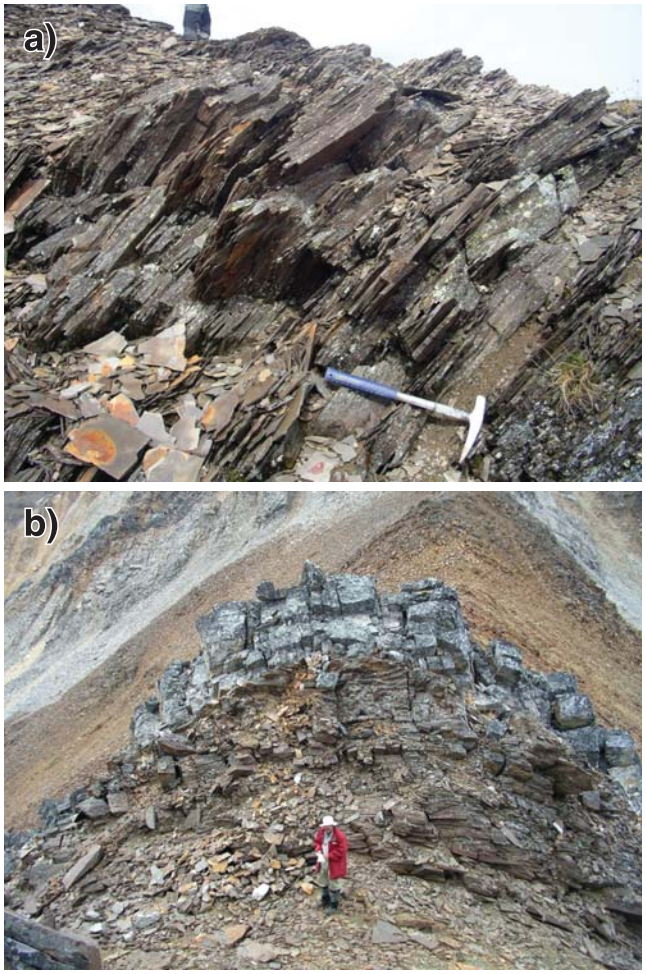

Figure 5. Outcrop photographs, section MWB07-02. **a)** Shale and siltstone, interval 1 of section, about 190 m below top of Sheepbed Formation. These lithologies comprise the lower two-thirds or more of the formation along this belt of exposure; hammer handle is about 30 cm long. **b)** Upward-coarsening package in upper Sheepbed Formation (interval 10 of section). Geologist (1.8 m tall) stands upon siltstone that passes gradationally upsection into increasingly sandy beds. Package is capped by thick-bedded sandstone and abruptly overlain by siltstone of the next package.

Environments of deposition

Intervals 1–3 were deposited in a distal setting with low sand input. Sedimentary structures in the sandstone beds suggest deposition as turbidite sequences (Bouma T_{bc} and T_{ac} successions), which is consistent with the deep-marine setting of the Sheepbed Formation in other sections (Dalrymple and Narbonne, 1996). A change to shallow-water deposition is recorded by intervals 4–17. The upward-coarsening packages in this part of the section are characteristic of prograding shoreline settings (Bhattacharya and Walker, 1991). Presence of hummocky cross-stratification (Brenchley, 1985) and high-angle crossbedding (Howard and Reineck, 1981) in the upper parts of the packages suggest a wave-dominated shoreface. Well developed soft-sediment deformation suggests high sedimentation rates.

Transitional strata between the Sheepbed and Gametrail formations were deposited in shallow water, under wave-dominated conditions, as indicated by the abundance of sandstone and the presence of carbonate breccia, hummocky cross-stratification, and crossbedding (Brenchley, 1985). The sedimentology of the Gametrail Formation will be addressed under ‘Section MWB07-03’.

Section MWB07-03

Description

The entire Gametrail Formation (101.8 m) was measured at this section (Fig. 6, 7a). Here, as elsewhere in the study area, the Gametrail Formation is a resistant, cliff- and ridge-forming unit that weathers pale grey.

A small thickness of the uppermost Sheepbed Formation, consisting of siltstone and sandstone with hummocky cross-stratification, makes up the basal part of the section (interval 1). As at section MWB07-02, the contact between the Sheepbed and Gametrail formations is gradational (Fig. 7a) and placed at the first bed of dolostone. The basal Gametrail Formation (intervals 2 and 3) is dominated by dolostone and sandy dolostone, with lesser sandstone, siltstone, and carbonate breccia (Fig. 7b). The remainder of the

formation (intervals 4–6) is mainly pale grey- to pale cream-weathering, medium- to thick-bedded particulate dolostone to sandy dolostone. Parallel lamination, ripple crosslamination, high-angle cross-stratification (including trough crossbedding), and low-angle crosslamination are abundant (Fig. 7c). Minor sandstone, siltstone, and carbonate breccia are present.

The contact between the Gametrail Formation and the overlying Backbone Ranges Formation (lower member) is well exposed. The contact surface is sharp, irregular, and locally stained deep rusty red. Basal strata of the Backbone Ranges Formation (not measured) are crossbedded, locally dolomitic quartz sandstone.

No fossils were observed in section MWB07-03.

Environments of deposition

Sedimentary structures in the Gametrail Formation, notably the presence of hummocky cross-stratification in association with parallel-lamination, trough crossbedding, and low-angle crosslamination, suggest shallow-marine deposition in wave-dominated settings (e.g. Clifton et al., 1971; Howard and Reineck, 1981; Brenchley, 1985).

Section MWB07-04

Description

This section through the lower two members of the Backbone Ranges Formation (Fig. 8) followed a sharp arête where the authors could not examine strata laterally.

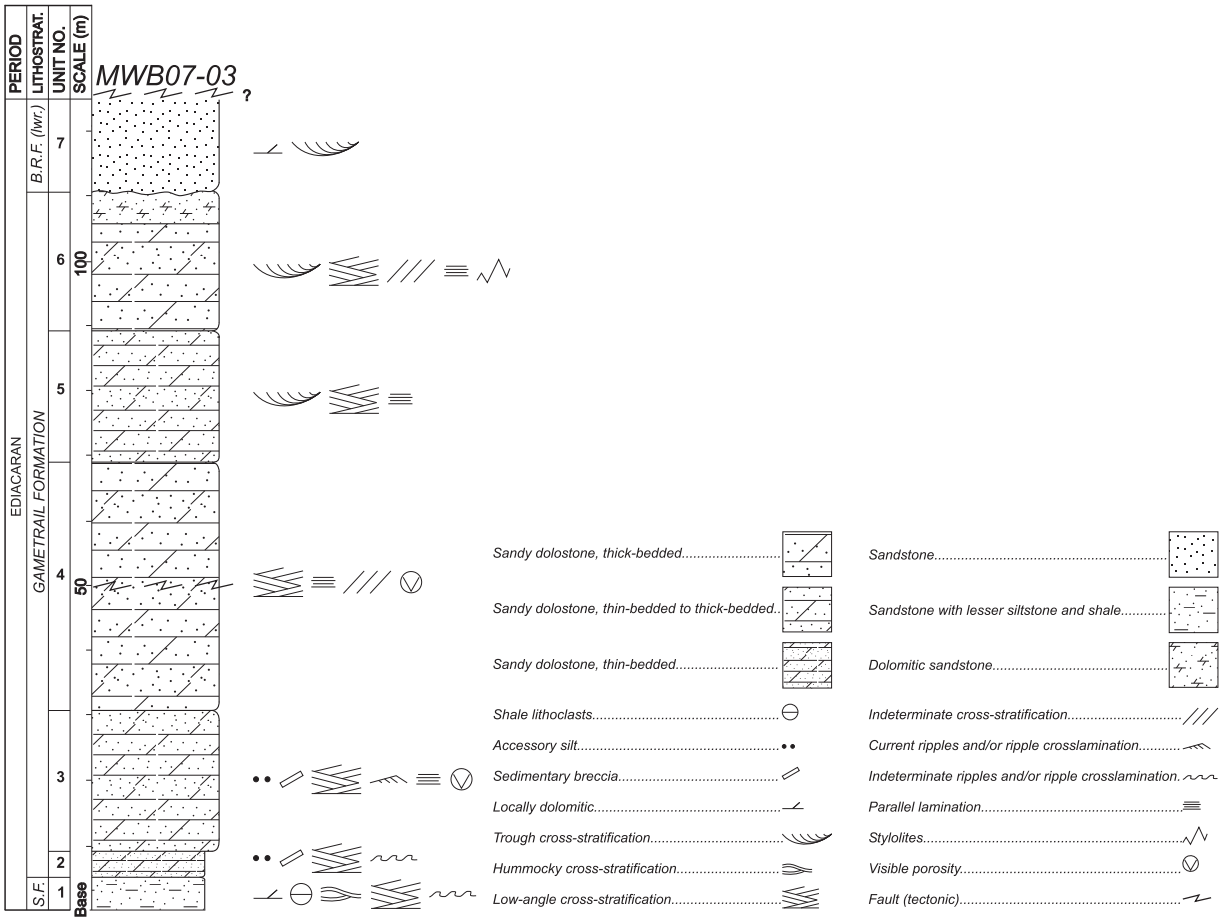

Figure 6. Measured section MWB07-03 through Gametrail Formation. Fault within interval 4 does not noticeably affect thickness of section. Fault at top of section is inferred (*see* text). Section profile approximates weathering profile of intervals within section. B.R.F. (lwr.) = lower member, Backbone Ranges Formation. S.F. = Sheepbed Formation; Lithostrat. = lithostratigraphic name.

Outcrop exposure was discontinuous in the lower member, but continuous in the middle member. In the Godlin River region, the lower member is semiresistant to resistant and forms a distinctive, dark-weathering band in cliff exposures. The middle member forms a resistant, variegated band when viewed at a distance (*see* below).

At section MWB07-04, the contact between the Backbone Ranges and Gametrail formations is sharp and erosional. The basal bed of the lower member contains cobbles of particulate dolostone derived from the Gametrail Formation (Fig. 9a). The lower member (67.5 m; intervals 1–4) includes grey-weathering quartz sandstone and quartz granule to pebble conglomerate (locally with dolostone clasts), orange-weathering dolomitic siltstone and sandy dolostone, and maroon- to brown-weathering siltstone and siltstone with sandstone (Fig. 9b). Sandstone and conglomerate are trough crossbedded; silty intervals preserve current ripple crosslamination and synaeresis cracks.

The contact between the lower and middle members is covered, but apparently abrupt. Total measured thickness of the middle member was 128 m. The lower part of the middle member (interval 5) is very thin- to thin-bedded, microcrystalline to very finely crystalline carbonate that weathers pink, maroon, and grey (Fig. 9c). Intraclastic flat-pebble conglomerate is common. In the lower part of interval 5, maroon-weathering siltstone partings are pervasive between beds. Parts of interval 5 alternate between maroon- and pink-weathering dolostone with abundant siltstone partings, and grey-weathering limestone with rare partings.

The upper part of the middle member corresponds to interval 6 in the measured section. Its contact with underlying strata is gradational over approximately 5 m. This part of the middle member consists of orange- and cream-weathering, very thin- to thin-bedded, very finely crystalline dolostone (Fig. 9d) with current ripple crosslamination and microbial lamination. Silty partings are markedly less

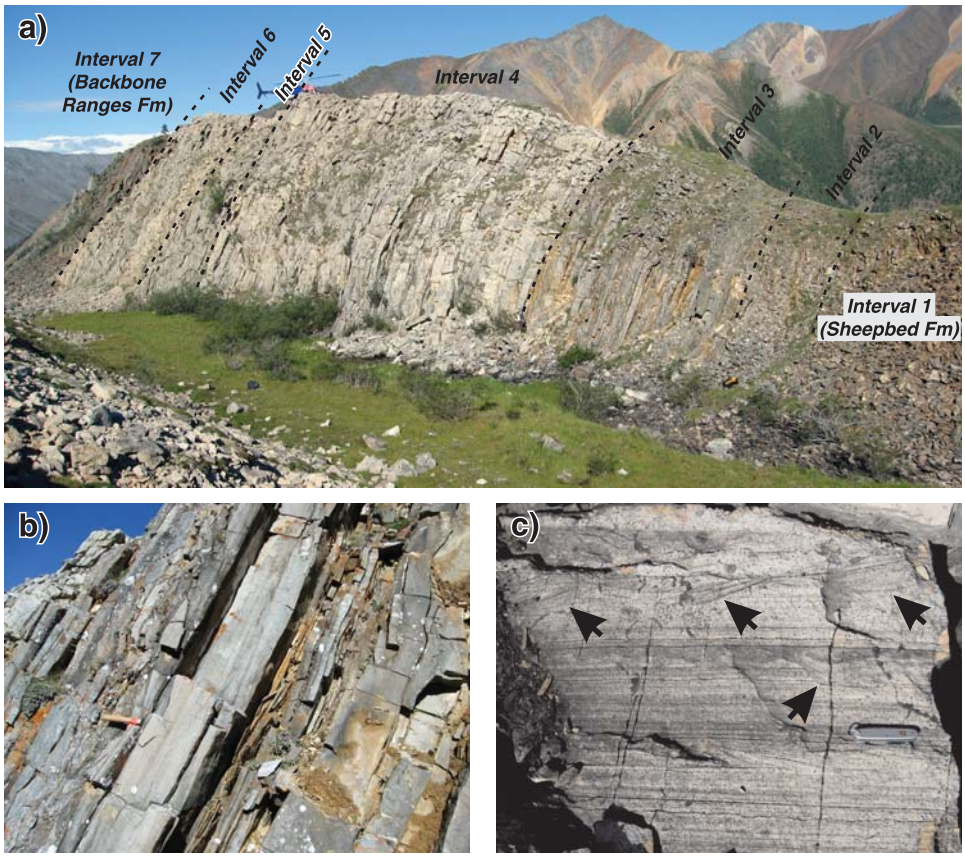

Figure 7. Outcrop photographs, section MWB07-03. **a)** Oblique view of Gametrail Formation, the underlying Sheepbed Formation, and the overlying Backbone Ranges Formation. Section was measured along the base of outcrop; described intervals within section are labelled. Note gradational basal contact and associated colour change, and note sharp upper contact. Helicopter, landed on interval 5 atop ridge, is approximately 12 m long. **b)** Characteristic bedding in lower part of Gametrail Formation (interval 3). Note contorted bedding at upper right, and low-angle to parallel lamination in pale-weathering bed to right of hammer; hammer rests on carbonate breccia. Stratigraphic top is to the left. Hammer handle is approximately 30 cm long. **c)** Physical sedimentary structures in Gametrail Formation (interval 4), preserved in a talus block. Note presence of scours (examples indicated by arrows), crossbedding, and sharply defined parallel bedding. Stratigraphic top of block is to the top. Clasp knife is approximately 10 cm long.

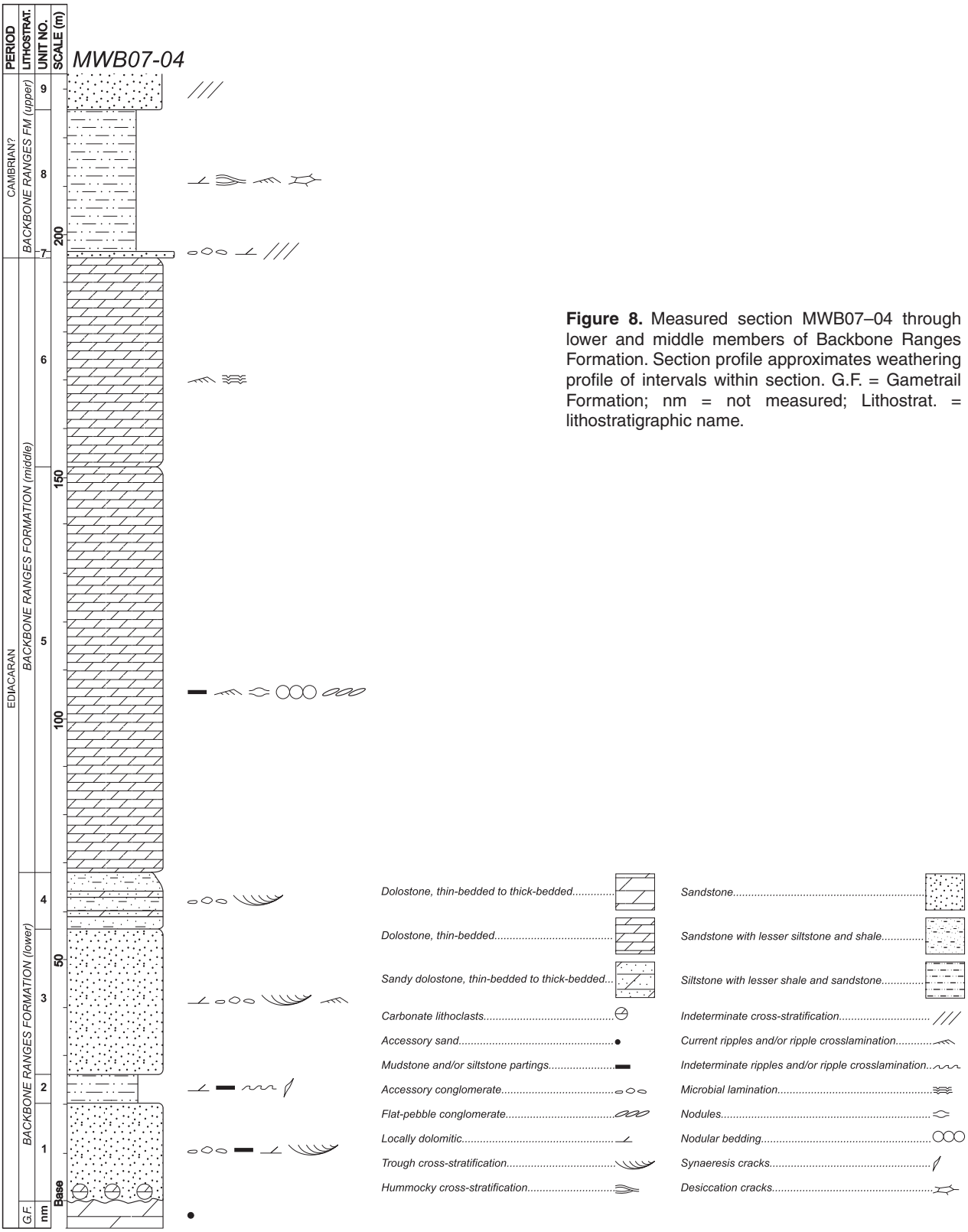

Figure 8. Measured section MWB07–04 through lower and middle members of Backbone Ranges Formation. Section profile approximates weathering profile of intervals within section. G.F. = Gametrail Formation; nm = not measured; Lithostrat. = lithostratigraphic name.

common than in interval 5. The colour succession of the middle member observed at section MWB07-04 is not developed consistently along strike. At various locations, viewed from a distance, the succession of colours within the middle member is similarly dominated by pink, tan, or grey, but the succession is not consistent.

The base of the upper member is sharp. No evidence for erosion was observed at outcrop scale, but the upper surface of the middle member appeared irregular when viewed from aircraft. The contact is overlain by 1 m of dolomitic sandstone to pebble conglomerate (interval 7), above which is 27 m of maroon-weathering siltstone (interval 8) with abundant polygonal shrinkage cracks. The section ended in an interval of crossbedded quartz sandstone (interval 9, not measured). Mapping traverses documented that the upper member here is dominated by quartz sandstone with lesser siltstone, shale, and dolostone (Fig. 10).

No fossils were observed in section MWB07-04.

Environments of deposition

This section was not studied in detail, so only preliminary sedimentological comments are possible. Rock types and sedimentary structures in the lower member of the Backbone Ranges Formation are consistent with deposition in shallow-marine settings (siltstone and dolomitic facies) and possibly also in nonmarine settings (trough crossbedded sandstone, conglomerate). Notably, synaeresis cracks may indicate fluctuating salinity levels (Plummer and Gostin, 1981). The middle member apparently was deposited in relatively quiet-water, marine environments that possibly were below wave base or otherwise sheltered from wave action. Intervals of higher energy ((?)storms) presumably were required to produce the flat-clast conglomerate units. Polygonal shrinkage cracks (desiccation cracks) in the upper member point to deposition in an environment subject to periodic subaerial exposure. The overlying, crossbedded quartz sandstone resembles fluvially deposited strata reported from other sections in the Backbone Ranges Formation (cf. MacNaughton et al., 1997).

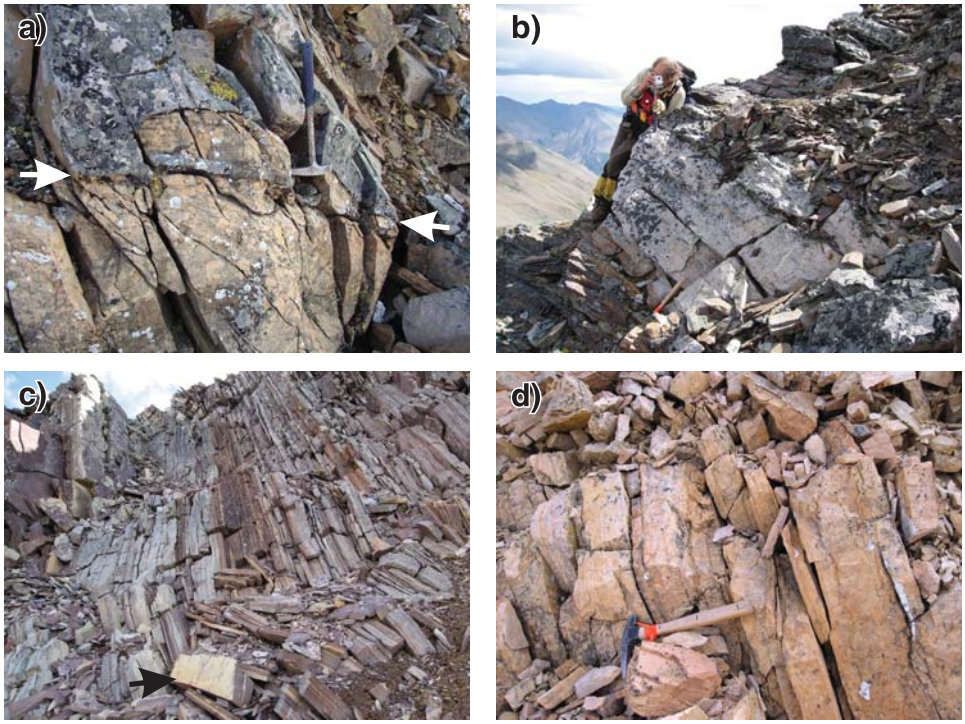

Figure 9. Outcrop photographs, section MWB07-04. **a)** Erosional contact (at arrows) of Backbone Ranges Formation (lower member), upon Gametrail Formation. Note reworked clast of laminated dolostone to left of hammer point. Stratigraphic top is top of photograph. Hammer is approximately 30 cm long. **b)** Rock types in the lower member of Backbone Ranges Formation. Lower and upper parts of outcrop expose interbedded sandstone, siltstone, and shale. Note orange-weathering sandy dolostone by geologist's feet and well bedded quartz sandstone at geologist's waist level. Beds are upright. For scale note geologist's hammer handle is 30 cm long. **c)** Well bedded, pink- to maroon-weathering carbonate in middle member, Backbone Ranges Formation. Bright coloured block in foreground (indicated by arrow) is approximately 30 cm along its long axis. Beds young to right. **d)** Cream-weathering, well bedded dolostone in upper part of middle member. Marks on hammer handle are 10 cm apart. Beds young to the right.

COMPARISON WITH TYPE AND REFERENCE SECTIONS

Comparison of formations documented at Godlin River with their type sections and key reference sections suggests that our lithostratigraphic assignments are robust. Upward-coarsening in the uppermost Sheepbed Formation was noted at Sheepbed Creek by Gabrielse et al. (1973). Also, in beds beneath the type section of the Backbone Ranges Formation, the upper Sheepbed Formation coarsens upward from deep-water mudrocks into much sandier lithofacies that preserve hummocky cross-stratification (MacNaughton et al., 1999).

In its type area at Sekwi Brook, the Gametrail Formation overlies the Sheepbed Formation and is a thin-bedded, slope-deposited carbonate (Aitken, 1989; MacNaughton et al., 2000). More proximally deposited strata in Wrigley Lake (NTS 95 M) and Mount Eduni (NTS 106 A) map areas preserve platformal facies of the Gametrail Formation (Aitken, 1989) that are dominated by medium- to thick-bedded, locally oolitic, dolograinstone. Strata the present authors assign to the Gametrail Formation are sandier than those documented by Aitken (1989), but have similar bedding and preserve sedimentary structures consistent with platform deposition.

An erosional upper surface to the platformal Gametrail Formation was previously reported by Aitken (1989) from the region around Shale Lake (also commonly known as 'Palmer Lake') in west-central NTS 106 A map area and south of the Moosehorn Range in northwest NTS 95 M map area (Fig. 1). Erosion at this level may explain the absence of Gametrail Formation between the Sheepbed and Backbone Ranges formations at Sheepbed Creek (Gabrielse et al., 1973; Fritz, 1982).

The lower and middle members of the Backbone Ranges Formation comprise similar rock types at Godlin River and at Sheepbed Creek. In both areas, the lower member is dominated by quartz sandstone, with lesser siltstone and dolostone, and is probably of shallow-marine to nonmarine origin (cf. Fritz, 1982; MacNaughton et al., 1999). In both areas, outcrops of the middle member are dominated by thin-bedded dolostone that weathers pink, orange, and maroon (Gabrielse et al., 1973; MacNaughton et al., 1999). At Godlin River, the irregular upper surface of the middle member may record the same erosional event that produced deep karst weathering atop the middle member at Sheepbed Creek (cf. Fritz, 1982; MacNaughton et al., 1999).

At Godlin River, the upper member of the Backbone Ranges Formation is several hundred metres thick, contains numerous intervals dominated by well bedded quartz sandstone, and at least locally preserves evidence for nonmarine deposition. In these regards, it is similar to the upper member as documented in the Sheepbed Creek type area (Gabrielse et al., 1973; Fritz, 1982; MacNaughton et al., 1999). Interestingly, these features also characterize strata assigned to the Backbone Ranges Formation (*sensu lato*) to the southwest in NTS 105 P map area (MacNaughton et al., 1997).

IMPLICATIONS FOR CORRELATION

The present work enables the authors to address the proposed correlation between the Gametrail Formation and the middle member of the Backbone Ranges Formation. That proposal (MacNaughton et al., 1999) was based on the absence of Gametrail Formation between the Sheepbed and Backbone Ranges formations at Sheepbed Creek. At Godlin River, however, the middle member is present in the same

Figure 10. Backbone Ranges Formation viewed looking southeast from co-ordinates 518626E 7084434 N (NAD83). Photograph taken standing on basal maroon siltstone of upper member. Stratigraphic top is to the right. Gt = Gametrail Formation; lBR = lower member, Backbone Ranges Formation; mBR = middle member, Backbone Ranges Formation. In the upper member, note resistant sandstone alternating with recessive siltstone. In section MWB07-04, which was measured nearby, the thickness of the middle member of the Backbone Ranges Formation is 128 m.

section as the 'platformal facies' of the Gametrail Formation. Thus, the Gametrail Formation cannot be correlative with the middle member of the Backbone Ranges Formation.

The authors' observations are less conclusive regarding the suggested correlation between the middle member of the Backbone Ranges Formation and the Risky Formation (Fritz, 1982; Fritz et al., 1991). Figure 11 presents the correlations that follow if these units are, in fact, correlative. An important implication is that units of member rank at Sheepbed Creek and Godlin River are equivalent to units of formation rank at Sekwi Brook and June Lake. Also, it implies that the lower and middle members of the Backbone Ranges Formation are correlative with part of the Windermere Supergroup, whereas the upper member is not. This appears to be a flaw in the proposal of Fritz et al. (1991) to raise the Backbone Ranges Formation to group status. Without fossil data from the present authors' sections, the age of the upper member cannot be directly constrained. Data from elsewhere suggest it is at least partly Early Cambrian (Gabrielse et al., 1973; Fritz, 1982).

The alternative correlation of tripartite Backbone Ranges Formation with the Ingta to Vampire formation succession (Aitken, 1989, 1991) also remains a working hypothesis. The present authors note, however, that correlating Risky Formation to the middle member yields a one-to-one match of carbonate-dominated and siliciclastic rock-dominated units of formation scale (Fig. 11). The model of Aitken (1989, 1991), by contrast, implies an unexplained, basinward pinch-out of a major carbonate unit (the middle member).

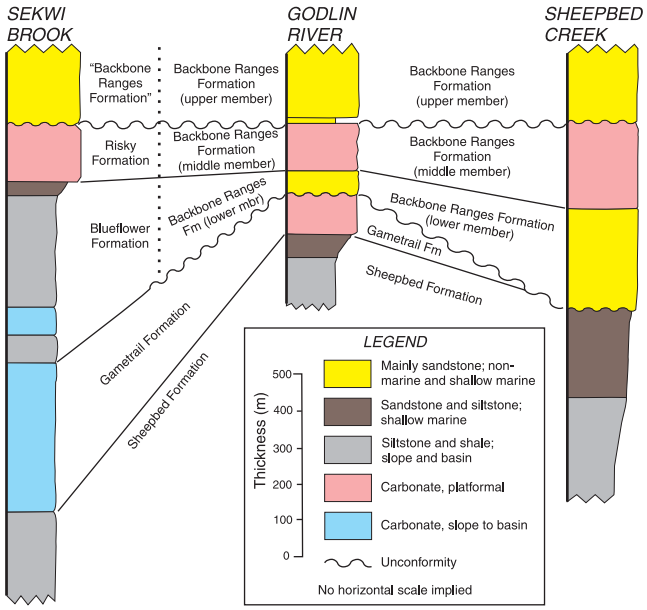

Figure 11. Schematic regional correlations, assuming correlation between basinal and platformal facies of Gametrail Formation (Aitken, 1989) and between Risky Formation and middle member of Backbone Ranges Formation (e.g. Fritz, 1982; Fritz et al., 1991). Data sources, from Blusson (1972), Gabrielse et al. (1973), Fritz (1982), Aitken (1989), and MacNaughton et al. (1997).

CONCLUSIONS

Examination of the Godlin River locality revealed that the interval assigned to map unit 12 by Blusson (1972) contains both the Gametrail and Backbone Ranges formations. Measured sections clarify the regional character of these units, given that this locality is 150 km and 50 km north of the type sections of Backbone Ranges and Gametrail formations, respectively.

The Gametrail Formation at Godlin River forms a blue-grey-weathering, dolostone cliff band. Its base is transitional from sandstone and siltstone of the upper Sheepbed Formation. Physical sedimentary structures indicate a shallow-marine depositional setting. This contrasts with the slope-deposited lithofacies described at the formation's type section (Sekwi Brook; Fig. 1), but is consistent with the reported presence of platformal Gametrail Formation in Moosehorn Range (90 km southeast) and near Shale Lake (100 km northwest) (Aitken, 1989). The present authors' work supports the view that the Gametrail Formation undergoes a transition from deep-water facies in the southwest to platform facies in the northeast (Aitken, 1989; Narbonne and Aitken, 1995).

Recognition of an erosional surface atop the Gametrail Formation points out a similarity with at least two other platformal Gametrail Formation localities, one of which preserves extensive (karst) breccia at the formation's upper contact (Aitken, 1989). It appears that the Gametrail Formation platform was exposed, and an unknown thickness of the formation eroded, prior to deposition of the Backbone Ranges Formation.

At Godlin River, the Backbone Ranges Formation is dominated by resistant rock types like those recorded in the formation's type area (Sheepbed Creek; Fig. 1). Although the interval examined by the present authors is less than half the thickness of coeval strata measured at the type section (Gabrielse et al., 1973), a similar tripartite lithological division is present. Because the Godlin River locality is along the same structural grain as the type section at Sheepbed Creek, the present authors infer that both occupy a similar relative position on the platform-to-basin continuum.

The presence of Gametrail Formation in the same section as the middle member of the Backbone Ranges Formation rules out a correlation between these units (*contra* MacNaughton et al., 1999). The question of the basinward correlation of the Backbone Ranges Formation requires further study, although correlating its middle member with the Risky Formation (Fritz et al., 1991) yields one-to-one correspondence of siliciclastic and carbonate map units between regions.

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APPENDIX

Location data (NAD83; UTM zone 9N) for measured sections.

MWB07-02

Top of section: 515630E, 7088366N

Base of section: 515916E, 7088569N

MWB07-03

Top of section: 512354E, 7091668N

Base of section: 512452E, 7091700N

MWB07-04

Top of section: 520618E, 7083113N

Base of section: 520768E, 7083234N