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Abstract
The Neoproterozoic Coates Lake Group is a known host for copper mineralization in the central Mackenzie Mountains. The previously documented 300 km long northwest-southeast trending outcrop belt of Coates Lake Group is extended by approximately 85 km to the northwest based on mapping observations from the Geo-mapping for Energy and Minerals program of the Geological Survey of Canada. Two units of the Coates Lake Group, Thundercloud Formation and Coppercap Formation, are herein documented from the Bonnet Plume Lake (NTS 106B) and Ramparts River (NTS 106G) map areas, including the region around Arctic Red River. No evidence of copper mineralization within the Coates Lake Group was observed in the Bonnet Plume Lake or Ramparts River map areas; however, observations in the region are limited.

Introduction

Coates Lake Group is a Neoproterozoic (late Tonian) succession known from a narrow (<15 km) outcrop belt over 300 km long in the Mackenzie Mountains of the Northwest Territories (Eisbacher, 1977; Jefferson, 1983; Jefferson and Ruelle, 1986). The presence of stratabound copper sulphide occurrences within the succession led to use of the informal name 'copper cycle' (Aitken, 1981) for the succession and 'Redstone Copper Belt' (Eisbacher, 1977; Jefferson, 1983; Jefferson and Ruelle, 1986) for its outcrop belt. Previously studied outcrop lies within the Glacier Lake (NTS 95L), Wrigley Lake (NTS 95M), Sekwi Mountain (NTS 105P), and Mount Eduni (NTS 106A) map areas (Fig. 1). Reconnaissance maps published in the 1970s did not indicate the presence of Coates Lake Group west of 130°W (Aitken and Cook, 1974 and 1979). Subsequently, some workers suggested the possibility of Coates Lake strata being exposed in the Bonnet Plume Lake (NTS 106B) map area (Aitken, 1977; Eisbacher, 1977; Jefferson and Ruelle, 1986), but detailed relationships were not provided. This report documents the distribution of Coates Lake Group within the Bonnet Plume Lake and Ramparts River (NTS 106G) map areas based on observations made during mapping activities conducted from 2016 to 2018 under the Geo-mapping for Energy and Minerals (GEM) program of the Geological Survey of Canada (GSC). In doing so, this report extends the known distribution of the Coates Lake Group into the Arctic Red River area of the Mackenzie Mountains, which has potential implications for copper exploration in the region.

Stratigraphy

The Coates Lake Group was defined by Jefferson and Ruelle (1986) to encompass strata assigned to the Redstone River and Coppercap formations of Gabrielse et al. (1973) and the 'copper cycle' of Aitken (1981). It is bounded by unconformities at base and top, overlying

strata of the Little Dal Group in the upper part of the Mackenzie Mountains Supergroup, and is overlain by strata of the Rapitan Group in the lower part of the Windermere Supergroup (Jefferson and Ruelle, 1986). Local occurrences of the 'Little Dal basalt' between strata of the Little Dal and Coates Lake groups have also been documented by Aitken (1981) and Jefferson (1983). For a discussion of the affinity of the Coates Lake Group to the Mackenzie Mountains and Windermere supergroups, see Jefferson and Parrish (1989). The Coates Lake Group comprises three formations in ascending order: Thundercloud Formation, Redstone River Formation, and Coppercap Formation (Fig. 2). Earlier work by Gabrielse et al. (1973) and Eisbacher (1977) only recognized Redstone River and Coppercap formations and strata now assigned to Thundercloud Formation appear to have been previously included in the upper part of the underlying 'Upper Carbonate' of the Little Dal Group of Aitken (1981), now known as the Ram Head Formation (Turner and Long, 2012). It is also possible that strata of the Thundercloud Formation have locally been assigned to Redstone River Formation by earlier workers (Aitken, 1981).

As defined by Jefferson and Ruelle (1986), Thundercloud Formation is a succession, up to 300 m thick, of recessive, red, maroon, tan, and grey weathering, interbedded mudstone, shale, and dolostone overlain by sandstone and dolostone. Dark green volcanic conglomerate is found locally at the base of the unit. The Redstone River Formation is a recessive succession, up to 1200 m thick, comprising white evaporite overlain by red, pink, maroon or tan weathering laminated mudstone, siltstone, and carbonate. Carbonate conglomerate and/or solution-collapse breccia is found locally between the evaporite and mudstone portions. Jefferson and Ruelle (1986) identify a gradational boundary between the Redstone River and Coppercap formations, known as the 'Transition Zone', typically included in the Coppercap Formation. Up to 100 m thick, it includes red, green, and tan weathering mudstone and carbonate. The 'Transition Zone' is a known host for copper mineralization in the Glacier Lake (NTS 95L) and Wrigley Lake (NTS 95M) map areas. The main portion of the Coppercap Formation is a resistant, light- to dark-grey or tan weathering limestone and minor dolostone succession up to 300 m thick.

Coates Lake Group in the Arctic Red River area

Mapping activities conducted in the Arctic Red River area by the GSC from 2016 to 2018 as part of the GEM program included the Bonnet Plume Lake (NTS 106B) and Ramparts River (NTS 106G) map areas (Fig. 1). Strata recognized as Coates Lake Group were visited and described at nine localities, and mapped from the eastern boundary of the Bonnet Plume Lake area at 130°W, in a discontinuous outcrop belt to the northwest beyond Arctic Red River, in the

Ramparts River area (MacNaughton et al., 2018). The resulting distribution of units of the Coates Lake Group is shown in Figures 3, 4, 5, and 6. This mapping extends the known range of the Coates Lake Group by up to 85 km beyond the previously documented 'Redstone Copper Belt'. Outcrop of the Coates Lake Group in this region is limited to the hanging wall of the Plateau Fault (Fig. 7), which is mapped as two linked and overlapping segments, the Stone Knife segment in eastern Bonnet Plume Lake map area and the Arctic Red segment in Bonnet Plume Lake and Ramparts River map areas. Near the headwaters of Gayna River, a 30 km gap in outcrop of the Coates Lake Group occurs where the Arctic Red and Stone Knife segments of the Plateau Fault overlap and strata directly above the fault surfaces are younger than the Coates Lake Group (Fig. 4). North-northwest- to northeast-striking normal faults cutting strata of the Little Dal Group and Coates Lake Group in the hanging wall of the Plateau Fault also affect the distribution and thickness of Coates Lake Group along the outcrop belt (Figs. 3, 5, and 6).

Observed lithologies include interbedded mudstone, shale, dolostone, and sandstone of the Thundercloud Formation (Fig. 8), and dolostone of the Coppercap Formation (Figs. 8f, 9b and c). The basal contact of the Thundercloud Formation is typically marked by a change from resistant, light brownish-grey dolostone of the Ram Head Formation (Little Dal Group) to recessive, moss-covered slopes underlain by shale or mudstone (Figs. 7, 8a). Thin, resistant ribs of orange dolostone and grey quartz sandstone crop out at intervals within the unit (Figs. 7b, 8a-e). The maximum thickness of Thundercloud Formation in this area is estimated at 100 to 150 m. Lack of evaporite or other lithologies characteristic of the Redstone River Formation suggests it is not present in this region, so the Coppercap Formation directly overlies the Thundercloud Formation. The contact between the two units is typically marked by a sharp upward change to resistant, light grey-weathering carbonate of the Coppercap Formation (Figs. 7, 8a). The thickness of the Coppercap Formation varies from 0 m to in excess of 250 m. The upper contact of the Coppercap Formation is unconformable (Fig. 9), with carbonate-clast conglomerate deposited locally along the unconformity. Units of the Coates Lake Group are overlain by Cryogenian Windermere Supergroup strata of the Rapitan Group (Sayunei or Shezal formations), or more commonly the younger Twitya Formation (Fig. 7) of the Hay Creek Group (Yeo, 1978).

Implications for mineralization

Stratabound copper sulphide mineralization is known from the Coates Lake Group and is documented to greater or lesser degree in each of the formations within the group (Jefferson and Ruelle, 1986). Rare occurrences have also been documented from the underlying Ram Head Formation (Stone and Turner, 2019), and from faults associated with the overlying

Rapitan Group (Helmstaedt et al., 1979). Jefferson and Ruelle (1986) suggest that mineralization was associated with early diagenesis in favourable sabkha environment deposits found in the 'Transition Zone' between the Redstone River and Coppercap formations. They also suggest a possible source of copper available to diagenetic fluids is the 'Little Dal basalts' locally found between the underlying Ram Head Formation of the Little Dal Group, and the overlying Coates Lake Group in the Glacier Lake (NTS 95L) and Wrigley Lake (NTS 95M) map areas (Fig. 1).

In the Bonnet Plume Lake (NTS 106B) and Ramparts River (NTS 106G) map areas documented in this report, the lack of evaporitic facies of the Redstone River Formation may pose a risk to copper exploration. The absence of 'Little Dal basalt' in the region may also point to a lack of source for copper. There are however, numerous exposures in the region of mafic intrusions (gabbro or diabase sills and dykes) within strata of the Mackenzie Mountains Supergroup, including the Little Dal Group, underlying the Coates Lake Group. Chemical similarity between the intrusions and the basalts have led some to suggest these represent the same igneous event (Jefferson and Parrish, 1989; Sandeman et al., 2014). An unconfirmed occurrence of mafic igneous rocks that appear to intrude Ram Head Formation of the Little Dal Group, and are in fault contact with strata of the Coates Lake Group, has been observed in the hanging wall of the Plateau Fault in the eastern Bonnet Plume Lake map area (Fig. 10). It is possible that such intrusions are a local source for copper.

Observations made during mapping activities of the GEM program from 2016 to 2018 did not document the presence of copper mineralization within the study area. These observations represent a limited sampling of the units in this region – 9 observations along the 85 km outcrop belt. Stream-sediment sampling in the Bonnet Plume Lake (NTS 106B) map area by Ozyer (2012) noted a moderate potential for copper showings on the east side of the Arctic Red River in the northern Bonnet Plume Lake area. This area overlaps a mapped outcrop of Thundercloud and Coppercap formations (see central portion of Fig. 5 and compare with Fig. 12 of Ozyer, 2012) and may suggest a link between the outcrop and the elevated prospectivity for copper. Other aspects of potential copper mineralization associated with the Coates Lake Group are yet untested in this area.

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Blake, R. Blake-MacLeod, J. Blake-McLeod, A. Edgi, and S. Rabisca. Work was carried out under research permits issued by Aurora Research Institute, on lands within the Gwich'in and Sahtu land settlement districts.

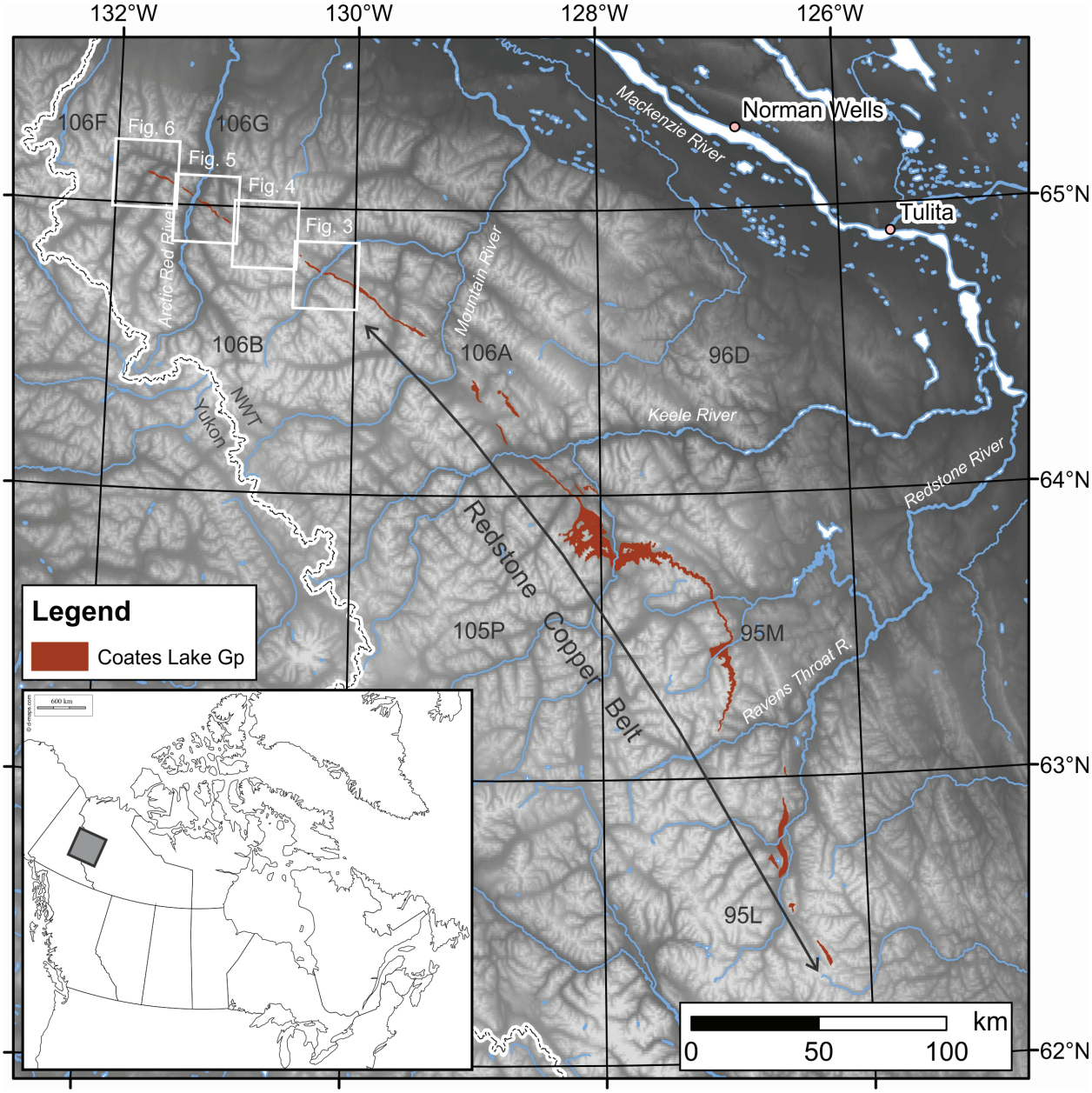

Figure 1. Map of the Mackenzie Mountains showing the mapped distribution of the Coates Lake Group. Segment marked as Redstone Copper Belt is the outcrop belt documented by Jefferson (1983) based on a series of measured sections. Outcrop shown in NTS map areas 106B and 106G is based on GSC mapping from 2016 to 2018. Inset map shows study area location within Canada. White boxes indicate areas shown in Figures 3, 4, 5, and 6.

Stratigraphic Units

Paleozoic strata	Cambrian to Devonian strata dominated by carbonate rocks with lesser amounts of shale and sandstone.
Windermere Supergroup	Cyogenian and Ediacaran strata dominated by siliciclastic rocks with minor intervals of dolostone.
Coates Lake Group (late Tonian)	
Coppercap Formation 0-300 m	Light grey-weathering, thin- to medium-bedded particulate limestone and minor dolostone.
Redstone River Formation 0-1200+ m	Not present in study area. Described to the southeast of study area as white-weathering evaporite overlain by red or pink laminated siltstone, mudstone, and carbonate. Minor conglomerate in middle part.
Thundercloud Formation 0-300 m	Orange, tan, reddish, or maroon-weathering interval of interbedded mudstone or shale, dolostone, quartz sandstone, and conglomerate.
Mackenzie Mountains Supergroup (Tonian)	
Little Dal Group	Succession of carbonate, mudstone, and minor evaporite. Uppermost unit underlying Coates Lake Group is Ram Head Formation, a unit dominated by resistant, brownish-grey to light-orange dolostone with minor mudstone intervals in the upper part.
Katherine Group	Succession dominated by cream to grey-weathering quartzite or quartz arenite with minor shale and carbonate intervals.

Figure 2. Chart of map units shown in Figures 3, 4, 5, and 6 with generalized descriptions. Redstone River Formation is included for reference, but is not mapped in the study area.

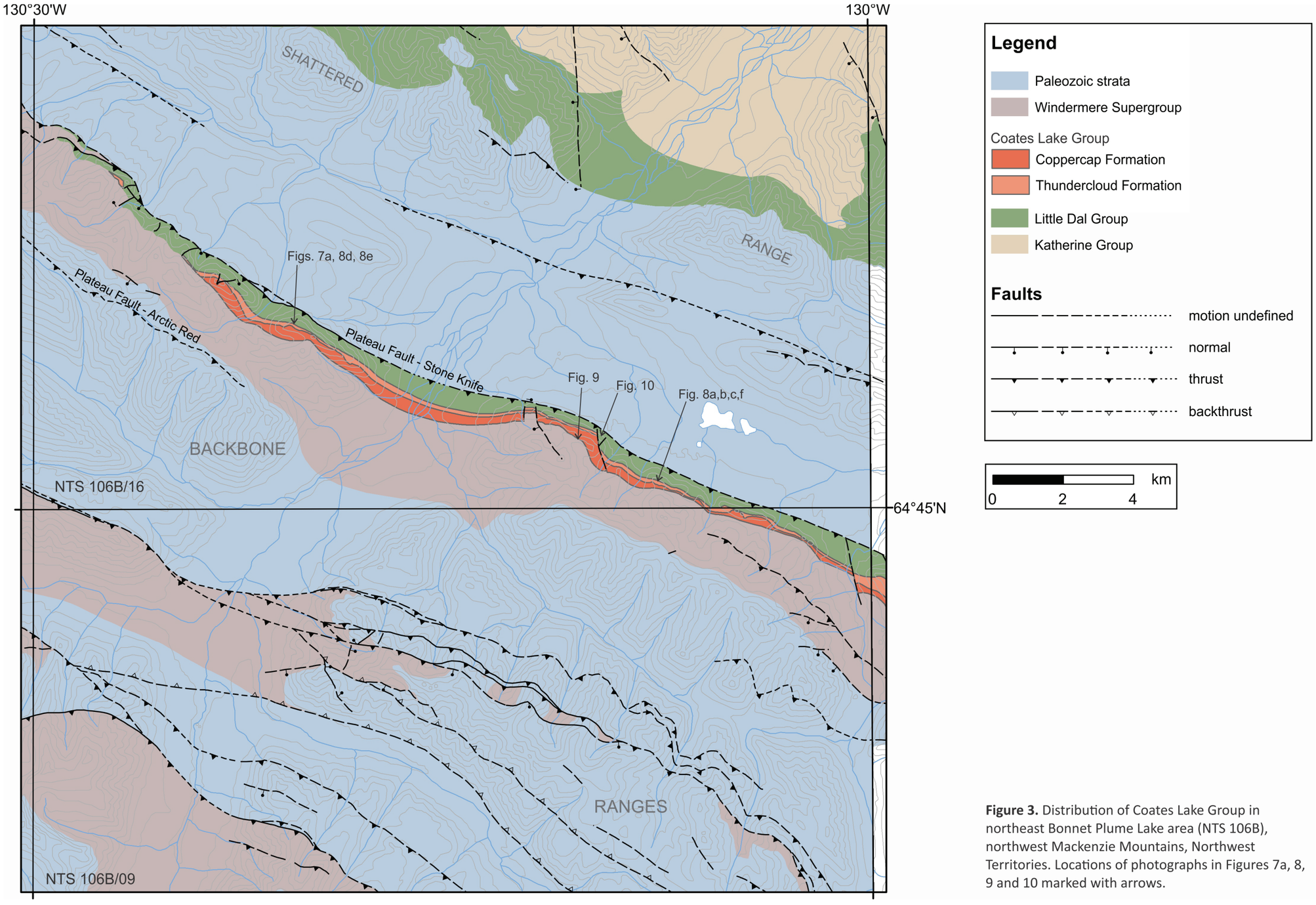

Figure 3. Distribution of Coates Lake Group in northeast Bonnet Plume Lake area (NTS 106B), northwest Mackenzie Mountains, Northwest Territories. Locations of photographs in Figures 7a, 8, 9 and 10 marked with arrows.

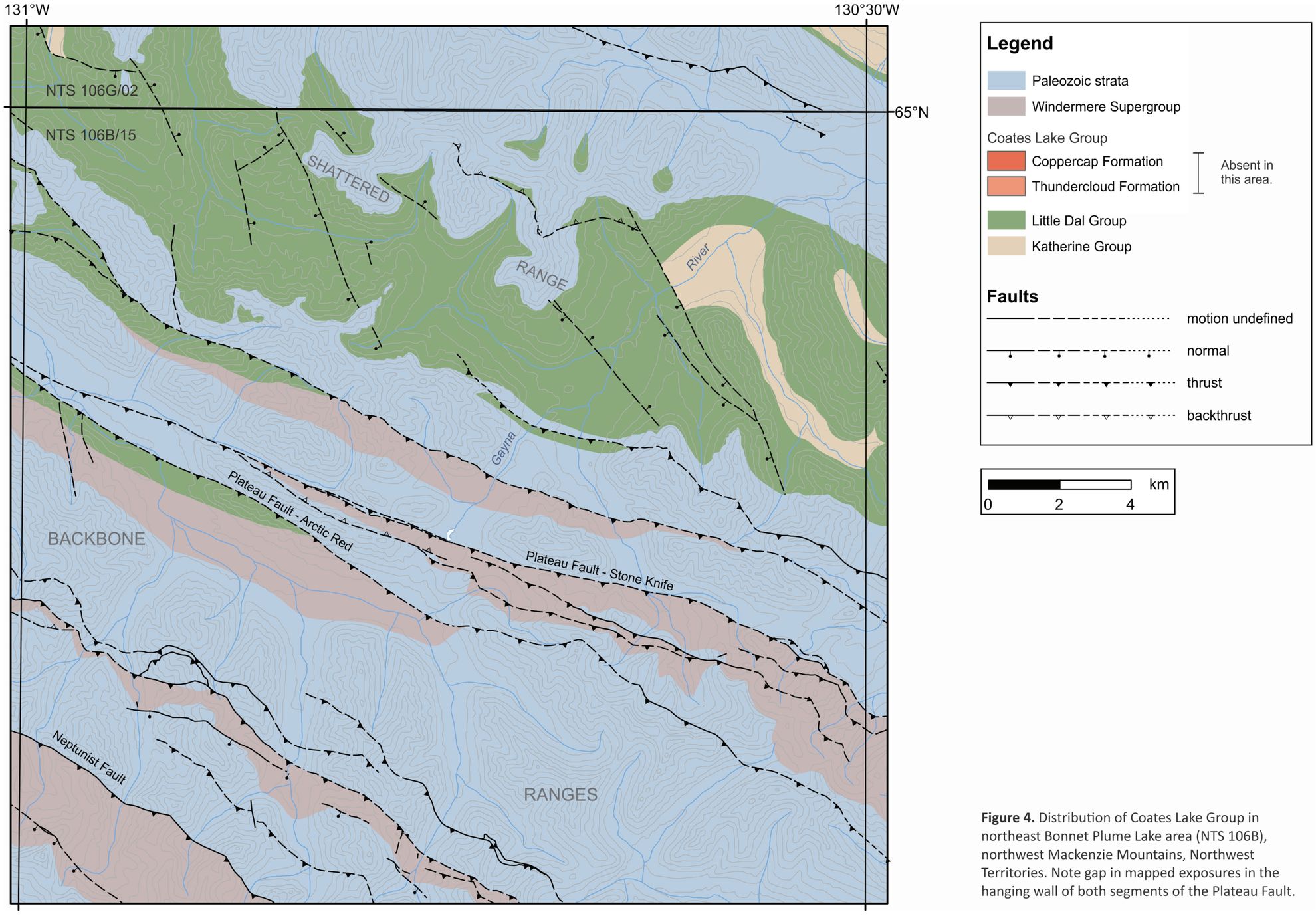

Figure 4. Distribution of Coates Lake Group in northeast Bonnet Plume Lake area (NTS 106B), northwest Mackenzie Mountains, Northwest Territories. Note gap in mapped exposures in the hanging wall of both segments of the Plateau Fault.

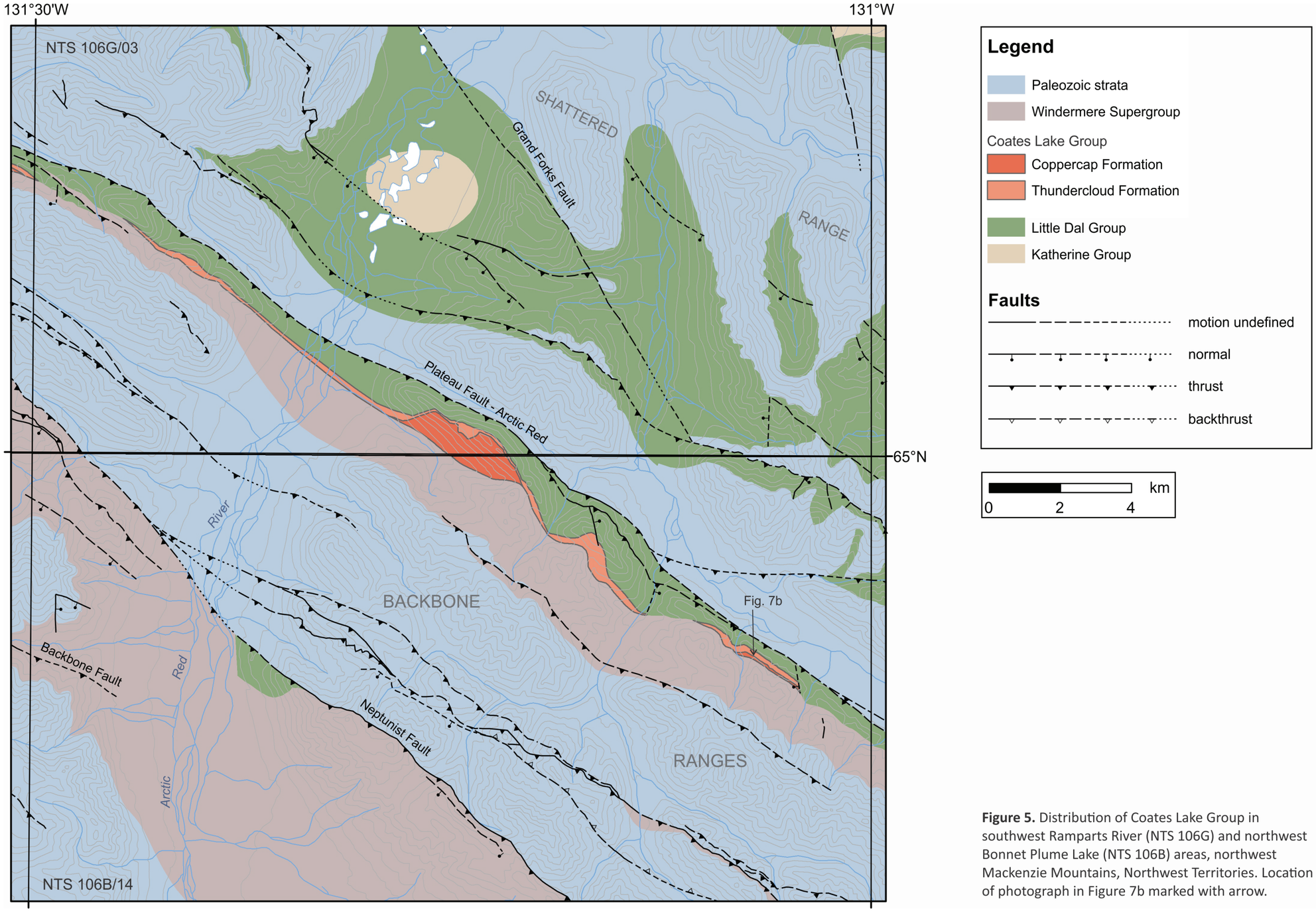

Figure 5. Distribution of Coates Lake Group in southwest Ramparts River (NTS 106G) and northwest Bonnet Plume Lake (NTS 106B) areas, northwest Mackenzie Mountains, Northwest Territories. Location of photograph in Figure 7b marked with arrow.

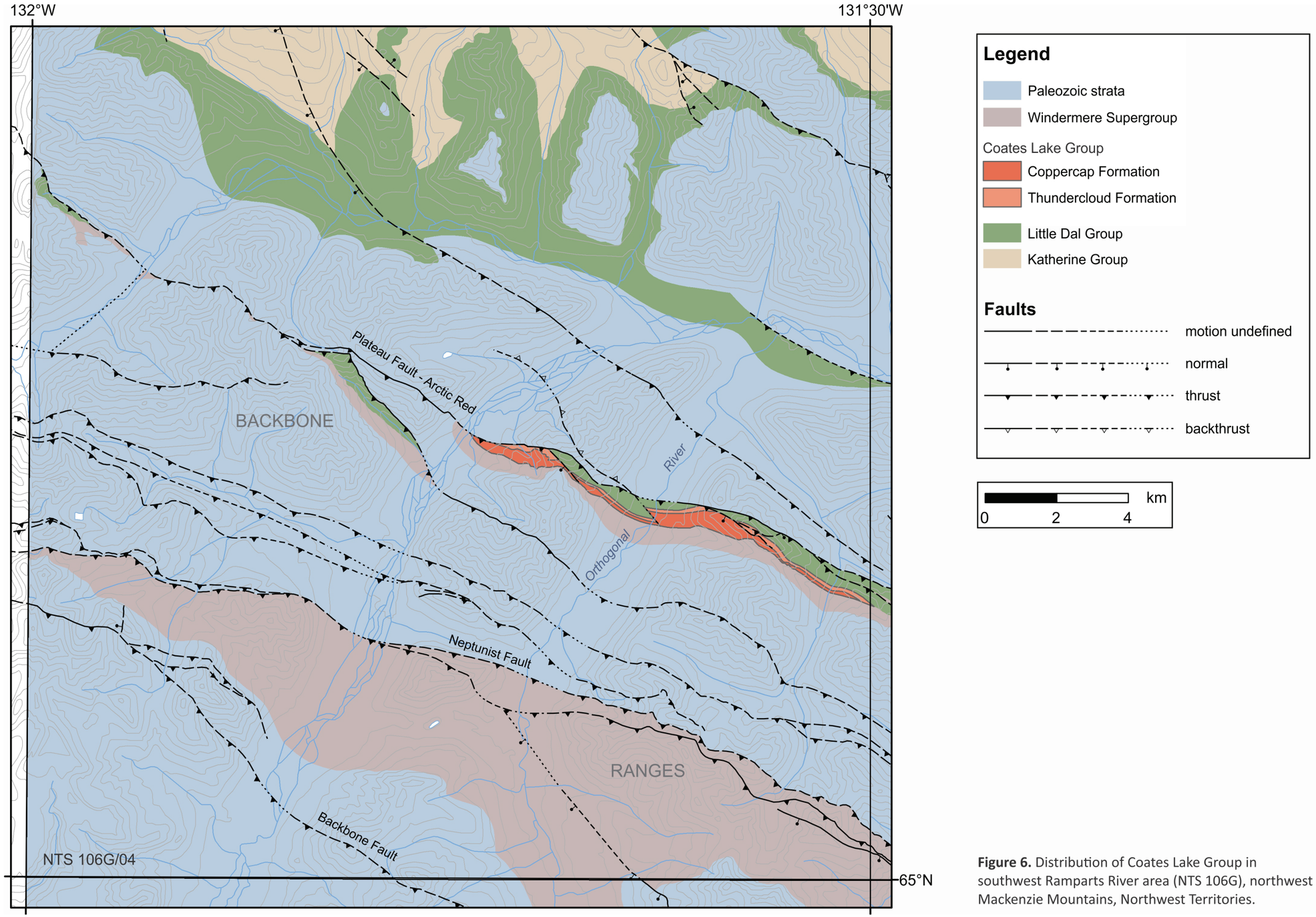

Figure 6. Distribution of Coates Lake Group in southwest Ramparts River area (NTS 106G), northwest Mackenzie Mountains, Northwest Territories.

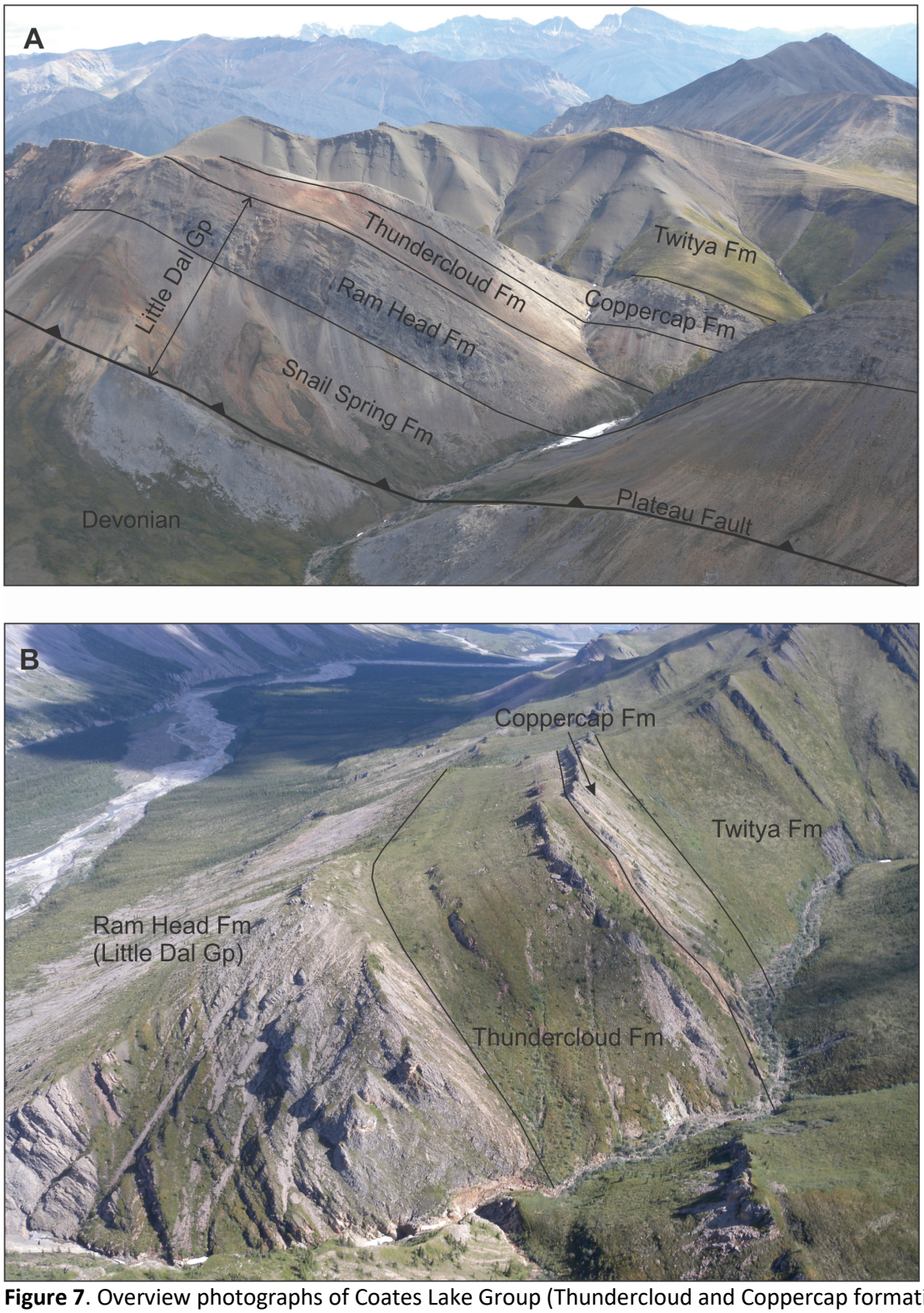

Figure 7. Overview photographs of Coates Lake Group (Thundercloud and Coppercap formations) in the hanging wall of the Plateau Fault in the northern part of the Bonnet Plume Lake map area (NTS 106B). Locations as marked in Figures 3 and 5; A) view to the south (photograph by K. Fallas, NRCan photo 2019-270); B) view looking southeast (photograph by K. Fallas, NRCan photo 2019-271).

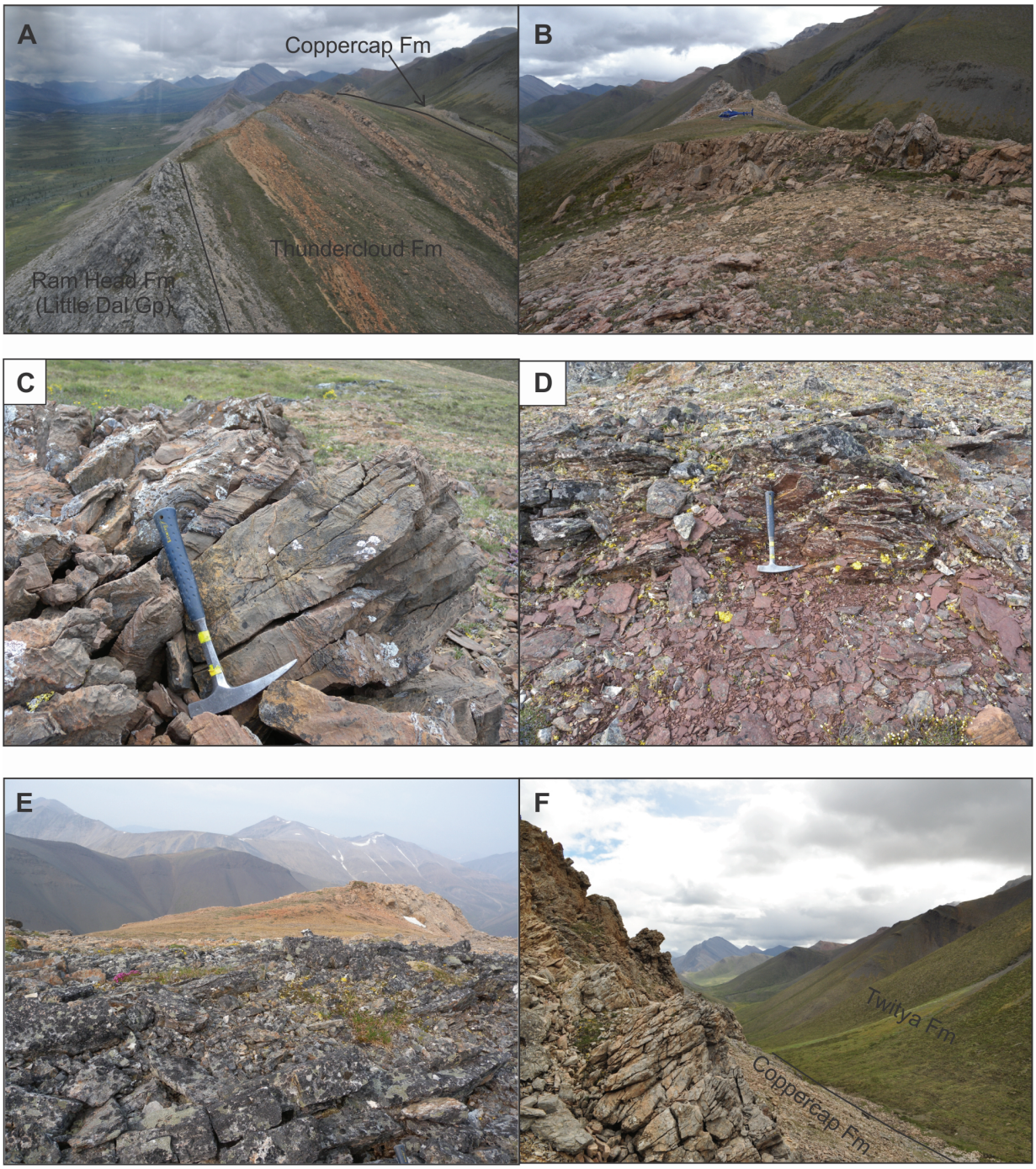

Figure 8. Strata of the Thundercloud and Coppercap formations at localities marked in Figure 3. A) View to the southeast of Thundercloud Formation, approximately 50 m thick (photograph by T. Finley, NRCan photo 2019-773); B) mudstone and dolostone of Thundercloud Formation, Coppercap Formation lies beyond helicopter (photograph by K. Fallas, NRCan photo 2019-771); C) dolostone with quartz sand laminae in Thundercloud Formation (photograph by K. Fallas, NRCan photo 2019-772); D) red shale and grey quartz arenite in Thundercloud Formation (photograph by K. Fallas, NRCan photo 2019-776); E) grey quartz arenite and orange dolostone in Thundercloud Formation (photograph by K. Fallas, NRCan photo 2019-777); F) tan dolostone of Coppercap Formation overlain by dark grey shale of Twitya Formation (photograph by T. Finley, NRCan photo 2019-774).

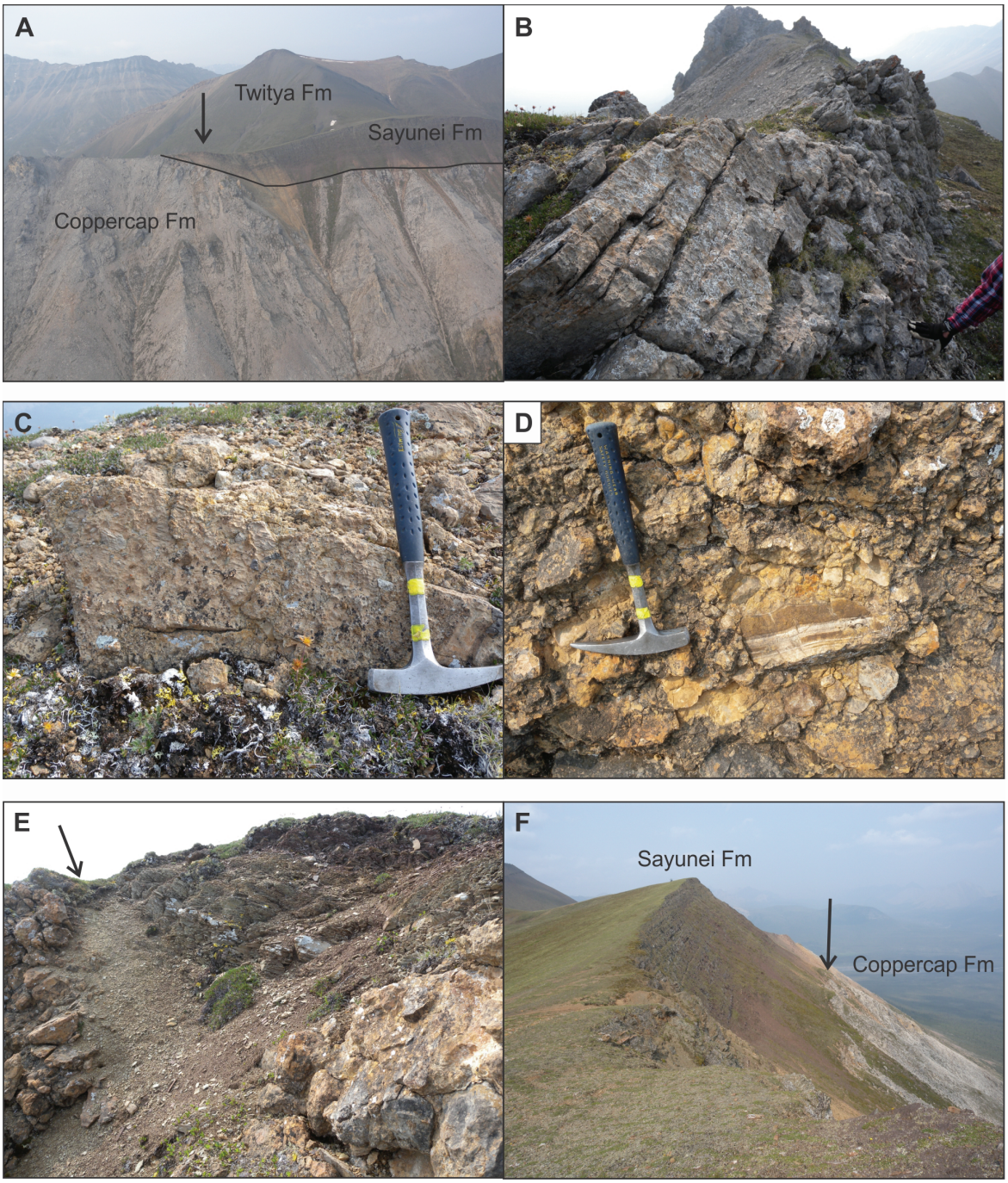

Figure 9. Features at the upper contact of the Coppercap Formation. A) View to southwest of unconformable contact between Coppercap Formation and Sayunei Formation; arrow marks location of photographs b-f (photograph by K. Fallas, NRCan photo 2019-778); B) dolostone in upper part of Coppercap Formation (photograph by K. Fallas, NRCan photo 2019-779); C) conglomeratic dolostone in upper part of Coppercap Formation (photograph by K. Fallas, NRCan photo 2019-780); D) carbonate-clast conglomerate at unconformity (photograph by K. Fallas, NRCan photo 2019-781); E) view looking southeast along unconformity (marked with arrow); weathered carbonate of Coppercap Formation on left, reddish-weathering shale of Sayunei Formation on right (photograph by K. Fallas, NRCan photo 2019-782); F) view of the unconformity (marked with arrow) looking northwest (photograph by K. Fallas, NRCan photo 2019-783).

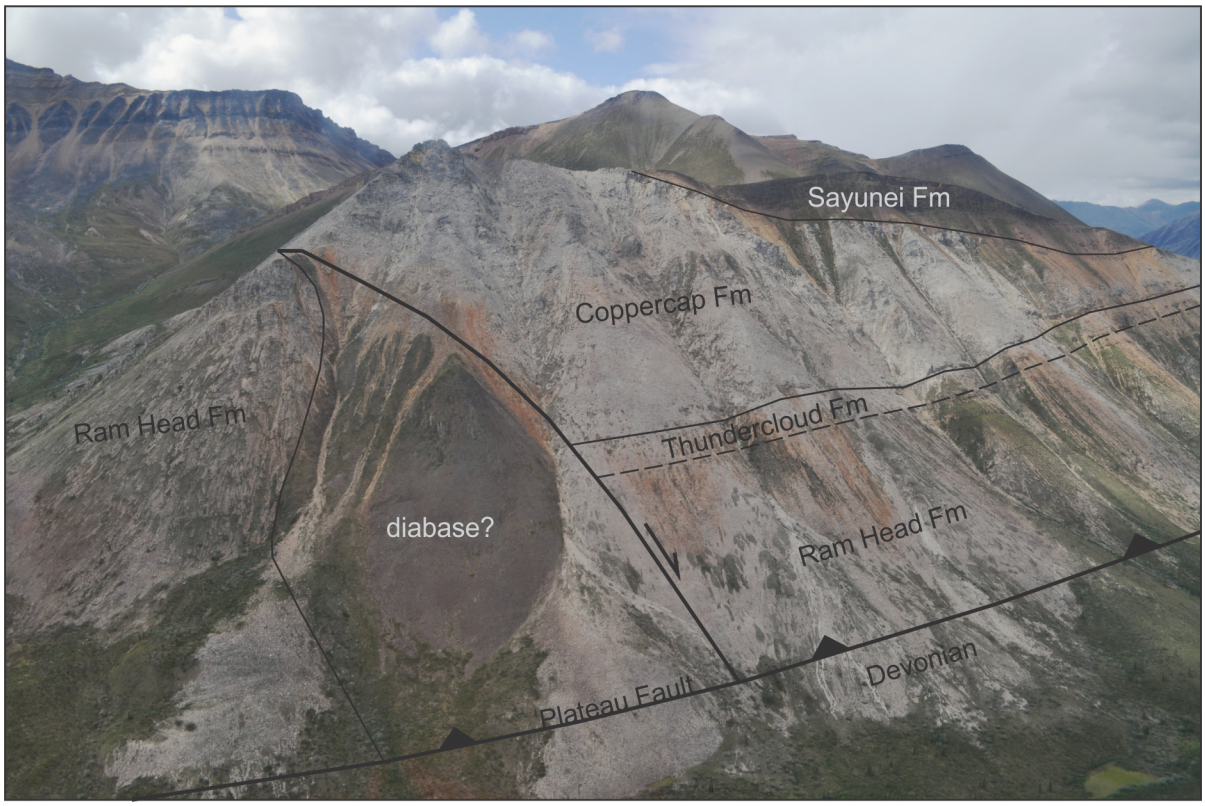

Figure 10. View looking west-southwest of intrusive and fault relationships in the hanging wall of the Plateau Fault. Area labelled as diabase is unverified, but other lithologies are unlikely in this setting. Normal fault shown is truncated beneath the Twitya Formation higher in the section (photograph by T. Finley, NRCan photo 2019-775).

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