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FOREWORD (PROVIDED BY GEM COORDINATION OFFICE)

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to responsible land-use and resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the 2018 field season, research scientists from the GEM program successfully carried out 18 research activities, 16 of which will produce an activity report and 14 of which included fieldwork. Activities applied a variety of geological, geochemical, and geophysical methods. These activities have been undertaken in collaboration with provincial and territorial governments, Northerners and their institutions, academia and the private sector. GEM will continue to work with these key partners as the program advances.

PROJECT SUMMARY

The fieldwork documented in this report is part of the **"Shield-to-Selwyn geo-transect: studying the evolution of sedimentary rocks of the northern mainland NWT"**. This activity is a regional, integrated effort to place the bedrock of Mackenzie Mountains, Franklin Mountains, and the adjacent interior plains into a modern stratigraphic framework, while updating bedrock maps for the Colville Hills and northern Mackenzie Mountains. This will better enable industry and Northerners to responsibly find and develop energy and mineral natural resources, while making informed land-use decisions, thereby helping to optimize economic and societal impact.

This report summarizes fieldwork in the Mackenzie Mountains, NWT, during July and early August, 2018 (Figure 1). Most of the work was in Bonnet Plume Lake (NTS 106-B) map area (Figure 2). At the end of the field season, we carried out several days of reconnaissance work in Wrigley Lake (NTS 95-M) map area (Figure 2), including several site visits in adjacent map areas: Glacier Lake (NTS 95-L) and Sekwi Mountain (NTS 105-P). The preliminary results presented here focus on bedrock geological mapping, stratigraphy, and structural geology.

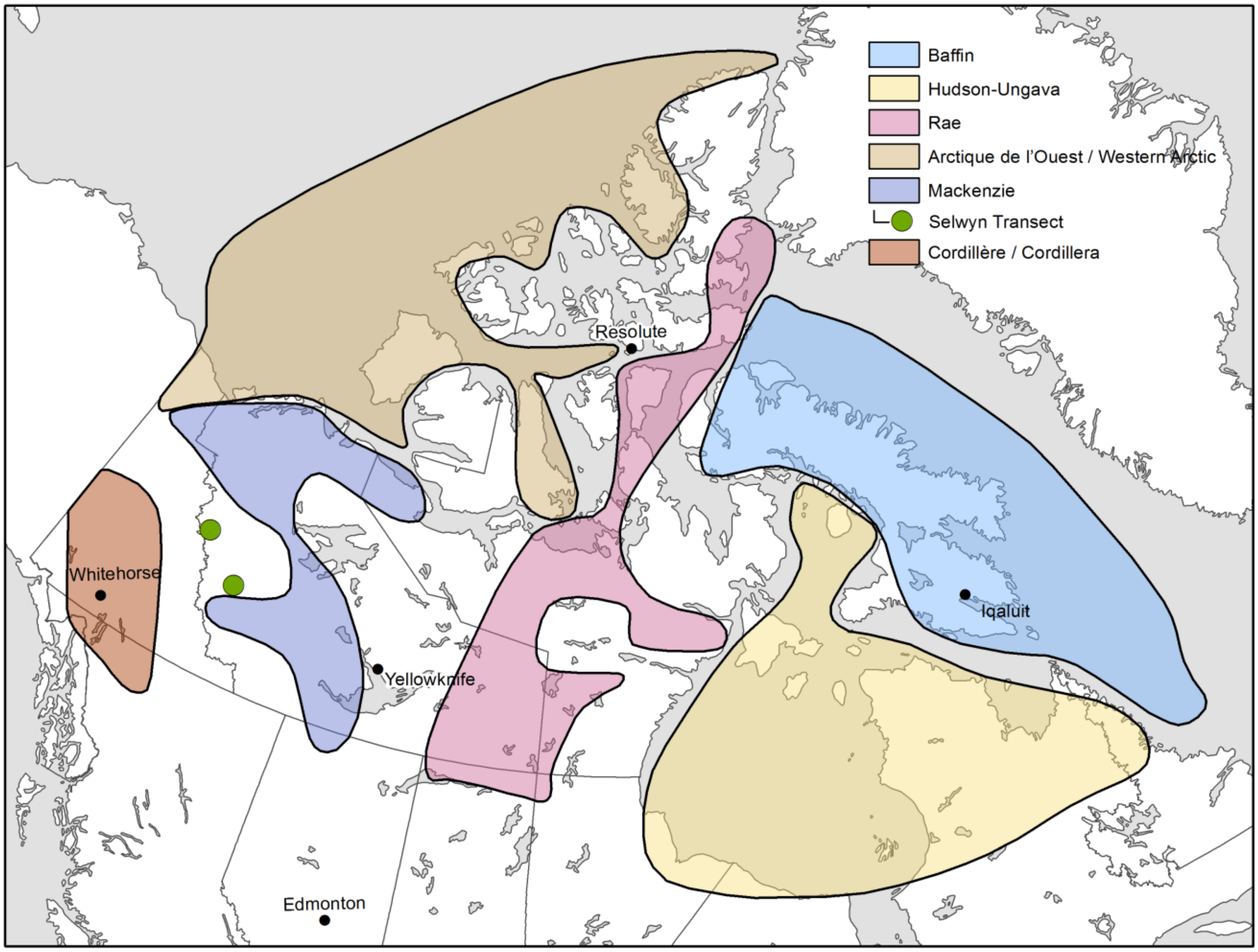


Figure 1: Location map, showing outlines of GEM-2 areas of interest. Green dots show generalized locations of study areas discussed in this report. See Figure 2 for a detailed location map of the study areas. This figure provided by the GEM Coordination Office.

INTRODUCTION

Fieldwork by the Geological Survey of Canada (GSC) in the Mackenzie Mountains of the Northwest Territories during the summer of 2018 (Figures 1 and 2) had two primary purposes. First, 1:100 000 scale bedrock mapping was undertaken in the northern half of Bonnet Plume Lake map area (NTS 106B), with the goal of completing the mapping begun in that region the previous summer (MacNaughton et al., 2017). This part of the work included supporting stratigraphic studies on Proterozoic, Cambrian, Ordovician, and Silurian units. Second, attention was given to resolving several longstanding questions regarding structural relationships and Neoproterozoic-Cambrian stratigraphy in Wrigley Lake (NTS 95-M) and adjacent map areas (Glacier Lake: NTS 95L; and Sekwi Mountain: NTS 105-P). While operating in NTS 106-B, the main field party provided logistical support to a small party from Laurentian University and to a combined party from Stanford University and Dartmouth College. However, the present report deals only with the work of the main GSC party.

Bedrock map units exposed in the two study areas range in age from Neoproterozoic to Devonian (Figures 3 and 4). GSC previously mapped NTS 106-B at reconnaissance scale, which led to the publication of hand-drafted, hand-lettered GSC Open File maps (Aitken and Cook, 1974; Blusson, 1974). More recently, Fischer (2016) remapped or recompiled parts of NTS 106B. New mapping for that work focused on the southern part of the map sheet. The published GSC map for NTS 95-M was part of the GSC "A" Series (Gabrielse et al., 1973) and was based on fieldwork conducted in the 1960s. The GSC Memoir that accompanied the map (Gabrielse et al., 1973) established important elements of the lithostratigraphic framework of the Mackenzie Mountains. More recently, part of the southern edge of the map was mapped at 1:50 000 scale (Colpron and Augereau, 1998) and the northwest quadrant of the map area was mapped at 1:100 000 scale (Fallas et al., 2011).

The present report provides a preliminary account of the summer's fieldwork, focusing on bedrock mapping, structural geology, and Proterozoic to lower Paleozoic stratigraphy. Most of the discussion and results presented deal with the NTS 106B study area, but a brief summary of results for NTS 95-M also is presented.

METHODOLOGY

Field activities took place in NTS 106-B between July 4 and July 25, and in NTS 95-M between July 27 and August 3. Work in NTS 106-B was staged from a base camp at Poacher Lake, along the western edge of the map area (Figure 2)[a]. Work in NTS 95-M and adjacent areas was staged from Norman Wells. During work from the Poacher Lake base camp, two full and four part days were lost to rain and low cloud ceilings. During the work in NTS 95-M, three full days and one part day were lost to bad weather.

Bedrock Geological Mapping

Bedrock exposure in the Mackenzie Mountains is good to excellent, particularly on peaks and ridges. However, the terrain in NTS 106-B is steep and includes many precipitous cliffs, particularly in areas underlain by resistant-weathering Neoproterozoic and lower Paleozoic strata. This makes foot

[a] Poacher Lake is an informal name but is widely used by outfitters, guides, and helicopter and fixed-wing companies working in the region.

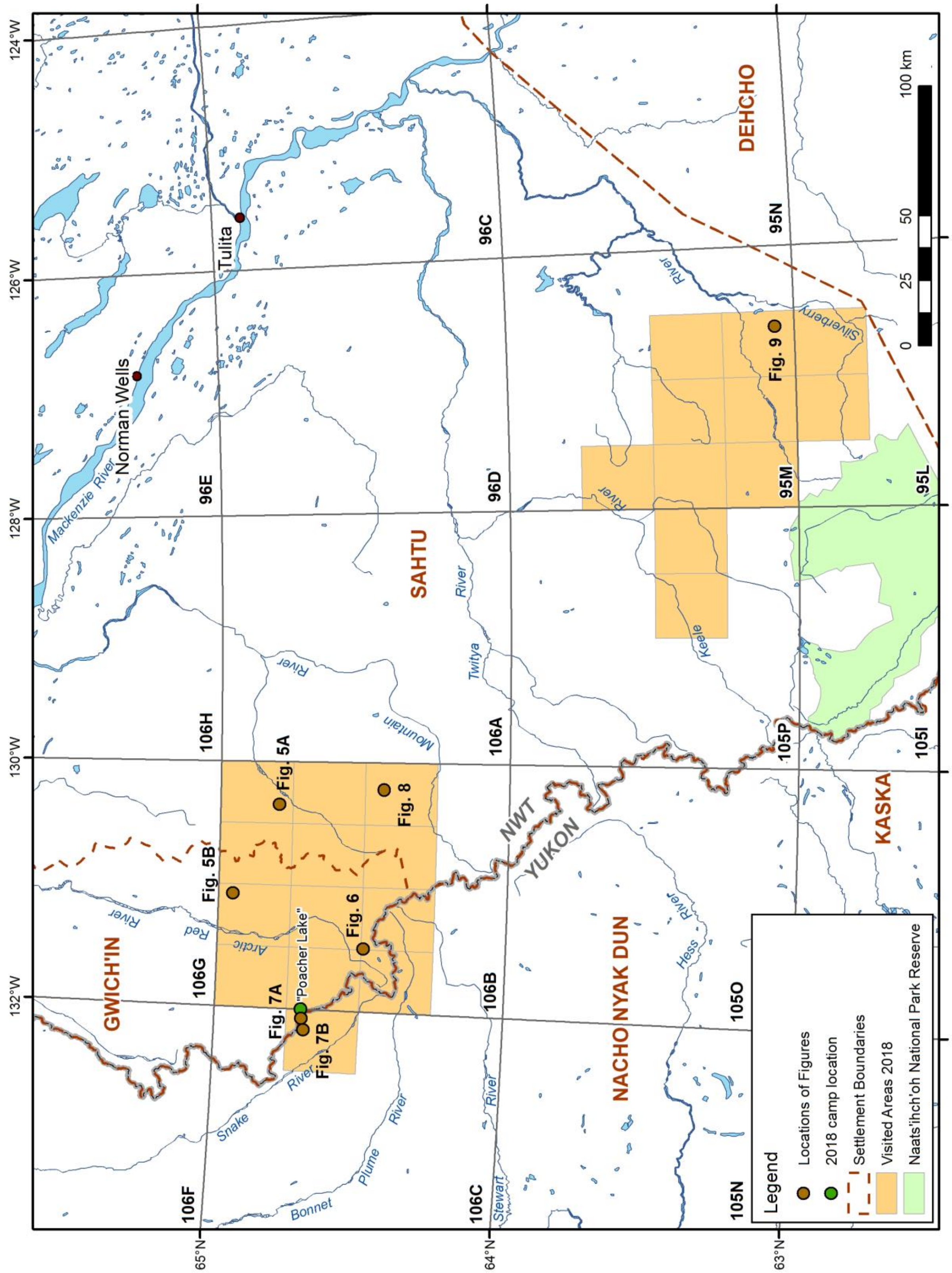


Figure 2: Map showing areas of 2018 GSC fieldwork in Mackenzie Mountains, with boundaries between Land Settlement Areas and Land Claim Areas. Locations of photo illustrations in other figures are labelled.

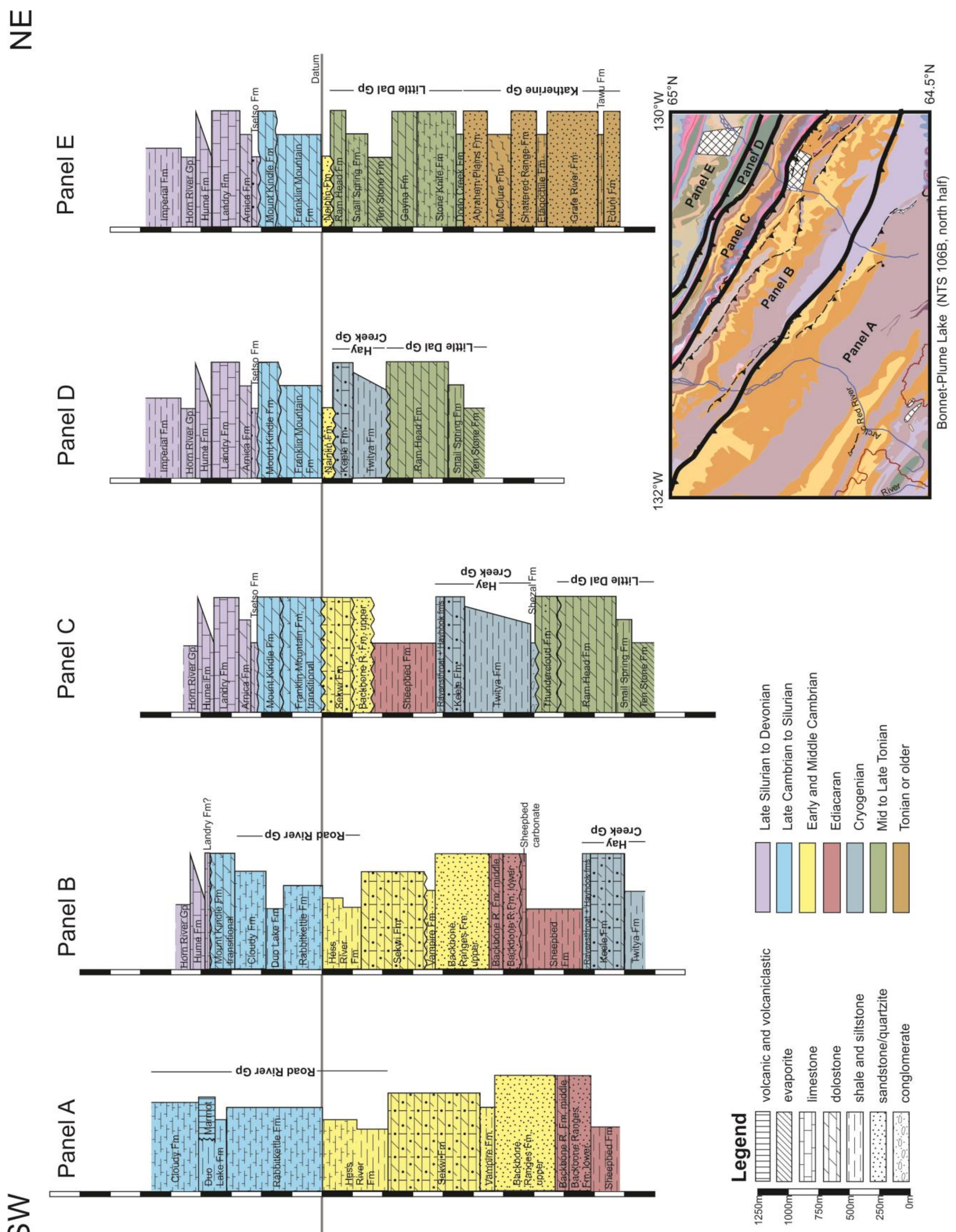


Figure 3: Stratigraphic relationships within the NTS 106-B study area. Each column shows the order and approximate thickness of units within structural domains as delineated in the map key. This figure previously appeared in MacNaughton et al. (2017).

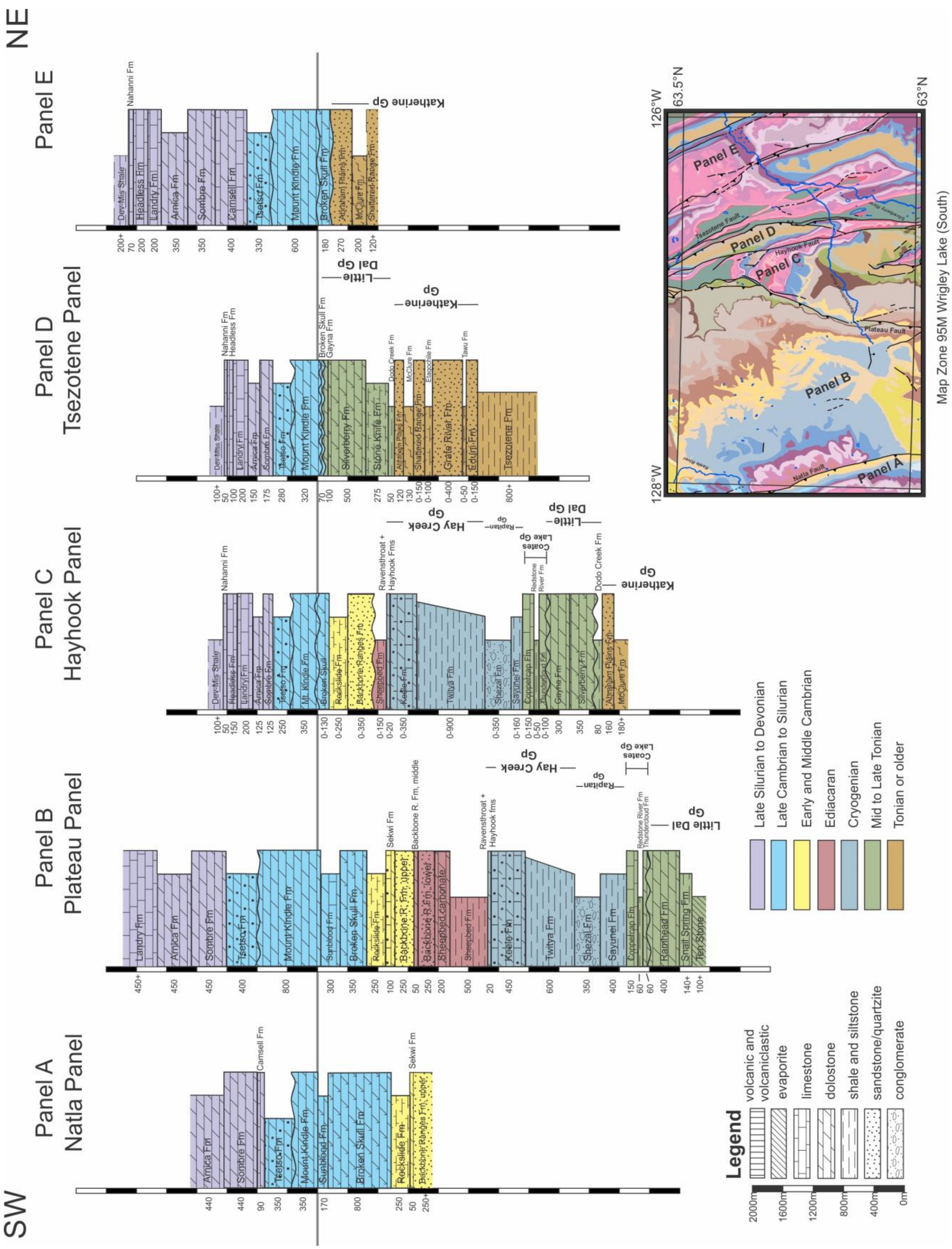


Figure 4: Stratigraphic relationships within the NTS 95-M study area. Each column shows the order and approximate thickness of units within structural domains as delineated in the map key. Map key modified after Gabrielse et al. (1973).

traverses difficult to plan and conduct. Mapping in river valleys is hampered by Quaternary cover. As was reported for the 2017 field season (MacNaughton et al., 2017), helicopter spot-checking is the most efficient means of bedrock mapping, augmented by foot traverses and measured sections where possible. This was particularly true for the focused bedrock mapping in NTS 106-B, and also for the more selective studies in NTS 95-M. Fallas had the primary responsibility for planning and conducting bedrock mapping in 2018.

Stratigraphic Studies

The “Mackenzie-Selwyn” activity is part of the “Shield to Selwyn geo-transect”, a longer-term initiative that aims, in part, to improve understanding of Proterozoic to Silurian stratigraphy (Figures 3 and 4) and tectonics between the Brock Inlier and the northeast edge of Selwyn Basin. During fieldwork in NTS 106-B, partial or complete sections were measured through the Sheepbed Formation, the “Sheepbed carbonate”, the Backbone Ranges Formation, and the Cloudy Formation. Collections for biostratigraphy, stable-isotope chemostratigraphy, and detrital-zircon geochronology were made from several of these units. During 2018, MacNaughton had the primary responsibility for planning and conducting stratigraphic studies.

RESULTS

Bedrock Geological Mapping, NTS 106-B

GSC bedrock geology maps for NTS 106-B (Aitken and Cook, 1974; Blusson, 1974) reflect the lithostratigraphy that was current in the 1960s and early 1970s. Work in 2018 continued the last two summers’ efforts (Fallas et al., 2016; MacNaughton et al., 2017) to apply current lithostratigraphic units in the northern Mackenzie Mountains, building also on the efforts of Fischer (2016). Project maps will update the lithostratigraphy of the following large-scale stratigraphic packages: Mackenzie Mountains Supergroup (Long and Turner, 2011; Turner and Long, 2011); Rapitan and Hay Creek groups (Gabrielse et al., 1973; Yeo, 1978; Eisbacher, 1978; Turner et al., 2011); Devonian platformal units (Morrow, 1991); and Cambrian to Silurian units of the basinal Road River Group (Cecile, 1982). Figure 3 summarizes the current lithostratigraphic framework of the NTS 106-B study region.

The exposed stratigraphy changes from northeast to southwest across the map area (Figure 3). Structural panels in the northeast expose rocks of the Tonian Mackenzie Mountains Supergroup (Tsezotene Formation, Katherine Group, and Little Dal Group), which are overlain unconformably by Middle to Late Cambrian strata. Cryogenian to Middle Cambrian units appear incrementally southwest of the Plateau Fault. Several of these units thicken and show an increasingly distal sedimentary character to the southwest. This change to the southwest also is displayed in the transition from Paleozoic platform carbonates (Mackenzie Platform) to more basinal rocks of the Road River Group (Selwyn Basin/Misty Creek embayment). Notwithstanding the significant stratigraphic complexity within the Road River Group, as documented in published measured sections (Cecile, 1982), it was possible to recognize workable map-scale units using established formation names.

Of note from an economic perspective, strata of the Tonian Coates Lake Group (Thundercloud and Coppercap formations) were documented at several locations in the hanging-wall of the Plateau Fault (Figure 5). These units, not previously recognized in NTS 106-B, are part of the “Redstone

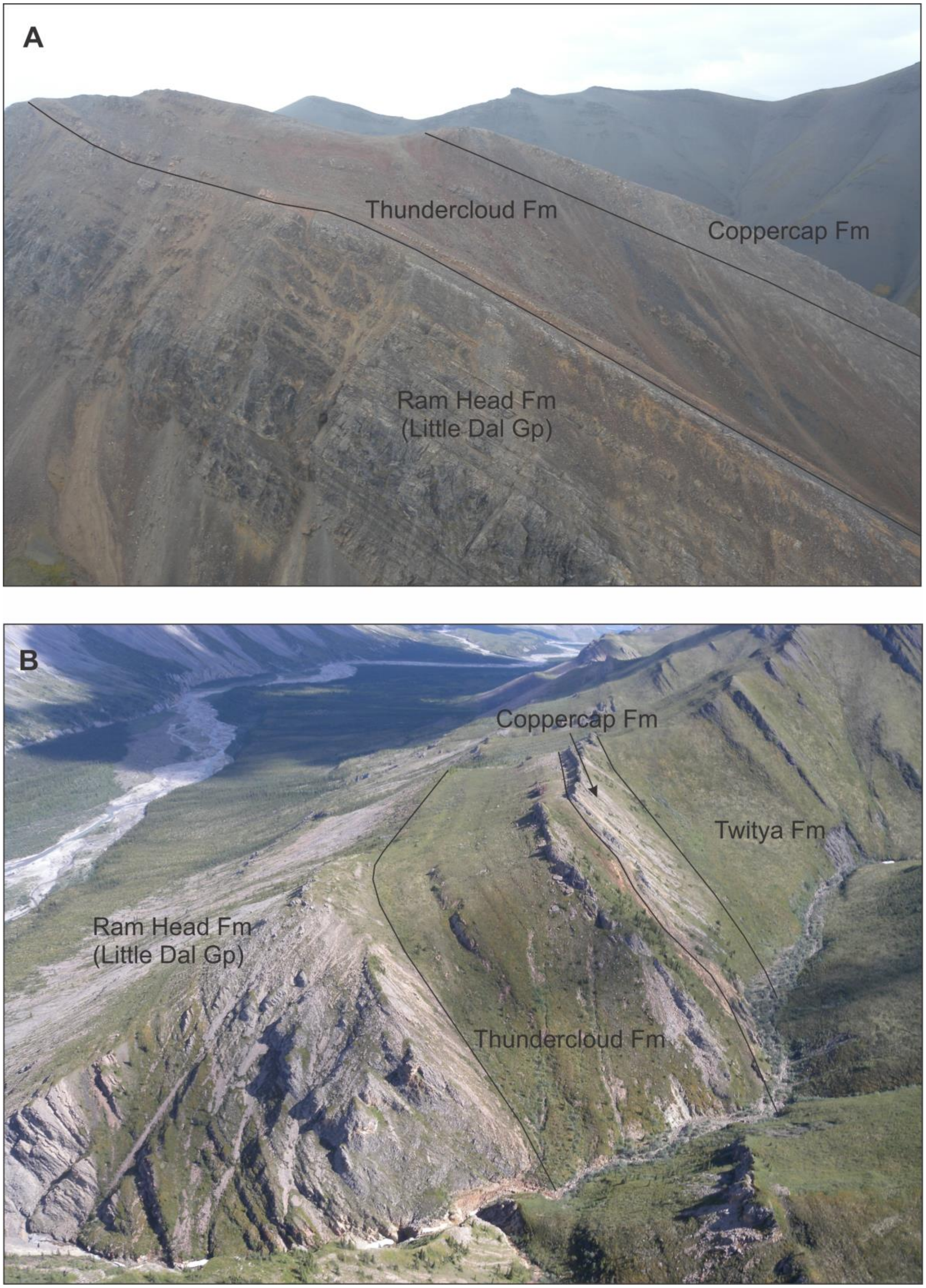


Figure 5: Coates Lake Group (Thundercloud and Coppercap formations) exposed in the hanging wall of the Plateau Fault in NTS 106-B. Strata in A located at 64.797881, -130.350652 (NAD83); view is looking to south. Strata in B located at 64.952091, -131.075250 (NAD83); view is looking to southeast. Except where noted, these and all other cited coordinates were measured by GPS in the field. Thundercloud Formation is approximately 150 m thick in photo A and approximately 160 m thick in photo B.

Copper Belt" and have been extensively explored to the southeast, around the headwaters of Redstone River (Jefferson and Ruelle, 1986). Ozyer (2012) previously recognized an area of moderate copper exploration potential that is roughly coincident with some of the newly recognized occurrences of the Coates Lake Group.

During the bedrock mapping, sandstone samples were collected from units in the Katherine Group (Mackenzie Mountains Supergroup), Coates Lake Group, and Hay Creek Group for detrital-zircon studies. These samples will form the basis for a BSc thesis project by Edgeworth, aimed at addressing controversies regarding the stratigraphic affinities of the Coates Lake Group (see, e.g., discussions in Jefferson and Parrish, 1989; Aitken, 1991; and Long et al., 2008).

MacNaughton et al. (2017) described the general structural style of the Mackenzie Mountains in the Bonnet Plume Lake map area. Structural work in 2018 focussed on clarifying the links between major faults and distinguishing extensional versus contractional movement on steeply-dipping faults. A newly recognized structural feature from 2018 field work is a set of north-south trending dextral strike-slip faults cut by back-thrusts, found 2-8 km north of Misfortune Lake (Figure 6). One fault from this set had been mapped by Blusson (1974), but the dextral offset had not been recognized. The map published by Fischer (2016) also shows one of these faults with an apparent dextral offset but without designating the fault as strike-slip. This dextral fault set is truncated to north and south by back-thrusts associated with Cordilleran deformation, and it is currently unclear why this fault set has developed in this location.

Stratigraphic Studies, NTS 106-B

During the 2018 field season, most stratigraphic studies dealt with the Ediacaran-Cambrian succession in the central and southwestern part of NTS 106-B. This work focused on map units that will require formalization prior to the publication of project maps. Two sections were measured through the informal "Sheepbed carbonate" (Figure 7A). This unit previously was considered part of the Gametrail Formation of Aitken (1989), but subsequently was excluded from it based on evidence from carbon-isotope chemostratigraphy (Macdonald et al., 2013). In the studied sections, the unit is dominated by dolostone, commonly particulate, with lesser amounts of dolomitic/calcareous sandstone. The "Sheepbed carbonate" is a mappable unit and we anticipate returning it to the status of a formal, properly named formation.

The main subject of GSC stratigraphic studies was the Backbone Ranges Formation of Gabrielse et al. (1973). This widespread unit has its type section well to the southeast, in NTS 95-L, where it is more than 1 km thick and consists of a basal siliciclastic member, a middle carbonate member, and an upper member dominated by cliff-forming quartz arenite. It has been mapped across several NTS 1:250 000 map areas, including NTS 106-A, immediately east of the present study area (Martel et al., 2011). Notwithstanding its widespread distribution, the regional correlation of the unit has been controversial (compare, e.g., Aitken, 1989, and Fritz et al., 1991). During the 2018 field season, two sections were measured through the lower member, confirming its mainly siliciclastic, sandstone-dominated character. However, the sections also suggest that a unit dominated by siliciclastic mudrocks may be present between the lower member and the underlying Sheepbed carbonate (Figure 7A). This finer-grained unit may be a tongue of the informal Nadaleen formation recognized in nearby parts of Yukon by Moynihan (2014). A similar unit in this position was documented during the 2017 field season in the western part of NTS 106A (MacNaughton et al., 2017).

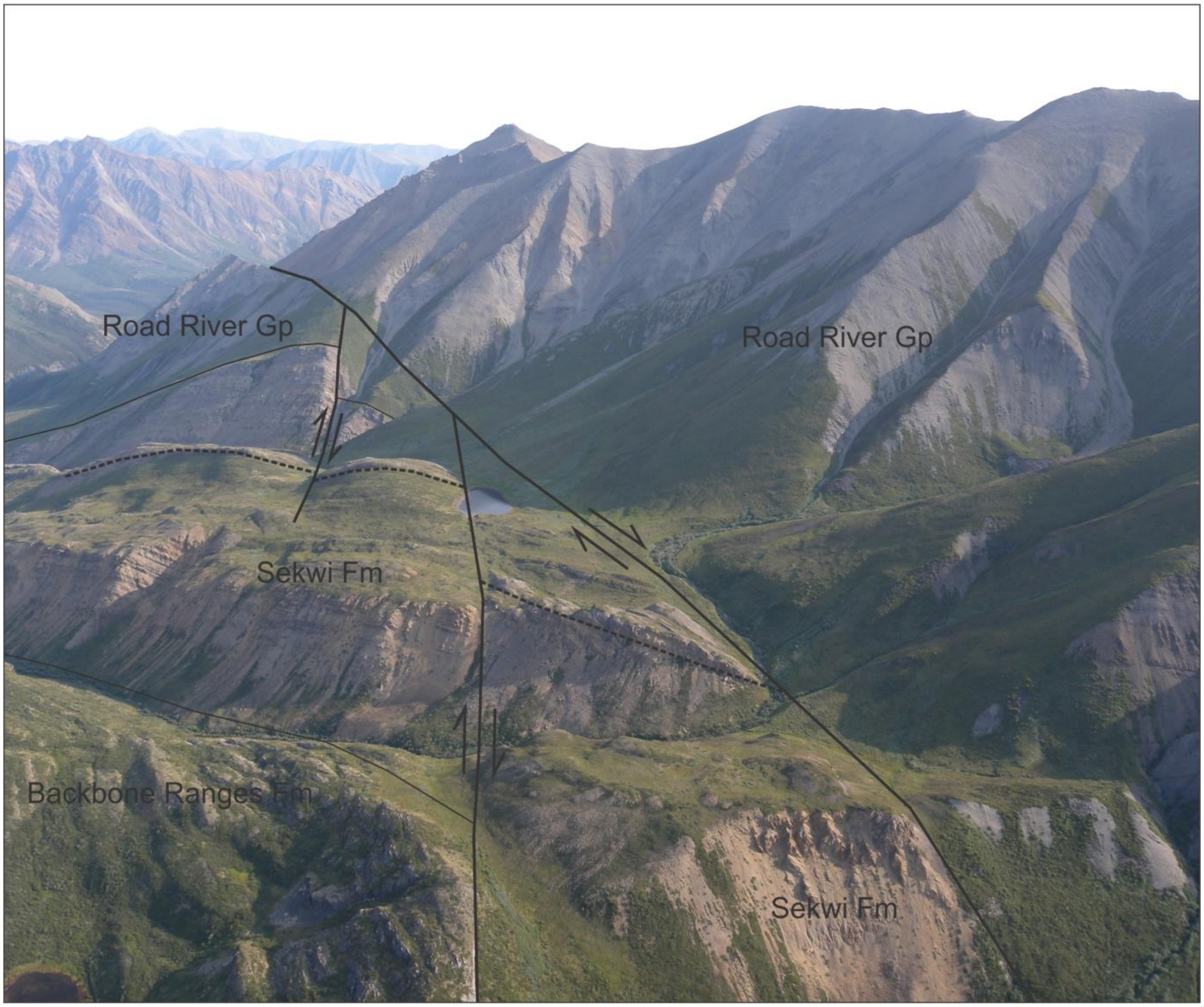
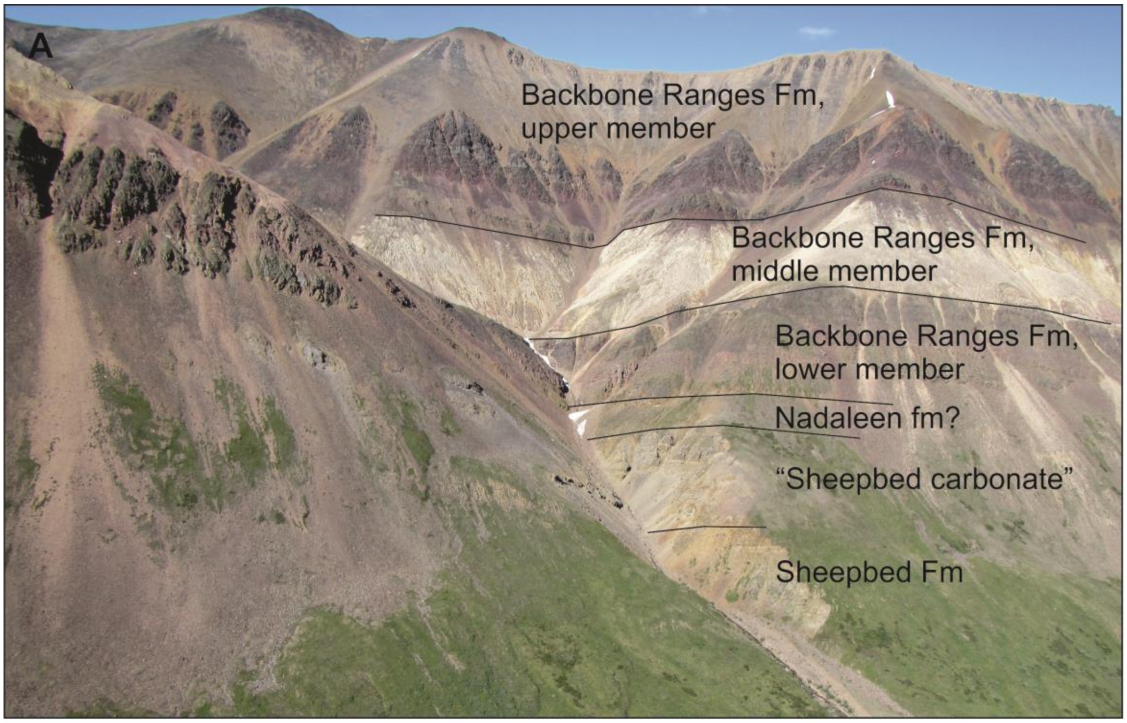


Figure 6: View looking approximately north from 64.481422, -131.497311 (NAD83) at part of a set of dextral strike-slip faults north of Misfortune Lake in NTS 106-B. Relief from lower foreground to top of ridge is approximately 700 m.

The middle member of the Backbone Ranges Formation was the focus of one measured section, where it included the pink to grey intraclast rudstones (“flat-pebble conglomerates”) with maroon shale partings that characterize it in other areas (e.g., Gabrielse et al., 1973; MacNaughton et al., 1999, 2008). The top of the middle member locally preserves evidence for karst, including grikes filled with quartz-pebble conglomerate.

During the latter part of the 2017 field season, it became apparent that the upper member of the Backbone Ranges Formation displayed greater stratigraphic complexity in the southwest part of NTS 106B than had been recorded in other areas. During the 2018 field season, several sections were measured to document this complexity. The upper member in this area may be divisible into at least four mappable, formation-scale units (Figure 7B). A basal, semi-resistant succession (Unit A: approximately 225 m thick) is dominated by maroon and grey weathering sandstone and siltstone, and contains a distinctive medial marker of grey-weathering, platy, locally fetid limestone. The basal unit is overlain in turn by a mainly recessive succession (Unit B: approximately 170 m thick) dominated by brown siltstone with lesser sandstone and dolostone. This succession is capped by a grey- to orange or brown-weathering carbonate that is generally only a few metres thick in the project area, but that thickens into a potentially mappable unit to the south and west. Above this is a second recessive succession (Unit C: approximately 50 m thick), consisting of brown siltstone and sandstone and locally containing abundant trace fossils. The uppermost part of the succession is dominated by quartzite (Unit D: approximately 220 m thick) that mimics the cliff-forming character of the upper Backbone Ranges Formation as seen in other areas. These newly recognized subdivisions of the upper member may form the basis for new units when the project maps are published. Since they are subdivisions of the upper member, it currently would be necessary to define them as submembers. However, their mappable scale and significant lateral distribution emphasizes the long-standing need for a review and revision of the Backbone Ranges Formation. The completion of such a review will be a major focus of our efforts in the coming months.

Martell measured a 712 m section within the Cloudy Formation (Figure 8). This is part of an ongoing study of the Late Ordovician-Silurian Cloudy and Mount Kindle formations (MacNaughton et al., 2017). Samples were collected for thin section and stable isotope analysis, and conodont samples for biostratigraphic correlation. The lower 350 m of the section consisted mainly of nodular, thin-bedded, grey to dark grey lime mudstone (Figure 8) with common chert beds/nodules. The upper 362 m of the section consists of thin- to medium-bedded, grey to dark grey lime mudstone with frequent crinoid wackestone to grainstone interbeds. The Cloudy Formation here is capped by 75 m of skeletal grainstone interbedded with coral-bryozoan bafflestone of the Mount Kindle Formation. The abundance of dark coloured lime mudstone, lack of macrofossils and occasional wackestone to grainstone beds indicates the Cloudy Formation was deposited in a deeper water environment of the Misty Creek Embayment. The overlying Mount Kindle Formation records a substantial shallowing. Analyzing thin sections will aid in determining depositional environment, and stable isotope samples will be used to reconstruct paleoclimate and temporal constraints for these strata.



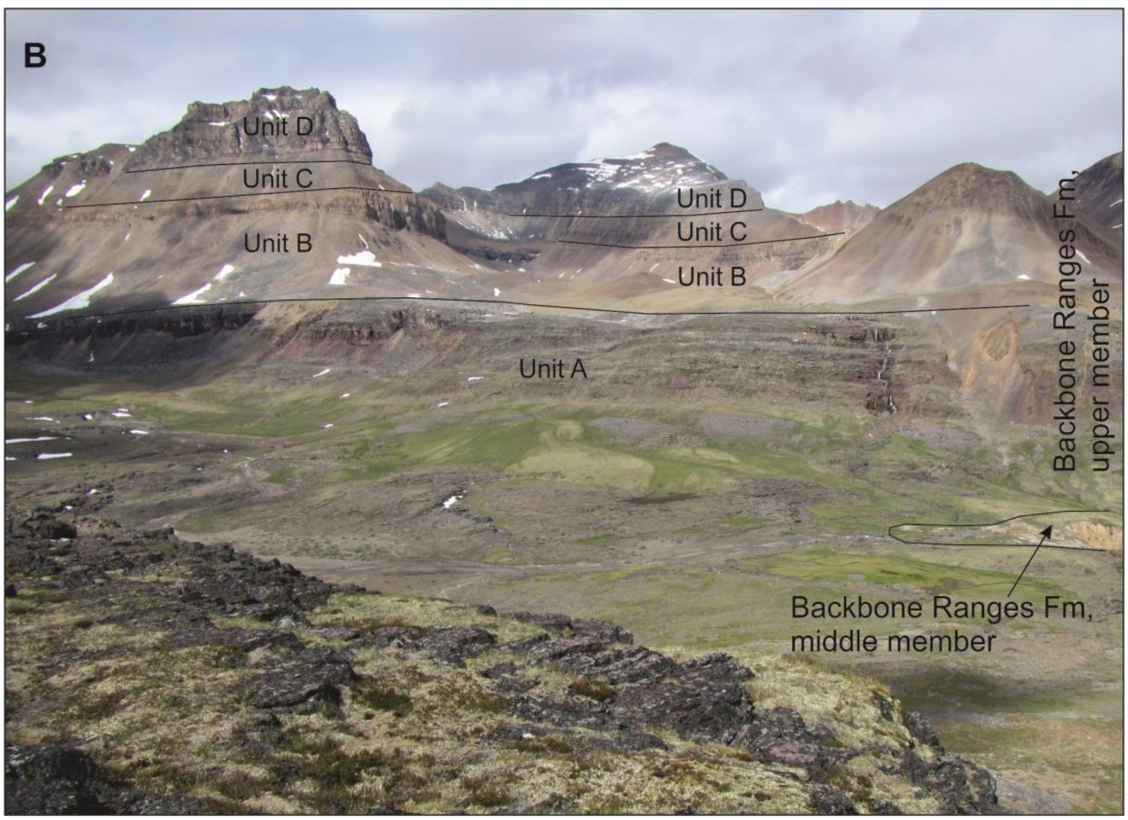


Figure 7: Ediacaran-Cambrian stratigraphy, headwaters of Reptile Creek. A. Sheepbed Formation to Backbone Ranges Formation. Lowest exposures of Sheepbed Formation along creeek are at 64.69656001, -132.07110168 (NAD83); view is to northeast. Middle member of Backbone Ranges Formation in this area is approximately 100 m thick. B. Internal divisions of upper member, Backbone Ranges Formation. Unit labels are keyed to descriptions in the text. Unit C is approximately 50 m thick. Photograph looking northwest from 64.685042, -132.132602 (NAD83; coordinates from digital imagery).

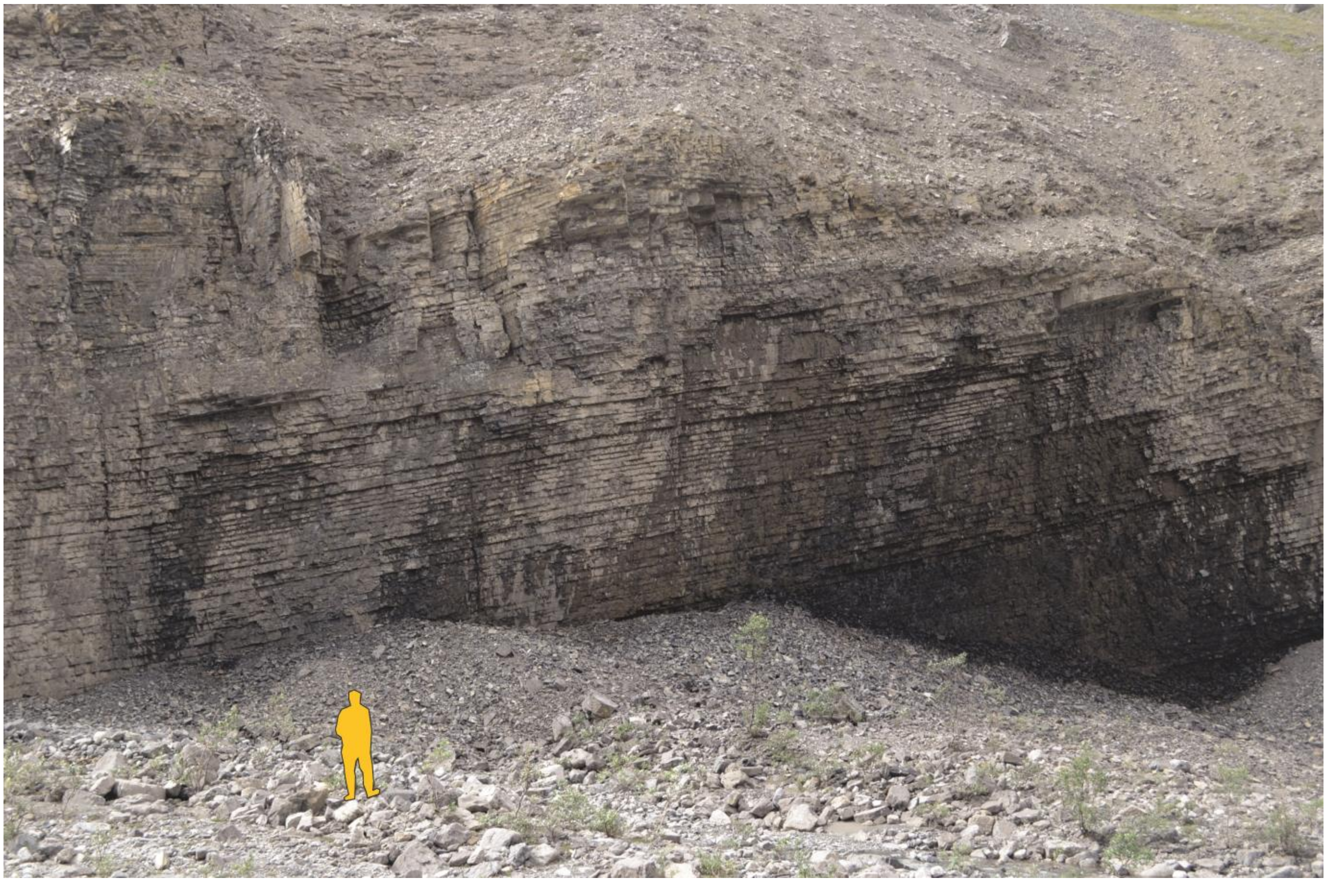


Figure 8: Thin-bedded, grey-weathering limestone of the Cloudy Formation in NTS 106-B. Outline of person provides scale. Photograph taken near 64.427482, -130.219668 (NAD83).

Preliminary Observations, NTS 95-M

A key focus of work by MacNaughton and Fallas in NTS 95-M and adjacent 105-P was the examination of previously documented Ediacaran and basal Cambrian strata (Figure 4). This included the successions in the June Lake and Sekwi Brook regions in NTS 105-P (e.g., MacNaughton et al., 1997, 2000), as well in the western part of NTS 95-M (e.g., Gabrielse et al., 1973). The observations suggest that it will be possible to apply the newly recognized subdivisions of the upper Backbone Ranges Formation into these areas, albeit with some modifications. MacNaughton and Edgeworth spent part of one day documenting a measured section in western NTS 95-M that may contain a thinned version of the uppermost Ediacaran Risky Formation (Aitken, 1989), the first time this unit has been recorded east of its type area near Sekwi Brook in eastern NTS 105-P.

East of the Plateau Fault, between the Ravens Throat and Silverberry rivers (NTS 95-L and 95-M), strata of the Little Dal Group, Coates Lake Group, and Rapitan Group are preserved in stratigraphic and faulted contact with each other. Some time was spent investigating outcrops that allow for the application of updated formation-scale terminology as well as checking relationships between faults and unconformities to constrain timing of faulting. Preliminary observations reinforce the evidence for pre-Rapitan uplift, tilting, and localized extensional faulting, as shown in Colpron and Jefferson (1998), and suggest the Coates Lake Group (Figure 9) is preserved in a wider area than was previously documented by Gabrielse et al. (1973).

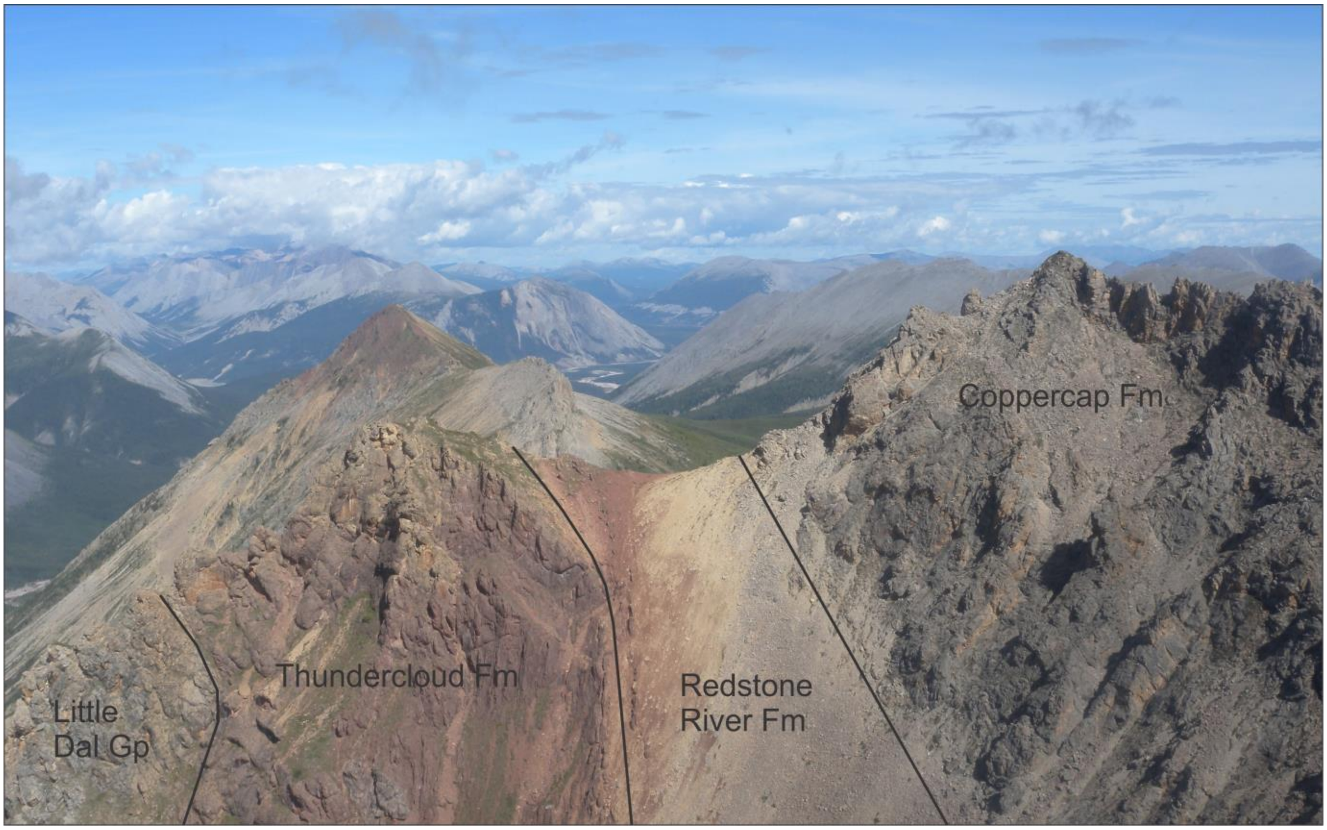


Figure 9: Previously undocumented Coates Lake Group strata exposed on a ridge southwest of Dal Lake in NTS 95-M. Saddle in Redstone River Formation is located at 63.068822, -126.614494 (NAD83); view is looking north. Redstone River Formation is approximately 45 m thick.

CONCLUSIONS

Fieldwork in Bonnet Plume Lake map area (NTS 106-B) during July, 2018, built upon the two previous years' efforts to improve the delineation of map units and update the lithostratigraphy applied in the northern Mackenzie Mountains (Fallas et al., 2016; MacNaughton et al., 2017). Detailed stratigraphic sections were measured through the Sheepbed, Backbone Ranges, and Cloudy formations, and these will be presented in subsequent reports. It is expected that this work will lead to a full-scale revision of the Backbone Ranges Formation and the subdivision of its upper member into several formation-scale, mappable units. Preliminary investigations suggest that these units can be applied immediately to the east in NTS 106-A, and well to the southeast in NTS 105-P and 95-M.

Improved delineation of Proterozoic to Silurian units has helped with the identification and characterization of structures in Bonnet Plume Lake area. These improvements will be captured in new bedrock geology maps for the north half of NTS 106-B. Preliminary observations in NTS map areas 95-L, 95-M, and 105-P suggest that continued work on the Proterozoic to Silurian succession will resolve aspects of the structural history during that time interval.

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