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2017

Permanent link: https://doi.org/10.4095/306133

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

Recommended citation
MacNaughton, R.B., Fallas, K.M., Fischer, B.J., Pope, M.C., Chan, W.C., Finley, T.D., and Martell, J., 2017. Report of activities for GEM 2 Mackenzie Project: Bonnet Plume Lake map area (NTS 106B) bedrock mapping, stratigraphy, and related studies, Northwest Territories and Yukon; Geological Survey of Canada, Open File 8333, 14 p. https://doi.org/10.4095/306133

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

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 2017 field season, research scientists from the GEM program successfully carried out 27 research activities, 26 of which will produce an activity report and 12 of which included fieldwork. Each activity included geological, geochemical and geophysical surveying. 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

Northern Mackenzie Mountains bedrock mapping and stratigraphic studies are a component of the Mackenzie-Selwyn geo-transect: studying the evolution of sedimentary rocks of the northern mainland NWT to improve exploration success for petroleum resources and base metal deposits (Figure 1). This activity will initiate the first regional integrated effort to place Proterozoic to Cenozoic strata of Mackenzie Platform, Selwyn Basin, and adjacent regions into a modern tectono-stratigraphic and metallogenic framework, and will better enable industry and Northerners to responsibly find and develop energy and mineral natural resources, maximizing their economic and societal impact.

The present report provides an account of field activities in the Bonnet Plume Lake map area (NTS 106B) of the Mackenzie Mountains, NWT, during July and early August, 2017. Preliminary results presented in this report touch upon bedrock geological mapping, stratigraphy, structural geology, and mineral deposits.

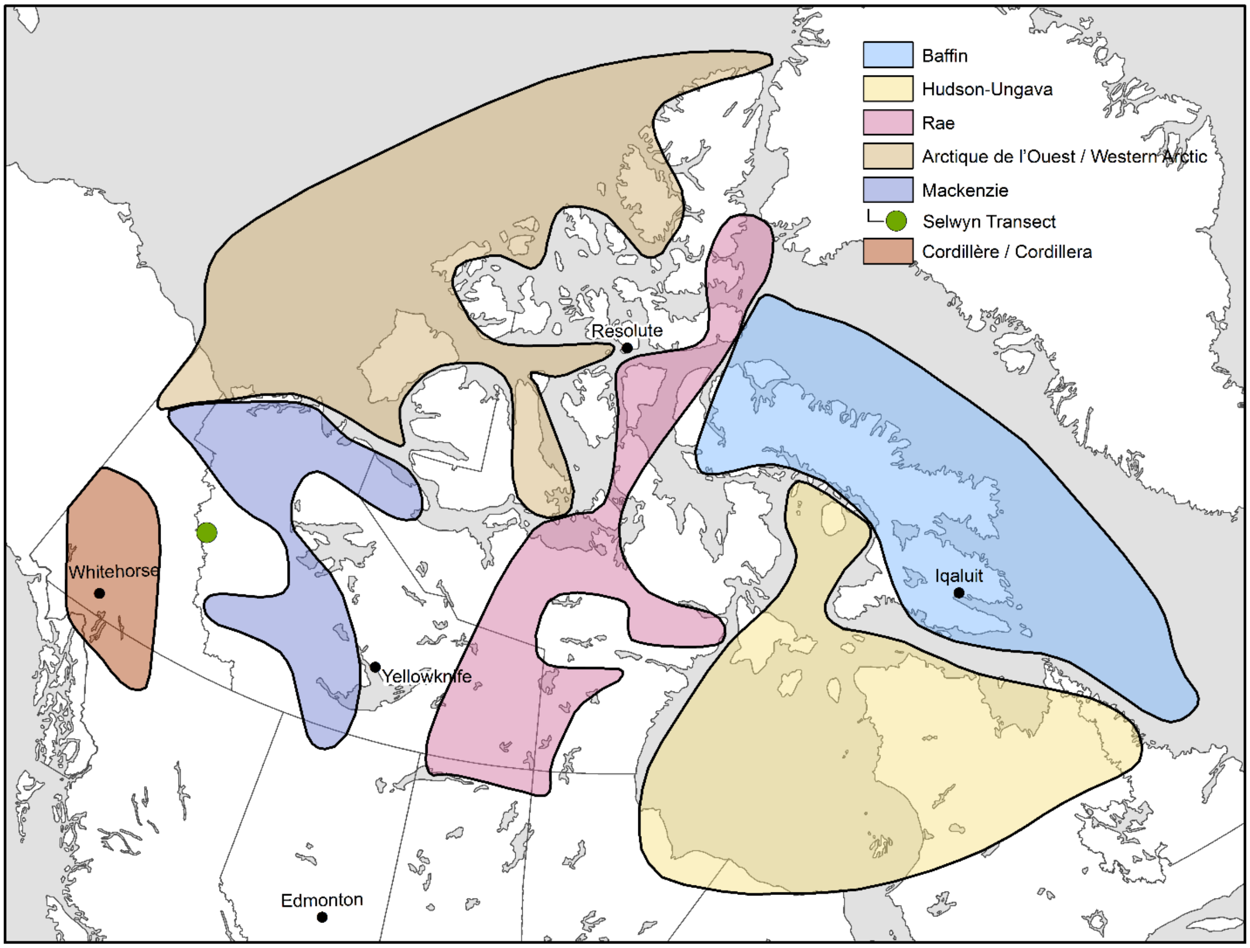

Figure 1: Location map, showing outlines of GEM-2 areas of interest. Study area of present report is shown by green dot. See Figure 2 for a location map of the actual study area. This figure provided by courtesy of the GEM Coordination Office.

INTRODUCTION

This report summarizes field work undertaken during the summer of 2017 as part of the Mackenzie-Selwyn Geo-transect activity of the GEM Program (Figure 1). For four weeks, 1:100 000 scale bedrock mapping was undertaken in the northern half of Bonnet Plume Lake map area (NTS 106-B), Mackenzie Mountains, Northwest Territories (Figure 2). A small number of sites also were visited in map areas immediately adjacent to the main study region to provide a broader context for the rocks observed in NTS 106B. The goal of the work was to update bedrock geology maps for the study region. This is a direct continuation of the previous Shield-to-Selwyn GEM activity (Fallas et al., 2015, 2016).

GSC scientists previously mapped the study region at reconnaissance scale, which led to the publication of hand-drafted, black-and-white GSC Open File maps (Aitken and Cook, 1974; Blusson, 1974). Fischer (2016) remapped and/or recompiled the southern parts of NTS 106B.

The present report provides a preliminary account of the summer's field work, focusing on bedrock mapping, structural geology, and Proterozoic to lower Paleozoic stratigraphy. Comments on economic geology also are offered. Devonian biostratigraphic studies carried out with the field support of the Mackenzie-Selwyn activity are reported elsewhere (Gouwy et al., 2017).

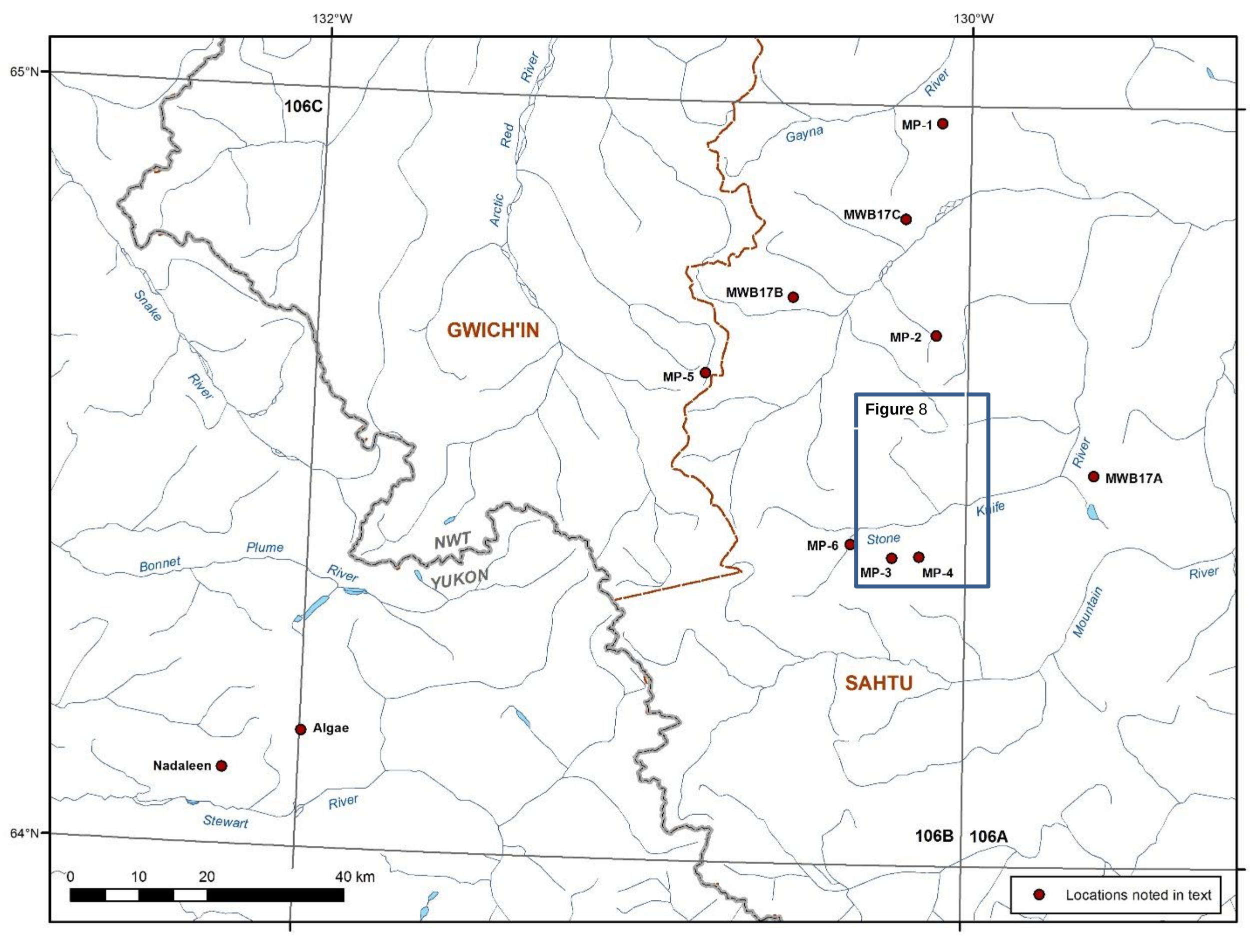

Figure 2: Detailed location map of 2017 study area (NTS 106-B). Blue inset box shows general area of mineral deposit studies; for detailed map of visited mineral localities, see Figure 8.

METHODOLOGY

Field activities took place between July 7 and August 4, not including time spent travelling to and from the study area. Work was conducted from two base camps, the first at Goober Lake in the northeastern part of the map area, and the second at Poacher Lake along the western edge of the map area[a]. During work from the Goober Lake base camp (July 7-18), two part days and one full day were lost to rain. For two days, the helicopter was incapacitated and it was necessary to conduct foot traverses in the immediate vicinity of the base camp. Heavy smoke haze from forest fires was a periodic impediment early in the field season. Following a camp move on July 19, a smaller crew worked out of Poacher Lake from July 20 to August 3. During this time, parts of four days and the entirety of two days were lost to rain. The remaining members of the field party returned to Norman Wells on August 4.

Bedrock Geological Mapping

Map units exposed in the study area range in age from Neoproterozoic to Devonian (Figure 3). Bedrock is well exposed on peaks and ridges in the northern Mackenzie Mountains, although Quaternary cover hampers mapping in the valleys. Foot traverses are difficult or impossible in many areas due to steep terrain with precipitous cliffs. The greatest progress in mapping was made by means of helicopter spot-checking, augmented by foot traverses.

Stratigraphic Studies

The “Mackenzie-Selwyn” activity is part of the longer-term “Shield to Selwyn geo-transect” study, a key goal of which is to improve the understanding of Proterozoic to Silurian tectonostratigraphy along a line from the edge of the Brock Inlier to the northeastern edge of Selwyn Basin. Two key subjects to be addressed are the Ediacaran-Cambrian tectonostratigraphic evolution of the region, and the evolution of lower Paleozoic formations adjacent to the Misty Creek Embayment (see below). To address the first question, sections were measured through the Sheepbed, Backbone Ranges, and Nainlin formations, as well as through an as-yet unassigned unit of Ediacaran shale. To address the second goal, partial or complete sections were measured through the Hess River, Cloudy, Mount Kindle, and Tsetso formations.

Mineral Showings

Mineral showings in two areas, the RIS and Red, were examined and sampled (Figure 2). The RIS showings are of interest because of reported gold values of up to 13.0 g/t across 2.4 m, as well as combined zinc and lead values including 4.18% across 7.3 m and 54.81% across 1.7 m in continuous “chip-channel” samples (Guild and Brock, 1974). The Red area was mapped in detail by industry in 1974 and more than 20 occurrences of carbonate-hosted zinc ± lead ± silver or fluorite were discovered; it was found that although mineralization was locally of high grade, it lacked lateral continuity (Wares and Keyte, 1975).

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

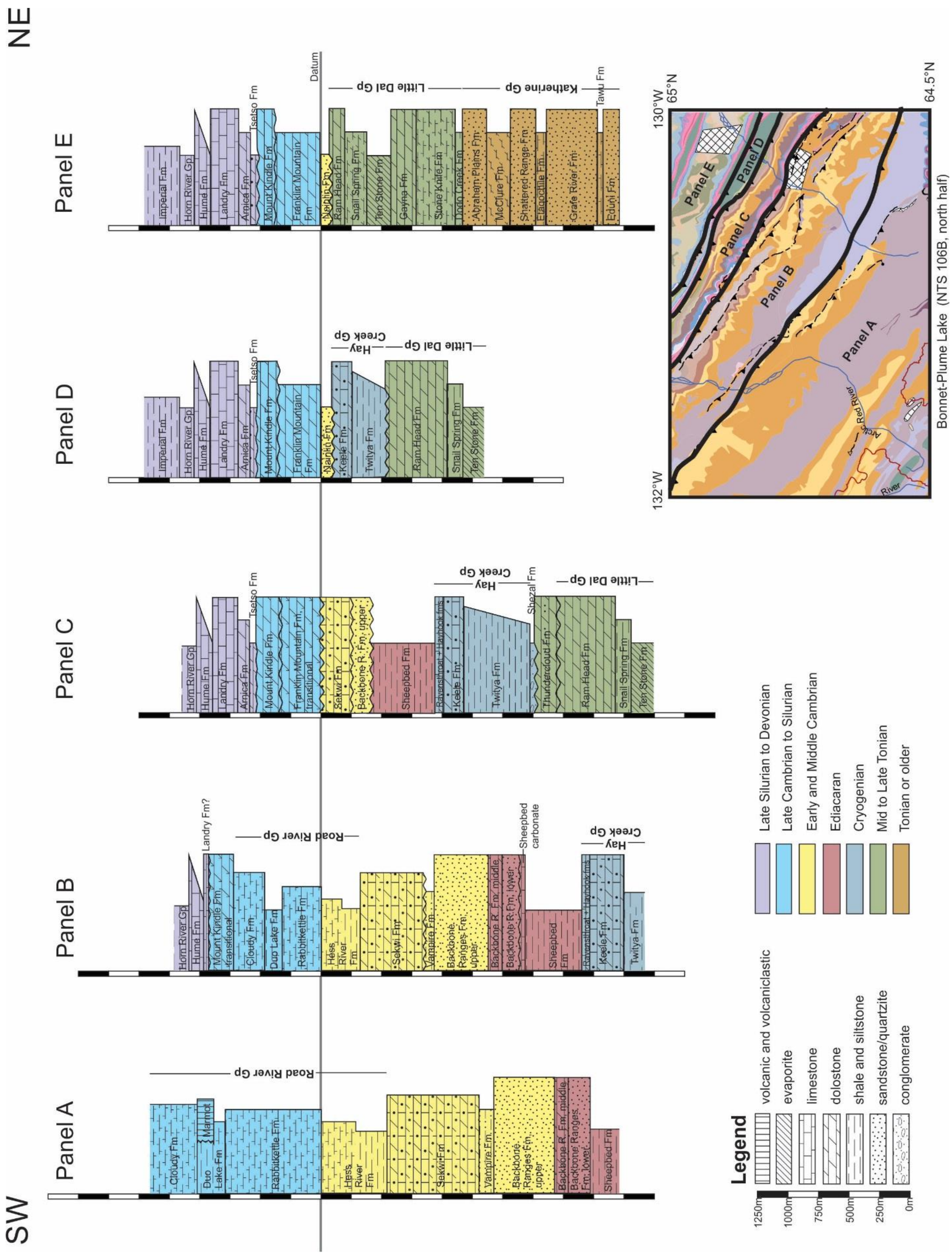

Figure 3: Stratigraphic relationships within the study area. Each column shows the order and approximate thickness of units within structural domains as delineated in the map key (modified from Aitken and Cook, 1974; Blusson, 1974)

RESULTS

Bedrock Geological Mapping

Bedrock geology maps for the study area currently available from the GSC (Aitken and Cook, 1974; Blusson, 1974) were based on data from the 1960s and early 1970s and reflected the lithostratigraphic framework current at that time. Because those maps were based on reconnaissance mapping, it was necessary to "lump" large packages of strata together, and a few areas on the maps were left un-interpreted due to lack of observations. The intervening decades have seen numerous changes to the lithostratigraphy of the region, including: revision (e.g., Aitken et al, 1978; Aitken, 1981) and formalization (Long and Turner, 2012; Turner and Long, 2012) of units within the Mackenzie Mountains Supergroup; changes in the definition of the Rapitan and Hay Creek groups (Eisbacher, 1978; Turner et al., 2011); clarification of the extent and internal divisions of Cambrian (e.g., MacNaughton and Fallas, 2014) and Devonian (e.g., Morrow, 1991) platformal units; and subdivision of the basinal Road River Group into formations (e.g., Cecile, 1982).

The focus of bedrock mapping activities was on the application of these stratigraphic revisions at the map scale to better illustrate stratigraphic and structural relationships, continuing efforts begun to the north in 2016 (NTS 106-G and 106-H; see Fallas et al., 2016). It proved possible to subdivide the lumped map units of Blusson (1974) using current stratigraphic terminology, and to fill in the unmapped areas of Aitken and Cook (1974). This included updating terminology and subdividing units within the Katherine Group, the Little Dal Group, the Rapitan Group, the upper Windermere Supergroup, the Backbone Ranges Formation, and the Road River Group. For a summary of the lithostratigraphic framework of the study region as of this writing, see Figure 3.

Structural Geology

The northern half of the Bonnet Plume Lake map area (NTS 106-B) preserves structural styles that subdivide into three domains: a fold-dominated region in the northeast corner; a central region dominated by thrust faults; and a mixed fold-and-thrust region to the southwest. The northeast domain, within the Canyon Ranges, is characterized by broad anticlines and tight synclines with a 15-25 km wavelength. Folded strata include the Mackenzie Mountains Supergroup and platformal carbonates of the Lower Paleozoic. The central domain, approximately 30 km wide within the Backbone Ranges, includes a series of contractional faults (thrust, reverse, and back-thrust) where folding is minor (Figure 4, A-D). Strata involved in faulting are dominantly Windermere Supergroup and Cambrian siliciclastic and carbonate units. To the southwest, folds incorporate shale-dominated strata of the Road River Group, as well as Ediacaran to Cambrian siliciclastic and carbonate units. Faulting is a minor feature in this domain. Folding within shale-dominated units of the Road River Group varies from minor parasitic folds with wavelengths of tens to a few hundred metres, up to anticlinoria and synclinoria with wavelengths of 10-15 km (Figure 4E). Strain associated with folding was sufficiently intense to have developed penetrative cleavage locally within shale-dominated units (Figure 4F).

During the 2017 mapping season, the general character and location of major structures identified in previous work (Aitken and Cook, 1974; Blusson, 1974; Fischer, 2016) were verified and adjusted for position where necessary. Additionally, some previously unrecognized faults were identified (Figure 4A, C, and D), adding complexity and altering constraints on cross-cutting relationships. Improved stratigraphic detail within the interval of the Backbone Ranges and Sekwi formations significantly aided the identification of additional faults as well as resolving the nature of some previously known, but uncharacterized faults.

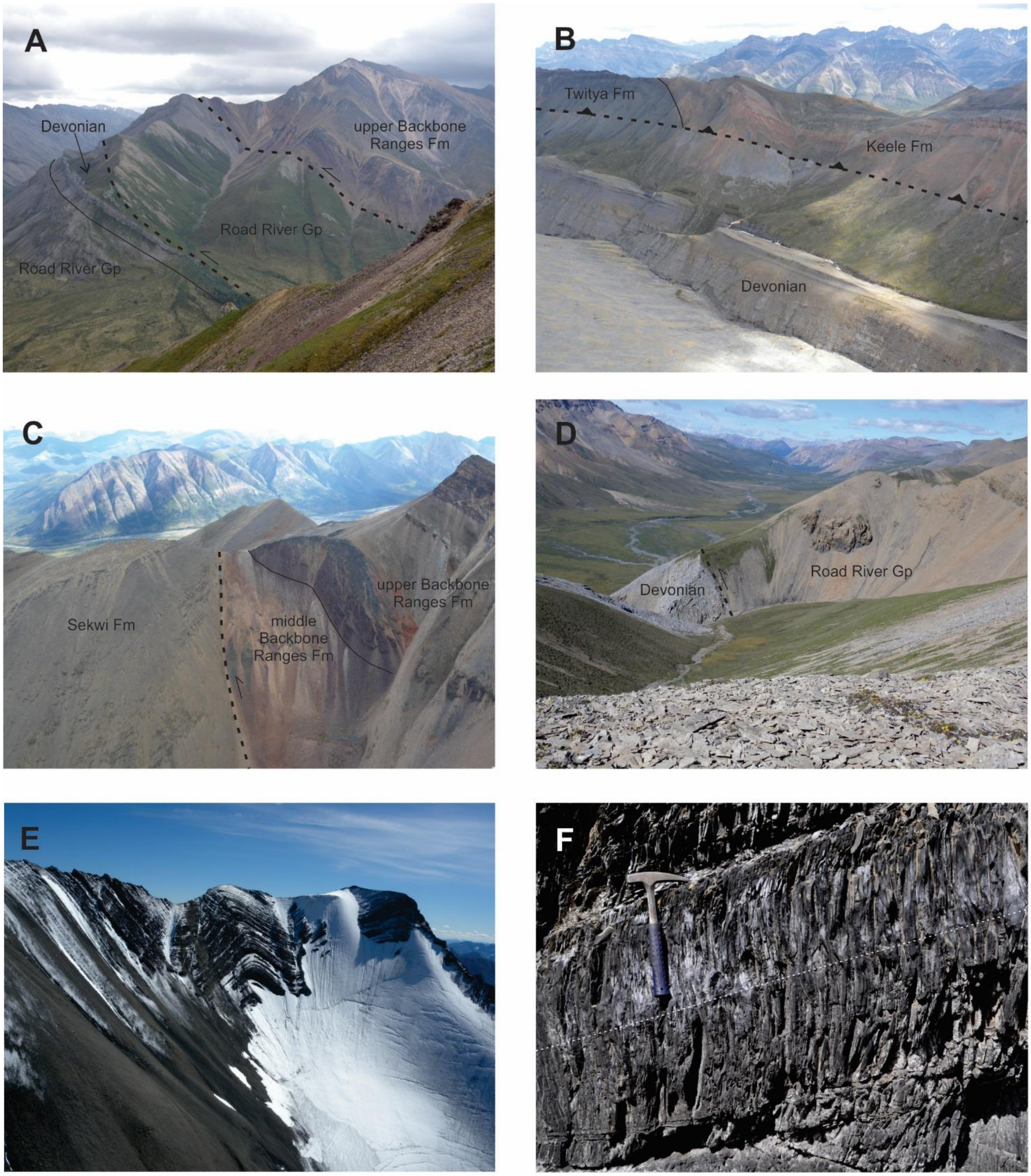

Figure 4. Structural Features. A) Looking SE from 64.7318N, 131.1599W at thrust faults (dashed lines with motion indicator arrows); lower fault newly identified. B) Looking S from 64.7757N, 130.5149W at hanging wall lateral ramp in the Neptunist Fault panel. C) Looking E from 64.8746N, 131.8716W at newly identified high-angle reverse fault. D) Looking NW from 64.5916N, 130.0486 at previously unmapped backthrust. E) Looking SE from 64.5190N, 130.9162W at folds within the Rabbitkettle Formation. F) Near vertical cleavage developed in lime mudstone of Rabbitkettle Formation, white dashed line follows bedding (at 64.5795N, 131.0995W).

Stratigraphic Studies: Ediacaran-Cambrian

Stratigraphic sections were measured by MacNaughton and Chan through two Ediacaran units. Measured section MWB17B (Figure 2) included a complete exposure (13 m) of the informal “Sheepbed carbonate” (MacDonald et al., 2013). This unit was formerly referred to as a platformal facies of the Gametrail Formation of Aitken (1989; see also Turner et al., 2011), but more recent work has falsified that correlation (MacDonald et al., 2013). The Sheepbed carbonate is a mappable unit through much of the Mackenzie Mountains (Turner et al., 2011) and it may be appropriate to define it as a new formation.

Measured section MWB17A (Figure 2), studied in the western part of NTS 106-A near Shale Lake, documented a succession (258 m) of dark-weathering shale that lies above the Sheepbed carbonate but below the Backbone Ranges Formation. These currently unnamed strata may be correlative with exposures of the informal “June beds” previously documented in the same region by MacDonald et al. (2013).

Additional work on Ediacaran strata consisted of a day spent in the Rackla River region of Yukon by MacNaughton and Fallas. During that visit it was possible to study several units previously described by Moynihan (2014), which he is in the process of formalizing (D.P. Moynihan, work in progress). Observations from this excursion may influence our interpretations of Ediacaran stratigraphy within the study area.

Fallas and MacNaughton devoted significant attention to the Ediacaran-Cambrian Backbone Ranges Formation. The three members originally defined by Gabrielse et al. (1973) in Glacier Lake map area (NTS 95-L) were present throughout much of the study area, although in the most northeastern exposures only the upper member was present. Where present, the brightly coloured, carbonate-dominated middle member is an excellent marker for mapping purposes. Measured section MWB17B (documented by MacNaughton and Chan) included the complete thickness of the siliciclastic-dominated lower member (72 m) and carbonate-dominated middle member (45 m), as well as the basal 25 m of the quartzite-dominated upper member (Figure 5). During bedrock mapping, it became clear that the upper member thickens markedly to the south and southwest. This may be due to addition/preservation of member-scale packages of rock below the thick-bedded quartz arenite that is typical of the upper member.

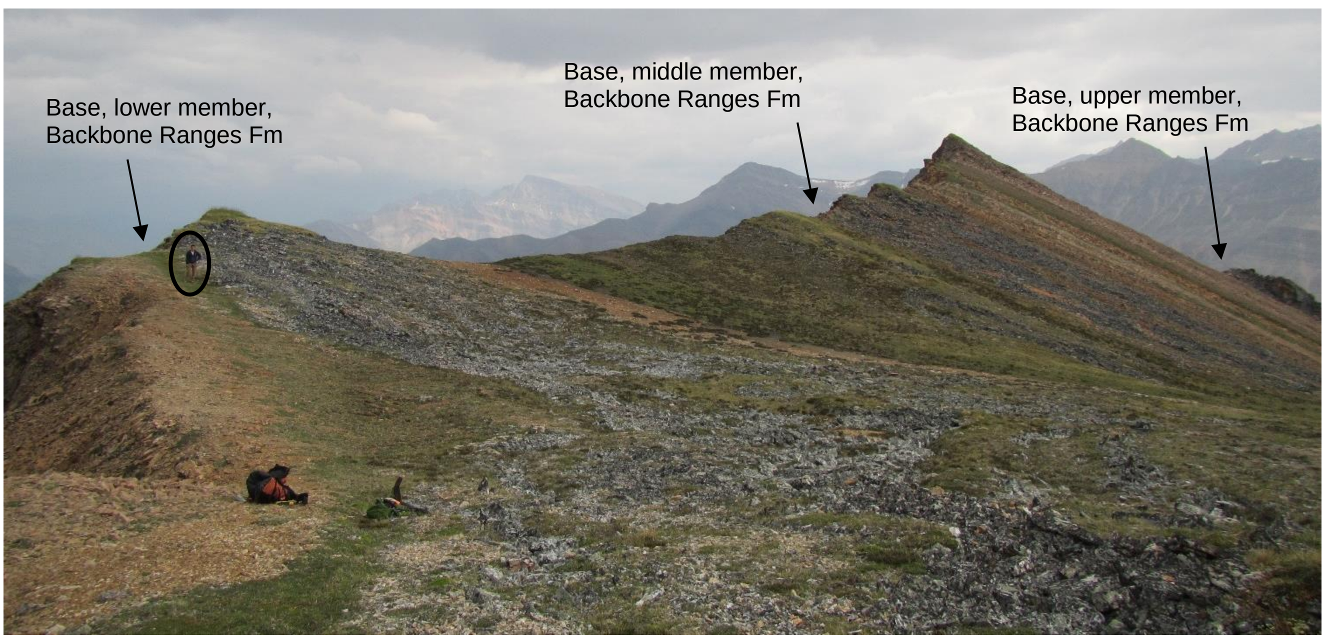

Figure 5: Overview of measured section MWB17B. Orange-weathering strata at left belong to the “Sheepbed carbonate”. Basal contacts of members of Backbone Ranges Formations are marked by arrows (labelled). Person for scale (circled at left) . See Figure 2 for location.

MacNaughton and Fallas continued their efforts (e.g., Fallas et al., 2016) to more accurately delineate the northern and western extents of the Nainlin Formation, a recently defined Cambrian unit (MacNaughton and Fallas, 2014). Newly discovered outcrops of Nainlin Formation were documented in northeast 106B, including a measured stratigraphic section (MWB17C, Figure 2). At this locality (Figure 6), Nainlin Formation is 40 m thick and dominated by red-weathering siltstone with lesser quartz sandstone and minor dolostone.

Figure 6: Upper part of measured section MWB17C, showing characteristic red-weathering colour of mudrocks in upper Nainlin Formation, and gradational contact with overlying, cream- to grey-weathering, carbonate-dominated strata of Franklin Mountain Formation. Person for scale (circled). See Figure 2 for location.

Stratigraphic Studies: Misty Creek Embayment

The transition of the Mount Kindle Formation carbonate platform into the Misty Creek Embayment (MCE; Cecile et al., 1982) was studied by Pope, Fischer, and Martel. Six full or partial sections were measured and sampled (Figure 2) in the Cloudy Formation, Mount Kindle Formation, or Mount Kindle "transitional unit" next to and within the embayment. The first measured section (MP-1, Figure 2) was a partial section of the Mount Kindle Formation, approximately 30 m thick. At this location, the formation was deposited on the margin of the MCE and consisted of an open marine succession of coral, stromatoporoid, and sponge boundstone. The second section of the Mount Kindle Formation (MP-2, Figure 2) was only 15 m thick, being faulted at its top. Here also, Mount Kindle Formation was deposited on the carbonate platform, as it contained abundant coral and stromatoporoid boundstone.

The lower part of the third measured section (MP-3, Figure 2) consists of approximately 700 m of Cloudy Formation calcisiltstone and lime mudstone, recording deep-water deposits in the MCE. These strata are overlain by platformal deposits of the Mount Kindle Formation, consisting of about 60 m of planar-bedded dolostone and skeletal dolostone, followed by 50 m of coral and stromatoporoid boundstone that shallows upwards into cross-bedded skeletal grainstone (10 m thick). The fourth measured section (MP-4, Figure 2) began in dark grey dolosiltstone or dolomudstone (60 m) near the top of the Cloudy Formation. The section then passed upsection into Mount Kindle Formation, which at its base preserved a thrombolite reef that was approximately 230 m thick. Above the reef was a succession of stromatoporoid, coral, and brachiopod boundstone. These strata comprise at least two and possibly three reef horizons, but are difficult to decipher due to extensive dolomite recrystallization and greater than 50% cover. The total thickness of the Mount Kindle Formation at section MP-4 is approximately 400 m. The Late Silurian to Middle Devonian(?) Tsetso

Formation, containing cyclic peritidal facies, conformably overlies the Mount Kindle Formation at sections MP-3 and MP-4 (Figure 2), indicating that the MCE was filled by this time at these locations.

Section MP-5 (Figure 2) encompasses approximately 340 m of the Mount Kindle transitional unit (previously reported as part of Section 21 of Morrow, 1991), and consists primarily of calcisiltstone with rare polymictic carbonate conglomerate beds or nodular carbonate beds, that transitions into bedded chert or nodular chert beds in its upper 50 m. Section MP-6 was from a portion of a large (greater than 200 m thick), light gray, crystalline dolostone "reef" within the Mt. Kindle Formation. The base of the reef was not measured but the reef forms a cliff more than 300 m high (Figure 7).

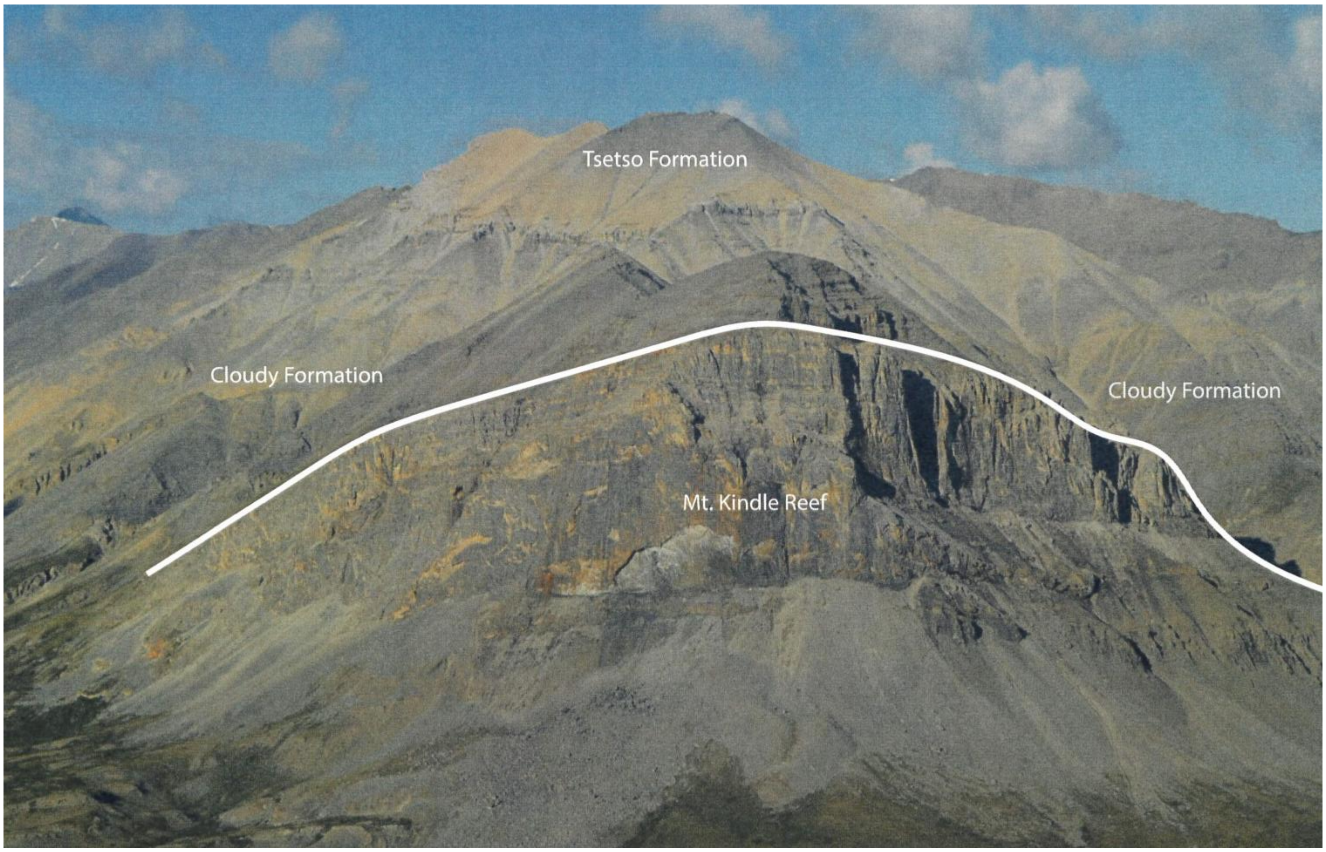

Figure 7: Dolostone reef within Mount Kindle Formation at locality MP-6. Reef is more than 300 m thick. For location, see Figure 2.

The carbonate shelf around the MCE was an open marine environment supporting abundant corals and stromatoporoids and some sponges, and locally, microbial reefs, whereas the MCE was deeper, with abundant carbonate siltstone and mudstone and a paucity of skeletal components. Rare skeletal wackestone/packstone and polymictic conglomerate beds in the MCE suggest its slopes were not steep, nor were they tectonically very active.

As part of a study of basinal units in the Misty Creek Embayment (MCE) led by Elizabeth Turner at Laurentian University, with support from NTGS and GSC, Cecile's (1982) section 5 of Hess River Formation was re-visited by Fischer in 2017. At this location, Hess River Formation includes a thick sandstone member. Black calcareous shale and silty lime mudstone intervals above and below the sandstone member were sampled at intervals of approximately 3 m for carbon isotope analyses. The data will be examined for secular changes in isotopic ratio patterns that can be compared to published patterns from other areas for correlation and age control. Paleocurrent measurements were taken from the top and bottom of the sandstone member. Measurements and analyses will be presented with other data on the MCE basinal units in a separate report.

Mineral Showings

A brief summary of visits to mineral showings is presented here. A more detailed account will be published by Fischer as a Northwest Territories Geological Survey report.

During the 2017 field season, Fischer spent one and a half days in the RIS area (Figure 8), studying the structural and stratigraphic setting of the showings, and sampling them for modern multi-element geochemical analyses. The RIS showings consisted of eight separate Pb-Zn occurrences hosted in carbonate rocks exposed in steep gullies separated by scree and unconsolidated slumps (Guild and Brock, 1974). Aitken and Cook (1974) assigned the host rocks to the Devonian Hume and Landry formations. About 60 m northeast of the showings, a southwest-verging reverse fault cuts off the Devonian host-rock succession. In the hanging-wall are strata previously mapped as undivided Road River Group (Ordovician to Silurian), overlain by platformal carbonate of the Silurian Mount Kindle Formation.

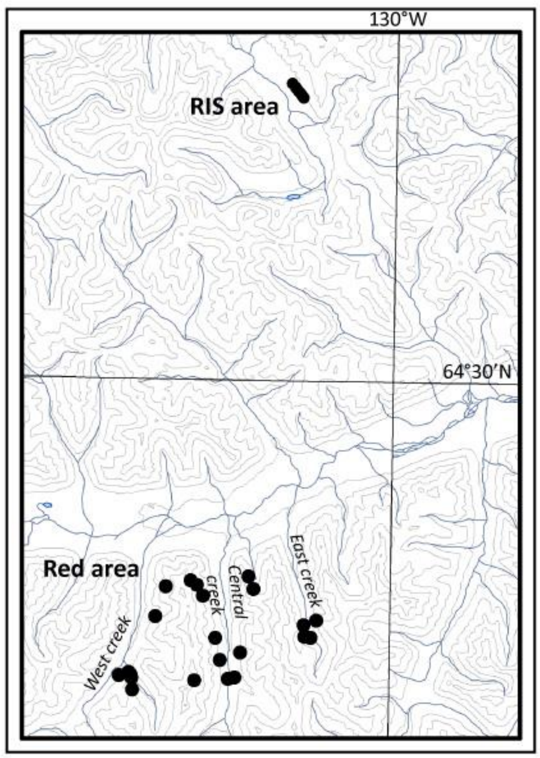

Figure 8: Locations of RIS and Red areas. Black dots are mineralized occurrences.

The original showings could not be found during the present work, apparently because active slumping and erosion has covered them (Figure 9). However, rocks in the footwall of the fault were studied in three of the originally reported gullies, and also in the next gully to the southeast. Below the fault, traces of pyrite are common, with up to 2% pyrite locally. No sphalerite or galena was found, although many outcrops have surficial coatings of smithsonite(?). Nine samples of such rock were taken for geochemical analysis. No silicified zone was found in the footwall of the fault.

In the hanging-wall, the lowest exposed beds consist of variably argillaceous lime mudstone of the Rabbitkettle Formation. However, stratigraphy above this unit in the hanging-wall is not straightforward, and likely is structurally complicated. Geochemical sampling above the fault included four samples from a unit of pyritic, siliceous breccia that lies structurally above Rabbitkettle Formation, and two samples of Road River Group dark shale that is (structurally?) in contact with the brecciated zone.

Figure 9: Debris apron in foreground encroaching on outcrops of silicified skeletal limestone breccia of Hume(?) Formation. Looking north from southeast of the reported showing locations.

During the re-compilation of southern NTS 106B mentioned above, Fischer (2016) determined that the area around the Red Pb-Zn showing (Figure 8) is underlain by a gently south-dipping succession of Ordovician to Devonian basinal limestone (Cloudy Formation, Mount Kindle Formation, Tsetso Formation, and younger Devonian carbonate units). The Cloudy to Tsetso succession in the Red area was part of the study of the Silurian platform-to-basin transition discussed above, during which BF also examined the mineral showings. The majority of mineral occurrences are hosted by reef-facies dolostone of the Mount Kindle Formation. Three samples were collected for geochemical analysis: a sample of dolostone breccia from the reef facies that was cemented by white dolomite and pinkish orange sphalerite; a piece of well-bedded off-reef dolostone of Mount Kindle Formation; and a sample from a small patch of dissolution breccia in thin-bedded lime mudstone of Cloudy Formation. Fluorite was observed with dolomite cementing a dolostone breccia in float that fell from a reef facies or an overlying unit (Figure 10).

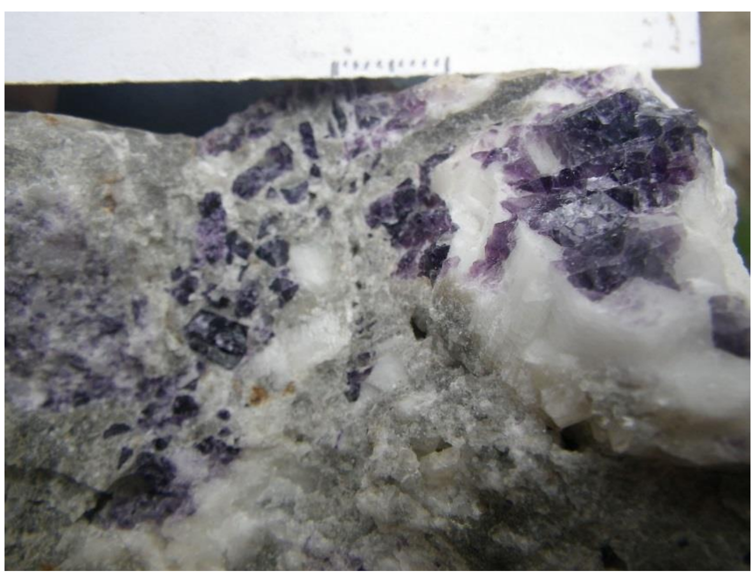

Figure 10: Purple fluorite and white dolomite cement a dolostone breccia in the Red area. From float.

CONCLUSIONS

Field work in Bonnet Plume Lake map area (NTS 106-B) during the summer of 2017 led to significant improvements in the delineation of map units, essentially for all parts of the stratigraphic record. Notable progress was made in subdividing the Backbone Ranges Formation and the Road River Group in terms of up-to-date lithostratigraphic units. Detailed stratigraphic sections were measured through the Sheepbed, Backbone Ranges, Hess River, Nainlin, Mount Kindle, Cloudy, and Tsetso formations. These sections will be presented in subsequent reports. The enhanced understanding of the region's stratigraphy helped significantly to clarify structural relationships within the region, as will be reflected in revised bedrock geology maps for the northern half of NTS 106-B, projected for future publication. Observations made during visits to mineral showings will be the subject of a report to be published by the Northwest Territories Geological Survey.

ACKNOWLEDGEMENTS

Logistical support was provided by Arctic Red River Outfitters; in particular we thank Tavis Molnar and his staff members, Peter Oxtoby, Joan Schuppli, Connie Smith, Brennan Grove, and Tyrell Birch for their cheerful assistance. We thank Sahtu Helicopters, and especially pilot Scott Douglas and engineer Adam Loder, for careful and reliable flying. Fixed-wing support was provided by North Wright Airways. Leanne Tingley and Christine Deblonde are thanked for conscientious help in the field. Wildlife monitors were Geraldine Blake, Robert Blake-MacLeod, and Audrey Edgi. Marlene Francis and Paul Wozniak are thanked for assistance in preparing for the field season. Work was carried out under research permits issued by Aurora Research Institute and Yukon Tourism and Culture, on lands within the Gwich'in, Sahtu, and Na-Cho Nyak Dun land settlement districts.

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