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Formal definition of the Neoproterozoic Mackenzie Mountains Supergroup (Northwest Territories), and formal stratigraphic nomenclature for terrigenous clastic units of the Katherine Group

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PREFACE

The Mackenzie Mountains Supergroup is long-standing lithostratigraphic unit that contains much of the Proterozoic depositional record of northwestern Canada. Despite its importance, neither it nor many of its internal subdivisions have been properly formalized. Geological Survey of Canada Open File Reports 7112 and 7113 are intended to correct this long-standing omission. The authors of these reports have extensive experience in the study of the Mackenzie Mountains Supergroup. The formalization that they propose will solidify the nomenclatural status of this important stratigraphic succession.

These reports were prepared so as to honour the spirit of the North American Code of Stratigraphic Nomenclature. They have been reviewed by two critical readers (R. Rainbird and R. MacNaughton) who are well-versed in Proterozoic stratigraphy. The typescript was copy-edited by R.B. MacNaughton, who has experience as Editor-in-Chief of an earth-science journal. Although these works are part of a series of "Open File Reports", they are intended as final reports and a permanent record of the work. Publications by the Geological Survey of Canada are permanently archived online and in branches of the Natural Resources Canada Library and can be downloaded free of charge, ensuring their long-term availability.

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ABSTRACT

The Mackenzie Mountains Supergroup in NWT is formalised in this and a companion paper. The supergroup includes carbonate rocks of the Tabasco Formation, mudstones, sandstones and minor carbonate rocks of the Tsezotene Formation, sandstones, mudstones and carbonate rocks of the Katherine Group (formalised), and carbonate rocks, evaporite rocks and mudstones of the Little Dal Group. Descriptions and type sections are provided for seven new formations in the Katherine Group (Eduni, Tawu, Grafe River, Etagochile, Shattered Range, McClure, and Abraham Plains formations).

INTRODUCTION

Young et al. (1979, 1982) proposed that Proterozoic strata in western and northern Canada be divided into three major unconformity-bounded packages (sequences A, B and C). These correspond approximately to the Mesoproterozoic, early Neoproterozoic, and late Neoproterozoic, with unconformities dated at approximately 1000 Ma (A-B) and 750 Ma (B-C). Strata of sequence B that underlie the Coates Lake Group in the Mackenzie Mountains were informally named the Mackenzie Mountains supergroup (Young, 1979). This informal usage has been followed by subsequent authors (e.g., Young, 1992; Young et al., 1979; Aitken, 1981; Narbonne and Aitken, 1995; Long et al., 2008; Turner and Long, 2008; Long, 2011), without formal definition. The supergroup, as originally established, was constructed as follows, from oldest unit to youngest.

1) Shallow-water dolostone of the informal “map-unit H1” (Aitken et al., 1973, 1978a,b; Aitken and McMechan, 1991), now formally recognised as the Tabasco Formation [(new; see companion paper (Turner and Long, 2012)].

2) Progradational shelf deposits of the Tsezotene Formation (Gabrielse et al., 1973), that include a lower “grey member” consisting predominantly of dark grey to black mudstone, overlain by an upper “red member” including carbonate rocks,

sandstones and varicoloured mudstone of shallow-water origin (Long, 1982, 1991; Long et al., 2008; Long, 2011).

3) Fluvial and marine sandstones, mudstones and minor carbonate rocks of the informal Katherine Group (Hume and Link, 1945). These strata were informally divided into seven formation-scale units, (K1 to K7; Aitken et al., 1978a; Long et al., 2008; Long, 2011) that are herein named in ascending order the Eduni, Tawu, Grafe River, Etagochile, Shattered Range, McClure and Abraham Plains formations (new).

4) Carbonate rocks, evaporite rocks and minor fine-grained terrigenous clastic rocks of the Little Dal Group (Gabrielse et al., 1973; Aitken et al., 1978a,b; Aitken, 1981), which are divided into seven formations in a companion paper (Turner and Long, 2012), named in ascending order the Dodo Creek, Stone Knife, Silverberry, Gayna, Ten Stone, Snail Spring, and Ram Head formations (new).

Strata of the Mackenzie Mountains Supergroup are overlain unconformably by a succession of locally preserved volcanic strata (the "Little Dal basalt") and siliciclastic and carbonate rocks of the Coates Lake Group. Jefferson (1983), and Jefferson and Ruelle (1986) included these latter units in the informal Mackenzie Mountains supergroup, whereas others (Aitken, 1981; Morris and Aitken, 1982; Park and Aitken, 1986a, 1986b; Aitken and McMechan, 1991; Narbonne and Aitken, 1995; Thorkelson et al., 2005; Long et al., 2008; Turner and Long, 2008) considered them to be part of the overlying Windermere Supergroup. An alternate view presented by Jefferson and Parrish (1989), placed the "Little Dal basalt" in the Mackenzie Mountains supergroup, but excluded the Coates Lake Group from either supergroup, as did Jefferson and Colpron (1998). The present paper follows the usage of Narbonne and Aitken (1995), Thorkelson et al. (2005), Long et al. (2008) and Turner and Long (2008), in excluding the "Little Dal basalt" and Coates Lake Group from the Mackenzie Mountains Supergroup.

This paper presents a formal definition of the Mackenzie Mountains Supergroup, and seven new formations (with type sections) in the Katherine Group. It is the intent of this paper and its companion (Turner and Long, 2012) to establish a complete formal stratigraphic nomenclature for the early Neoproterozoic strata in the Mackenzie Mountains in order to facilitate future mapping and correlation of Neoproterozoic strata in northwestern Canada.

MACKENZIE MOUNTAINS SUPERGROUP

Definition

The Mackenzie Mountains Supergroup (new; Figs. 1 and 2) in the Mackenzie Mountains, Northwest Territories, is defined here and in a companion paper (Turner and Long, 2012) to include carbonate rocks of the Tabasco Formation, mudstones, sandstones and minor carbonate rocks of the Tsezotene Formation, sandstones, mudstones and carbonate rocks of the Katherine Group, and carbonate rocks, evaporite rocks and mudstones of the Little Dal Group. The Mackenzie Mountains Supergroup unconformably overlies weakly deformed strata of the Pinguicula Group in the Wernecke Mountains (Thorkelson, 2000; Thorkelson et al., 2005, Turner, 2011), but its base is not exposed in the Mackenzie Mountains. The supergroup underlies volcanic rocks known as the "Little Dal basalt" and strata of the Coates Lake Group in the Mackenzie Mountains. Structural studies (Aitken and Pugh, 1984; Cook, 1992; Cook and MacLean, 2004) indicate that the supergroup is underlain by several kilometres of older sedimentary rocks that may be equivalent to Sequence A (≈1.7-1.2 Ga) of Young et al. (1979), which, in turn, may be underlain by metamorphic and plutonic rocks similar to those exposed to the east in the Wopmay orogen (Hoffman and Bowring, 1984; Parrish, 1991). This interpretation is supported by analysis of zircon grains in granitic clasts recovered from an Ordovician diatreme near Coates Lake by Jefferson and Parrish (1989), which yielded an inherited age of at least 1.75 Ga. The Shaler Supergroup of Victoria Island and adjacent parts of the mainland is directly correlative to the Mackenzie Mountains Supergroup (Rainbird et al., 1996; Long et al., 2008). The depositional age of Mackenzie Mountains Supergroup strata above the base of the Katherine Group is currently bracketed by a maximum age of 1005 Ma (youngest detrital zircon in Katherine Group; Leslie, 2009) and minimum age of 779 Ma (Rb-Sr on cross-cutting intrusive body; Jefferson and Parrish, 1989; Fig. 2).

Type Area

The Mackenzie Mountains Supergroup is exposed in the Mackenzie Mountains, Northwest Territories, from 62°20' to 65°30'N and 126°00' to 134'30'W (Fig. 1). Parts of the supergroup have been tentatively correlated with strata as far west as Alaska, and as far to the northeast as the Minto Inlier of Victoria Island (Fig. 1; Long et al., 2008). At least part of the Mackenzie Mountains Supergroup is presumed to be present in the subsurface west of the Plateau fault, and the basal contact of the supergroup and direct equivalents of its lowest strata are exposed in the Wernecke Mountains (YT; Turner, 2011) as units formerly included in the upper part of the Pinguicula Group (Eisbacher, 1981). Putative equivalents are exposed in the Ogilvie Mountains (Abbott, 1997; Thorkelson et al., 1998, 2001, 2005; Long et al., 2008). Seismic data indicate that equivalent rocks are locally present in the subsurface of the interior plains east of the Mackenzie Mountains (Cook and MacLean, 2004).

Composite Stratotype

No complete section of the Mackenzie Mountains Supergroup exists in the Mackenzie Mountains, and so a composite stratotype is proposed (Fig. 2), consisting of the type section of the Tabasco Formation in NTS 96D, the type section of the Tsezotene Formation in NTS 95M (63°24'N / 126°40'W; Gabrielse et al. 1973, section G1), the principal reference section of the Katherine Group in NTS 95L (62°38'N / 126°32'W; Gabrielse et al., 1973, Section G2 = Section 022 in appendix), and the type sections of the seven formations of the Little Dal Group. Type sections for all hitherto unformalised formation-scale units in the Mackenzie Mountains Supergroup are presented in this and a companion paper (Turner and Long, 2012).

TSEZOTENE FORMATION

Description

The Tsezotene Formation is the only formation-scale unit in the Mackenzie Mountains Supergroup that has existing formal status (Gabrielse et al., 1973). It is a thick, predominantly argillaceous succession named from a type section in the Tsezotene Range of the Mackenzie Mountains in the Glacier Lake (NTS 95L) map area (63°24'N / 126°40'W). The basal contact with shallow-water carbonate rocks of the Tabasco Formation represents a flooding surface (Long et al., 2008; Turner and Long, 2008). The formation has been divided into two members: a lower grey member consisting predominantly of drab grey to black mudrocks, and an upper member characterised by sandstones interbedded with red, green and grey mudstones and minor carbonate rocks. Both members are well exposed in the vicinity of Mount Eduni (NTS 106A) where the formation is >1.5 km thick (Section 019 in Appendix).

New data

No new stratigraphic divisions of the formation are recognised in this study. Representative sections are provided by Gabrielse et al. (1973, sections 1 to 3), and in the Appendix (Sections 005, 006, 010, 011, 015, 106, 017, 019, 020, 022, 026, 027, 033). The formation may be present in the subsurface northwest of the Mackenzie Mountains, but has no stratigraphic equivalents in the Amundsen Basin, due to an erosional unconformity at the base of the Nelson Head Formation (Rainbird et al., 1996; Long et al., 2008). A probable stratigraphic equivalent in the Wernecke Mountains (YT) is a succession of shallow-water mudstone, siltstone, and sandstone now known as the Tarn Lake Formation (Turner, 2011; formerly part of unit D of the upper Pinguicula Group; Thorkelson, 2000; Long et al., 2008; Martel et al. 2011).

KATHERINE GROUP (new)

Introduction

The Katherine Group (Fig. 2) consists predominantly of unmetamorphosed sandstones with minor mudstone and carbonate rock, with a presumed early Neoproterozoic depositional age (Rainbird et al., 1996, 1997; Long et al., 2008; Long, 2011). The group overlies mudstones and minor sandstones and carbonate rocks of the Tsezotene Formation (Gabrielse et al., 1973), and is overlain by carbonate and minor evaporite rocks of the Little Dal Group. Strata considered to be equivalent to the Katherine Group in the Amundsen Basin span the Rae Group and Reynolds Point Group, including all or parts of the Nelson Head, Aok and Grassy Bay formations (Rainbird et al., 1996; Long et al., 2008). In Yukon, possible equivalents to the Katherine Group include unit E of the upper Pinguicula Group (= Corn Creek quartzite of the Hematite Creek Group; Katherine Group of Turner, 2011) in the Wernecke Mountains

(Thorkelson, 2000; Thorkelson et al., 2005), unit D1 in the Hart River Inlier (Abbott, 1997), and unit R5 in the Coal Creek Inlier (Abbott, 1997).

Definition

The Katherine Group (new) was first described informally in an unpublished Imperial Oil report by Link (1921) as the "Early Paleozoic Mt. Katherine Series". Link appears to have based his descriptions on exposures along Katherine Creek (NTS 96D/13 and 96E/4), extending to a 1908 m-high peak located on the north side of the creek that he named Mount Katherine (64°50'25'N, 127°52'W). This name does not appear on current topographic maps. Link (1921) estimated the unit to be about 1914 m thick, dominated by quartzites with minor mudstones, but did not provide a detailed section. The Mt. Katherine Series was renamed the Katherine group by Hume and Link (1945), and Hume (1954), based on unpublished reports associated with the Canol Pipeline Project in the front ranges of the Mackenzie Mountains by Link and his associates at Imperial Oil. No new lithostratigraphic details or sections were provided, although Aitken et al. (1973) indicate that an incomplete "type section" (presumably along Katherine Creek) was described briefly by Nauss (1944) in an unpublished Canol Project Report, cited by Hume (1954).

Gabrielse et al. (1973), working in the Wrigley Lake and Glacier Lake map sheets, named equivalent strata the Tigonankweine Formation, with a type section in the Glacier Lake map area (NTS 95L; 62°38'N, 126°32'30"W). This name was later discarded once the unit's continuity with strata to the north was confirmed by mapping (Aitken et al., 1973; Aitken and Cook 1974a, 1974b).

Type Area and Distribution

Following the original description of the Katherine Series, the type area of the Katherine Group should be in NTS 96D/13, although its base is not exposed in this area. Regionally, the measured thickness of the group is between 300 m and 1377 m; it typically thickens to the southwest and has a zero edge north and east of the mountain front (Fig. 3).

Type and Principal Reference Section

The best-exposed complete section of the Katherine Group is the type section of the (abandoned) Tigonankweine Formation, as proposed by Gabrielse et al. (1973; their section 2), established in the Thundercloud Range, immediately south of the Keele River in the Glacier Lake map area (NTS 95L) between 62°37’57”N, 126°34’15”W and 62°37’58”N, 126°35’24”W. This section was re-measured as Section 022 (Long et al., 2008; Appendix 1). Because no detailed sections have been established in the type area along Katherine Creek, the Keele River section (Gabrielse et al., 1973) should be considered as the type section for the group. A second, principal reference section has been measured near the Cranswick River (NTS 106F, between 65°16’59”N, 132°10’43”W and 65°16’35”N, 132°12’03”W; Section 020 in the Appendix).

Subdivision

The Katherine Group was divided into seven regionally mappable, informal units of formation rank, named K1 to K7, by Aitken et al. (1978a). Much of the outcrop belt is covered by an extensive felsenmeer of pink-weathering boulders, such that Gabrielse et al. (1973), Colpron and Augereau (1998), Jefferson and Colpron (1998), and Roots and Martel (2008) chose to divide the group into only three mappable units (lower Katherine Group = units K1 to K5; middle Katherine Group = K6; upper Katherine Group = K7) in the Glacier Lake and Wrigley Lake map-areas. In contrast, to the north, Aitken and Cook (1974a, 1974b) divided the group into two mappable units, the lower Katherine Group (units K1 to K5) and the upper Katherine Group (units K6 and K7). The K1 to K7 divisions of Aitken et al. (1978a) were retained by Long et al. (2008), Turner and Long (2008) and Long (2011). The present paper provides a formal definition of each of the seven mappable divisions (Fig. 2; Table 1). From base to top, these are: (1) Eduni Formation, (2) Tawu Formation, (3) Grafe River Formation, (4) Etagochile Formation, (5) Shattered Range Formation, (6) McClure Formation, and (7) Abraham Plains Formation.

EDUNI FORMATION (New)

Definition and Type Area

The Eduni Formation (new) is named after Mount Eduni, a prominent peak immediately north of the Keele River in NTS 106A/1. It constitutes the basal division of the Katherine Group and is equivalent to unit K1 of Aitken et al. (1978a). It is exposed in the cores of many of the anticlinal structures of the front ranges of the Mackenzie Mountains (Fig. 4). The formation is sandstone-dominated, with a thickness of 300 to 600 m in the Shattered Range and Tigonankweine anticlines (Sections 019 at 64°13'30"N, 128°03'W, and 030 at 65°09'N, 129°51'W). It thins northwestward to as little as 126 m in the front ranges, immediately north of the type area of the Katherine Group along Katherine Creek. Its lower contact with mudrocks of the Tsezotene Formation is typically sharp, with local evidence of erosion, and up to 1.5 m local relief. Sandstones in the Eduni Formation are interpreted to be predominantly fluvial (ephemeral and perennial shallow sandy-braided rivers, and minor meandering sand-bed rivers). Mudstone intervals include interfluvial deposits (overbank), abandoned channel-fills, and minor intertidal incursions (Long, 2011). The Eduni Formation typically forms the upper part of a third-order transgressive-regressive cycle (T-R sequence of Embry, 1995, 2002) that begins at the base of the underlying Tsezotene Formation (Long et al., 2008; Turner and Long, 2008). The base of the sandstone-dominated part of the formation typically marks a sharp transition from shallow marine (intertidal) to fluvial conditions (Long, 2011). Isopach maps (Fig. 4 right) indicate thickening to the west with local irregularities caused by differential subsidence on extensional faults (Turner and Long, 2008).

Type section

The proposed type section for the Eduni Formation is on the south face of Mount Eduni, facing the Keele River between 64°12'46"N, 128°01'40"W and 64°13'30"N, 128°03'00"W, where it is 315 m thick (Fig. 4, NTS 106A/1, Section 019 in Appendix). In this section, which is typical of much of the unit, 87% of the formation is light pink-weathering, fine- to very fine-grained sandstone (quartz arenite), and 3% is black and red mudstone and siltstone (with the remaining10% covered). Seventy-seven percent of the sandstones are characterised by medium- to large-scale planar cross-stratification, with an average bed thickness of 50 cm. Low-angle or sinusoidal cross-stratification and local current lineation are present in 9% of the section. The remaining sandstones are either ripple- or plane-laminated. Mudstone intraclasts are rare. Most of the sandstone beds represent sheet elements. Local channels are 2 to 8 m deep and several hundred metres wide. Additional reference sections for the Eduni Formation include sections 011, 016, 020, 022, 026, 027, 030 and 033 (Appendix 1) and Section U4 (Aitken et al., 1973).

TAWU FORMATION (New)

Definition and type area

The Tawu Formation (new) is named after the Tawu mountain range. It constitutes the second-lowest division of the Katherine Group, and is equivalent to unit K2 of Aitken et al. (1978a). The Tawu Formation is an inter-stratified unit of thin-bedded sandstone and mudstone, with minor carbonate rocks. It is 25 to 138 m thick in the Shattered Range and Tigonankweine anticlines (Fig. 5), and is equivalent to unit K2 of Aitken et al. (1978a). The formation thins northwestward to as little as 11 m in the Stony anticline (NTS 106H, Section 030 at 65°09'N, 129°51'W). The lower contact with sandstones of the Eduni Formation is typically sharp but non-erosive. Sandstone content typically increases up-section, and the upper contact with the Grafe River Formation appears to be transitional.

The base of the Tawu Formation is interpreted as a third-order sequence boundary (Long et al., 2008; Turner and Long, 2008). Most of the strata can be interpreted as products of deposition on a shallow-marine shelf (mudstones and carbonate rocks), shoaling to intertidal in the upper, sandstone-dominated parts of the succession (Long, 2011).

Type section

The proposed type section for the Tawu Formation is on the north side of a tributary of the Stone Knife River in the Tawu anticline, between 64°52'28"N, 129°54'48"W, and 64°52'05"N, 129°55'52"W (Fig. 5, NTS 106A/13, Section 002, Appendix 1), where it is 26 m thick. The name Tawu is based on the name of the local mountain range. This section has ~40% thin, plane-laminated, grey-weathering mudstone, 20% thin to thick, plane-laminated, orange-weathering dolostone (some with microbial lamination), and 40% thick-laminated, wavy-laminated and ripple cross-laminated, dull red- to pink-weathering, very fine- and fine-grained sandstones, with minor mudstone intraclasts. In this and other measured sections, there is a general up-section increase in abundance of sandstone beds. Carbonate rocks are absent from sections in the front ranges or the Tigonankweine anticline. Additional reference sections include Sections 003, 006, 012, 013, 016, 018, 020, 022, 025, 027, 030, 031, 032, 033, 034 (Appendix 1) and Sections U2 and U4 (Aitken et al., 1973).

GRAFE RIVER FORMATION (New)

Definition and Type Area

The Grafe River Formation is named after the Grafe River, which cuts the formation about 9 km east of the type section near the mountain front in the Carcajou Range (NTS 96E/4). The formation is equivalent to unit K3 of Aitken et al. (1978a), and is sandstone-dominated, with a thickness of 22 to 454 m (Fig. 6). The lower contact with mudrock and sandstone of the Tawu Formation is sharp or gradational, and is marked by the appearance of planar cross-stratified sandstones and the absence of mudstone. As with the Eduni, Shattered Range and Abraham Plains formations, most of the exposure areas are covered with boulder-rubble, and so this unit can be distinguished only when adjacent, recessive, mud-rich units can be identified.

Type section

The type section for the Grafe River Formation is in the front ranges of the Mackenzie Mountains, in the Carcajou Range, between 65°03’30”N, 127°47’40’W, and 65°03’53”N, 127°47’36’W (Fig. 6, NTS 96E/4, Section 016 in Appendix). At the type section, 98% of the rock is light pink-weathering, fine- to very fine-grained sandstone (quartz arenite), and 2% is black and red mudstone and siltstone. Eighty-five percent of the sandstones are characterised by medium- to large-scale planar cross-stratification, and 2% are characterised by trough cross-stratification (average thickness = 64 cm). Fourteen percent of the sandstones exhibit low-angle or sinusoidal cross-stratification and local current lineation. The remaining sandstones are either ripple- or plane-laminated. Mudstone intraclasts are common in some of the wavy- and ripple-laminated sandstones, and locally are concentrated at the base of channel-fill successions. Granule conglomerate forms a very minor part of the formation, in a one-metre-thick channel at the 800 m level, and a decimetre-scale lag near the top of the formation. Downward-tapering sand-filled cracks are common in some of the finer-grained intervals. Most polygonal forms are interpreted as desiccation cracks, but orthogonal systems may be of seismic origin (Long, 2011). Most of the sandstone beds represent sheet elements. Local channels are up to 12 m deep and several hundred metres wide.

As in the Eduni Formation, most of the sandstones in this unit are deposits of ephemeral and perennial, shallow, sandy-braided rivers, with minor evidence of meandering (or high sinuosity) sand-bed rivers (Long, 2011). Mudstone intervals include both interfluvial deposits (overbank), abandoned channel-fills and possible minor intertidal incursions. The Grafe River Formation typically forms the upper part of a third-order transgressive-regressive cycle (T-R sequence of Embry, 1995, 2002) that begins at the base of the underlying Tawu Formation (Long et al., 2008; Turner and Long, 2008). The base of the sandstone-dominated part of the formation typically marks a sharp transition from shallow marine (intertidal) to fluvial conditions (Long, 2011). Isopach maps (Fig. 6 right) indicate thickening to the west with local irregularities caused by differential subsidence on extensional faults (Turner and Long, 2008).

Additional reference sections for the Grafe River Formation include Sections 002, 003, 006, 013, 016, 018, 020, 022, 025, 027, 030, 031, 032, 033, 034 (Appendix 1) and Sections U4 and U11 of Aitken et al. (1973).

ETAGOCHILE FORMATION (New)

Definition and Type Area

The Etagochile Formation consists of inter-stratified thin-bedded sandstone, mudstone and minor carbonate rock, with a thickness of 16 to 92 m in the Shattered Range and Tigonankweine anticlines (Fig. 7). The name is derived from a small tributary of the Stone Knife River (Etagochile Creek) located to the west of the proposed type section in NTS 106A/13. The Etagochile Formation is equivalent to unit K4 of Aitken et al. (1978a). The unit is 51 to 91 m thick in the Tawu anticline and thins to 37 to 59 m in the Stony and Foran anticlines in the front ranges (Fig. 7 right), with maximum thickness (99 m) recorded in the Snake River area (NTS 106B/16, Section 022). The lower contact with the Grafe River Formation is typically sharp but non-erosive and is taken at the first laterally extensive mudstone unit. Where sandstone is present near the base of the unit, the succession appears to be transitional (e.g., Section 031). Sandstone content typically increases up-section, and the upper contact, which is generally gradational, is arbitrarily placed at the base of the first thick cross-stratified sandstone in the Shattered Range Formation.

Type section

The type section for the Etagochile Formation is on the south side of the Stone Knife River, in the Tawu anticline between 64°51'53"N, 129°52'56"W and 64°52'53"N, 129°52'52"W (Fig. 7, NTS 106A/13, Section 003 in Appendix) where it is 91 m thick. The type section is dominated (65%) by thin to thick, plane-laminated grey to black mudrock, part of which is only poorly exposed. Synaeresis cracks are present locally. Most of the very fine- to fine-grained sandstones are confined to the upper part of the unit. Fifty-five percent of these sandstones are characterised by large-scale planar cross-stratification, and 35% by thin plane-lamination (with abundant current lineation). The remaining 10% are characterised by wavy and ripple cross-lamination. Intraclast horizons are rare.

Carbonate rocks are present locally in Sections 006, 013, 022, 025 and 039 as thin, flaggy beds of orange-weathering dolostone with flat to wavy lamination and abundant polygonal mudcracks, and as thicker units of microbially laminated dolostone.

The base of the Etagochile Formation is interpreted as a third-order sequence boundary (Long et al., 2008). Most of the formation can be interpreted as products of deposition on a shallow-marine shelf (mudstones and carbonates), shoaling to intertidal in the upper, sandstone-dominated parts of the formation (Long, 2011). Thicker, planar cross-stratified sandstones (sheet elements) near the top of the unit may be of distal braided fluvial origin. The presence of current lineation and rare swash marks in some of the plane-laminated sandstone co-sets suggests that these are beach deposits (Long, 2011).

Additional reference sections for the Etagochile Formation include Sections 002, 006, 013, 016, 018, 020, 022, 023, 025, 027, 030, 031, 032 and 034 (Appendix 1), and Sections U4 and U11 of Aitken et al. (1973).

SHATTERED RANGE FORMATION (New)

Definition and Type Area

The Shattered Range Formation is sandstone-dominated, with a thickness of 124 to >300 m in the Shattered Range (from which it derives its name) and Tigonankweine anticlines (Fig. 8). It is 154 to 222 m thick in the Tawu anticline, and 180 to 223 m thick in the Stony and Foran anticlines in the front ranges. The maximum recorded thickness (376 m) is from the Thundercloud Range (Section 022, in NTS 95L/10). It is equivalent to unit K5 of Aitken et al., 1978a. The lower contact with mudrock and sandstone of the Etagochile Formation is typically sharp and possibly erosional, with relief up to 1.5 m, or is locally gradational. The base is typically marked by thick-bedded, massive or planar cross-stratified sandstones, and an absence of mudstone units. As with the Eduni, Grafe River and Abraham Plains Formations, most of the exposure areas are covered with boulder-rubble, such that the Shattered Range Formation can be distinguished only when adjacent, recessive, mud-rich units are obvious.

Type section

The type section for the Shattered Range Formation is located in the Shattered Range of the Mackenzie Mountains between 64°51’50”N, 130°05’33”W and 64°52’23”N, 130°07’22”W (Fig. 8, NTS 106B/16, Section 031 in Appendix), where the formation is 174 m thick. In this section, which is typical of much of the unit, 97% of the strata are light pink-weathering fine- to very fine-grained sandstone (quartz arenite). Remaining strata consist of roughly equal parts of black and red mudstone and siltstone or of interbedded very fine sandstone and mudstone. Eighty-six percent of the sandstones are characterised by medium- to large-scale planar cross-stratification (average thickness = 51 cm), 10% appear massive, and the remainder are either ripple- or plane-laminated, or are characterised by low-angle or sinusoidal cross-stratification with local current lineation.

Mudstone intraclasts are common in some of the wavy- and ripple-laminated sandstone units, and are locally concentrated at the bases of channel-fill successions. Downward-tapering sand-filled cracks are common in some of the finer-grained intervals, as are syneresis cracks. Most of the sandstone beds represent sheet elements. Local channels are 4 to 8 m deep and several hundred metres wide. Thin carbonate layers are present locally near the top of the formation in the vicinity of Cranswick River (NTS 106F/07, Section 20).

As in the Eduni and Grafe River Formations, most of the sandstones of this unit are deposits of ephemeral and perennial, shallow sandy-braided rivers, with minor evidence of meandering or high sinuosity sand-bed rivers (Long, 2011). Mudstone intervals include interfluvial deposits (overbank), abandoned channel-fills, and possible minor intertidal or marine deposits. Water-escape structures (sand volcanoes) in the uppermost sandstone units of Section 035 may have been triggered by seismic activity along nearby transfer faults (Turner and Long, 2008).

Additional reference sections for the Shattered Range Formation include Sections 002, 003, 006, 007, 016, 018, 020, 022, 023, 025, 030, 032 (Appendix 1), and Sections U4 and U11 (Aitken et al. 1973).

McCLURE FORMATION (New)

Definition and Type Area

The McClure Formation is equivalent to unit K6 of Aitken et al. (1978a), and the middle Katherine group of Gabrielse et al. (1973), Colpron and Augereau (1998), Jefferson and Colpron (1998), and Roots and Martel (2008). The formation is named after McClure Lake, 25 km southwest of the type section. The McClure Formation consists of interlayered thin-bedded mudstone, dolostone and sandstone and is 201 to 253 m thick in the Shattered Range and Tigonankweine anticlines (Fig. 9). It is 150 to 219 m thick in the Tawu anticline and thins to 123 m in the MacDougal anticline at Dodo Canyon (Section 014, Appendix 1). The lower contact with sandstone of the Shattered Range Formation is typically sharp, but non-erosive. Sandstone is locally present in the upper part of the unit, suggesting a transitional contact with overlying strata of the Abraham Plains Formation. The upper contact is placed at the base of the first thick, cross-stratified sandstone in the Abraham Plains Formation.

Type section

The type section for the McClure Formation is in the Tawu anticline, in the Canyon Range, in Section 023 (Appendix 1), between 64°44'30"N, 128°40'00"W and 64°43'30"N, 128°41'W (NTS 106A/10; Fig. 9), where it is 219 m thick. The section is dominated (68%) by thin to thick plane-laminated grey-green to black mudrock. Dolostone forms 21%, and very fine-grained sandstone (quartz arenite) about 1% of the section (Fig. 9). Sandstone is more abundant in other sections, and tends to be concentrated near the top of the unit. Large- and small-scale domical and branching columnar stromatolites (*Inzeria*) locally form up to half of the carbonate beds. Inter-stromatolitic beds commonly contain abundant intraformational conglomerate and large oncoids. Most of the stromatolitic beds are underlain by, and interbedded with, thin to thick, plane-laminated dolostone and siliciclastic mudstone, with local gutter casts, 3D ripples and hummocky cross-stratification. Molar-tooth structure is present in one massive dolostone bed in Section 035. Rare sandstone is dominated by thin, very fine-grained co-sets, with flat to wavy lamination and few ripples. Some units contain polygonal mudcracks. Interbedded mudrocks locally contain syneresis cracks.

The base of the McClure Formation coincides with a third-order sequence boundary (Long et al. 2008; Turner and Long 2008). Most of the unit is interpreted as shallow-marine shelf deposits, with evidence of repeated shoaling that produced laterally extensive stromatolite biostromes (Long, 2011). Minor storm influence is indicated by hummocky cross-stratification. The increase in sand content near the top of the unit in many sections indicates shoaling to shallow subtidal to intertidal conditions, and suggests a transitional contact with overlying sandstones of the Abraham Plains Formation. The presence of two or more stromatolitic horizons in many of the measured sections allows this unit to be directly correlated with the Aok Formation, at the top of the Rae Group in the Amundsen Basin (Aitken et al. 1978 a, b; Jefferson and Young 1988; Long et al. 2008).

Additional reference sections for the McClure Formation include Sections 001, 002, 003, 007, 014, 018, 020, 021, 022, 023, 024, 025, 029, 032, 035, 036, 037 and 038 (in Appendix), and Sections U5, U10 and U12 (Aitken et al., 1973).

ABRAHAM PLAINS FORMATION (New)

Definition and Type Area

The Abraham Plains Formation is the uppermost division of the Katherine Group. It is equivalent to unit K7 of Aitken et al. (1978a). The name is derived from the Plains of Abraham (94°38'N, 127°28'W, in NTS 96D/10), an area 65 km southeast of the type section that has extensive rubbly exposures of the Katherine Group, flanked by strata of the Abraham Plains Formation. The formation is sandstone-dominated, with a thickness of 85 to 270 m in the Shattered Range and Tigonankweine anticlines (Fig. 10). It thins northwestward to as little as 15 to 39 m in the front ranges of the Mackenzie Mountains. The lower contact with the McClure Formation is sharp, and is marked by the first appearance of large-scale cross stratification, or transitional, where it is dominated by wavy- and ripple-laminated sandstone, with few to no mudstone intervals.

Type section

The type section for the Abraham Plains Formation is in the Tawu anticline, in Section 023 (Appendix 1), between 64°44'30"N, 128°40'00"W and 64°43'30"N, 128°41'W (NTS 106A/10; Fig. 10), where it is 114 m thick. In the type section, 96% of the rock is light pink-weathering fine- to very fine-grained sandstone (quartz arenite), and 4% is red mudstone and siltstone. Seventy-seven percent of the sandstones are characterised by medium- to large-scale planar and trough cross-stratification, with an average thickness of 25 cm. Eight percent of the sandstones exhibit low-angle or sinusoidal cross-stratification, with local current lineation. The remaining sandstones are either ripple-, plane- or wavy-laminated. Mudstone intraclasts are common in wavy-laminated units.

Sandstones in this unit are predominantly fluvial (ephemeral and perennial shallow sandy-braided rivers, and minor meandering sand-bed rivers). Mudstone intervals include both interfluvial deposits (overbank) and abandoned channel-fills (Long 2011). Where thick intervals of planar- and wavy-laminated very fine-grained sandstones are present, these may represent nearshore or beach deposits. The base of the unit appears to be gradational, reflecting a facies transition from shallow-marine and pro-deltaic deposits of the McClure Formation. The upper contact of the formation with the Dodo Creek Formation [new – see companion paper (Turner and Long, 2012)] of the Little Dal Group is typically sharp, and represents a third-order sequence boundary (Turner and Long, 2008).

Additional reference sections for the Abraham Plains Formation include Sections 001, 003, 007, 008, 009, 014, 018, 020, 021, 022, 023, 024, 029, 032, 035, 036, 037 and 038 (in Appendix), and Sections U5, and U10 in Aitken et al. (1973).

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REFERENCES

Abbott, G., 1997. Geology of the upper Hart River area, eastern Ogilvie Mountains, Yukon Territory (116A/10,116A/11). Indian and Northern Affairs Canada, Exploration and Geological Services Division, Yukon Region, Bulletin 9.

Aitken, J.D., 1974. Geological maps showing bedrock geology of the northern parts of Mount Eduni and Bonnet Plume Lake map areas, District of Mackenzie, NWT. Geological Survey of Canada, Open File 221.

Aitken, J.D., 1981. Stratigraphy and sedimentology of the upper Proterozoic Little Dal Group, Mackenzie Mountains, Northwest Territories. *In* Proterozoic Basins of Canada. Edited by F.H.A. Campbell. Geological Survey of Canada, Paper 81-10: 47-71.

Aitken, J.D., and Cook, D.G., 1974a. Carcajou Canyon map-area, District of Mackenzie, Northwest Territories. Geological Survey of Canada, Paper 74-13.

Aitken, J.D., and Cook, D.G., 1974b. Geological maps showing bedrock geology of the northern parts of mount Eduni and Bonnet Plume lake map area, District of Mackenzie, N.W.T. Geological Survey of Canada, Open File 221.

Aitken, J.D., and McMechan, M.E., 1991. Middle Proterozoic assemblages, Chapter 5 *in* H. Gabrielse and C.J. Yorath (editors), Geology of the Cordilleran Orogen in Canada; Geological Survey of Canada, Geology of Canada 4, p. 97-124.

Aitken, J.D., and Pugh, D.C., 1984. The Fort Norman and Leith Ridge structures: major, buried, Precambrian features underlying Franklin Mountains and Great Bear and Mackenzie plains. Bulletin of Canadian Petroleum Geology 32: 139-146.

Aitken, J.D., Long, D.G.F., and Semikhatov, M.A., 1978a. Progress in Helikian stratigraphy, Mackenzie Mountains. In Current Research, Part A, Geological Survey of Canada, Paper 78-1A: 481-484.

Aitken, J.D., Long, D.G.F., and Semikhatov, M.A., 1978b. Correlation of Helikian strata, Mackenzie Mountains - Brock Inlier - Victoria Island; Geological Survey of Canada, Paper 78-1A, p. 485-486.

Aitken, J.D., Macqueen, R.W., and Usher, J.L., 1973. Reconnaissance studies of Proterozoic and Cambrian stratigraphy, lower Mackenzie River area (Operation Norman), District of Mackenzie. Geological Survey of Canada, Paper 73-9.

Aitken, J.D., Turner, E.C., and MacNaughton, R.B., 2011. Thirty-six archival stratigraphic sections in the Katherine, Little Dal, Coates Lake, and Rapitan groups (Neoproterozoic), Mackenzie Mountains, Northwest Territories. Geological Survey of Canada Open File 6391, 6 p., 41 sheets.

Colpron, M., and Augereau, C., 1998. Preliminary geology of the Dal Lake area, Mackenzie Mountains, Northwest Territories (NTS 95M/2). NWT Geology Division, Indian and Northern Affairs Canada, EGS 1998-03, 1:50,000 scale.

Cook, D.G., and MacLean, B.C., 2004. Subsurface Proterozoic stratigraphy and tectonics of the western plains of the Northwest Territories. Geological Survey of Canada Bulletin 575.

Cook, F.A., 1992. Racklan Orogeny. Canadian Journal of Earth Sciences 29: 2490-2496.

Eisbacher, G.H., 1981. Sedimentary tectonics and glacial record in the Windermere Supergroup, Mackenzie Mountains, northwestern Canada. Geological Survey of Canada, Paper 80-27.

Embry, A.F., 1995. Sequence boundaries and sequence hierarchies: problems and proposals. *In* R.J. Steel, V.L. Felt, E.P. Johannessen and C. Matthieu (Eds.), Sequence stratigraphy on the northwest European margin. Norwegian Petroleum Society, Special Publication 5: 1-11.

Embry, A.F., 2002. Transgresive-Regressive (T-R) sequence stratigraphy. *In* J.M. Armentrout (Ed.), Sequence stratigraphic models for exploration and production: evolving methodology, emerging models, and application histories. Proceedings of the 22nd Annual Bob F. Perkins Research Conference 2002, Gulf Coast Section, SEPM, CD GCS 022: 151-170.

Gabrielse, H., Blusson, S.L., and Roddick, J.A., 1973. Geology of Flat River, Glacier Lake and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory; Geological Survey of Canada, Memoir 366.

Hoffman, P.F., and Bowring, S.A., 1984. Short-lived 1.9 Ga continental margin and its destruction, Wopmay Orogen, Northwest Canada. Geology 12: 68-72.

Hume, G.S. 1954., The lower Mackenzie River area, Northwest Territories and Yukon. Geological Survey of Canada, Memoir 273.

Hume, G.S., and Link, T.A., 1945. Canol geological investigations in the Mackenzie River area, Northwest Territories and Yukon. Geological Survey of Canada, Paper 45-16.

Jefferson, C.W., 1983. The Upper Proterozoic Redstone Copper Belt, Mackenzie Mountains, N.W.T.; Ph.D thesis, University of Western Ontario, 445 p.

Jefferson, C.W., and Colpron, M., 1998. Geology of the Coppercap Mountain area, Mackenzie Mountains, Northwest Territories (NTS 95 L/10). NWT Geology Division, Indian and Northern Affairs Canada, EGS Open File 1998-04, 1 map, 1:50,000 scale.

Jefferson, C.W., and Parrish, R.R., 1989. Late Proterozoic stratigraphy, U-Pb zircon ages, and rift tectonics, Mackenzie Mountains, northwestern Canada. Canadian Journal of Earth Sciences 26: 1784-1801.

Jefferson, C.W. and Ruelle, J.C.L., 1986. The Late Proterozoic Redstone Copper Belt, Mackenzie Mountains, N.W.T. *In* J.A. Morin (Ed.), Mineral Deposits of the Northern Cordillera. Canadian Institute of Mining and Metallurgy, Special Volume 37: 154-168.

Jefferson, C.W., and Young, G.M., 1988. Late Proterozoic orange-weathering stromatolite biostrome, Mackenzie Mountains and western Arctic Canada. *In* H. Gelsetzer (Ed.), Reefs in Canada and adjacent areas. Canadian Society of Petroleum Geologists, Memoir 13: 72-80.

Leslie, C.D., 2009. Detrital zircon geochronology and rift-related magmatism: central Mackenzie Mountains, Northwest Territories. M.Sc. thesis, University of British Columbia, Vancouver, BC, 224 p.

Link, T.A., 1921. Geological Report on the Fort Norman area. Unpublished report for Imperial Oil Ltd.

Long, D.G.F., 1982. Depositional setting and stratigraphic setting of rocks of the Tsezotene Formation and Katherine group, Mackenzie fold belt, Yukon and Northwest Territories, Canada. *In* R.R. Reid and G.A. Williams (Eds.), Society of Economic Geologists, Coeur d'Alene Field Conference, Idaho – 1977. Idaho Bureau of Mines and Geology, Bulletin 24: 119.

Long, D.G.F., 1991. The Tsezotene Formation: a Helikian prograding muddy shelf deposit in the Mackenzie Mountains, N.W.T. Geological Association of Canada, Program with Abstracts 16: A75.

Long, D.G.F., 2011. Katherine Group. Section 3.1.3 *in* E. Martel, E.C.Turner, and B. Fisher (eds.) Geology of the central Makenzie Mountains of the Northern Canadian Cordillera. NWT Special Volume 1, NWT Geoscience Office, p. 39-56.

Long, D.G.F., R.H. Rainbird, R.H., Turner, E.C., and MacNaughton, R.B., 2008. Early Neoproterozoic Strata (Sequence B) of mainland Northern Canada and Victoria and Banks Islands: a contribution to the Geological Atlas of the Northern Canadian Mainland Sedimentary Basin. Geological Survey of Canada, Open File 5700.

Martel, E., Turner, E.C., and Fisher, B., 2011. Geology of the central Makenzie Mountains of the Northern Canadian Cordillera. NWT Special Volume 1, NWT Geoscience Office, p. 39-56.

Morris, W.A. and Aitken, J.D., 1982. Paleomagnetism of the Little Dal Lavas, Mackenzie Mountains, Northwest Territories, Canada. Canadian Journal of Earth Sciences 19: 2020-2027.

Narbonne, G.M., and Aitken, J.D., 1995. Neoproterozoic of the Mackenzie Mountains, northwestern Canada. Precambrian Research 73: 101–121.

Park, J.K., and Aitken, J.D., 1986a. Paleomagnetism of the late Proterozoic Tsezotene Formation of northwestern Canada. Journal of Geophysical Research 91 (B5): 4955-4970.

Park, J.K., and Aitken, J.D., 1986b. Paleomagnetism of the Katherine Group in the Mackenzie Mountains; implications for post-Grenville (Hadrynian) apparent polar wander. Canadian Journal of Earth Sciences 23: 308-323.

Parrish, R.R., 1991. Precambrian Basement rocks of the Canadian Cordillera. *In* H. Gabrielse and C.J. Yorath (Eds.), Geology of the Cordilleran Orogen in Canada. Geological Survey of Canada, Geology of Canada 4: 87-96.

Rainbird, R.H., Jefferson, C.W., and Young, G.M., 1996. The early Neoproterozoic sedimentary Succession B of northwestern Laurentia: correlations and paleogeographic significance. Geological Society of America, Bulletin 108: 454-470.

Rainbird, R.H., McNicoll, V.J., Thériault, R.J., Heaman, L.M., Abbot, J.G., Long, D.G.F., and Thorkelson, D.J., 1997. Pan-continental river system draining Grenville Orogen recorded by U-Pb and Sm-Nd geochronology of Neoproterozoic quartzarenites and mudrocks, northwestern Canada; Journal of Geology v. 105, p. 1-17.

Roots, C., and Martel, E., 2008. Preliminary geologic map of Sekwi Mountain map area (NTS 105P and parts of 106A, 95M, and 96D), Mackenzie Mountains, Northwest Territories. Northwest Territories Geoscience Office, NWT Open File 2008-04. 1 map sheet, various scale maps, and accompanying report, 17 p.

Thorkelson, D.J., 2000. Geology and mineral occurrences of the Slats Creek, Fairchild Lake and 'Dolores Creek' areas, Wernecke Mountains (106D/16, 106C/13, 106C/14), Yukon Territory. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 10, 73 p.

Thorkelson, D.J., Abbott, J.G., Mortensen, J.K., Creaser, R.A., and Villeneuve, M.E., 1998. Proterozoic sedimentation, magmatism, metasomatism and deformation in the Wernecke and Ogilvie mountains, Yukon. *In* F. Cook and P. Erdmer (Eds.), Slave-Northern Cordillera Lithospheric Evolution (SNORCLE) and Cordilleran tectonics workshop. Lithoprobe Report 64: 110-119.

Thorkelson, D.J., Mortensen, J.K.. Davidson, G.J., Creaser, R.A., Perez, W.A., and Abbott, J.G., 2001. Early Mesoproterozoic intrusive breccias in Yukon, Canada; the role of hydrothermal systems in reconstructions of North America and Australia. Precambrian Research 111: 31-55.

Thorkelson, D.J., Abbott, J.G., Mortensen, J.K., Creaser, R.A., Villeneuve, M.E., and McNicoll, V.J., 2005. Early and middle Proterozoic evolution of Yukon, Canada; the Lithoprobe Slave-NORthern Cordillera lithospheric evolution (SNORCLE) transect. Canadian Journal of Earth Sciences 42: 1045-1071.

Turner, E.C., 2011. Stratigraphy of the Mackenzie Mountains supergroup in the Wernecke Mountains, Yukon. *In:* Yukon Exploration and Geology 2010, K.E. MacFarlane, L.H. Weston and C. Relf (eds.), Yukon Geological Survey, p. 207-231.

Turner E.C., and Long, D.G.F., 2008. Syndepositional fault activity during deposition of the Neoproterozoic Mackenzie Mountains Supergroup, N.W.T., Canada: Implications for evolution of the Mackenzie Basin and the Mackenzie Mountains Zn District. Canadian Journal of Earth Sciences 45: 1159-1184.

Turner, E.C. and Long, D.G.F., 2012. Formal definition of the Neoproterozoic Mackenzie Mountains Supergroup (NWT), and formal stratigraphic nomenclature for its carbonate and evaporite formations. Geological Survey of Canada Open File 7112.

Turner, E.C., James, N.P., and Narbonne, G.M., 1997. Growth dynamics of Neoproterozoic calcimicrobial reefs, Mackenzie Mountains, northwest Canada; Journal of Sedimentary Research 67: 437-450.

Turner, E.C., Narbonne, G.M., and James, N.P., 2000a. Framework composition of early Neoproterozoic calcimicrobial reefs and associated microbialites, Mackenzie Mountains, N.W.T., Canada; in, Carbonate Sedimentation And Diagenesis *In* J.P. Grotzinger and N.P. James (Eds.), The Evolving Precambrian World. SEPM Special Publication 67: 179-205.

Turner, E.C., James, N.P., and Narbonne, G.M., 2000b. Taphonomic control on microstructure in early Neoproterozoic reefal stromatolites and thrombolites. Palaios 15: 87-111.

Young, G.M. 1992. Late Proterozoic stratigraphy and the Canada-Australia connection; Geology, v. 20, p. 215-218.

Young, G.M., Jefferson, C.W., Delaney, G.D., and Yeo, G.M., 1979. Middle and Upper Proterozoic evolution of the northern Canadian Cordillera and Shield. Geology 7: 125-128.

Young, G.M., Jefferson, C.W., Delaney, G.D., Yeo, G.M., and Long, D.G.F., 1982. Upper Proterozoic stratigraphy of northwestern Canada and Precambrian history of the North American Cordillera. Society of Economic Geologists' Coeur d'Alene field conference. Idaho Bureau of Mines and Geology, Bulletin 24: 73-96.

Figure Captions

Figure 1. (A, B) Location and distribution of early Neoproterozoic strata in northwestern Canada. (C) Exposure area of the Mackenzie Mountains Supergroup in the Mackenzie Mountains (NWT; based on Turner and Long, 2008).

Figure 2. Generalised stratigraphy of the Mackenzie Mountains Supergroup. Cross-cutting dikes and sills (black) have been dated at 779 Ma (Rb-Sr) by Jefferson and Parrish (1989).

Figure 3. Regional thickness of the Katherine Group in metres. Dark grey indicates outcrop, pale grey indicates inferred subsurface extent.

Figure 4. Left- Log of type section of Eduni Formation: legend at the bottom is for all stratigraphic columns in figures 4 to 10. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Light colours indicate inferred lithology in covered intervals. Right- isopach map for Eduni Formation: numbers in boxes refer to sections in the appendix. Further details of this and other sections are provided in Appendix 1

Figure 5. Left- Log of type section of Tawu Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Tawu Formation: numbers in boxes refer to sections in the appendix.

Figure 6. Left- Log of type section of Grafe River Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Grafe River Formation: numbers in boxes refer to sections in the appendix.

Figure 7. Left- Log of type section of Etagochile Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Etagochile Formation: numbers in boxes refer to sections in the appendix.

Figure 8. Left- Log of type section of Shattered Range Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Shattered Range Formation: numbers in boxes refer to sections in the appendix.

Figure 9. Left- Log of type section of McClure Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for McClure Formation: numbers in boxes refer to sections in the appendix.

Figure 10. Left- Log of type section of Abraham Plains Formation: for legend see Fig. 4.

Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Abraham Plains Formation: numbers in boxes refer to sections in the appendix.

Table 1. Nomenclature for the Katherine Group, with location of type sections. Details of all sections are provided in Appendix 1.

KATHERINE GROUP	*NTS Sheet*	*Unit*	*Type Section*	*Latitude Base*	*Longitude Base*	*Latitude Top*	*Longitude Top*
Abraham Plains Fm	*106A/10*	*K7*	*023*	*64°44’30”N*	*128°40’00”W*	*64°43’21”N*	*128°41’51”W*
McClure Fm	*106A/10*	*K6*	*023*	*64°44’30”N*	*128°40’00”W*	*64°43’21”N*	*128°41’51”W*
Shattered Range Fm	*106B/16*	*K5*	*031*	*64°51’50”N*	*130°05’33”W*	*64°52’23”N*	*130°07’22”W*
Etagochile Fm	*106A/13*	*K4*	*003*	*64°51’53”N*	*129°52’56”W*	*64°52’53”N*	*129°51’52”W*
Grafe River Fm	*96E/4*	*K3*	*016*	*65°03’30”N*	*127°47’40”W*	*65°03’53”N*	*127°47’36”W*
Tawu Fm	*106A/13*	*K2*	*002*	*64°52’28”N*	*129°54’48”W*	*64°52’05”N*	*129°55’52”W*
Eduni Fm	*106A/1*	*K1*	*019*	*64°12’46”N*	*128°01’40”W*	*64°13’30”N*	*128°03’00”W*

Table 1. Nomenclature for the Katherine Group, with location of type sections. Details of all sections are provided in Appendix 1.

APPENDIX 1, MEASURED SECTIONS IN THE KATHERINE GROUP AND TSEZOTENE FM.

Section Number (Formation)	Abraham	McClure	Shattered Range	Etagochile	Grafe	Tawu	Eduni	Tsezotene red mbr	Tsezotene grey mbr	Location	NTS Sheet	Latitude base	Longitude base	Latitude top	Longitude top
# 001	175	205								Mountain River	106A/11	64°42'02"N	129°13'43"W	64°41'47"N	129°13'51"W
# 002		148	204	16	217	**26**	>113			Stone Knife River	106A/13	64°52'28"N	129°53'48"W	64°52'05"N	129°55'51"W
# 003	85	239	174	**91**	73	25	>153			Stone Knife River	106A/13	64°51'53"N	129°52'56"W	64°51'53"N	129°51'52"W
# 005								>275		Mountain River	106A/14	64°53'26"'N	129°08'04"W	64°53'25"N	129°08'30"W
# 006		>20	155	95	459	142	140	>305		Mountain River	106A/14	64°53'39"N	129°04'45"W	64°53'46"N	129°02'52"W
# 007	199	151	168	~50	>150					Mountain River	106A/15	64°54'16"N	129°01'35"W	64°54'25"N	129°01'12"W
# 008	127	>78								Mountain River	106A/11	64°42'00"N	129°13'00"W	64°41'47"N	129°13'51"W
# 009	208	>151								Deca Creek	106A/2	64°13'34"N	128°30'28"W	64°13'20"N	128°30'49"W
# 010							>55	420	>702	Keel River	96D/4	64°09"17"N	127°59'13"W	64°09'15"N	127°57'35"W
# 011						>11	583	>88		Five Lakes, north	96D/4	64°06'31"N	127°49'54"W	64°06'29"N	127°50'11"W
# 012					>66	128	>455			Five Lakes, south	96D/4	64°05'54"N	127°49'49"W	64°05'47"N	127°49'38"W
# 013			>81	49	618	42	>50			Five Lakes, west	96D/4	64°05'37"N	127°50'21"W	64°05'33"N	127°50'44"W
# 014	39	123	>32							Dodo Canyon	96D/14	64°53'21"N	127°13'46"W	64°52'56"N	127°13'57"W
# 015							>60	207	>124	Imperial Canyon	106H/1	65°04'26"N	128°03'48"W	65°05'20"N	128°04'01"W
# 016		>75	180	41	**276**	58	126	246	>268	Carcajou Range	96E/4	65°02'22"N	127°49'16"'W	65°03'53"N	127°47'36"'W
# 017								315	>322	Arctic Red River	106G/3	65°13'56"N	131°02'27"W	65°14'07"N	131°01'30"W
# 018	103	186	179	73	49	14	>235			Arctic Red River	106G/3	65°10'39"N	131°17'37"W	65°10'30"N	131°19'00"W
# 019						>31	**315**	365	>43	Mount Eduni	106A/1	64°12'46"N	128°01'40"W	64°13'30"N	128°03'00"W
# 020	21	115	114	78	22	28	353	>43		Cranswick River	106F/8	65°16'42"N	132°08'44"W	65°16'32"N	132°12'09"W
# 021	214	252	>20							South of Keel River	106A/1	64°08'04"N	128°06'55"W	64°07'31N	128°08'12"W
# 022	254	148	376	17	356	41	73	165	>336	Thundercloud Range	95L/10	62°38'25"N	126°33'30"W	62°38'05"N	126°36'33"W
# 023	**114**	**219**	223	51	>10					Tawu Anticline	106A/10	64°44'06"N	128°40'00"W	64°43'21"N	128°41'51"W
# 024	180	231	>25							Upper Ramparts River	106G/2	65°04'58N	130°39'16"W	65°04'33"N	130°39'47"W
# 025	>100	285	335	38	213	30	>20			Tigonankweine Range	96D/4	64°05'00"N	127°54'00"W	64°03'25"N	127°55'41"W
# 026							244	>240		Tawu Mts, Ramparts River	106G/1	65°08'30"N	130°29'20"W	65°07'50"N	130°29'46"W
# 027			>20	95	81	26	111	>290		Tawu Mts, Ramparts River	106G/1	65°06'25"N	130°25'30"W	65°06'21"N	130°26'39"W
# 029	138	281	>50							Shattered Range Anticline	106A/8	64°23'00"N	128°17'40"W	64°22'35"N	128°18'00"W
# 030			195	59	63	11	567	334	>30	Gayna River	106H/4	65°09'23"N	129°49'29"W	65°08'46"N	129°50'16"W
# 031		>200	**174**	99	70	38	>25			Snake River	106B/16	64°51'50"N	130°05'33"W	64°52'23"N	130°07'22"W
# 032	193	216	124	92	78	29	>221			Mt River, tributary	106A/13	64°49'14"N	129°39'32"W	64°48'36"N	129°41'44"W
# 033				>10	175	14	187	>803		Rapitan Creek	106E/1	65°13'06"N	134°06'24"W	65°12'40"N	134°04'20"W
# 034				>10	368	77	>197			Keel River, Tawu Anticline	96D/3+6	64°14'36"N	127°18'55"W	64°15'35"N	127°20'21"W
# 035	270	196	>59							Ram Head Lake	95M/13	63°56'06"N	127°41'16"W	63°56'53"N	127°41'55"W
# 036	270	353	>5							Tigonankweine Range	96D/4	64°03'40"N	127°52'52"W	64°02'42"N	127°35'05"W
# 037	137	201	>50							Backbone Ranges	96D/3	64°01'47"N	127°24'31"W	64°01'44"'N	127°23'56"'W
# 038	179	217	>85							Tributary of Keel River	96D/5	64°15'12"N	127°42'22"W	64°15'24"N	127°41'16"'W
Published Sections (G = Gabrielse et al 1973; U, MQ = Aitken et al 1973)															
G 1								277	832	Tsezotene Range	95M	63°24'N	126°40'W		
G 2 =022	245	114	277	46	91	37	481	165	>336	Ridge S of Little Dal Lake	95L	62°38'N	126°32'30"W		
U 3				(see 017)				246	>196	Arctic Red River, east side	106G	65°14'N	131°01'W		
U 4			196	68	52	14	94			Arctic Red River, west side	106G	65°09'15"N	131°17'30"W		
U 5	155	133	>10	(see 024)						Arctic Red R., Tawu range	106G	65°04'N	130°40'W		
U 10	423	254		(See 009)						Deca Creek	106A/2	64°14'30N	128°26'30"W		
U 11		>75	236	37	16	24	>343			Loretta Canyon	96E	65°06'N	127°57'W		
U 12	41	108		(Close to 014)						Dodo Canyon	96D	64°52'30"N	127°13'W		
U 13	15	>118								Headwaters, Little Bear R	96D/7	64°29'N	126°52'W		
MQ 33	~78									Tributary of Keel River	96D	64°04'30"N	126°37'W		

Note: Boxes with solid outlines indicate the type section (shown here in bold)

Latitue and longitude verified using Google Earth images (2012)

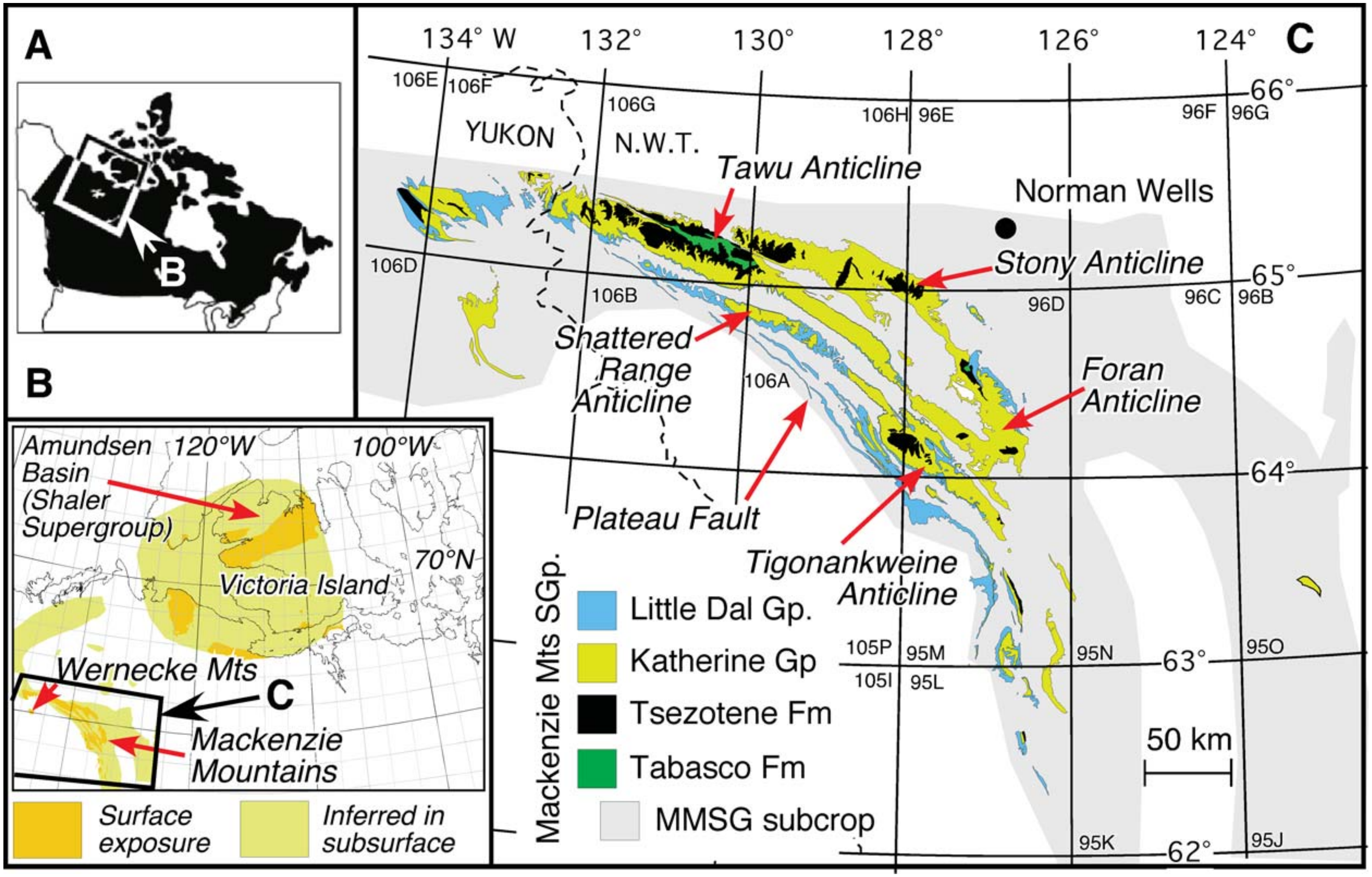

Figure 1. (A, B) Location and distribution of early Neoproterozoic strata in northwestern Canada. C) Exposure area of the Mackenzie Mountains Supergroup in the Mackenzie Mountains (NWT; based on Turner and Long, 2008).

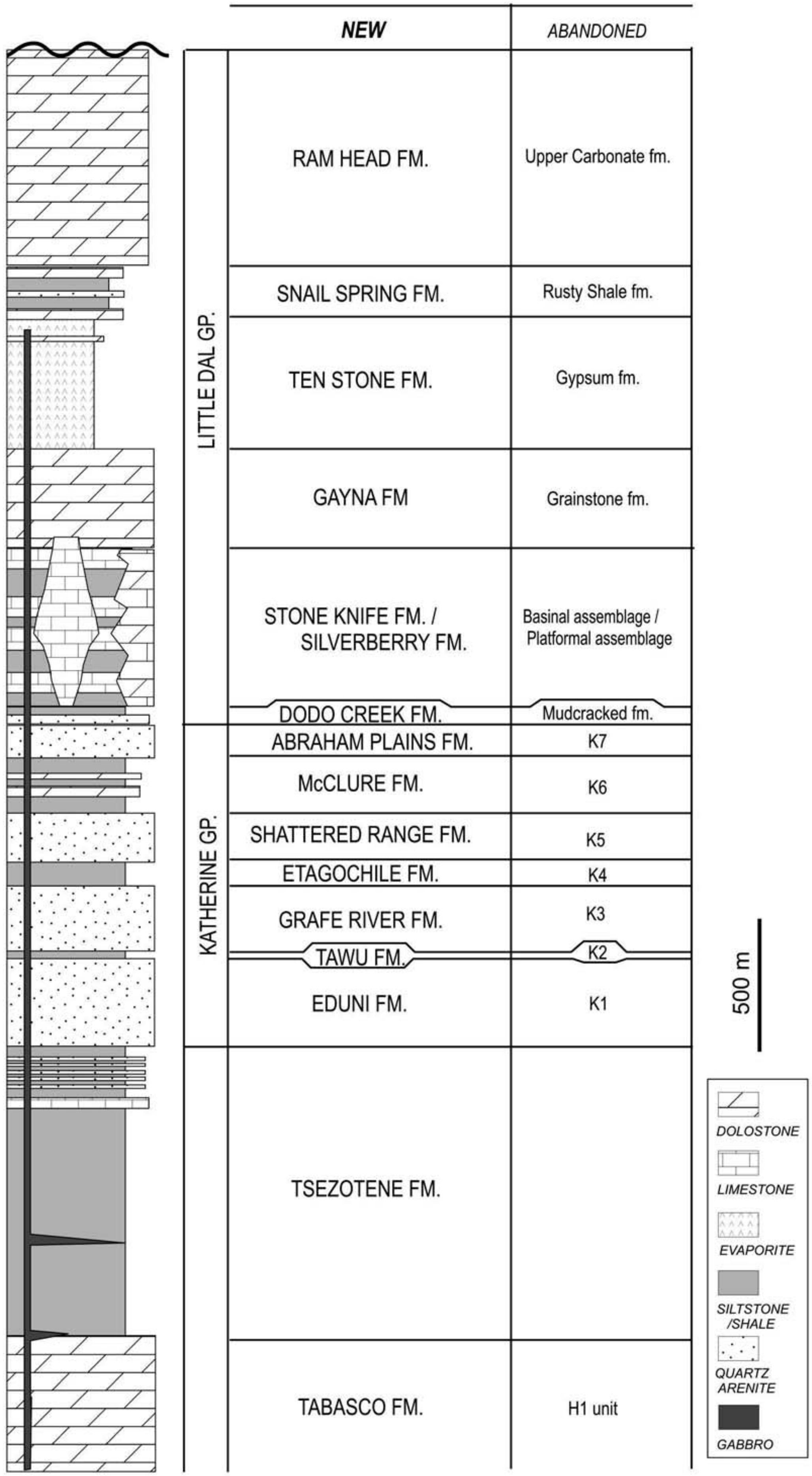

Figure 2. Generalised stratigraphy of the Mackenzie Mountains Supergroup.

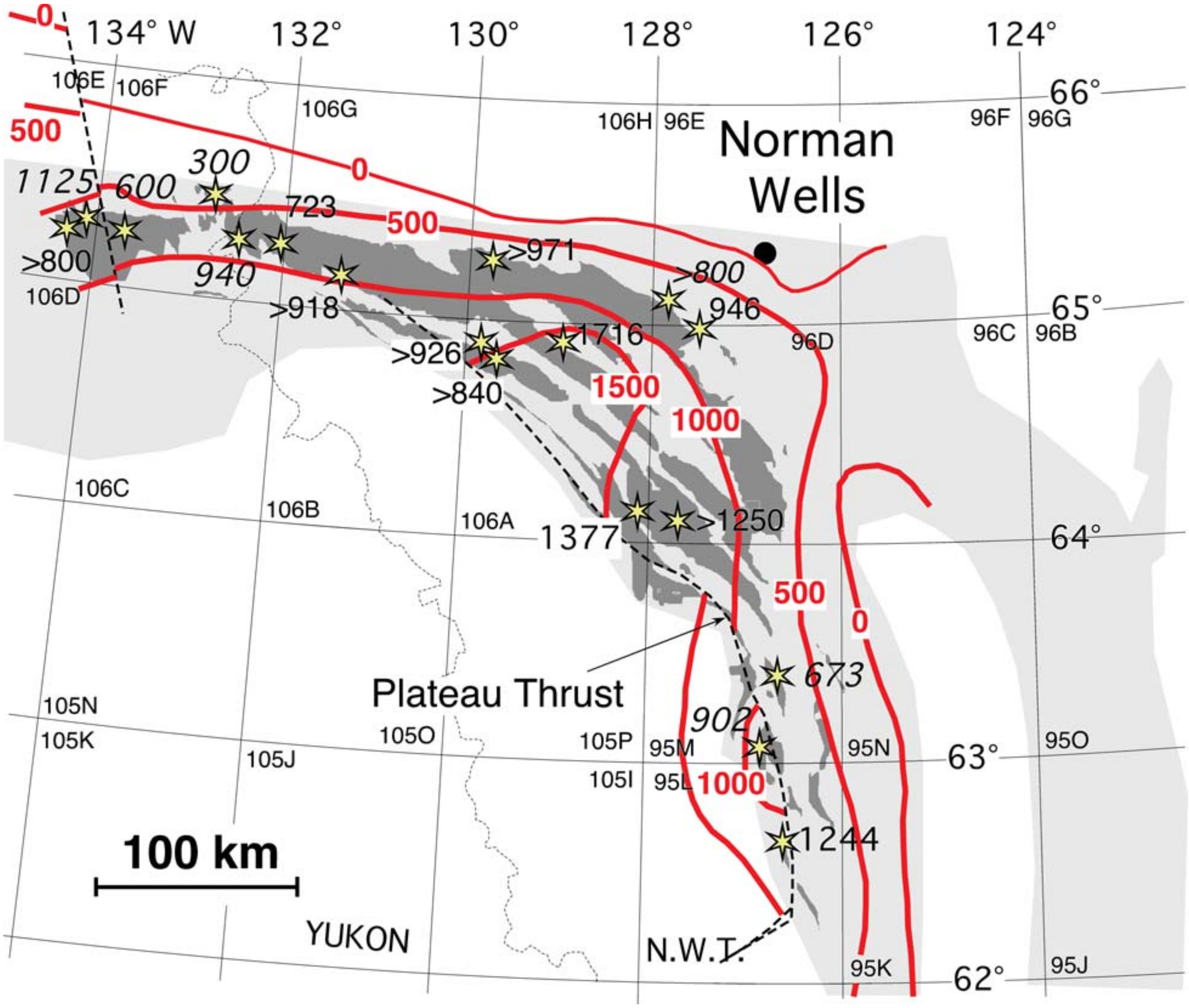

Figure 3. Regional thickness of the Katherine Group in metres. Dark grey indicates outcrop, pale grey indicates inferred subsurface extent.

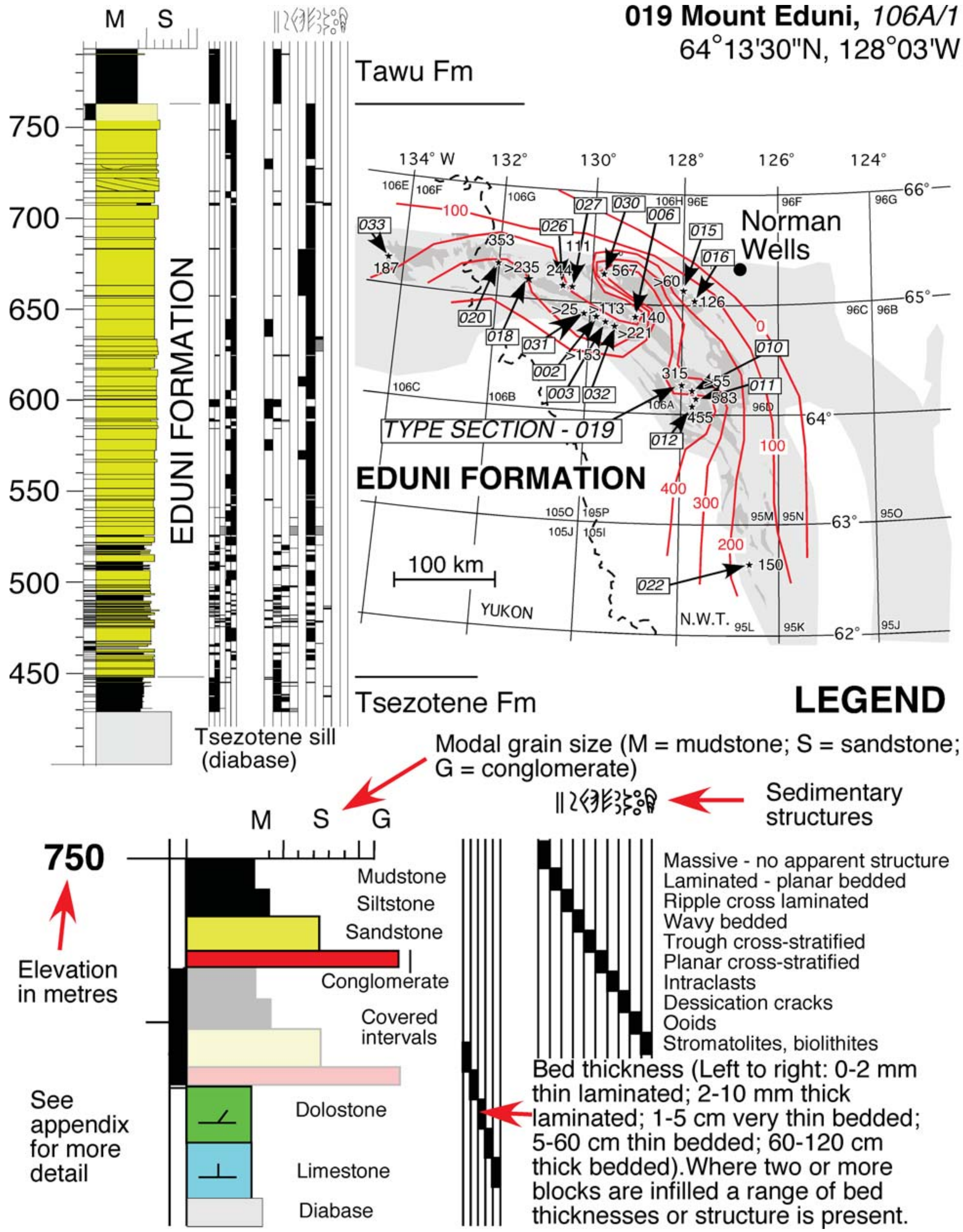

Figure 4. Left- Log of type section of Eduni Formation: legend at the bottom is for all stratigraphic columns in figures 4 to 10. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Light colours indicate inferred lithology in covered intervals. Right- isopach map for Eduni Formation: numbers in boxes refer to sections in the appendix. Further details of this and other sections are provided in Appendix 1.

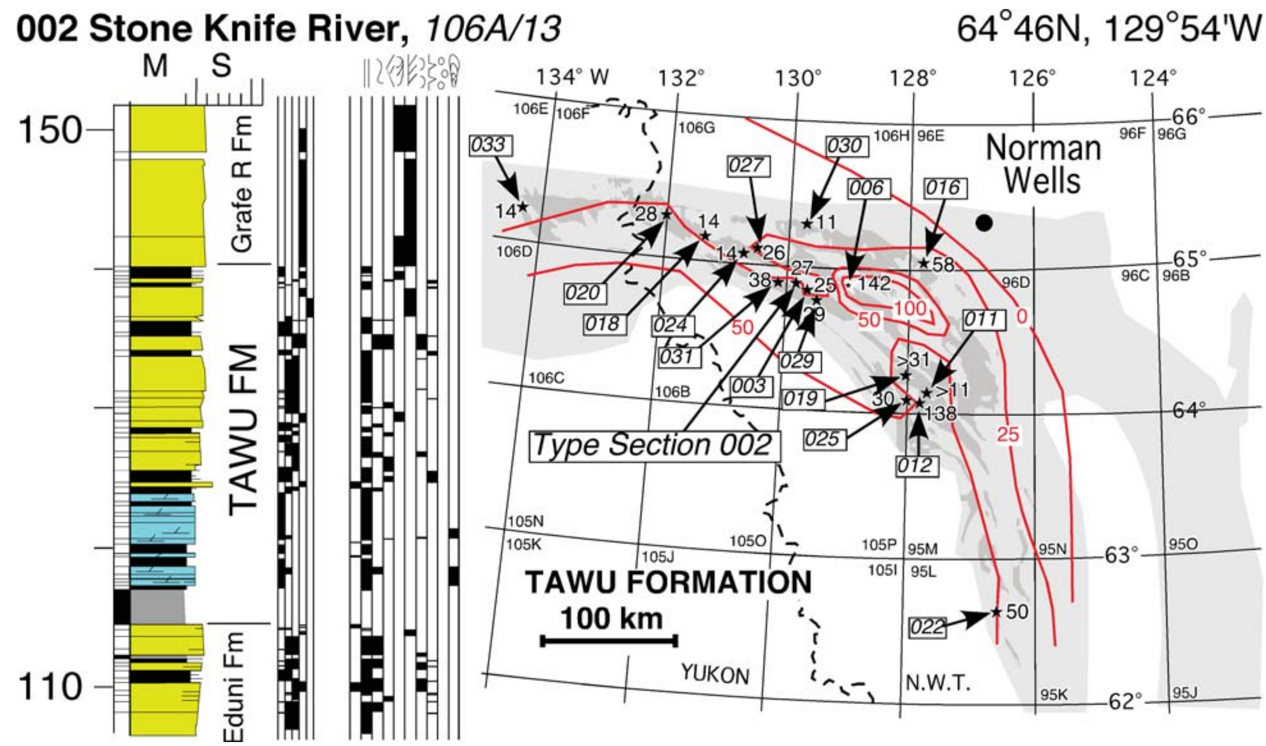

Figure 5. Left- Log of type section of Tawu Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Tawu Formation: numbers in boxes refer to sections in the appendix.

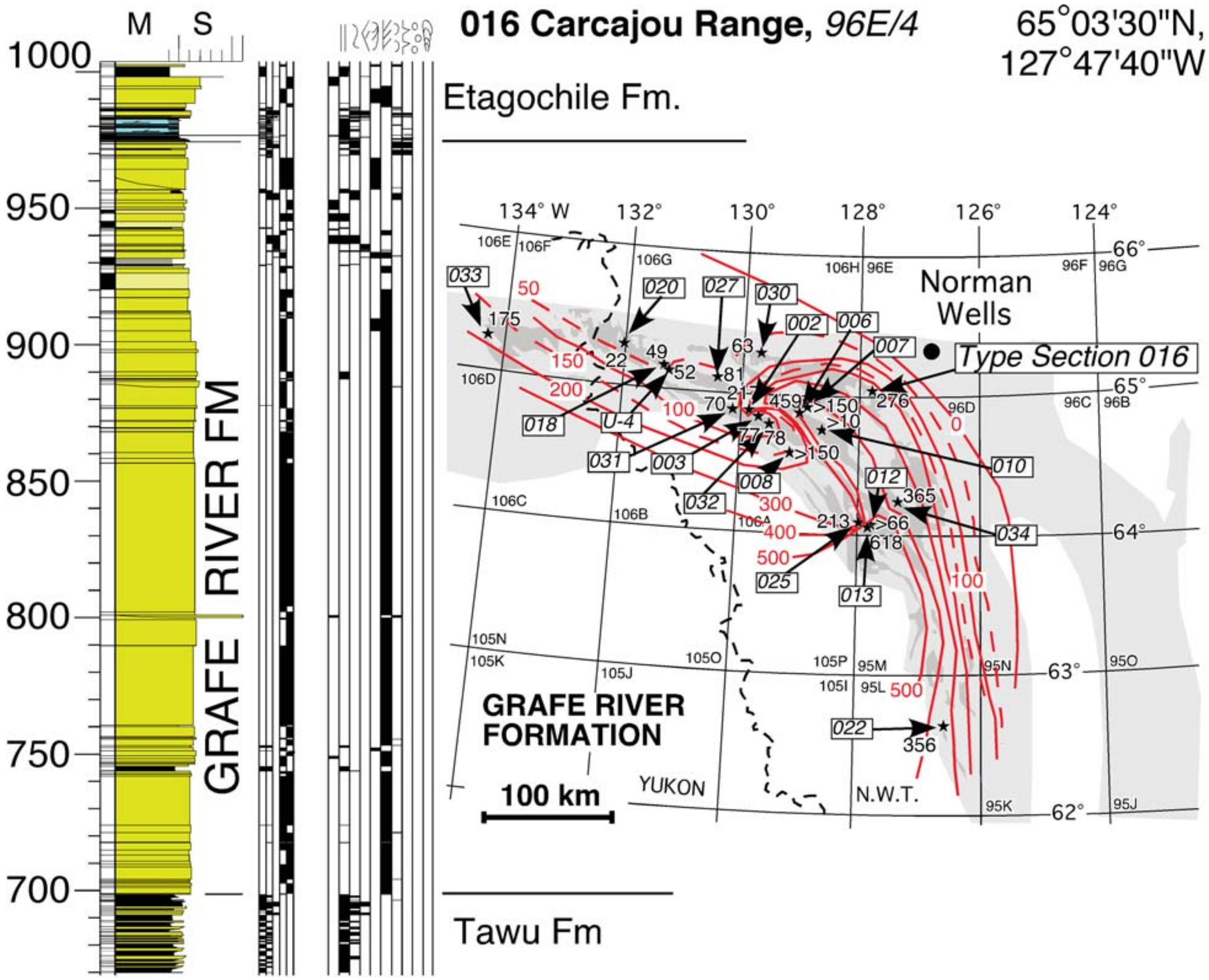

Figure 6. Left- Log of type section of Grafe River Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Grafe River Formation: numbers in boxes refer to sections in the appendix.

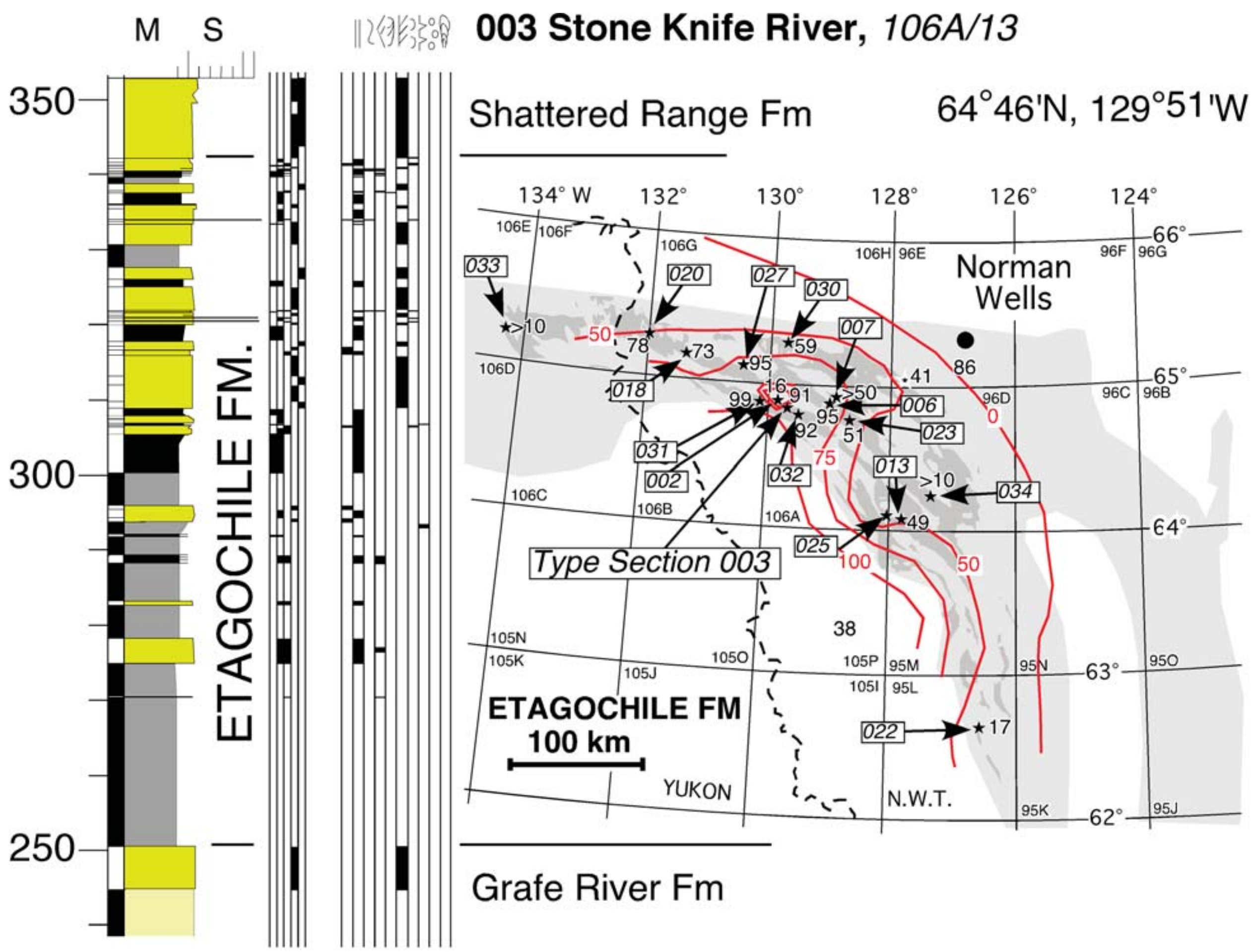

Figure 7. Left- Log of type section of Etagochile Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Etagochile Formation: numbers in boxes refer to sections in the appendix.

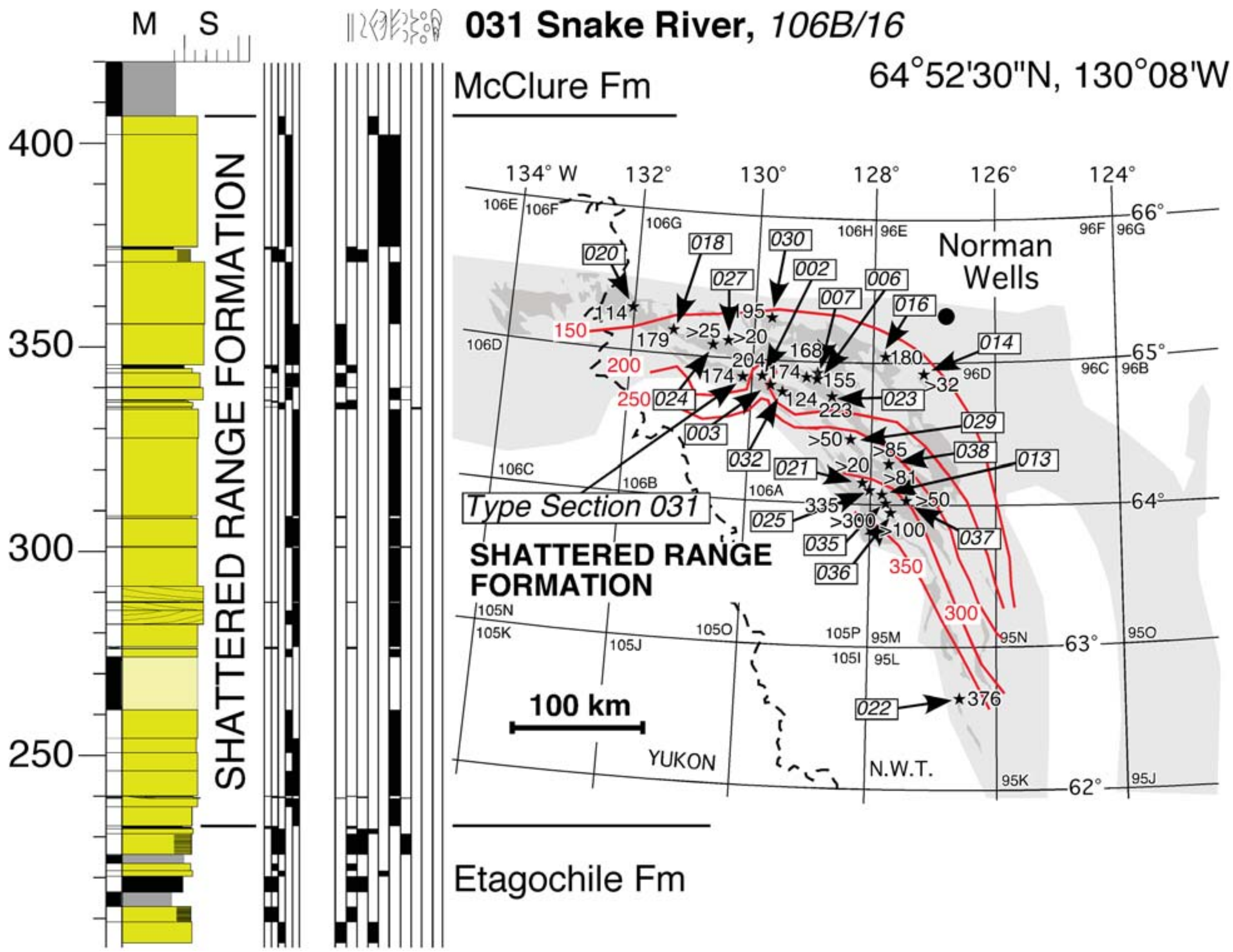

Figure 8. Left- Log of type section of Shattered Range Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Shattered Range Formation: numbers in boxes refer to sections in the appendix.

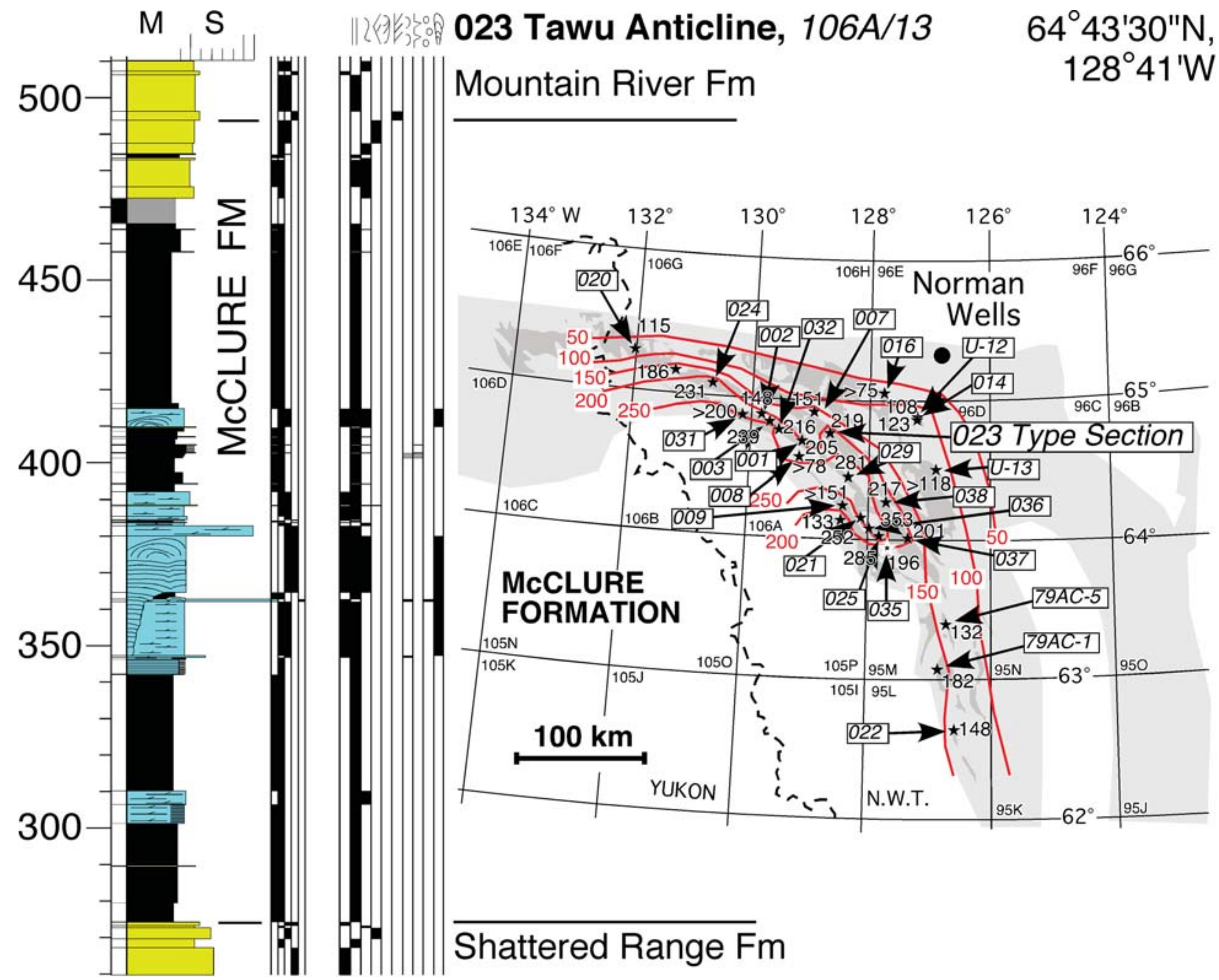

Figure 9. Left- Log of type section of McClure Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for McClure Formation: numbers in boxes refer to sections in the appendix.

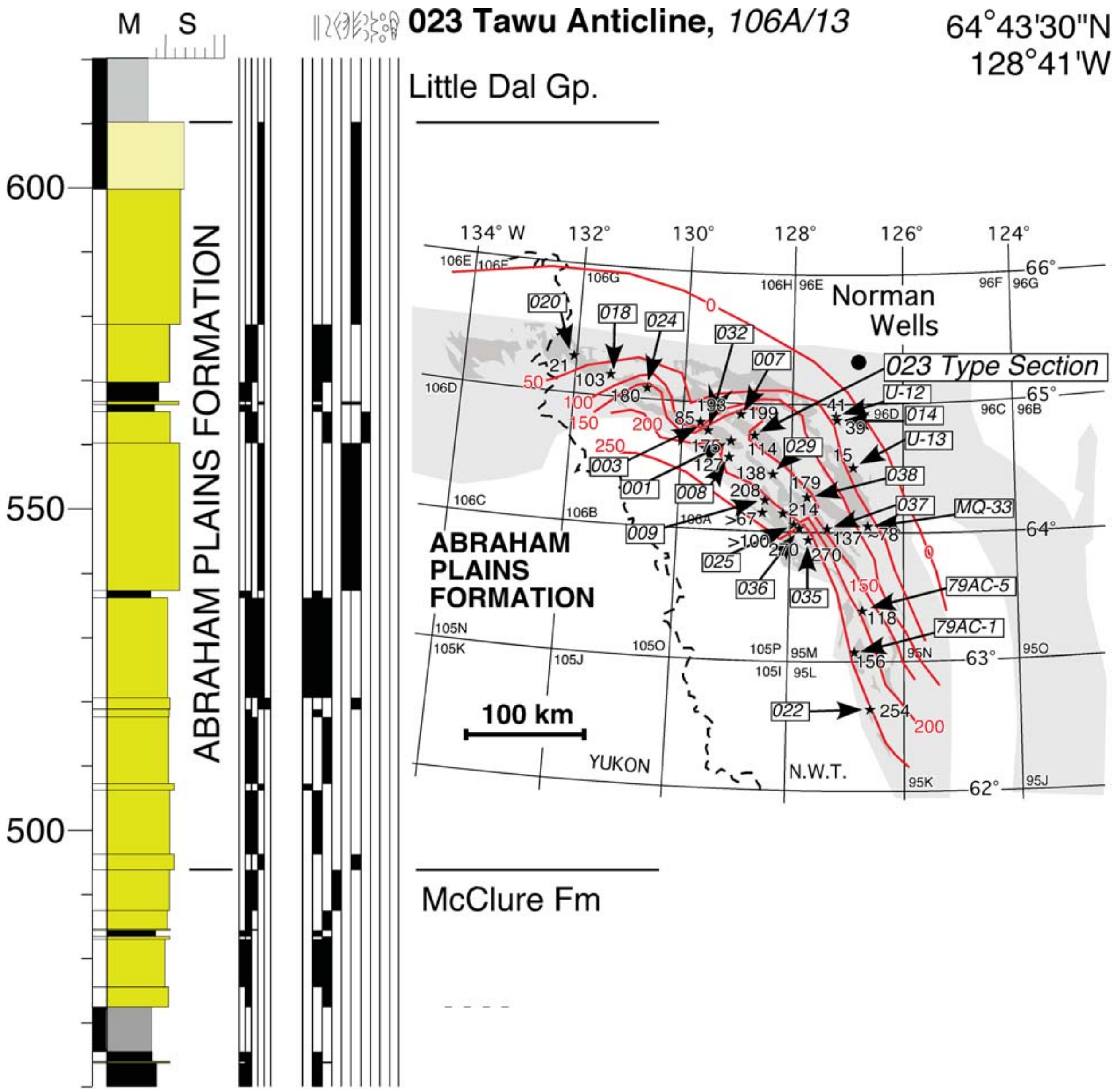

Figure 10. Left- Log of type section of Abraham Plains Formation: for legend see Fig. 4. Column profile indicates grain size. Yellow = sandstone (S), black = mudstone (M), blue = limestone, green = dolostone. Right- isopach map for Abraham Plains Formation: numbers in boxes refer to sections in the appendix.