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# Neoproterozoic–Cambrian stratigraphy of the Mackenzie Mountains, northwestern Canada, part II: archival stratigraphic data for the Backbone Ranges Formation and related units, Mackenzie Mountains, Northwest Territories, Canada (NTS 95-L and 105-P)

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# Neoproterozoic–Cambrian stratigraphy of the Mackenzie Mountains, northwestern Canada, part II: archival stratigraphic data for the Backbone Ranges Formation and related units, Mackenzie Mountains, Northwest Territories, Canada (NTS 95-L and 105-P)

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Publications in this series have not been edited; they are released as submitted by the author.

**SUMMARY**

This report presents archival stratigraphic data for the Ediacaran-Cambrian Backbone Ranges Formation that have not appeared previously in formal publications. Included are unpublished notes for two stratigraphic sections from Glacier Lake map area (NTS 95-L), documented by the late W.H. Fritz; these include notes from a re-examination of the formation in its type area. Also included are stratigraphic data from the Sekwi Brook area in southeastern Sekwi Brook map area (NTS 105-P). These data include a summary of descriptive information from an unpublished mineral industry report (DAR property; report is in the public domain), as well as measured section notes and observations by the compiler of the present report, collected during visits to Sekwi Brook in 1997 (at Risky Peak) and 2006 (at DAR property).

**INTRODUCTION**

The Backbone Ranges Formation (Gabrielse et al., 1973) is of Ediacaran–Cambrian age and widely distributed in the Mackenzie Mountains of northwestern Canada. This report places in the public domain stratigraphic data related to this formation and associated units that previously were unpublished or were not widely available. Unpublished descriptive notes are presented for two stratigraphic sections measured in NTS 95-L by the late W.H. Fritz of the Geological Survey of Canada (GSC); previously, only graphic logs were available for these sections (Fritz, 1982). Also presented are stratigraphic data for units in the Sekwi Brook region (NTS 105-P) that are at least in part correlative with the Backbone Ranges Formation. These data include information summarized from a mineral industry exploration report on the DAR claims (Hitchins and Leary, 1975; report is in public domain), and unpublished measured sections and observations by the compiler of the present report.

The data presented in this report are intended as background information for a regional analysis and reassessment of the Backbone Ranges Formation.

**LITHOSTRATIGRAPHIC CONTEXT**

Lithostratigraphic correlations of the Backbone Ranges Formation are summarized in Figure 1. At the unit's type section, and in exposures to the north and northwest in the hanging-wall of the Plateau Fault (Gabrielse et al., 1973; Fritz, 1982; MacNaughton et al., 1999), the Backbone Ranges Formation lies unconformably upon the shale-dominated Sheepbed Formation (Ediacaran); an intervening informal unit, the "Sheepbed carbonate", is preserved only locally (Aitken, 1984; Macdonald et al., 2013). The Backbone Ranges Formation consists of three informal members: a lower member of sandstone, siltstone, and dolostone; a middle member of dolostone and limestone that generally is brightly coloured; and an upper member dominated by quartz arenite. To the west and southwest, the lower two members lose their distinctive character and likely correlate with units of the uppermost Windermere Supergroup, although the details of these correlations remain controversial (Aitken, 1989; Fritz et al., 1991; MacNaughton et al., 1999, 2008). The upper member is interpreted to pass into finer-grained, correlative strata of the Vampire Formation (Fritz, 1982) in the southwestern parts of NTS 95-L (Glacier Lake map area) and 105-P (Sekwi Mountain map area). In the eastern and central parts of NTS 105-P, a quartzite-dominated basal Cambrian unit is likely equivalent to at least part of the upper member and has been referred to as Backbone Ranges Formation (e.g., MacNaughton and Narbonne, 1999), although the details of this correlation are problematic (see discussions in MacNaughton, 2011; also MacNaughton and Fallas, 2019). Across much of central, eastern, and northern NTS 105-P, this quartzite package is overlain by a tongue of Vampire Formation and, in the June Lake anticline, is underlain by variegated shales of the Ingta Formation (Aitken, 1989). Much or all of this succession is of earliest Cambrian age (MacNaughton and Narbonne, 1999; Carbone and Narbonne, 2014), and probably correlates with the upper part of the upper member (MacNaughton and Fallas, 2019).

The detailed correlation of the Backbone Ranges Formation is a source of long-standing controversy (see, e.g., Aitken, 1989; Fritz et al., 1991). A thorough treatment of these issues is beyond the scope of the present report; for recent reviews, the reader is directed to MacNaughton (2011) and MacNaughton and Fallas (2019). It is hoped that these issues will be clarified by the results of fieldwork recently undertaken by the GSC in the Mackenzie Mountains, as part of the "Shield-to-Selwyn" activity of the Geo-mapping for Energy and Minerals program (Fallas et al., 2016; MacNaughton et al., 2017, 2018; MacNaughton and Fallas, 2019).

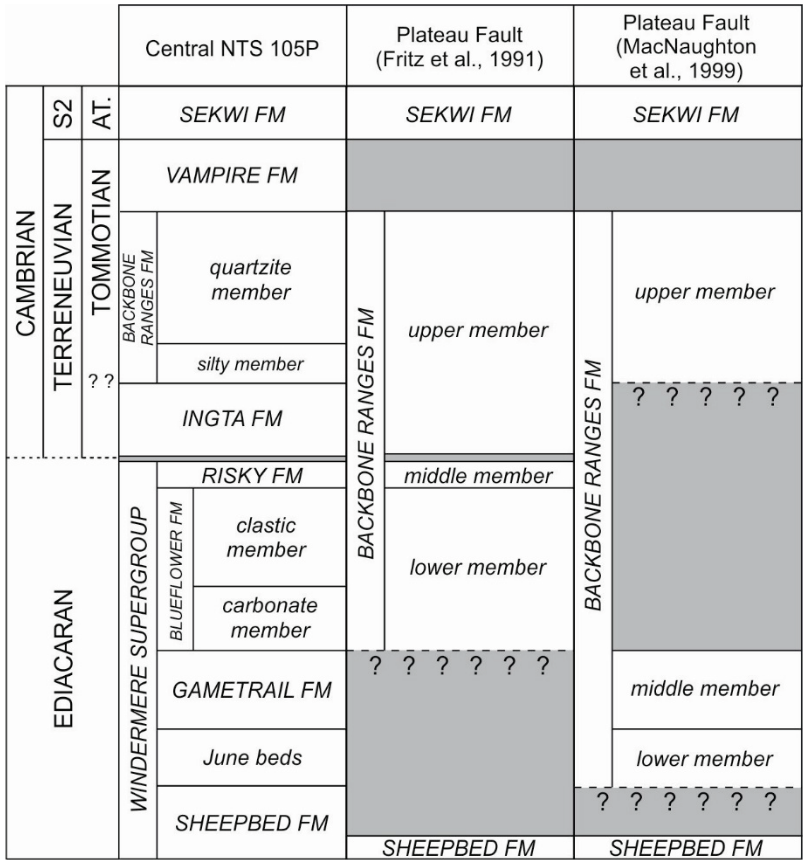


***Figure 1.*** *Stratigraphic chart for Ediacaran-Cambrian units of the Mackenzie Mountains; chart modified after MacNaughton and Fallas (2019). Stratigraphy for NTS 105-P is after Aitken (1989), MacNaughton et al. (1997a,b, 2000), Macdonald et al. (2013), and MacNaughton and Fallas (2019). Stratigraphy of Plateau Fault panel follows Gabrielse et al. (1973a). Two possible correlations are presented (sources provided in column headings). Additionally, the upper member of the Backbone Ranges Formation may span the Ediacaran-Cambrian boundary (MacNaughton and Fallas, 2019). Abbreviations: "FM" = "Formation"; "S2" = Cambrian Series 2; "AT" = Atdabanian. Grey shading shows unconformities.*

**UNPUBLISHED MEASURED SECTION NOTES, NTS 95-L (MEASURED BY W.H. FRITZ)**

In 1980 and 1981, W.H. Fritz measured several stratigraphic sections (locations in Figure 2) as part of formalizing the Vampire Formation (Fritz, 1979, 1981, 1982). These included three sections in South Nahanni anticline, one in Broken Skull anticline, and one adjacent to the Backbone Ranges Formation type section (Figure 3). Sections in South Nahanni anticline, including the Vampire Formation type section, were published with detailed descriptions (Fritz, 1981, 1982). The other two sections appeared as graphic logs without descriptive notes, and were summarized only briefly in the text of Fritz (1982).

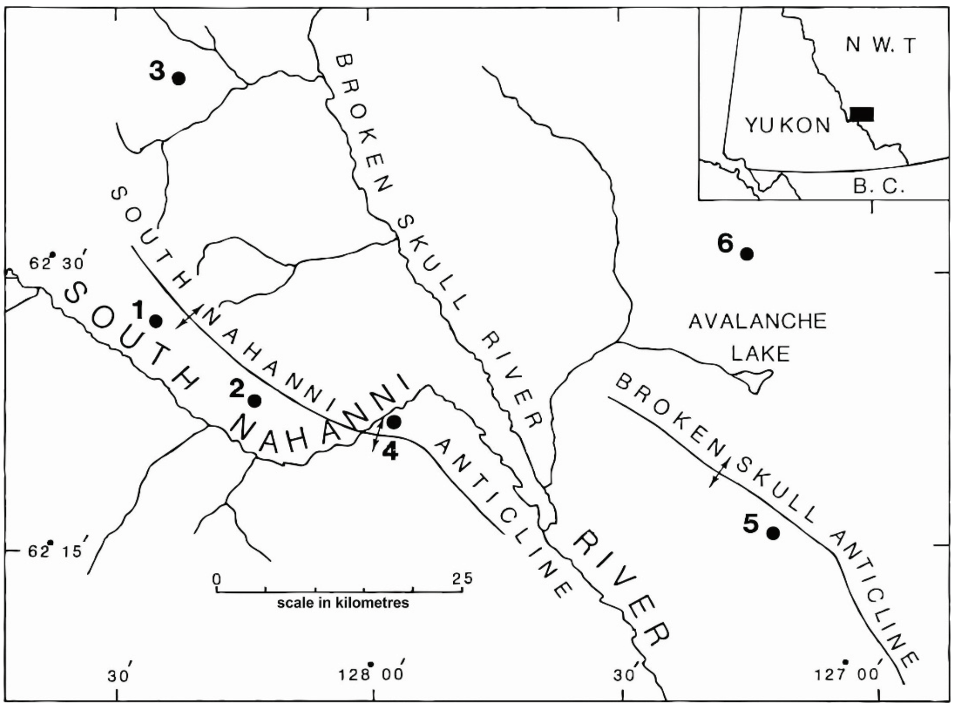


***Figure 2.*** *Index map from Fritz (1982); solid circles are measured sections. Present report provides descriptive notes for sections 5 and 6. Section 6 is adjacent to type section of the Backbone Ranges Formation. Coordinates for sections 5 and 6 are in Appendix 1 herein. For section 1, see Fritz (1979). For sections 2 and 3, see Fritz (1981). Section 4 is type section of the Vampire Formation (Fritz, 1982).*

In 1998, Dr. Fritz provided the compiler of the present report with copies of hand-drafted logs for the sections in the Broken Skull anticline and near the type section; these included Fritz's descriptive notes. Some years later, Dr. Fritz stated that his notes and the original logs for the sections subsequently had been lost and that the materials given to MacNaughton were the only surviving copies.

The present report reproduces the legend (Figure 4) and graphic logs (Figures 5, 6) from Fritz (1982); Fritz's descriptive notes have been transcribed next to the published graphic logs. The Broken Skull anticline section (Figure 5) includes the entire upper member of the Backbone Ranges Formation, the uppermost part of the middle member of the same unit, and the lowermost beds of the overlying Avalanche Formation (Middle Cambrian). The measured section from the type area of the Backbone

Ranges Formation (Figure 6) includes all three members of that unit, as well the upper part of the underlying Sheepbed Formation. Note that much of the original type section was measured in the bottom of a broad, glacially scoured valley (Gabrielse et al., 1973), whereas Fritz (pers. comm., 1998) studied more continuous exposures atop a long ridge that forms the valley's northern wall (Figure 3).

Fritz's notes have been lightly edited for clarity and consistency. Insofar as possible, they are reproduced as he recorded them. In some cases, he used phrases like "medium light grey" or "medium light brown"; it is not clear if these were meant to imply a particular tone or a range of colours (the former is thought to be more likely) and they have been left as transcribed. Also, when Fritz recorded interval ranges (in metres) within a unit, the values referred to metres above the base of the unit, not of the section.

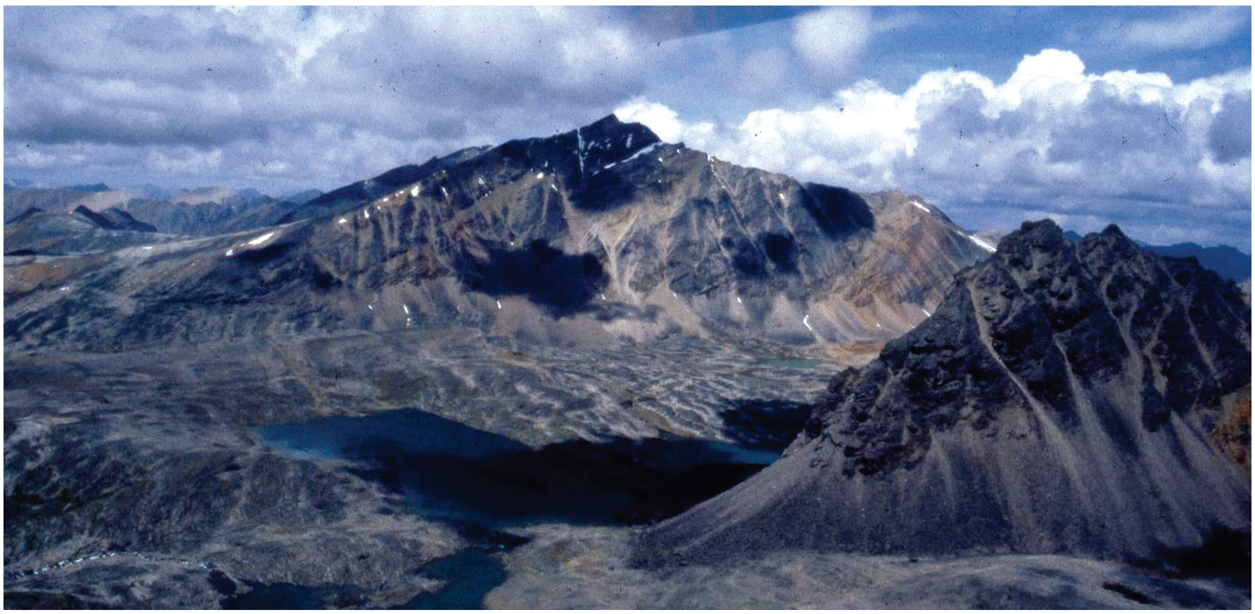

***Figure 3.*** *Type section, Backbone Ranges Formation, aerial view from south, summer 1998. Type section (Gabrielse et al., 1973) is mainly on flat ground immediately this side of prominent ridge. Fritz (1982) measured strata on the ridge. Middle member (orange) is visible at rightward end of ridge; most of ridge is upper member. Lower member continues to right. Photograph courtesy of R.B. MacNaughton.*

Fritz recorded paleocurrent observations from several intervals in the Brokenskull Anticline section (Figure 5); these are provided in Appendix 2 herein. Although the measurements were recorded only as cardinal or ordinal directions, they show a strong tendency toward northwest-directed flow (present-day coordinates), consistent with a (braided) fluvial depositional setting, as has been suggested for parts of the Backbone Ranges Formation elsewhere (MacNaughton et al., 1997a, 1999). At a small number of levels, apparent bidirectional paleocurrents were noted, perhaps suggesting local tidal influence.

The type section was later re-examined by MacNaughton et al. (1999). Although those workers summarized its overall character and commented briefly on its sedimentology, time constraints prevented complete logging of the entire succession. Thus, the notes collected by Fritz provide the most detailed measured section currently available for the Backbone Ranges Formation in its type area.

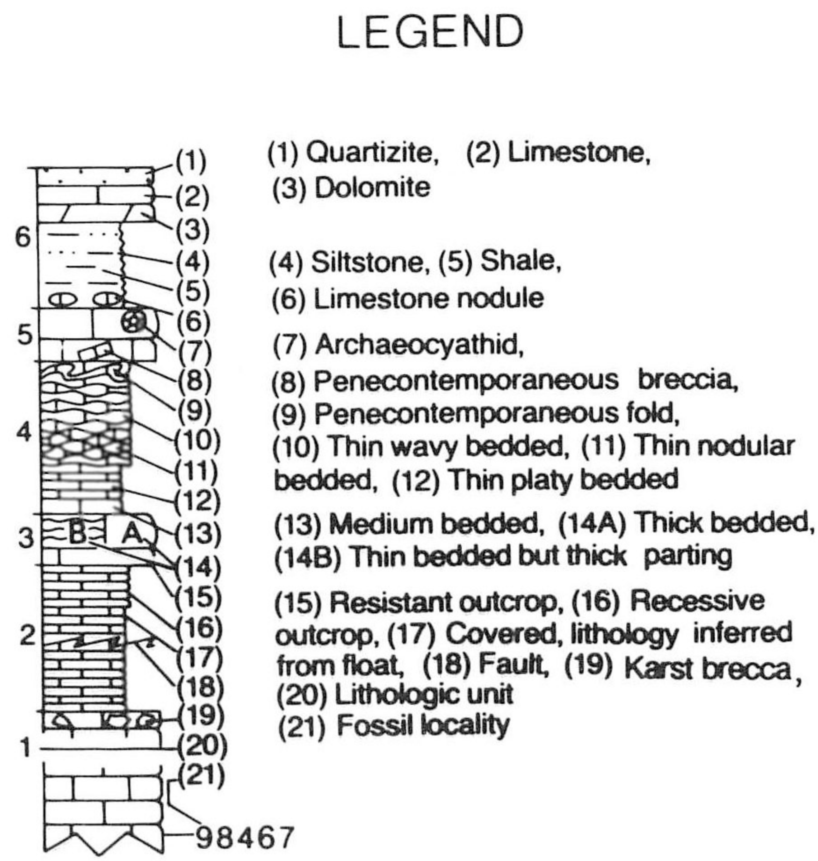


***Figure 4.*** *Legend for Figures 5 and 6, reproduced from Fritz (1982).*

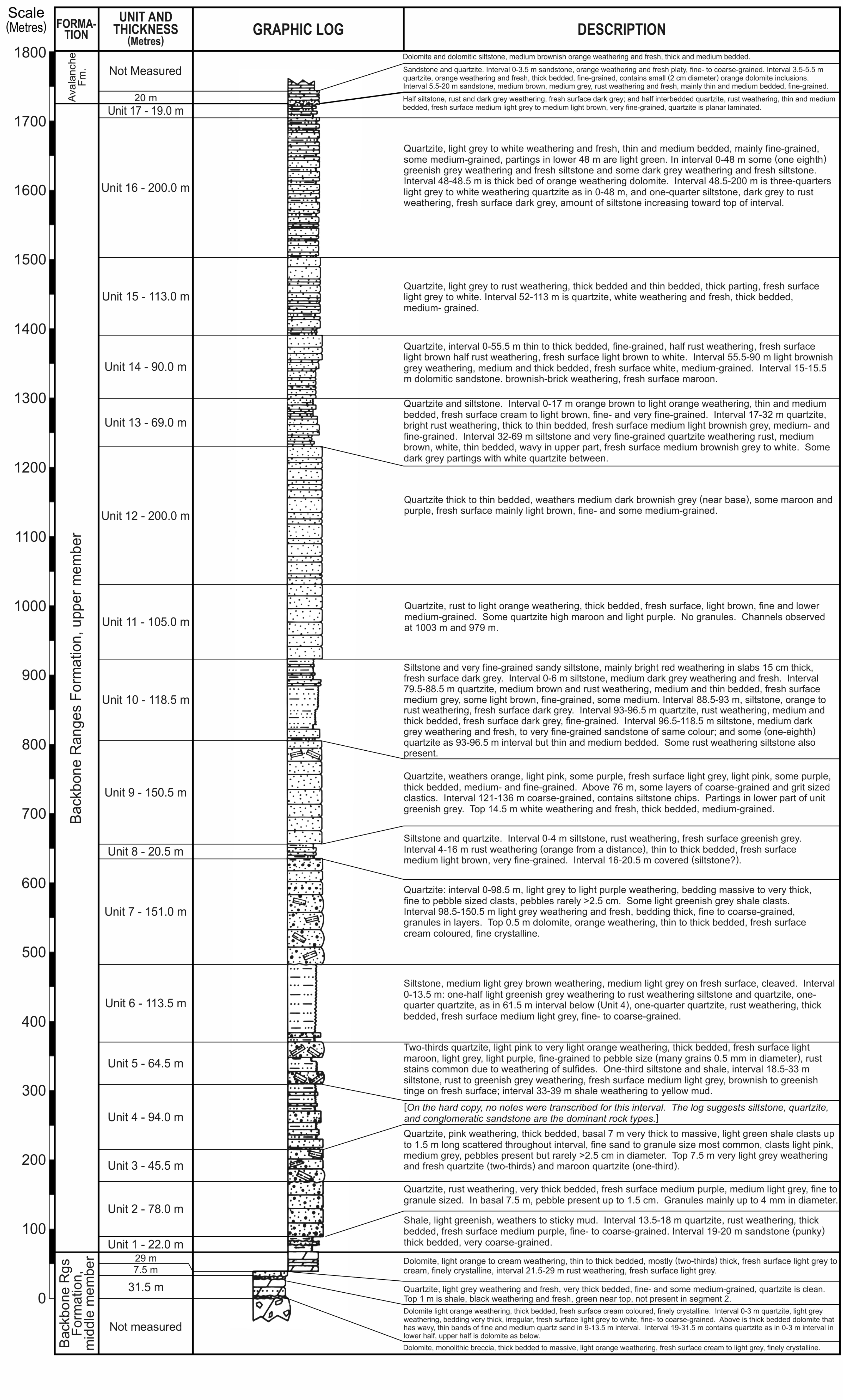


***Figure 5.*** *Broken Skull anticline section, upper member, Backbone Ranges Formation; graphic log reproduced from Fritz (1982), with addition of descriptive notes (see text). See Figure 4 for legend.*

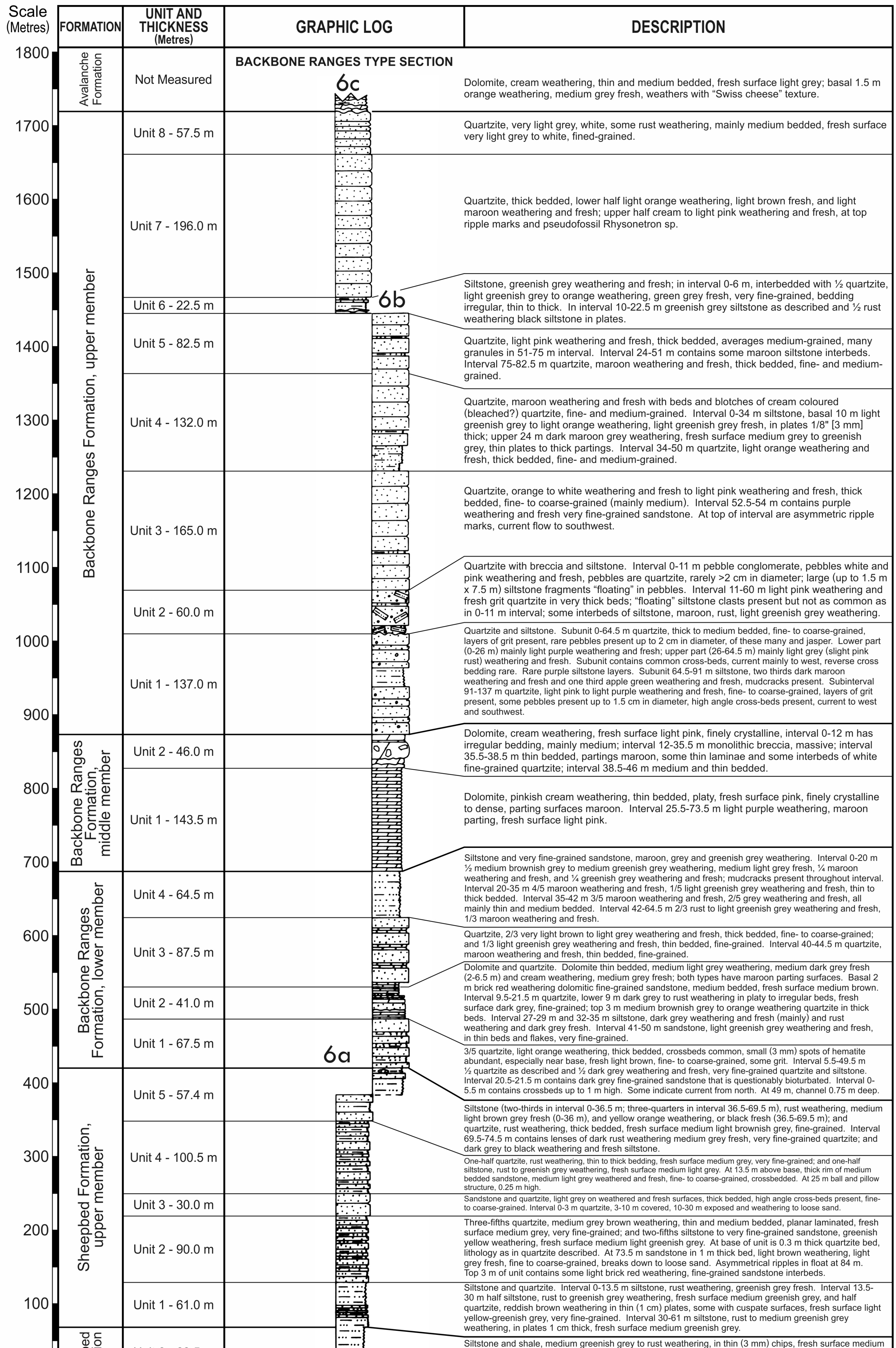


***Figure 6.*** *Graphic log and descriptive notes from a re-examination of the Backbone Ranges Formation at its type locality; graphic log reproduced from Fritz (1982), with addition of descriptive notes (see text). Use of square brackets indicates uncertainty in transcribing hand-written notes. See Figure 4 for legend.*

**STRATIGRAPHIC DATA FROM THE SEKWI BROOK REGION, NTS 105-P**

The Sekwi Brook structural panel in southeastern NTS 105-P (Figure 7) is the type area for the Ediacaran Gametrail, Blueflower, and Risky formations (Figure 1), which are the uppermost units of the Windermere Supergroup in the Mackenzie Mountains (Aitken, 1989). Several publications have documented the stratigraphy, sedimentology, and paleontology of these strata (e.g., Aitken, 1989; Narbonne and Aitken, 1990; MacNaughton et al., 2000, MacDonald et al., 2013; Carbone et al., 2015). Additionally, measured sections through the Sekwi Formation (Cambrian Series 2—i.e., lowest trilobite-bearing Cambrian) and Vampire Formation (map unit 13 in the terminology of Blusson, 1971; Terreneuvian—i.e., Cambrian below the first appearance of trilobites) also have been published from nearby locations (Fritz, 1976, 1979). However, no measured sections have as yet been published for the intervening quartzite-dominated Terreneuvian (sub-trilobite Cambrian) strata in the Sekwi Brook panel (Figure 8), which originally were assigned to map unit 12 by Blusson (1971). Aitken (1989) subsequently treated them as part of the Backbone Ranges Formation, although their correlation with the type section of that unit has been controversial. MacNaughton and Fallas (2019) suggested that the interval consisted of two informal units (Figure 8): a lower "silty member" and an upper "quartzite member".

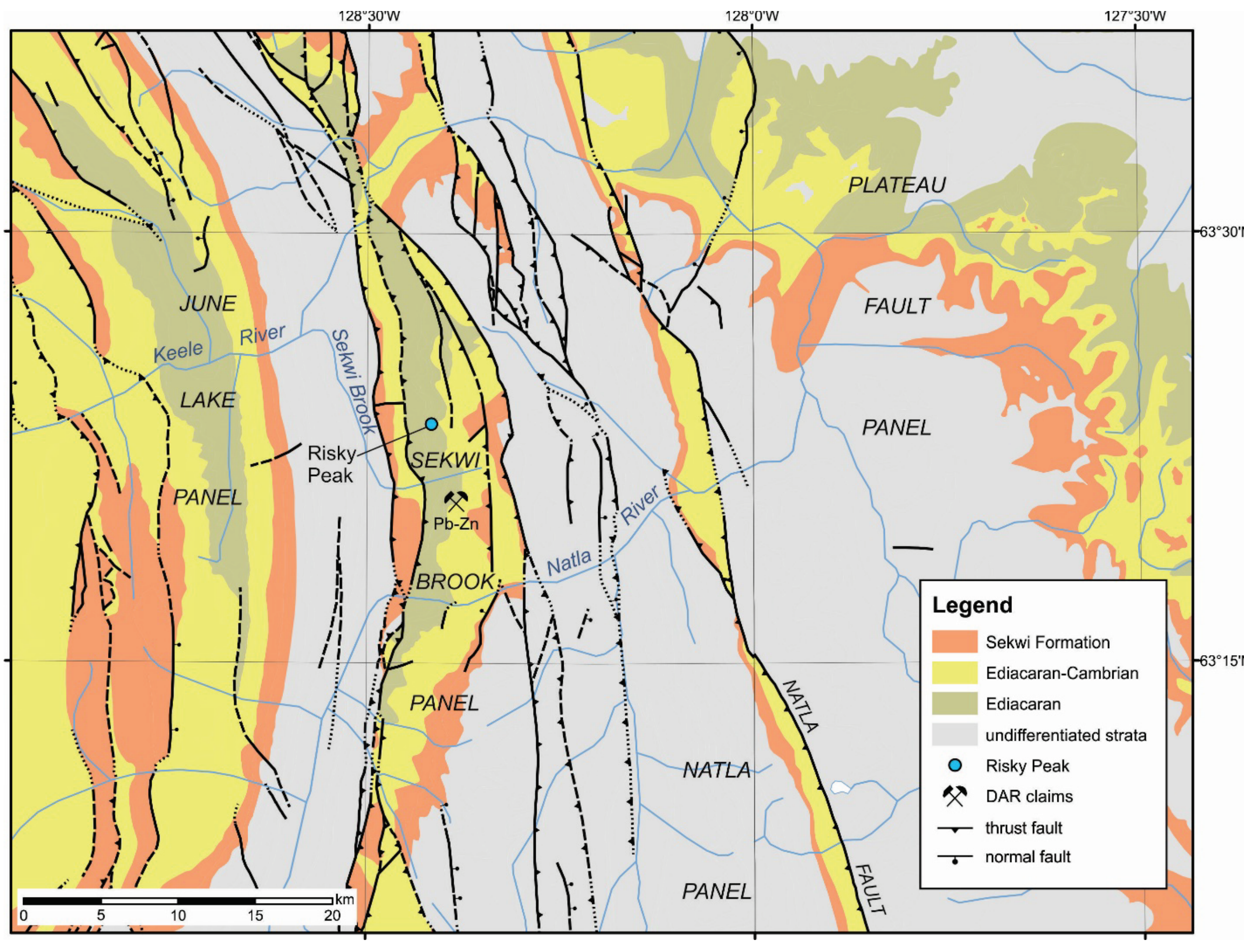


***Figure 7.*** *Location map for area around Sekwi Brook structural panel, showing major structure, simplified stratigraphy, and localities referred to in text. Modified after MacNaughton and Fallas (2019).*

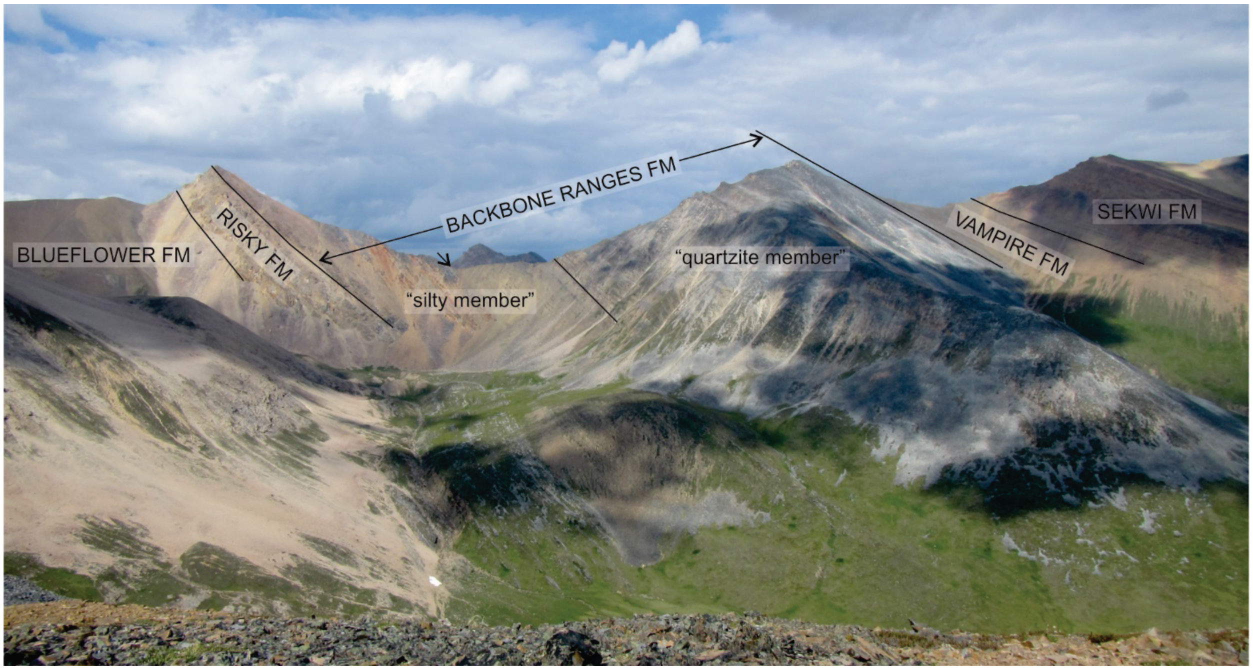


***Figure 8.*** *View of stratigraphy exposed at Risky Peak (peak at left), as seen from the south. See Figure 7 for location. Small arrow points to the level at which silty member of the Backbone Ranges Formation passes from lower sandstone unit into upper siltstone-rich unit. Photograph by R.B. MacNaughton. NRCan photograph 2019-005, previously figured in MacNaughton and Fallas (2019).*

### *Data from the DAR Claims, 1975*

The DAR claims (a.k.a. Sekwi Brook property) comprise at least a dozen galena-sphalerite-tetrahedrite showings in the east-central part of Sekwi Mountain map area (NTS 105-P/8), all hosted in the Ediacaran-aged Risky Formation (Aitken, 1989). An industry report describing stratigraphic units around the claims (Hitchins and Leary, 1975) is in the public domain and can be downloaded from the Northwest Territories Geological Survey. Hitchins and Leary (1975) described units that were numbered subdivisions of the mapping units recognized by Blusson (1971), and they appear to have used structural cross-sections to calculate unit thicknesses. Their summary stratigraphic column is the basis for Figure 9 in the present report, to which has been added unit descriptions derived from their report. Also shown are current lithostratigraphic subdivisions, as described in the preceding paragraph of the present report, to which the subdivisions of Hitchins and Leary (1975) correspond well.

In Figure 9, units 12a to 12e correspond to the strata now generally assigned to the Backbone Ranges Formation. Of these, units 12d and 12e correspond to the "silty member" of MacNaughton and Fallas (2019). Hitchens and Leary (1975) noted that unit 12e was dominated by coarse-grained, white orthoquartzite (quartz arenite) and 12d consisted of medium-grained sandstone with a greenish-brown colouration. More detailed documentation of the silty member is provided in the next section of the present report.

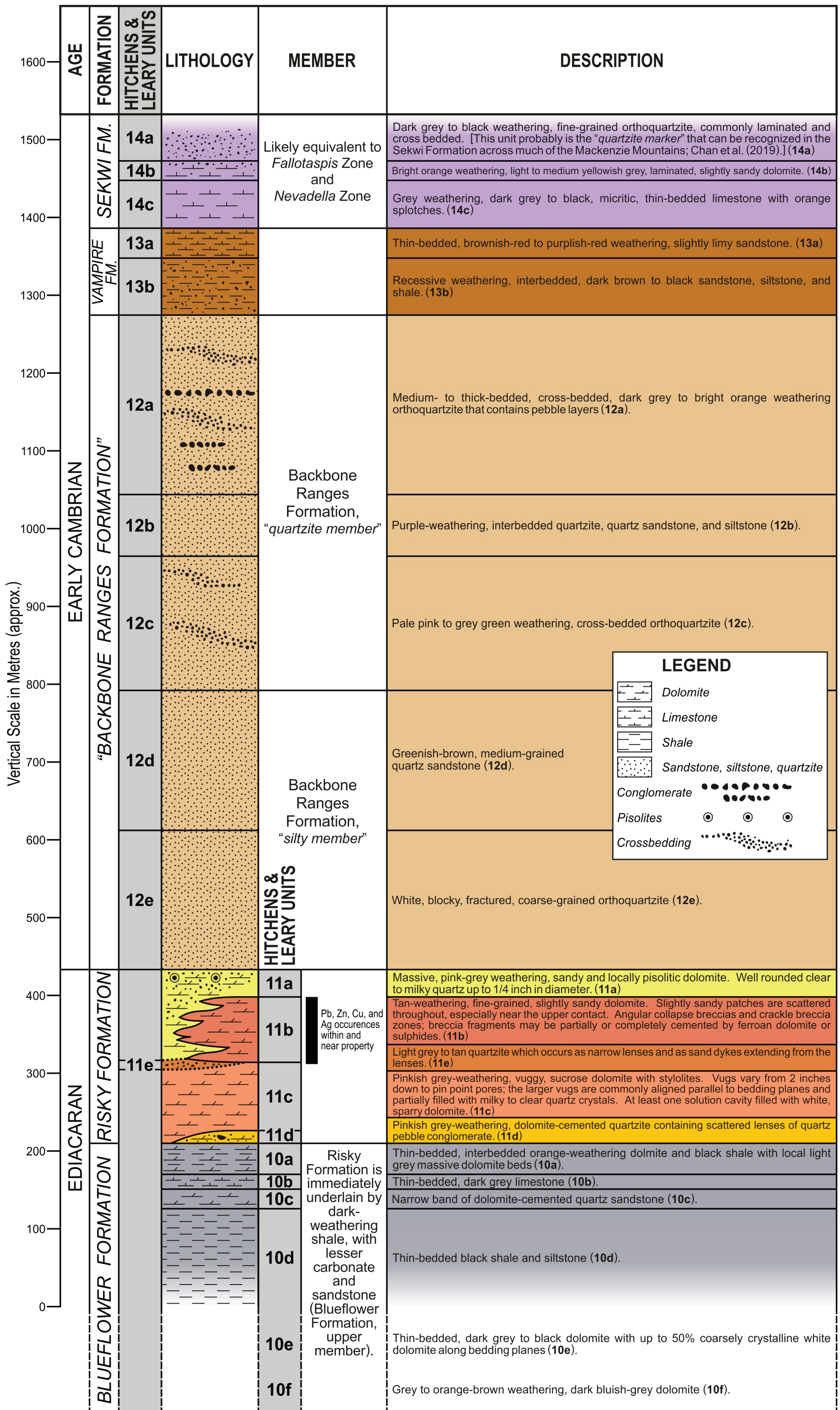


***Figure 9.*** *Summary descriptions of units at DAR property, after Hitchins and Leary (1975), including unit descriptions and showing comparison with present-day lithostratigraphic units (see text for additional details).*

The “quartzite member” of MacNaughton and Fallas (2019) corresponds to units 12a, 12b, and 12c of Hitchens and Leary (1975), whose report is at present the only published description of that interval in the Sekwi Brook panel. In ascending order, the succession consists of quartz arenite with cross-bedding (unit 12C), a thinner package of quartz arenite and siltstone (unit 12b), and a package of quartz arenite with cross-bedding and pebble layers (unit 12a). This compares favourably with a similar tripartite succession documented by MacNaughton et al. (1997b) in the quartzite member (their “upper member”) further west in the June Lake structural panel (Figure 7). MacNaughton et al. (1997b) considered the bases of the lower and upper quartz arenite packages (probably equivalent to the bases of units 12c and 12a) to be sequence boundaries, and documented local erosional removal of tens of metres of the medial package of quartz arenite and siltstone (probably equivalent to unit 12b) beneath the upper quartz arenite package.

***Observations at Risky Peak, 1997***

During the summer of 1997, the compiler of the present report studied exposures of Ediacaran formations in the Sekwi Brook area. This included measuring a composite section (Section D in MacNaughton et al., 2000) at Risky Peak, a short distance north of the DAR claims (Figure 7). Although the published section included only Ediacaran units, observations also were made on strata now assigned to the “silty member” of MacNaughton and Fallas (2019). The silty member consisted of a lower interval of quartz arenite and an overlying package with a higher siltstone content (Figure 8). These correspond, respectively, to units 12e and 12d of Hitchens and Leary (1975). A section was measured through the quartz arenite interval, and reconnaissance observations made of the siltier package of strata. Neither set of observations has been published previously.

The notes for the measured section (SBSa) are in Appendix 3 herein, and also include a complete section through the carbonate-dominated Risky Formation. The succession immediately above the Risky Formation is approximately 120 m thick and dominated by thick-bedded quartz arenite, with abundant cross-bedding. Where cross-beds were appropriately exposed to be measured, paleoflow was generally to the west and southwest. The quartz arenite intervals are very fine to fine grained, with the notable exception of a unit (up to 4.3 m thick) at the base of the formation that is dominantly medium to coarse-grained and locally contains granule-rich conglomeratic sandstone. (Along the route of the section, which was on the north-facing flank of Risky Peak, sandstone was exclusively silica-cemented. However, carbonate cements are locally developed in the sandstones along the ridge-crest extending east from Risky Peak.) Quartz arenite intervals are interstratified at various scales with packages of thin-bedded sandstone, siltstone, and shale. Bedding in the basal 14 m of the succession locally is distorted/slumped, likely reflecting karst-related collapse in carbonates of the underlying Risky Formation.

Strata corresponding to unit 12d (Figure 9) also were briefly examined. These rocks are stratigraphically above measured section SBSa, along the ridgecrest that extends east from Risky Peak. This interval displayed greenish brown and tan weathering colours but was more heterolithic than suggested by the brief description of Hitchins and Leary (1975). In ascending order, the interval consisted of:

1) a basal package (estimated thickness 40 m) of shale and bedded siltstone with at least two thin beds of orange-weathering, intraclastic dolostone;

2) a progradational parasequence set (estimated thickness 120 m), consisting of metre-scale upward-coarsening packages with shaly to silty bases that pass upward into grey, very fine-grained quartz arenite with strongly developed load casts and possible hummocky cross-stratification; and

3) a second progradational parasequence set (estimated thickness 60 m), which resembles the first, except that the parasequences in the second set are sandier, and the uppermost parasequence contains some beds of orange-weathering dolostone to dolomitic sandstone.

Total estimated thickness for unit 12d was 220 m, a figure derived by visually comparing the succession to the underlying (measured) unit 12e. A graphical calculation of the thickness of unit 12d (based on satellite imagery) was reported as 150 m (MacNaughton and Fallas, 2019). It is probable that the original values were overestimated due to perspective issues and should be reduced by a factor roughly of 0.7.

***Observations at DAR claims, 2006***

In 2006, the compiler of the present report measured a section through the unit 12d interval, i.e., the upper part of the "silty member", in the general vicinity of the DAR claims (Figure 7). This more detailed examination confirmed the general impressions gained in 1997, and the notes for the measured section (MWB-06-01) make up Appendix 4 of the present report.

Exposure generally was poor, but was of sufficient quality to demonstrate that the succession is dominated by brown to tan weathering sandstone and siltstone, with minor dolomitic facies. Sandstone is very fine to fine grained. The succession is organized into a number of upward-coarsening packages, which generally are siltier at their bases and sandy at their tops.

Measuring of the section was terminated at a point where sandstone float began to be dominated by light grey-weathering, very fine to medium-grained quartz sandstone. The measured thickness for unit 12d was 115.9 m. This is just over half the thickness of 220 m estimated graphically for unit 12d at Risky Peak by MacNaughton and Fallas (2019). It is possible that the point where measuring was terminated at MWB-06-01 did not correspond to the actual top of the silty member, and that the grey-weathering sandstone was talus from further upslope. Alternatively, MacNaughton et al. (1997b) suggested that the base of the overlying "quartzite member" (their "upper member") was a significant sequence boundary, and the variance in thickness between the DAR claims and Risky Peak could reflect differential erosion of unit 12d.

## ACKNOWLEDGEMENTS

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**Appendix 1:** Location data for localities included this report. Original coordinates are as given in the sources. Coordinates have been converted to NAD83 and decimal degrees for ease of use.

| LOCATION | ORIGINAL COORDINATES (NAD27) | CONVERTED COORDINATES (NAD83) | SOURCE |
|---|---|---|---|
| Backbone Ranges Formation type section | 62° 31′ 0″ N<br>127° 15′ 0″ W | 62.516581<br>127.251750 | Fritz (1982); section 6 |
| Broken Skull anticline section | 62° 15′ 45″ N<br>127° 12′ 30″ W | 62.262405<br>127.210073 | Fritz (1982); section 5 |
| Sekwi Brook Property | 63° 21′ N<br>128° 23′ W | 63.349939<br>128.385175 | Hitchins and Leary (1975) |

**Appendix 2:** Paleocurrent observations from Brokenskull Anticline section, upper member, Backbone Ranges Formation, as recorded by W.H. Fritz. All observations from cross-beds.

Unit 11:
1063 m paleoflow to NW
1068 m paleoflow to NW
1069 m paleoflow to NW (excellent)
1072 m paleoflow to NW (excellent)
1078 m paleoflow to NW
1218 m paleoflow to NW

Unit 10:
981 m paleoflow to NW
990 m paleoflow to NW
994.5 m paleoflow to SE
997.5 m paleoflow to NW
997.5 m paleoflow to SE
1001.5 m paleoflow to NW (excellent)

Unit 8:
684 m paleoflow to NE (very good)
688.5 m paleoflow to NW (good)
688.5 m paleoflow to SE, i.e., reverse (good)
697.5 m paleoflow to NW
707.5 m paleoflow to SW (very good)
712 m paleoflow to SW (good)
733 m paleoflow to NW (good)
734.5 m paleoflow to NW
745 m paleoflow to NW (good)
748 m paleoflow to NW (good)
752 m paleoflow to NW
754 m paleoflow to NW (good)
758 m paleoflow to NW (good)
761.5 m paleoflow to NW (very good)
761.5 m paleoflow to S (very good)
767.5 m paleoflow to S (good)
773.5 m paleoflow to NW (good)

**Appendix 3:** Measured section SBSa through Risky Formation and overlying, basal part of Backbone Ranges Formation (lower part of "silty member"). Section measured at Risky Peak, NTS 105P/08, July 28 and July 30, 1997. Section described by R.B. MacNaughton, measured by J.M. Cole. Base of section at approximate coordinates: 63.3954° N; 128.397° W (NAD83).

| Unit | Description | Thickness | Total from base |
|---|---|---|---|
| | *Top of measured section. Overlain by silty strata equivalent to unit 12d of Hitchins and Leary, 1975.* | | |
| 28 | Interbedded thick-bedded quartzite and recessive lithofacies, as described for underlying units; forms "step and bench" weathering profile on a dip slope. | 31.5 | 211.6 |
| 27 | Base erosional. Quartzite; at base of unit, thick-bedded with trough cross-beds; thins upward to thin-bedded with current ripples at top of unit. | 8.8 | 180.1 |
| 26 | Covered. Float along line of section suggests thin-bedded, very fine-grained quartz sandstone with some grey, micaceous siltstone to shale; possible poorly preserved burrows in the float; passes laterally into more thick-bedded quartz sandstone | 7.9 | 171.3 |
| 25 | Dominated by thick to very thick-bedded, very fine to fine-grained quartz sandstone; trough cross-bedding and parallel bedding. | 23.6 | 163.4 |
| 24 | Recessive, poorly exposed. Some thick-bedded sandstone, as in underlying units, separated vertically by recessive facies (shale and thin-bedded sandstone). | 4.9 | 139.8 |
| 23 | Semi-resistant; exposure of dubious quality. Dominated by thick-bedded quartz sandstone with trough cross-bedding; some recessive benches, suggesting presence of thinner-bedded facies. | 15.6 | 134.9 |
| 22 | Covered. At base, a poorly exposed interval of dark grey shale. Balance of unit is mixed shale and siltstone, with some thin beds of very fine-grained quartz sandstone. | 10.6 | 119.3 |
| 21 | Exposure and access poor. Two main facies, in approximately equal proportions: A) sandstone, as for unit 20; B) interbedded sandstone, siltstone, and shale, as described for unit 19, sandstone very fine grained, thin beds, possibly current-rippled, interbedded with brown shale, in roughly equal proportions. There are two packages of each facies, alternating vertically; basal package consists of facies B, and may form an upward-fining succession with unit 20. | 10.5 | 108.7 |
| 20 | Base sharp. Thick-bedded, very fine to fine-grained quartz sandstone; beds parallel-laminated to low-angle trough cross-bedded. Some bedding strongly distorted, possibly due to development of an ancient sinkhole in the underlying carbonate strata. | 3.8 | 98.2 |
| 19 | Base gradational. Thin and very thin-bedded quartz sandstone, fining upward to 0.5 m of interbedded siltstone and very thin-bedded, very fine-grained quartz sandstone. | 5.7 | 94.4 |

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| | One 10 cm bed of granules approximately halfway up unit. Capping finer-grained interval is of variable thickness laterally, and entire units passes laterally into thick-bedded quartz sandstone. | | |
| 18 | Base probably erosional. Thick-bedded, dark grey, mainly medium to coarse-grained quartz sandstone, locally with enough quartz granules to be a conglomeratic sandstone. Some mud-chip horizons. Beds parallel-laminated or contain very broad trough cross-beds. Locally has abundant iron staining and weathered pyrite blebs. Unit appears to fill in a karst-related depression (sinkhole?) in unit 17; to the south, unit 18 thins to nothing beneath slumped (somewhat folded) quartzite and unit 19 rests directly on unit 17. | 4.3 | 88.7 |
| | *Base of "Backbone Ranges Formation"; units 18-28 correspond to unit 12e of Hitchins and Leary (1975).* | | |
| 17 | Much like units 14 and 15. Percentage of quartz sand increases upsection; unit consists of sandy dolostone to dolomitic sandstone at base, but is dolomitic sandstone at the top. | 6.5 | 84.4 |
| 16 | Base sharp. Cream-weathering, mixture of sandy dolostone to dolomitic sandstone; lenses of dolomicrite with 10% floating, well-rounded quartz grains. As below, bedding poorly defined but stylolites are spaced like thick to very thick beds | 3.0 | 77.9 |
| 15 | As for unit 14 in terms of lithofacies, dominated by dolomitic sandstone; however unit 15 appears more massive, with beds apparently up to several metres thick; some relict smaller scale bedding to lamination as in unit 14. | 20.8 | 74.9 |
| 14 | Base sharp and stylolitized. Sandy dolostone to dolomitic sandstone; breaks into very irregular packages that are on the order of 1.5-2 m thick. Much "floating" quartz, including well-rounded grains up to granule size. Basal unit contains what may be relict low-angle (swaley?) cross-beds. | 7.2 | 54.1 |
| 13 | Base sharp and stylolitized. Dolomitic sandstone, very fine-grained, thin to medium bedded; parallel laminated or low-angle cross-bedded. | 1.6 | 46.9 |
| 12 | At least 1.5 m relief at base of unit. Dominated at base by large hemispherical stromatolites (up to at least 4 m across at base and 2 m high), made up of dolostone or sandy dolostone; fill between stromatolites is rubbly to massive dolostone, with some lenses of dolomitic quartz sandstone, up to coarse-grained, mainly fine to medium-grained, locally laminated. | 3.3 | 45.3 |
| 11 | Laterally discontinuous unit of thin to medium-bedded, dolomitic sandstone; largely massive with some relict, mostly sub-horizontal lamination. | 0.7 | 42.0 |
| 10 | Base covered, but apparently sharp. Dolomitic, fine-grained quartz sandstone, as for unit 8, but packaging here tends to be interbeds of medium beds with thick to very thick beds. | 5.7 | 41.3 |

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| 9 | Base sharp. Dolomitic sandstone to sandy dolostone; breaks into rough beds 30-50 cm thick, otherwise massive. Uppermost 0.5 m poorly exposed. | 2.2 | 35.6 |
| 8 | Base sharp. Dolomitic fine-grained quartz sandstone, orange to cream-weathering, thick to very thick bedded (some beds up to 1.5 m thick); same structures as units 2 and 3, with either broad troughs or swaley cross-stratification predominant, and lesser small troughs. | 4.3 | 33.4 |
| 7 | Base sharp. Very sandy dolostone to dolomitic sandstone; beds 30-40 cm, with large-scale current ripples or small-scale duneforms. Lower bed contains abundant quartz granules and reworked clasts of dolostone. Significant relief on upper surface, apparently reflecting presence of relict bedforms. | 2.9 | 29.1 |
| 6 | Base sharp. Sandy dolostone to dolostone with accessory sand grains; cream to orange weathering; thick bedded; largely massive, some sandy horizons show relict lamination reminiscent of trough cross-bedding. | 2.8 | 26.2 |
| 5 | Base sharp. Sandy dolostone with lesser dolomitic sandstone, proportion of sandstone increasing upsection; bedding very irregular; 30-40 cm high domal hemispherical stromatolites common at top and bottom of unit; fill between stromatolite heads may be more sandy than surrounding facies. | 3.2 | 20.4 |
| 4 | Base sharp. Sandy dolostone to, dominantly, dolomitic sandstone, with variable lenses of well-rounded quartz granules and coarse-grained quartz sandstone; strongly lichen covered, weathers orange to orange-tan; lacks any well-developed lamination but has relict beds, 30-40 cm thick, with wavy tops, locally with thin lenses of brown shale in the low points; some brecciated zones of what appears to have been reworked, early cemented sandstone; some relict textures like the cross-lamination in unit 3; topmost 30 cm bed is much more granular than underlying part of unit. | 2.1 | 17.2 |
| 3 | Quartz sandstone, very fine to fine-grained in basal part of unit; weathers tan to slightly orange; beds commonly 0.5 m and up 1.0 m thick, with irregular, erosional bases and trough cross-bedding; troughs up to several metres wide and thick, or thinner and tens of centimetres wide, with a blocky weathering style; some beds capped by large-scale current ripples. At least one bed shows in situ brecciation above an irregular basal surface (early cementation?). Upper part of unit somewhat dolomitic. Uppermost 4.0 m has upward-coarsening packages that consist of (ascending order): basal packet (up to 0.4 m) of very fine to fine-grained quartz sandstone with hummocky cross-stratification, local swales; medial packet (up to 0.9 m) of fine to medium-grained quartz sandstone, locally up to 10% granules, with trough cross-bedding; and upper packet (up to 0.3 m) of quartz granule conglomerate with some small pebbles. Possible synaeresis cracks at various levels. Iron staining | 7.5 | 15.1 |

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| | common. Uppermost 0.3-0.4 m of unit has abundant coarse granules and is calcareous and somewhat brecciated. | | |
| 2 | Base sharp. Quartz sandstone, very fine to fine-grained with up to 30-40% quartz granules and small pebbles in sporadic horizons. Beds 30-60 cm thick, with trough cross-bedding in sets up to 20 or 30 cm thick; bases of beds irregular. Grainiest horizons generally in upper parts of beds. Tops of some beds mantled by thinly laminated, deep red-brown iron-stained very fine-grained sandstone with granules. | 3.0 | 7.6 |
| 1 | Base covered. Quartz sandstone, very fine to fine-grained, thick-bedded and well-laminated; grey on fresh surfaces, weathers to tan, locally with an orange tone; beds up to 0.6 m thick, and may thicken upward (there are a few 10 cm thick beds at base). Swaley cross-stratification; trough cross-stratification in sets up to 30 cm thick, commonly amalgamated; sporadic current ripples; bases of beds wavy. Up to 10% of unit is sporadic mudstone partings, mainly in lower part of unit. | 4.6 | 4.6 |
| | *Section begins at base of exposure of sandstone that probably is basal part of Risky Formation.* | | |

**Appendix 4:** Measured section MWB-06-01 through upper part of "silty member" of Backbone Ranges Formation at the DAR property, NTS 105P/08. Section measured July 26, 2006. Section described by R.B. MacNaughton and measured by B. Fischer. Base of section at coordinates: 63.3866°N; 128.400°W (NAD83).

| Unit | Description | Thickness | Total from base |
|---|---|---|---|
| | *Measuring terminated at the point where orange-weathering sandstone chips disappeared from float. Above this level was float of thin to medium-bedded, very fine to medium-grained quartz sandstone; fresh surfaces light grey, white, tan, weathers light grey; heavy lichen cover.* | | |
| 19 | Felsenmeer of very fine-grained sandstone chips, very siliceous, fresh surfaces light grey, weathering a vivid orange. Some quartz veins in float. Up to 30% chips of grey siltstone in float, concentrated at various levels. Some blocks of medium-grained quartz sandstone in upper half of unit. | 18.0 | 115.9 |
| 18 | Felsenmeer of blocky to platy rubble of very fine-grained sandstone; fresh light brown, weathering brown to rusty brown; micaceous; "microbial ripples", parallel lamination. At base of unit, rubble is mainly chips and very thin plates; somewhat more blocky at top of unit. | 4.0 | 97.9 |
| 17 | Badly shattered, very fine to medium-grained quartz sandstone; fresh light brown to light grey, weathers brown, orange, rusty, with heavy lichen cover; blocky to platy with indeterminate cross-beds. | 5.2 | 83.9 |
| 16 | Felsenmeer of siltstone and sandstone. Siltstone is tan to olive-grey, thin laminated, present as very small chips; the tan siltstone is slightly sandy. Two types of sandstone: very fine-grained, micaceous, platy, parallel-laminated, as laminae; and blocky, very fine to fine-grained, as very thin beds. The second type is more prevalent in upper part of unit. Both types of sandstone light brown on fresh surfaces and weather brown, light brown, tan, or rusty. Simple horizontal burrows and microbial "tadpole nest" structures. | 9.9 | 88.7 |
| 15 | Base covered. Upward-coarsening and thickening package. Basal third recessive and float covered, dominated by tan-weathering, very fine-grained silty sandstone to mixed sandy siltstone and siltstone, all thickly laminated, weathering as small chips; some float of blocky, tan to brown-weathering, very fine-grained sandstone. Balance of unit dominated by blocky, very fine to medium-grained sandstone, very thin to medium bedded, light grey to tan on fresh surface, weathers tan, orange; sandstone makes up at least three lensoid packets, separated by mixed siltstone/sandstone (as in lower part of unit); uppermost packet up to medium grained, medium bedded, with indeterminate cross-bedding; lower packets finer-grained and thinner bedded, with more interbedded silty material. Local quartz veins. | 12.1 | 78.8 |
| 14 | Sandstone and siltstone; poorly exposed except for ribs of sandstone. Tan to greenish tan siltstone weathering as very small chips, locally to sandy siltstone or with very thin beds | 17.5 | 66.7 |

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| | of quartz sandstone. Very fine to fine-grained sandstone, rarely silty; light brown, greenish brown, tan, or grey on fresh surfaces, weathers grey, light grey, tan, or rusty; very thin, thin, or rarely medium bedded, with indeterminate cross-bedding, low-angle cross-bedding (possible swaley cross-stratification), possible hummocky cross-stratification, parallel lamination, and convolute bedding; simple horizontal burrows, microbial "tadpole nest" structures, *runzelmarken*; very fractured, breaking into slabs and blocks. Proportion of sandstone is 60% at base of unit, 80% at top, and sandstone is coarser grained, blockier, and thicker bedded in upper part of unit. | | |
| 13 | Poorly exposed. Interbedded sandstone and siltstone, in roughly equal proportions, resembling the fine-grained intervals in underlying units. Sandstone is very fine grained, very thin bedded, platy, tan on fresh surface, weathers brown; contains parallel lamination, load casts, sole marks (tools, flutes), simple horizontal burrows; green shale veneer is common, especially on soles of beds. Siltstone is tan (fresh and weathered) and locally sandy. | 3.8 | 49.2 |
| 12 | As for unit 11, but with siltstone making up lower half of unit and sandstone the upper half. Simple horizontal burrows. | 2.1 | 45.4 |
| 11 | Base covered. Lower interval is interbedded siltstone and sandstone as below, making up 60% of total thickness; upper interval is sandstone as below, and is fine-grained and blocky at the top of unit (40% of total thickness). Simple horizontal burrows. | 3.9 | 43.3 |
| 10 | Base covered. Upward-coarsening and thickening package, consisting of alternating intervals of sandstone and interbedded sandstone and siltstone. Lithologies very like unit 9; microbial structures especially common. Sandstone interval that caps this unit is much like the one that caps unit 9 (fine-grained, blocky, locally grey weathering). Some simple traces in float. | 8.6 | 39.4 |
| 9 | Base covered. Four packages of sandstone with intervening packages of interbedded sandstone and siltstone; all packages of roughly equal thickness. Interbedded sandstone and siltstone resembles unit 8; some of the sandstone shows light greenish-tan mudstone adhering to soles; structures include parallel lamination, tool marks, fluted sole markings, "tadpole nests", microbial ripples, load casts. Sandstone is very fine to fine grained, light grey or light brown on fresh surface, weathers brown, less commonly tan; generally platy, less commonly blocky; very thin to thin bedded, with parallel lamination, low-angle cross-lamination (swaley or hummocky cross-stratification?), and convolute bedding. Unit capped by a sandstone unit (approx. 0.8 m) that is dominantly thin bedded, fine grained, blocky, with well-developed low-angle cross-lamination (swaley cross-stratification?), locally weathers light grey. Thus unit | 6.8 | 30.8 |

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| | generally becomes more coarsely sandy upward, and with unit 8 may make up an upward-coarsening package. | | |
| 8 | Recessive; intensely weathered. Up to 80% siltstone to sandy siltstone, micaceous, tan on fresh and weathered surfaces, weathering to very small chips. Balance of unit is sandstone, very fine-grained, micaceous, weathering to slabs and chips; brown on fresh surface, weathers dark brown or dark brownish-grey; parallel lamination, possible hummocky cross-stratification, load casts, and several microbial structures ("tadpole nests", *runzelmarken*, microbial ripples). Poorly preserved simple burrows. | 4.0 | 24.0 |
| 7 | Covered, partly vegetated. Probably dominated by siltstone. Float contains some platy, very thin pieces of parallel-laminated, very fine-grained sandstone, tan on fresh surface, weathering light brown. | 8.1 | 20.0 |
| 6 | Base covered. Dolomitic very fine-grained sandstone, locally to sandy dolostone; fresh surface tan to light grey, weathers cream to orange; current-ripple cross-lamination; locally contains abundant small (0.5-2 cm long), flat clasts of creamy-orange dolomitic siltstone or dolosiltite. | 2.3 | 11.9 |
| 5 | Recessive dip slope, covered by talus derived from unit 4. | 2.6 | 9.6 |
| 4 | Base covered. Sandstone, very fine grained; fresh surface light brown, weathers brown to rusty; very thin to thin bedded, with possible swaley cross-stratification (low-angle cross bedding) and runzelmarken; highly fractured, breaking into blocks, slabs, and irregular pieces. Minor (less than 10%) brown silty very fine-grained sandstone, as laminae with parallel lamination. | 1.4 | 7.0 |
| 3 | Covered. | 1.4 | 5.6 |
| 2 | Base covered. Dolomitic sandstone, fine grained, locally to very coarse, with rounded quartz grains (coarse sand to granules) weathering out in positive relief; thin to medium bedded, mainly massive with suggestions of cross-bedding and parallel lamination; blocky to irregular partings. Abundant flat-pebble conglomerate of creamy-orange dolostone clasts (1-3 cm long) in dolomitic sandstone matrix. | 2.6 | 4.2 |
| 1 | Covered; talus of very fine-grained sandstone, mainly weathering rusty brown. Near middle of unit is one distinctive streak of massive sandstone, grey on fresh surface, weathering dark grey. | 1.6 | 1.6 |
| | *Base of section covered but apparently sharp at top of thick package of quartz sandstone ("unit 12e" of Hitchins and Leary, 1975) that overlies Risky Formation. Sandstone here is fine-grained, light grey to light brown on fresh surfaces, weathers grey, locally rusty, or brick red at one spot; medium to thick bedded. In the section above this point, all sandstones are quartzose, all covered zones are recessive, and zones of outcrop are semi-resistant at best.* | | |