Natural Resources Canada | Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8246

Cambrian lithostratigraphy of the Mount Clark, Mount Cap, and Saline River formations in the Carcajou Range and Norman Range, Northwest Territories (NTS 96E1, 3, and 4)

M.L. Bouchard and E.C. Turner

2017

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8246

Cambrian lithostratigraphy of the Mount Clark, Mount Cap, and Saline River formations in the Carcajou Range and Norman Range, Northwest Territories (NTS 96E1, 3, and 4)

M.L. Bouchard[1] and E.C. Turner[1]

[1]Harquail School of Earth Sciences, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario P3E 2C6

2017

https://doi.org/10.4095/302730

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

Recommended citation
Bouchard, M.L. and Turner, E.C., 2017. Cambrian lithostratigraphy of the Mount Clark, Mount Cap, and Saline River formations in the Carcajou Range and Norman Range, Northwest Territories (NTS 96E1, 3, and 4); Geological Survey of Canada, Open File 8246, 35 p. https://doi.org/10.4095/302730

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

TABLE OF CONTENTS

ABSTRACT

This report documents the Lower to Middle Cambrian Mount Clark, Mount Cap, and Saline River formations in the Carcajou and Norman ranges, western mainland Northwest Territories. The ”Bearpaw Creek” section (section 1), exposes the sandstone-dominated uppermost Abraham Plains Formation (Katherine Group; ~2.4 m measured), unconformably overlain by a complete section of the Cambrian sandstone-dominated Mount Clark (~11.6 m measured), dolostone and dolomitic-sandstone-dominated Mount Cap (~23.2 m measured) and gypsite-dominated Saline River formations (~66.7 m measured), and lowermost carbonate-dominated Cambrian-Ordovician Franklin Mountain Formation. Dodo Creek sections A and B (section 2A and B), consist of incomplete, overlapping sections of the Mount Cap Formation (section A ~35.5 m measured; section B ~28.8 m measured). The Norman Range section (section 3) is an almost complete section of the Saline River Formation (~182.4 m measured), which is conformably overlain by the lowermost units of the Franklin Mountain Formation.

REGIONAL GEOLOGY

The Cambrian Mount Clark, Mount Cap and Saline River formations, established by Williams (1922 and 1923), were deposited during continental subsidence in a semi-enclosed epicontinental marine basin (MacLean, 2011). These Cambrian strata are known from the interior plains (Cook and Aitken, 1970; Macqueen and Mackenzie, 1973; Hamblin, 1990; Dixon, 1997; Dixon and Stasiuk, 1998; Bouchard and Turner 2017), Mackenzie Plains (Balkwill and Yorath, 1970; Aitken et al., 1973), Mackenzie Mountains (Serié et al., 2013), and Peel region (Pugh, 1983 and 1993; Pyle et al., 2006; Pyle and Gal, 2007; 2011; 2014). The depositional limits of the "Cambrian basin" are the Aklavik arch (north), the Franklin Mountains (south), the cratonic edge east of Great Bear Lake (east), and the Mackenzie arch (west; approximately 50 kilometres from this study's sections 1 and 2).

This report presents the preliminary results of stratigraphic studies of Lower and Middle Cambrian formations exposed in the Carcajou Range (NTS 96E3 and 96E4) and Norman Range (NTS 96E1), western mainland Northwest Territories (Fig. 1,2, and 3). This study is a continuation of stratigraphic work on the same succession in the Hornaday River Canyon, northeastern mainland Northwest Territories (NTS sheet 97C8; Bouchard and Turner 2017). Previous correlation of these Cambrian strata in both subsurface and outcrop is addressed by Dixon and Stasiuk (1998), and further constraints were provided by seismic data (MacLean, 2011). The isopach patterns (Fig. 3) of the Mount Clark, Mount Cap and Saline River formations (Maclean, 2011; Dixon and Stasiuk, 1998) show significant regional thickness variability, resulting in correlation and comparison challenges for all three formations. The section documented at "Bearpaw Creek" (Fig. 4) is 2 km east of the 'unnamed creek' section of Pyle and Gal (2011), Hamel and MacNaughton (2013), and Serié et al. (2013). The Dodo Canyon section (Fig. 5) was previously documented by Aitken et al. (1973), Pyle and Gal (2011), and MacNaughton et al. (2013). The Norman Range section (Fig. 6) was previously examined by Aitken et al. (1973) and Turner (2011; only documented Franklin Mountain Formation).

Studies on the petroleum potential of the understudied ‘Cambrian basin’ of Northwest Territories are discussed in Hamblin (1990), Dixon and Stasiuk (1998), Pyle and Jones (2009), and Maclean (2011). In mainland, Northwest Territories, Mount Clark Formation sandstone acts as a reservoir, shale of the Mount Cap Formation is a primary source rock, and the Saline River Formation’s evaporites provide a seal (Maclean, 2011). This study focusses on documenting the lithology and refining the lithostratigraphy of these three formations.

SECTION LOCATIONS

Detailed stratigraphic sections were documented at three locations in the Carcajou Range and one in the Norman Range, NT (Fig 2). Section 1 (‘Bearpaw Creek’; Fig 4), approximately 10 km southeast of Imperial River in the Carcajou Range, includes the uppermost Abraham Plains Formation (undocumented), all of the Mount Clark Formation (11.6 m thick), all of the Mount Cap Formation (23.2 m thick), all of the Saline River Formation (approximately 66.7 m thick), and the lowermost units of the Franklin Mountain Formation (8.6 m measured) (Figs. 7 and 8). Section 2 (Fig. 5), in Dodo Canyon (approximately 26 km south-east of section 1), included two incomplete, overlapping sections of the Mount Cap Formation (section 2A – 35.5 m thick; section 2B - 28.8 m thick; Fig. 9). Section 3 (Fig. 6), in the Norman Range (approximately 62 km northeast of section 2), spanned an almost complete section of the Saline River Formation (182.4 m thick;) and the lowermost units of the Franklin Mountain Formation (2.1 m; Fig.10).

SECTION DESCRIPTIONS

"Bearpaw Creek" section (Section 1; near Imperial River; NTS 96E3)

Section 1 "Bearpaw Creek", ascends a steep slope and cliff beside a small waterfall (Figs. 4 and 8). The uppermost few metres of the Neoproterozoic Abraham Plains Formation (Katherine Group) are exposed at the base of the measured section (Fig. 11A). Unit 1 is the uppermost 2.4 m of the Abraham Plains Formation and consists of orange buff and medium red-weathering, resistant-weathering, trough cross-stratified, medium-grained quartz arenite with floating coarse quartz grains and bed thickness of 10 - 40 cm.

Mount Clark Formation

Abruptly and unconformably overlying the Abraham Plains Formation is 20 cm of dark purple-weathering, resistant-weathering, medium-grained, hematite-cemented quartz arenite (unit 2; 2.4 – 2.6 m) constituting the basal interval of the Mount Clark Formation (unit 2; Fig. 11B). Units 3 – 8 (2.6 - 14 m) consist of pale and medium buff, pale yellow-buff, medium orange-buff, medium red-buff, pale grey, medium grey, pale pink, medium orange-brown, and medium brown, resistant- and recessive-weathering, parallel-laminated and trough cross-stratified medium-grained quartz arenite with local horizontal and vertical traces, including rare *Skolithos*, and bedding thickness of 5 – 15 cm. The Mount Clark Formation is dominated by trough cross-stratified and burrowed quartz arenite with a total thickness of approximately 11.6 m (section 1; Fig. 8); its upper contact with the Mount Cap Formation is in a thin covered interval.

Mount Cap Formation

The basal contact of the Mount Cap Formation with the underlying Mount Clark Formation is in a 90-cm-thick covered interval (unit a) and is defined by an abrupt change from quartzose sandstone to medium-crystalline dolostone. The lowest exposure of the Mount Cap Formation (unit 9; 14.9 – 15.5

m) is medium orange and medium brown-weathering, resistant-weathering medium crystalline quartzose limestone and massive, coarsely crystalline limestone. Units 10 - 36 (17.1 - 24.9 m) consist of rusty, medium brown, medium orange-brown, medium grey, buff, orange-buff, pink, red-orange-weathering, ribbed-weathering, dolomitic glauconite sandstone (Fig. 11C), quartzose limestone, and medium-crystalline dolostone and limestone interbedded with shale. Horizontal (Fig. 11D) and vertical burrows are ubiquitous, and trilobite fragments are sparsely present (unit 20); layer thickness is 0.05 to 0.4 m. Units 37 – 41 (25.6 – 29.8 m) consist of dark grey, medium grey, pale brown, pale orange-buff-weathering, resistant- and recessive-weathering, massive medium-crystalline dolostone and limestone with locally interbedded shale (unit 38); layer thickness is 0.1 – 0.5 m (Fig. 8). The total thickness of the Mount Cap Formation at section 1 is approximately 23.2 m (Fig. 8). The upper contact with the overlying Saline River Formation is in a covered interval ("g"; Fig. 8). Therefore the contact is placed bellow the gypsite bearing siltstone unit 42 (Figs. 8 and 11E).

Saline River Formation

The Saline River Formation in section 1 (Fig. 8), consists of a lower undeformed interval (approximately 66.7 m thick) that is overlain by approximately 47 m of contorted, tectonically disrupted gypsite. The lowest exposed unit, unit 42 (38.05 - 39.25 m), consists of medium grey, orange-buff and buff-weathering, resistant- and recessive-weathering, rippled siltstone, and shale interbedded with fine-grained sandstone and massive, medium-crystalline dolostone with bedding thickness less than 1 mm to 1 cm. Units 43 – 47 (39.3 - 40.5 m) consist of medium to dark grey, medium green-grey, medium brown, and orange-buff-weathering, resistant- and recessive-weathering shale, massive finely crystalline dolostone, siltstone, and unlithified gypsiferous wacke. Units 48 – 54 (40.2 - 42.6 m) consist of pale blue-green and medium red-brown, pale green, pale to dark grey, pale grey with pink, golden brown, pale yellow, pale buff to white, buff, and orange-buff weathering, resistant- and recessive-weathering, poorly lithified to unlithified gypsiferous sand and clay, fine-

grained sandstone, and shale. Units 55 – 57 (42.6 - 43.9 m) consist of pale brown, pale brown-grey, medium grey and dark grey weathering, resistant-weathering, parallel-laminated and stromatolitic dolomudstone, severely brecciated and deformed porous medium-crystalline dolostone, and massive very finely to finely crystalline dolostone interbedded with shale. Units 58 – 59 (43.9 - 44.9 m) consist of pale green, pale grey, and medium grey-weathering, recessive-weathering, medium-crystalline gypsite, and gypsiferous fine-grained quartz arenite interbedded with siltstone and gypsiferous clay. Unit 60 (44.9 - 45.2 m) consists of pale pink and medium grey-weathering, recessive-weathering and chicken-wire-textured gypsite. Units 61 – 64 (45.2 - 45.9 m) consist of medium grey, pale brown-grey, green-grey, and pale yellow-grey-weathering, resistant- and recessive-weathering, unlithified gypsiferous clay, massive finely crystalline dolostone, and intraclastic limestone, interbedded with shale. Units 65 – 72 (45.9 - 48.3 m) consist of pale to dark grey, medium green-grey, pale to medium pink, orange-pink, dark purple-red, medium yellow, medium blue-green and medium yellow weathering, resistant- and recessive-weathering, locally rippled dolomudstone with local halite moulds (unit 70), massive medium-crystalline dolostone, dolomudstone, shale, gypsite, and gypsiferous sand and clay. Units 73 – 75 (48.3 - 50.3 m) consist of dark grey, pale brown, white to pink, and medium golden brown-weathering, resistant- and recessive-weathering, massive medium-crystalline dolostone interbedded with gypsite and minor hematitic gypsite (unit 74). Unit 76 – 79 (50.5 – 51.2 m) consist of orange-pink, dark purple-red, pale blue-grey, and pale green-grey weathering, recessive-weathering, massive, medium-crystalline dolostone, laminated lime mudstone, gypsite with local ripples, chicken-wire texture, and halite casts, siltstone, mudstone, and dolomudstone. Unit “m” (51.2 – 104.9 m) consists of a lower inaccessible section (~6.6 m) which is dominated by laminated, intraclastic limestone, very finely crystalline dolostone, and massive, medium-crystalline gypsite that is overlain by contorted gypsite (Fig. 11F). The upper 47 m of unit “m” consist of variably exposed, horizontally layered to pervasively deformed white- to pink-weathering gypsite. Owing to tectonic deformation, this interval could not be confidently measured, and it is depicted as a covered interval (Fig. 11F)

whose apparent thickness (47 m) may not be representative of its original thickness. Above this disrupted gypsite interval, regular, undeformed layering resumes. Units 80 – 85 (104.5 - 105.9 m) consist of medium brown, medium green-grey, pale purple-grey, medium - dark grey, medium blue-grey and pale golden brown-weathering, recessive-weathering dolomudstone interbedded with fine-grained sandstone, massive, fine- to medium-crystalline dolostone, gypsite and gypsiferous clay, and shale. The total thickness of the Saline River Formation at section 1 is approximately 66.7 m (Fig. 8). The upper contact with the overlying Franklin Mountain Formation is defined by a gradational change from gypsite-dominated strata to massive dolostone and quartzose dolostone interbedded with siltstone.

Franklin Mountain Formation

In section 1, units 86 – 94 (105.9 - 110.5 m) of the lowermost Franklin Mountain Formation are pale golden brown with medium-green lenses, medium grey, pale golden brown, pale brown, and medium green-grey weathering, resistant-weathering, rippled, and stromatolitic dolomudstone, and massive, medium-crystalline dolostone interbedded with siltstone and shale. Units 95 – 97 (110.5 - 112.6 m) consist of medium golden brown, dark to medium brown and light golden brown, medium green-grey, and medium yellow-weathering, resistant-weathering, dolomitic quartz wacke and dolomudstone. Unit 98 (112.6 - 112.9 m) consists of medium pinkish-brown-weathering, resistant-weathering, quartzose ooid packstone with local ripples. Units 99 – 104 (112.9 - 114.5 m) consist of pale yellow-brown, dark purple-brown, medium orange-brown, pale yellow-buff, medium grey, and green-grey weathering, resistant-weathering, dolomudstone with microbial lamination (unit 99) and local tempestite beds (unit 100) with intraclasts of microbially laminated dolomudstone, ooid packstone (base of unit 101), and quartzose dolostone. Documentation of this section ended in unit 105 (thickness not measured), which consists of green-grey-weathering, recessive-weathering siltstone.

Dodo Canyon section (Section 2; NTS 96E4)

Section 2 spans most of the Mount Cap Formation and was documented in two overlapping, incomplete sections up steep slopes in Dodo Canyon (Figs. 5A-C, 9A and B). The basal contact is below the river level at this location, and the lowest of the exposed units are inaccessible owing to steepness and the present position of the river bank. The contact with the overlying Saline River Formation is within a thick covered interval; the gypsite of the overlying Saline River Formation is severely deformed and poorly exposed and was not documented. Section 2A documents most of the lower and middle units of the Mount Cap Formation with a total measured thickness of approximately 26. 3 m (Fig. 9A), Section 2B, just downstream of section 2A (Fig. 5A), exposes part of the middle and upper Mount Cap Formation (Fig. 5C), with a total measured thickness of approximately 28.8 m (Fig. 9B).

Mount Cap Formation

In section 2A, units 1 – 8 (0 – 3.8 m; Fig. 12A) of the Mount Cap Formation consist of medium and dark grey-weathering, resistant-weathering, quartz-cemented, hematitic, medium- to coarse-grained quartz arenite with lithic clasts (quartzose and pyritic dolomudstone), interbeds (shale and siltstone) and bedding thickness of 0.1 to 0.5 m. Units 9 – 12 (3.8 – 5 m) consist of medium and dark brown and medium orange-brown-weathering, resistant-weathering, bioturbated limestone, cuspate-folded, thinly (mm-scale) parallel-laminated, and intraclastic limestone, massive, medium to coarsely crystalline limestone, quartzose limestone, and massive finely crystalline dolostone with local ripples, horizontal traces and trilobite fragments (unit 9), with bedding thickness of 0.1 to 0.7 m. Units 13 -14 (5 – 5.8 m) consist of medium brown to medium red-brown, pale grey and pale brown-weathering, resistant-weathering, massive, medium-crystalline limestone; in-situ brecciated clasts of fine-grained quartz arenite, dolomitic sandstone with mudstone lenses and horizontal traces, and bedding thickness of 0.4 m. Units 15 - 16 (5.8 – 7 m) consist of pale yellow-buff, medium orange-brown, medium red-brown,

medium to dark brown and dark purple-weathering, resistant-weathering, calcareous, fine-grained quartz arenite with floating coarse-grained quartz, minor mudstone clasts, and coarse-grained phosphate grains, calcareous intraclastic fine-grained quartz arenite with trace amounts of phosphatic grains, and dolomitic, quartz-cemented fine- to medium-grained glauconitic quartz arenite. This interval also contains local lenses of organic matter, horizontal traces, and hematite cement, and has bedding thickness of roughly 0.2 m. Units 17 – 20 (9.9 - 22.3 m) consist of pale yellow-buff, medium brown, medium orange-brown and dark grey weathering, resistant-weathering, bioturbated skeletal limestone; skeletal (brachiopod fragments) limestone and locally parallel-laminated limestone (Fig. 12B) and bedding thickness of 0.1 to 0.7 m. Unit 21 (22.3 - 22.4 m) consists of dark grey and dark green-weathering, recessive-weathering shale and glauconitic sand with a layering thickness of 0.1 m. Units 22 – 23 (22.4 - 26.3 m) consist of patchily rusty-weathering, pale orange-brown, medium brown and medium grey-weathering, resistant-weathering, massive, finely crystalline limestone and laminated lime mudstone with slumped beds, cuspate creep folds or expansion ridges (trend of cusp crests is ~325 degrees; Fig. 12C) and intraclasts; quartzose intraclastic limestone; and parallel-laminated dolostone; interbedded with millimetre-thick shale layers. Units 24 – 28 (26.3 m; section ended at unit 28 and thickness of unit 28 was not measured; Fig. 12D) consist of medium and dark grey, medium greenish grey, medium purple-brown, medium brown and medium orange-brown-weathering, recessive-weathering, shale containing fecal aggregates, trilobite fragments (Fig. 12E), and inarticulate brachiopods with local intraclastic and bioturbated limestone, and skeletal quartzose limestone layers (0.02 - 0.1 m thick).

In section 2B (Figs. 5C and 9B), material underlying the lowest well-exposed units consists of medium grey and rusty weathering, shale (unit a). Unit 1 (0 - 1.1 m) consists of medium grey with rusty-weathering patches, resistant weathering, intraclastic and parallel-laminated limestone, laminated dolostone and finely crystalline limestone clasts in a finely crystalline limestone matrix. Unit 2 (1.1 -

1.3 m) consists of dark grey and dark brown-weathering, recessive-weathering, shale, and unlithified clay and glauconitic sand with a thickness of approximately 0.05 m. Unit 3 (1.3 - 1.6 m) consists of medium grey, medium brown and rusty weathering, resistant-weathering, parallel-laminated and intraclastic limestone and massive finely crystalline pyritic limestone with bedding thickness of 0.3 m. Unit 4 (1.6 – 3.3 m) together with the overlying, mainly covered interval (b) consists of medium grey, medium brown and rusty-weathering, recessive-weathering shale. Unit 5 (19.3 - 28.8 m) consist of pale orange-buff, dark grey and medium and pale brown-weathering, resistant and recessive weathering, massive very finely and finely crystalline dolostone, very finely to finely and medium-crystalline limestone, very finely crystalline limestone, and shale interbeds (Fig. 12F).

Norman Range section (Section 3; NTS 96E1)

Section 3 (Figs. 6, 10 and 13A-D), is an incomplete section of Saline River Formation documented up a steep slope and cliff in the Norman Range (Fig. 6(Fig. 10). The basal contact of the Saline River Formation is not exposed, but the upper contact with the overlying Franklin Mountain Formation is conformable and gradational. The upper contact is placed at the stratigraphically highest bed >0.5 m thick of red or green shale or mudstone as defined by Norford and Macqueen (1975). The exposed thickness of the Saline River Formation at section 3 is approximately 182 m (Fig. 10).

Saline River Formation

In section 3, units 1 – 2 (0 - 2.3 m) of the Saline River Formation consist of medium bluish-grey and medium to dark grey weathering, recessive-weathering, parallel-laminated siltstone with intense gypsum veining and gypsum nodules, massive, medium-crystalline gypsite and medium-crystalline gypsite interbedded with finely crystalline limestone. Units 3 – 4 (2.3 – 4 m) consist of pale blue-grey and medium grey and pale green-grey with local pale pink-weathering, recessive-weathering, fine-grained quartz arenite and medium-grained quartz arenite with local ‘floating’ coarse-grained quartz.

Unit 5 (4 – 10 m) consists of white, pale, medium and dark grey, pale buff, and pale orangish buff-weathering, recessive-weathering, massive gypsite with minor rounded gypsite masses, massive, finely crystalline gypsite; massive, finely crystalline limestone, and intensely brecciated limestone with intraclasts of mudstone, and layer thickness 1 mm to 10 cm. Unit 6 (10 – 11 m) consists of pale green-buff-weathering, recessive-weathering, Medium-crystalline dolostone with discontinuous lenses of dolomitic mudstone. Units 7 - 8 (11 – 16. 4) consist of pale and medium grey- and white-weathering, recessive-weathering, parallel-laminated, massive gypsite, finely and medium-crystalline gypsite, massive gypsite with rounded coarsely crystalline anhydrite masses, and medium-crystalline dolostone. Units 9 – 11 (21.4 - 30.4 m; Fig. 13A) consist of pale blue-grey, medium grey, dark grey, white, rusty, medium red-brown, pale blue, pale green-blue, and pale yellow weathering, resistant-weathering, massive medium-crystalline gypsite with local, rounded, coarsely crystalline anhydrite masses, dolomudstone, and unlithified gypsiferous sand and clay. Units 12 – 15 (30.4 - 60.3 m) consist of orange-pink, green-grey, dark grey, dark purple-red, pale, medium and dark grey-weathering, recessive-weathering, dolomudstone, massive, medium-crystalline hematitic gypsite, dolomitic siltstone with hematitic lenses, siltstone, and laminated finely crystalline gypsite. Unit 16 (65.2 - 72.2 m) consists of dark purple-red, medium orange-pink, white, medium green-grey, medium buff and pale green-grey-weathering, recessive-weathering, unlithified and poorly lithified gypsiferous clay, brecciated clasts of finely crystalline gypsite and dolomudstone, dolomudstone, and finely crystalline dolostone. Units 17 – 18 (72.2 - 73.7 m) consist of pale buff, pale green-buff, and medium green-grey-weathering, recessive-weathering dolomudstone. Unit 19 (73.7 - 81 m) consists of the following rock types, all of which are medium green-grey, white to pale grey, blue-gray and dark purple-red-weathering and resistant-weathering: massive, medium-crystalline gypsite with laminae of coarsely crystalline anhydrite; massive finely crystalline gypsite with minor rounded coarsely crystalline anhydrite masses; unlithified clay and hematitic clay; and massive, finely crystalline dolostone. Units 20 – 21 (86.5 – 93.9 m) consist of pale red-buff, medium red-brown, pale green-grey, pale brown,

medium red-brown, and pale buff-weathering, recessive-weathering, massive, finely crystalline dolostone with local round spots of hematite, dolomudstone, and brecciated finely crystalline hematitic gypsite. Units 22 – 27 (109.5 – 149.2 m) consist of white, pale pink, medium orangish-red, dark purple-red, pale brown, pale pink-brown, medium red-brown, medium blue-green, pale greenish grey, medium grey, and orange-buff-weathering, resistant- and recessive-weathering, massive, medium-crystalline gypsite, dolomudstone, severely brecciated clasts of dolomudstone and hematitic gypsite, stromatolitic dolostone (Fig. 13B), unlithified mud, massive, medium- to finely crystalline gypsite with local minuscule ripples (Fig. 13C) and finely to medium and locally coarsely crystalline hematitic gypsite, and hematitic medium-crystalline dolostone. Units 28 – 29 (162.5 - 164.8 m) consist of medium grey, green-grey, pale purple grey, yellow-buff, yellow-green-buff, pale and medium green-buff, dark green, and medium purple-weathering, recessive-weathering, dolomudstone, siltstone, massive finely crystalline and parallel-laminated dolostone and dolomitic siltstone. Units 30 – 41 (164.8 – 181 m) consist of pale to medium grey, pale green-grey, yellow-buff, medium green-buff, medium purple, medium brown, buff, and medium blue-green-weathering, resistant-weathering, intraclast rudstone, laminated dolostone, laminated finely crystalline dolostone, dolomitic siltstone, dolomudstone, porous very finely crystalline lime mudstone, stromatolitic dolostone, lithic and quartzose dolostone, finely crystalline dolostone interbedded with irregular mudstone laminae, and finely crystalline dolostone (Fig, 13D).

Franklin Mountain Formation

In section 3, unit 42 (182 - 182.4 m) of the basal Franklin Mount Formation (as defined by Norford and Macqueen, 1973 and as used by Turner, 2011) is medium purple-red and medium blue-green weathering, resistant-weathering, finely crystalline dolostone. Units 43 – 45 (182.4 - 184.5 m) consist of medium yellow-brown, medium brown, medium grey, and pale buff-weathering, resistant-

weathering, stromatolitic dolostone, finely crystalline dolostone and limestone with local hummocky cross-stratification.

DISCUSSION

The Cambrian strata in "Bearpaw creek" section (section 1; Figs. 4 and 8), can be compared to nearby section U-11 of Aitken et al. (1973) in Loretta Canyon, described as a dolostone- and shale-dominated upper part of the Katherine Group unconformably overlain by 25 m of quartzite- and sandstone-dominated, *Skolithos*-bearing Mount Cap Formation and 97 m of shale, sandstone, gypsite, and dolostone (Saline River Formation). Despite the close proximity to the present study's "Bearpaw creek" section (section 1; Figs. 4 and 8), section U-11 differs significantly: the sub-Cambrian unconformity is at the top of a shale- and dolostone-dominated part of the Katherine Group, rather than in Katherine Group sandstone, the Mount Clark Formation is absent or misidentified as Mount Cap Formation, and the Saline River Formation is thinner but has similar lithology. The lower units of the Mount Cap Formation in section U-11 (Aitken et al., 1973) should probably be reassigned to the Mount Clark Formation because they contain abundant *Skolithos* ichnofacies, a characteristic typical of the Mount Clark Formation (Fallas and MacNaughton, 2012; Bouchard and Turner, 2017). The "Bearpaw creek" section (section 1; Figs. 4 and 8), compares favourably to nearby section LP-24 of Pyle and Gal (2007), which expresses similar stratigraphy: the sandstone- and shale-dominated upper Katherine Group is unconformably overlain by 39.9 m of cross-bedded sandstone, shale and dolostone of the Mount Clark and Mount Cap formations, 84 m of gypsum-bearing shale and sandstone of the Saline River Formation, and the dolostone-dominated Franklin Mountain Formation. MacNaughton et al. (2013) explained the varied sedimentology and the distribution of trilobite biozones in the lower Mount Cap Formation and Mount Clark Formation in the Mackenzie front ranges as a product of distance from the Mackenzie arch. For example, in the vicinity of 'Bearpaw Creek' (i.e., northeast

flank of the Stony anticline), basal sandstones can be readily assigned to the Mount Clark Formation based on the formation's established characteristics (cleans, cross-bedded sandstone; *Skolithos* ichnofacies), whereas one anticline farther east from the arch (MacDougal anticline; area of this study's Dodo Canyon section), the basal sandstone interval is identified as Mount Cap Formation, and has markedly different characteristics (wacke rather than sandstone; glauconite; *Cruziana* ichnofacies). The characteristics of the upper Mount Cap Formation also indicate pronounced eastward deepening (increasing shale) on the Mackenzie arch flank. Regardless of the nomenclature assigned, the basal sandstone represents a contiguous entity deposited in slightly different paleoenvironments northeastward from the flank of the Mackenzie arch, thereby expressing variable characteristics; the basal sand sheet is a laterally continuous unit that is assigned to Mount Cap or Mount Clark formations on the basis of lithofacies, and slight diachroneity is probably present reflecting basal sand deposition during Early to Middle Cambrian transgression (MacNaughton et al., 2013).

Cambrian strata documented in Dodo Canyon section (Section 2; Figs. 5 and 9) dip gently downstream (northeast) and can be compared to sections in Aitken et al. (1973; MQ-6) and Pyle and Gal (2011; Dodo Canyon section); all three versions of the Dodo Canyon section were documented in the same vicinity. The Dodo Canyon sections of Aitken et al. (1973; MQ-6) and Pyle and Gal (2011; Dodo Canyon section), according to their respective references and figures, were measured on the northwest side of the creek where it exits from the narrowest part of the canyon and approximately 50 m up-stream from the present study's Dodo Canyon section. Section MQ-6 (Aitken et al., 1973) depicts a complete section of Mount Cap that unconformably overlies the Neoproterozoic Stone Knife Formation, but tracing the strata exposed above the unconformity in the narrow part of the canyon just upstream indicates that approximately 35 m of Mount Cap Formation are not exposed at the location of the present study's measured section (i.e., the formation's lowermost strata are well below river-level). Comparison of the stratigraphic log and photo for MQ-6 with those produced by this study

shows that although the locations of the creek's gravel bars and channel have changed since 1973, this difference may not account for all of the discrepancy between MQ-6 and the present study. Similarly, the sections in both Pyle and Gal (2011) and Serié et al. (2013) were based on MQ-6 and do not compare perfectly with the present study's Dodo Canyon section (section 2; Figs. 5 and 9). Future workers should be aware that the basal contact of Cambrian strata in Dodo Canyon is not currently exposed at the location of the previously measured sections.

The strata in the Norman Range section (section 3; Figs. 6 and 10) documented in the present study can be compared to section MQ-2 of Aitken et al. (1973; MQ-2), which documents 162 m (incomplete section) of the Saline River Formation at the same location, dominated by interbeds of gypsiferous mudstone, finely crystalline dolomite and massive gypsum overlain by mudstone. The thickness of the Saline River Formation in section MQ-2 is similar to the present study's Norman Range section, but the rock types and textures differ owing to the level of detail documented. The Norman Range section (Section 3; Figs. 6 and 10) is dominated by gypsite but also includes minor interbeds of massive dolostone and limestone, sandstone and mudstone in addition with various sedimentary structures and stromatolites.

Sections from Bouchard and Turner (2017) documented the Mount Clark, Mount Cap and Saline River formations in the Hornaday River Canyon, mainland, N.W.T. The Mount Clark Formation in the Hornaday River Canyon (La Roncière Falls section and unconformity section; Bouchard and Turner, 2017) are similar to the present study, but the Mount Clark Formation is thicker in the Hornaday River Canyon (~78 m) than Mount Clark Formation in the "Bearpaw Creek" section (~11.6 m). The Mount Cap Formation in the Hornaday River Canyon consists of 5 – 10-m-thick units of massive finely to medium crystalline dolostone that are locally mottled, interbedded with bioturbated glauconitic sandstone, but the Mount Cap Formation from the present study's Carcajou Range sections ("Bearpaw

creek" section and Dodo Canyon section) contain thinner (<1 m to 3 m) units of massive finely to medium crystalline dolostone interbedded with 0.1-m-thick shale units. Both exposures of the Mount Cap Formation contain glauconite, but the Carcajou Range sections seem to have a locally higher abundance. The Mount Cap Formation in the Dodo Canyon section (Section 2: Figs. 5 and 9) contains thick intervals of shale and siltstone; although some such intervals are thinly covered, they are clearly dominated by shale, up to ~20 m thick, and contain trilobite fragments and inarticulate brachiopods that are not present in the Hornaday River Canyon sections (Bouchard and Turner, 2017). In the eastern Mackenzie Mountains, strata on the flank of the Mackenzie Arch are dominated by cross-bedded quartz arenite deposited in a moderate to high-energy environment, but slightly farther away from the Mackenzie Arch, the shale- and carbonate-dominated succession of the Mount Cap Formation exposed in Dodo Canyon is consistent with deeper water and a lower-energy environment (MacNaughton et al., 2013). In this study's section 2 (Dodo Canyon), thin graded beds in the Mount Cap Formation are consistent with deposition from turbidity currents, and cuspate possible creep folds suggest the presence of a significant slope.

The Waterfall Section in the Hornaday River Canyon (Bouchard and Turner, 2017) documented a complete section of the Saline River Formation that stratigraphically overlies the Mount Cap Formation and underlies the Franklin Mountain Formation; total thickness of Saline River Formation in that section was 40 m. The Saline River Formation documented in the Mackenzie Mountains and Norman Range is much thicker (~ 67 to >182 m thick) and contains abundant gypsite units, gypsiferous sand and clay, and local halite casts. The Hornaday River location is on the eastern margin of the Cambrian basin (Dixon and Stasiuk, 1998; MacLean, 2011), whereas the present study's locations are in the more central part of the basin (Norman Range) and near the Mackenzie Arch ("Bearpaw creek"). Based on these observations, the basin's cross-sectional profile during deposition

of the Saline River Formation seems to have had a gentle dip on its northeastern margin, but a more pronounced gradient near the Mackenzie Arch.

SUMMARY

The Mount Clark, Mount Cap and Saline River formations were documented at three locations in the Carcajou Range and one section in the Norman Range, NT (Figs.6 and 10). The locations of the present study are those briefly described in reconnaissance-level reports. The present study, although it focusses on only a few important sections, is intended to provide a detailed account of sedimentology and stratigraphic packaging as a test of, and building from, previous interpretations. The detailed work reported here supports the conclusions discussed in MacNaughton et al. (2013): basal Cambrian sandstone assigned to the Mount Clark Formation records sandy, high-energy conditions near the core of the Mackenzie arch, whereas laterally equivalent basal Cambrian sandstone and wacke farther east relative to the arch, and assigned to the Mount Cap Formation, record deeper-water conditions. An eastward-deepening trend is also confirmed in the upper part of the Mount Cap Formation based on the sedimentology of two well-exposed sections in the Carcajou Range, which also suggests the presence of a significant east-facing slope on the flank of the arch during that time. The Saline River Formation, as measured in the Carcajou and Norman ranges consists predominantly of nodular gypsum with interbedded sandstone and dolomudstone, with local ripples and halite moulds, and was deposited in a restricted, intermittently subaerially exposed environment under arid climate conditions, both near the Mackenzie arch and in the interior of the epicratonic basin to the east.

ACKNOWLEDGEMENTS

This study is part of an MSc thesis supported through Government of Canada Research Affiliate Program (RAP), funded by Natural Resources Canada (NRCan) through the Geological Survey of Canada's (GSC) Geo-mapping for Energy and Minerals (GEM) program, with additional support from Polar Continental Shelf Program (PCSP). The Geological Society of America (GSA) and American Association of Petroleum Geologists (AAPG) are thanked for their financial contributions towards helicopter time and travel expenses through a GSA research grant and the AAPG Grants-in-Aid program. A special thanks to Karen Fallas (from GSC Calgary, AB) for her contributions to the field planning, permitting and section selection as well as Robert MacNaughton (from GSC Calgary, AB) for review of the draft report.

REFERENCES

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 73-9 178 p.

Balkwill, H.R. and Yorath, C J., 1970. Brock River map-area, District of Mackenzie (97D). Geological Survey of Canada, Paper 70-32, 25 p.

Cook, D.G. and Aitken, J.D., 1970. Geology, Colville Lake map-area and part of Coppermine map-area (96 NW and NE, part of 86 NW), Northwest Territories; Geological Survey of Canada, Paper 70-12, 42 p.

Dixon, J., 1997. Cambrian stratigraphy of the northern Interior Plains, Northwest Territories. Geological Survey of Canada, Open File 3510, 27 p.

Dixon, J. and Stasiuk, L D., 1998. Stratigraphy and hydrocarbon potential of Cambrian strata, northern Interior Plains, Northwest Territories; Bulletin of Canadian Petroleum Geology vol. 46, p. 445-470.

Hamblin, A.P., 1990. Petroleum potential of the Cambrian Mount Clark Formation (Tedji Lake Play) Colville Hills area, N.W.T; Geological Survey of Canada, Open File 2309, 36 p.

Hamel, C.M. and MacNaughton, R.B., 2013. Petrographic assessment and stratigraphy of Neoproterozoic and Cambrian sandstones from measured sections, eastern Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Open File 7472, 125 p. doi:10.4095/292914

Hannigan, P.K., Morrow, D.W., and MacLean, B.C., 2011. Petroleum resource potential of the northern mainland of Canada (Mackenzie Corridor); Geological Survey of Canada, Open File 6757. doi:10.4095/289095

MacLean, B C., 2011. Tectonic and stratigraphic evolution of the Cambrian basin of northern Northwest Territories; Bulletin of Canadian Petroleum Geology vol. 59, no. 2, p. 172-194.

MacNaughton, R.B., Pratt, B.R., and Fallas, K.M., 2013. Observations on Cambrian stratigraphy in the eastern Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Current Research 2013-10, 7 p. doi:10.4095/292423

Macqueen R. W. and MacKenzie W. S., 1973. Lower Paleozoic and Proterozoic stratigraphy, Mobil Colville Hills E-15 well and environs, interior platform, District of Mackenzie; in, Report of activities, part B: November 1972 to March 1973; Blackadar, R G (ed.); Geological Survey of Canada, Paper no. 73-1B, 1973; p. 183-187

Mossop, G.D., Wallace-Dudley, K.E., Smith, G.G. and Harrison, J.C. (comp.) 2004. Sedimentary basins of Canada; Geological Survey of Canada Open File Map 4673; 1 sheet, doi:10.4095/215559

Norford, B.S. and Macqueen, R.W., 1975. Lower Paleozoic Franklin Mountain and Mount Kindle Formations, District of Mackenzie: their type sections and regional development; Geological Survey of Canada Paper 74-34.

Norris, A.W., 1965. Stratigraphy of middle Devonian and older Paleozoic rocks of the Great Slave Lake Region, Northwest Territories; Geological Survey of Canada Memoir 322, 180 p.
Pugh, D.C., 1983. Pre-Mesozoic geology in the subsurface of Peel River map area, Yukon Territory and District of Mackenzie; Geological Survey of Canada, Memoir 401, 61 pages, doi:10.4095/119498

Pugh, D.C., 1993. Subsurface geology of pre-Mesozoic strata, Great Bear River map area, District of Mackenzie; Geological Survey of Canada, Memoir 430, 137 pages, doi:10.4095/183985

Pyle, L.J., Jones, A. L., Gal, L.P., Abbott, J. G., McCracken, A. D., Fowler, M. G., and Stasiuk, L. D. 2006. Reconnaissance field program in Peel Plateau and Peel Plain region, Northwest Territories and Yukon Territory. Geological Survey of Canada, Current Research 2006-A6, 13 pages, doi:10.4095/223682

Pyle, L.J. and Jones, A.L. (editors), 2009. Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain: Project Volume; Northwest Territories Geoscience Office and Yukon Geological Survey, NWT Open File 2009-02 and YGS Open File 2009-25, 549p.

Pyle, L.J., and Gal, L.P., 2007. Lower to Middle Paleozoic Stratigraphy and Measured Sections, NTS 106F, G, H, I, Northwest Territories; Northwest Territories Geoscience Office, NWT Open Report 2007-004, 95 p.

Pyle, L.J., and Gal, L.P., 2011. Petroleum Potential Data from Cambrian Sections in the northern Mackenzie Mountains, NTS 96D and 106H, Northwest Territories; Northwest Territories Geoscience Office, NWT Open Report 2011-008, 59 p.

Pyle, L.J., and Gal, L.P., 2014. Petroleum Potential Data from Cambrian Sections in the northern Mackenzie Mountains and Franklin Mountains (NTS 96B, 96C, 96 D and 106H), Northwest Territories; Northwest Territories Geoscience Office, NWT Open Report 2014-003, 62 p.

Serié, C., Bergquist, C.L., and Pyle, L.J., 2013. Seventeen measured sections of Cambrian Mount Clark and Mount Cap formations, northern Mackenzie Mountains and Franklin Mountains, Northwest Territories; Geological Survey of Canada, Open File 6148 (Revised), 81 p. doi:10.4095/292553

Turner, E.C., 2011. A lithostratigraphic transect through the Cambro-Ordovician Franklin Mountain Formation in NTS 96D (Carcajou Canyon) and 96E (Norman Wells), Northwest Territories; Geological Survey of Canada, Open File 6994, 28 p. doi:10.4095/289612

Williams, M.Y., 1922. Exploration East of Mackenzie River, Between Simpson and Wrigley, Northwest Territories. Geological Survey of Canada, Summary Report 1921-b, p. 56-66.

Williams, M.Y., 1923. Reconnaissance across Northeastern British Columbia and the geology of the northern extension of Franklin mountains, Northwest Territories. Geological Survey of Canada, Summary Report 1922 Part B, p. 65-87.

LIST OF FIGURES

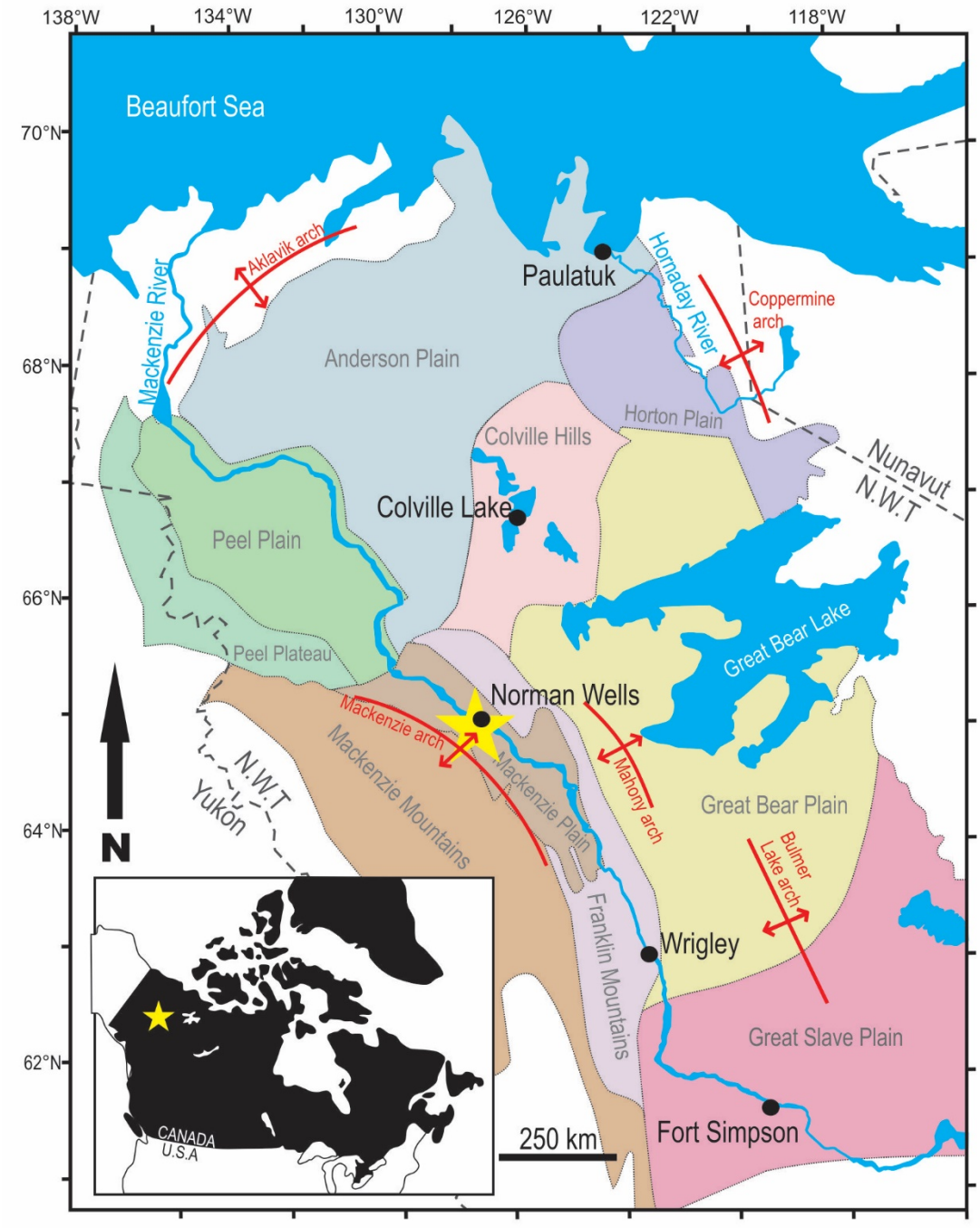

Figure 1. Location of the study area (yellow stars) in the Mackenzie front ranges and Norman Range, Northwest Territories, Canada and geological areas (modified from Mossop, 2004). Location of Cambrian arches after Hamblin (1990) and Dixon & Stasiuk (1998).

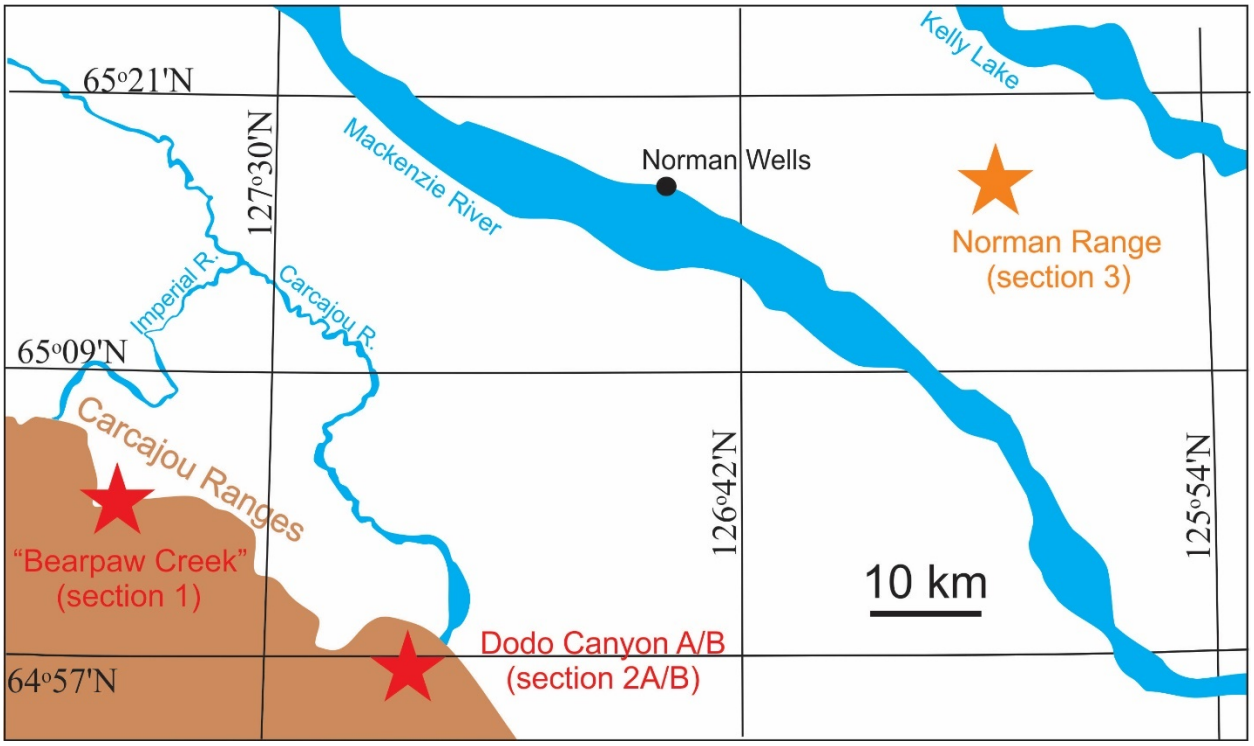

Figure 2. Locations of the measured sections of Mount Clark, Mount Cap and Saline River formations, in Carcajou Ranges (red stars), and Norman Range (orange star).

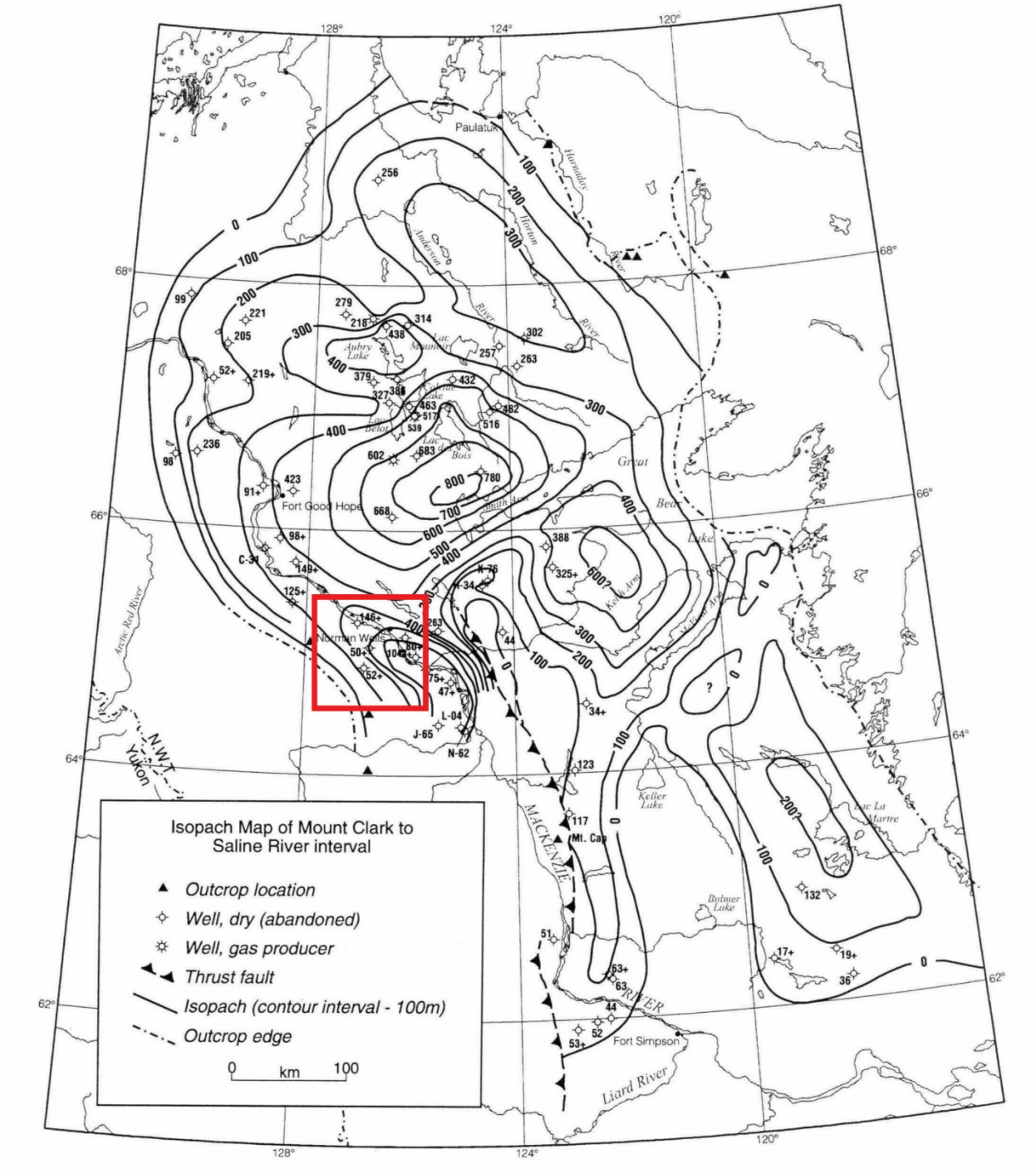

Figure 3. Isopach map for Mount Clark, Mount Cap, and Saline River formations (from Dixon & Stasiuk, 1998). Figure republished here with the permission of the Canadian Society of Petroleum Geologists. Location of this study's measured sections shown by a red box.

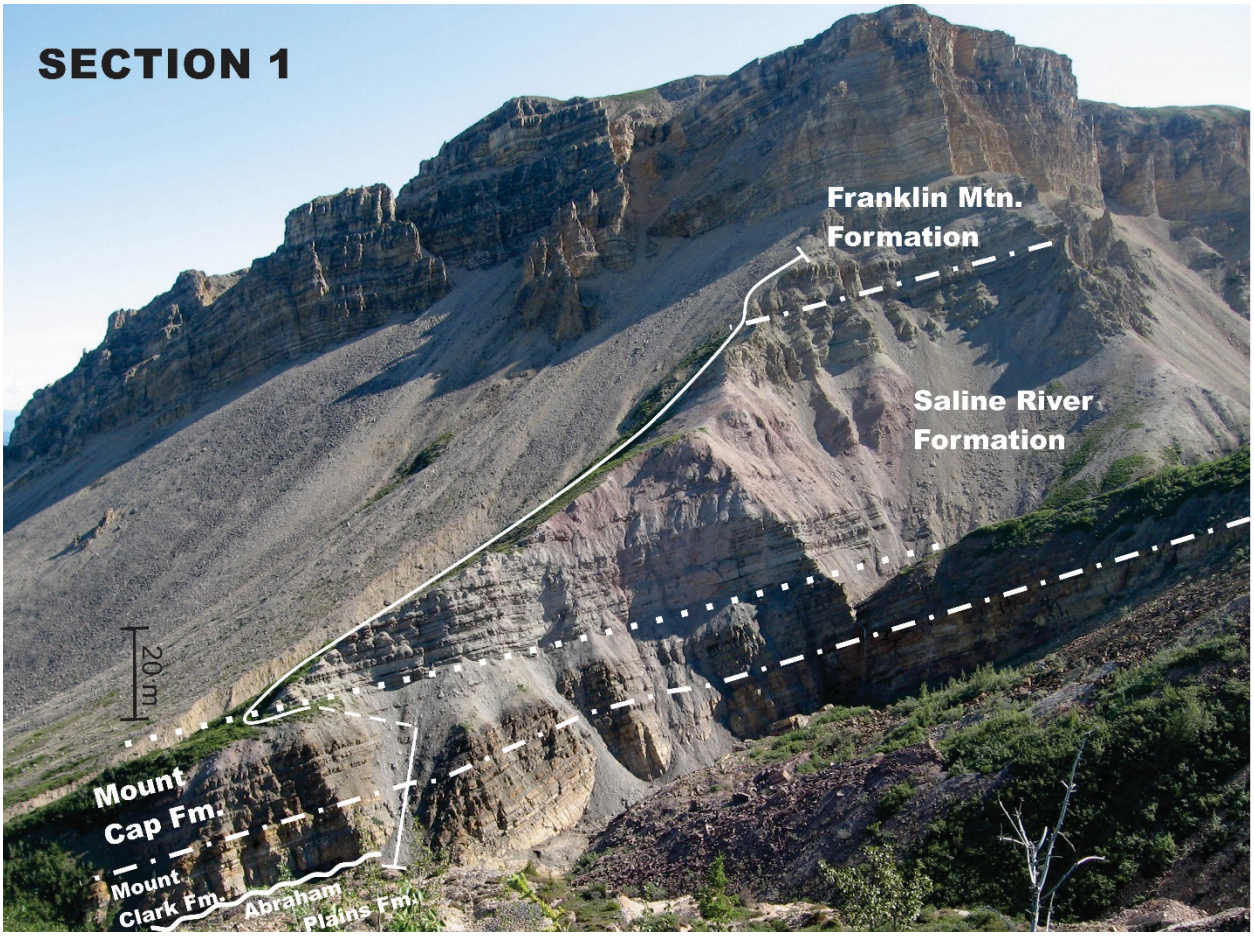

Figure 4. Section 1, the “Bearpaw Creek” section (65.0569598°N 127.7547881°W to 65.0569598°N 127.7547881°W) of the Abraham Plains, Mount Clark, Mount Cap and Saline River formations; measured section (white line), the conformable contact (white dashed and dotted line), unconformable contact (white wavy line) and the covered contact (dotted line).

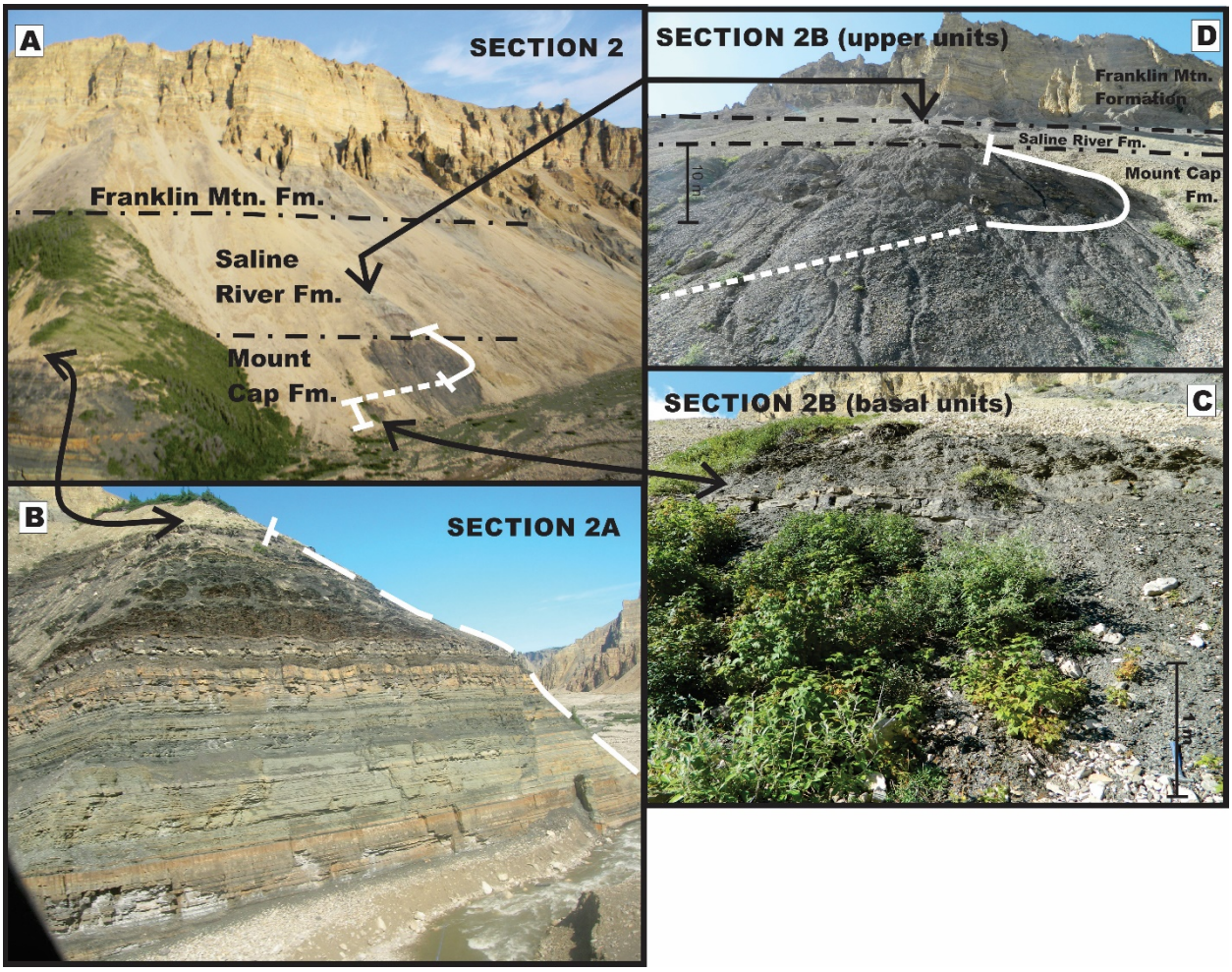

Figure 5. Section 2, the two Dodo Canyon sections (Section A 64.9382108°N 127.2642744°W to 64.9379981°N 127.2652828°W and Section B 64.9390861°N 127.2646833°W to 64.9397119°N 127.2652355°W) of the Mount Cap Formation. (A) The location of the two documented sections relative to each other, the traverse location for Section 2B (solid and dashed white line) and contacts (black dotted and dashed line). (B) Section 2A was measure along the brow of the top of the hill on right (white dashed line). (C) Exposure of units 1 - 4 of the Mount Cap Formation at section 2B. (D) Exposure of unit 5 of the Mount Cap Formation at section 2B; traverse shown by a white line and contacts shown by black dashed and dotted line.

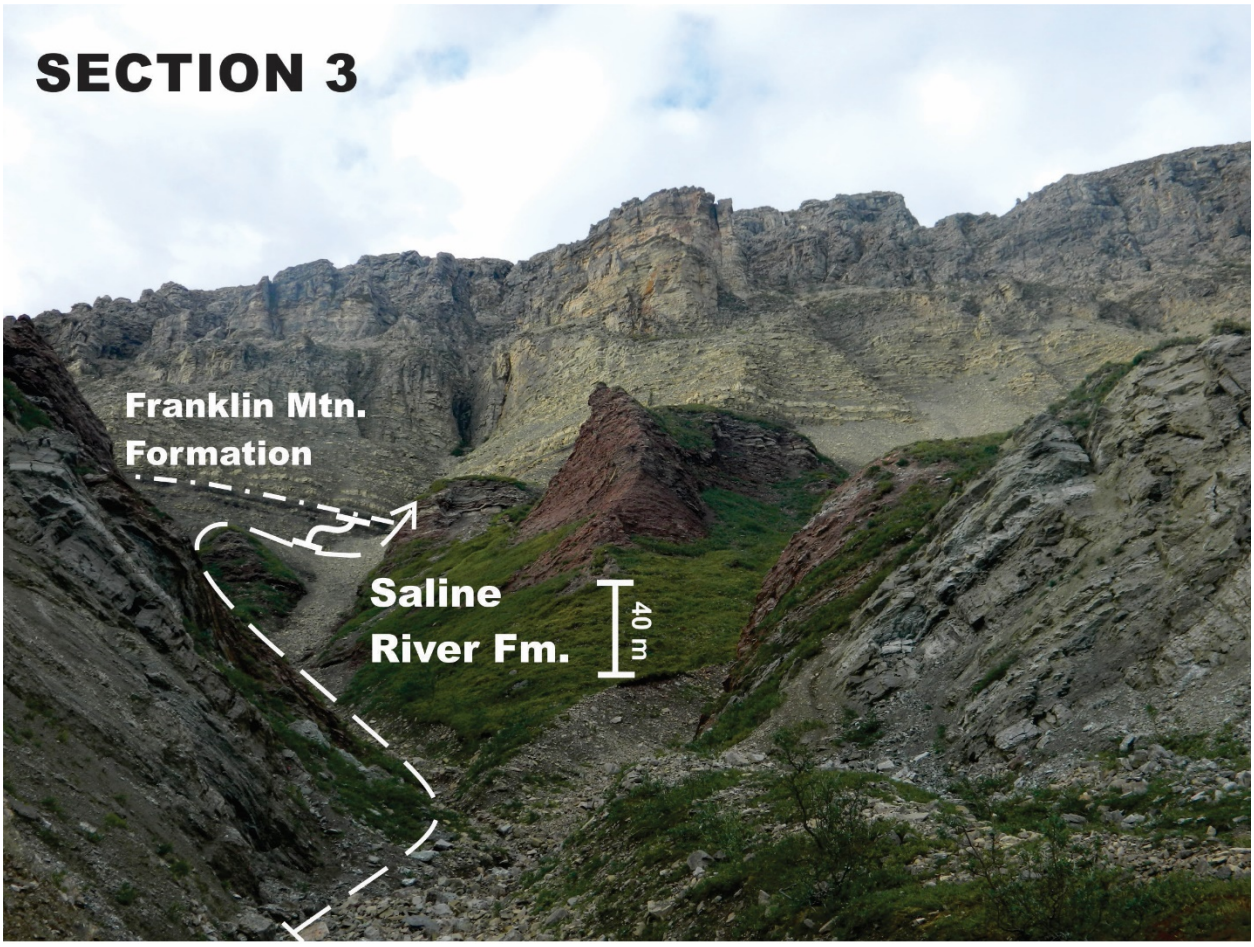

Figure 6. Section 3, the Norman Range section (65.2847458°N 126.2674976°W to 65.2833625°N 126.2679626°W) of the Saline River Formation, measured section (white dashed line) and contacts (white dashed and dotted line).

Figure 7. Legend for stratigraphic sections in Figures 8 - 10.

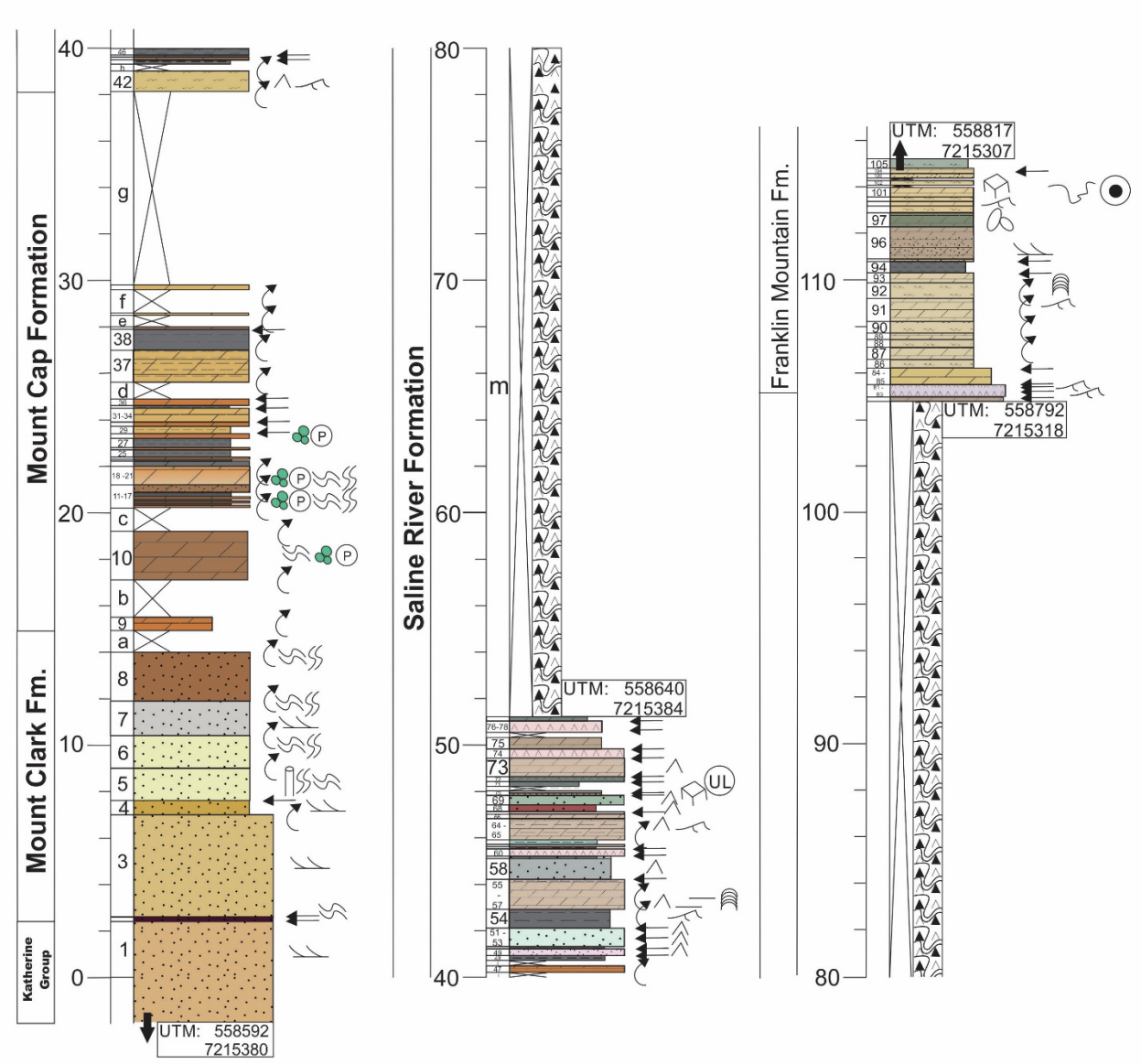

Figure 8. Stratigraphic section 1, ‘Bearpaw Creek’ section. Exposed units are numbered and covered intervals designated with lower-case letters. Column widths indicate weathering profile and coloured fill indicates weathering colour.

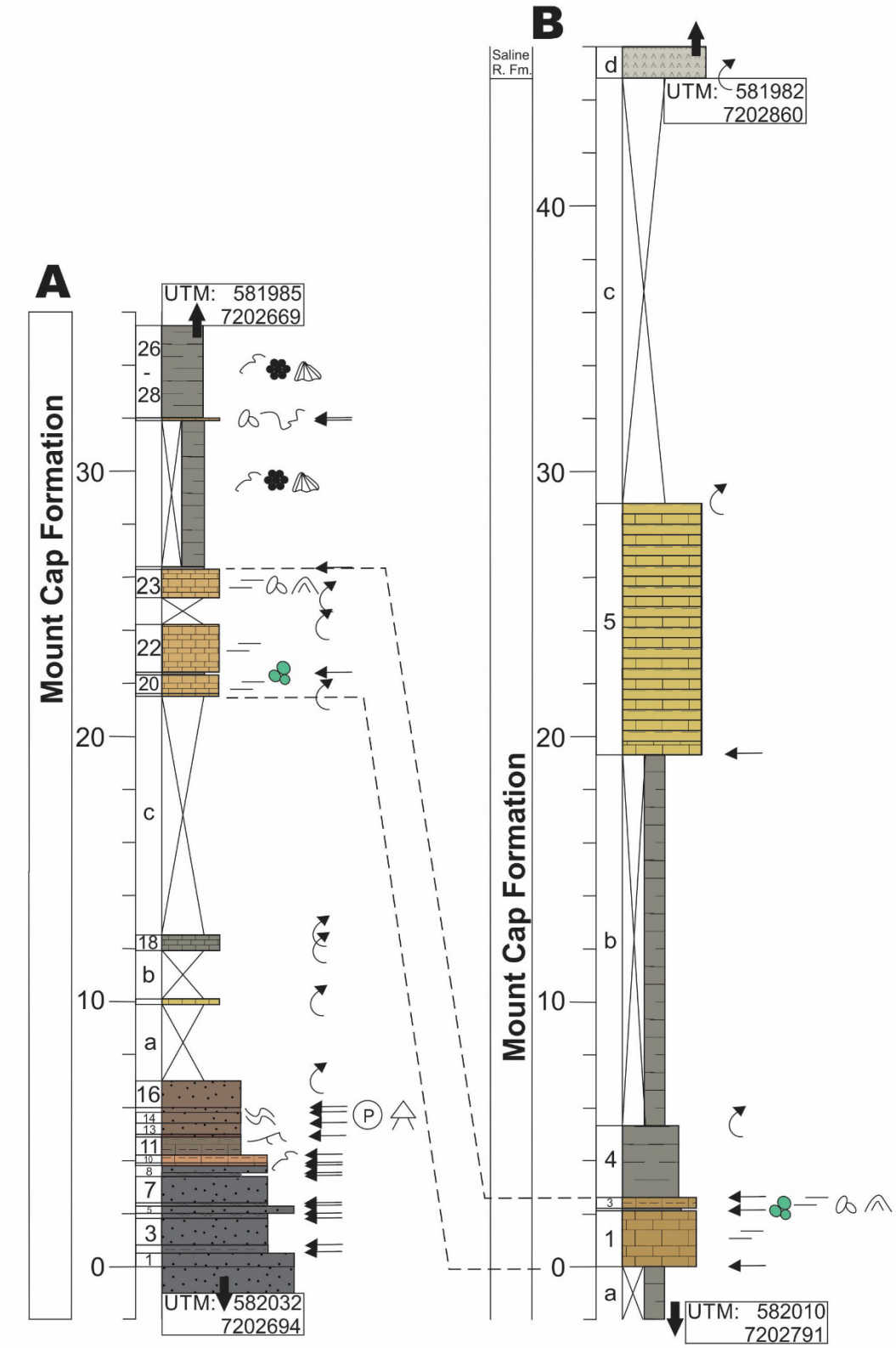

Figure 9. Stratigraphic section 2A and B, Dodo Canyon section A and B, of the Mount Cap Formation. Exposed units are numbered and covered intervals designated with lower-case letters. Column widths indicate weathering profile and coloured fill indicates weathering colour.

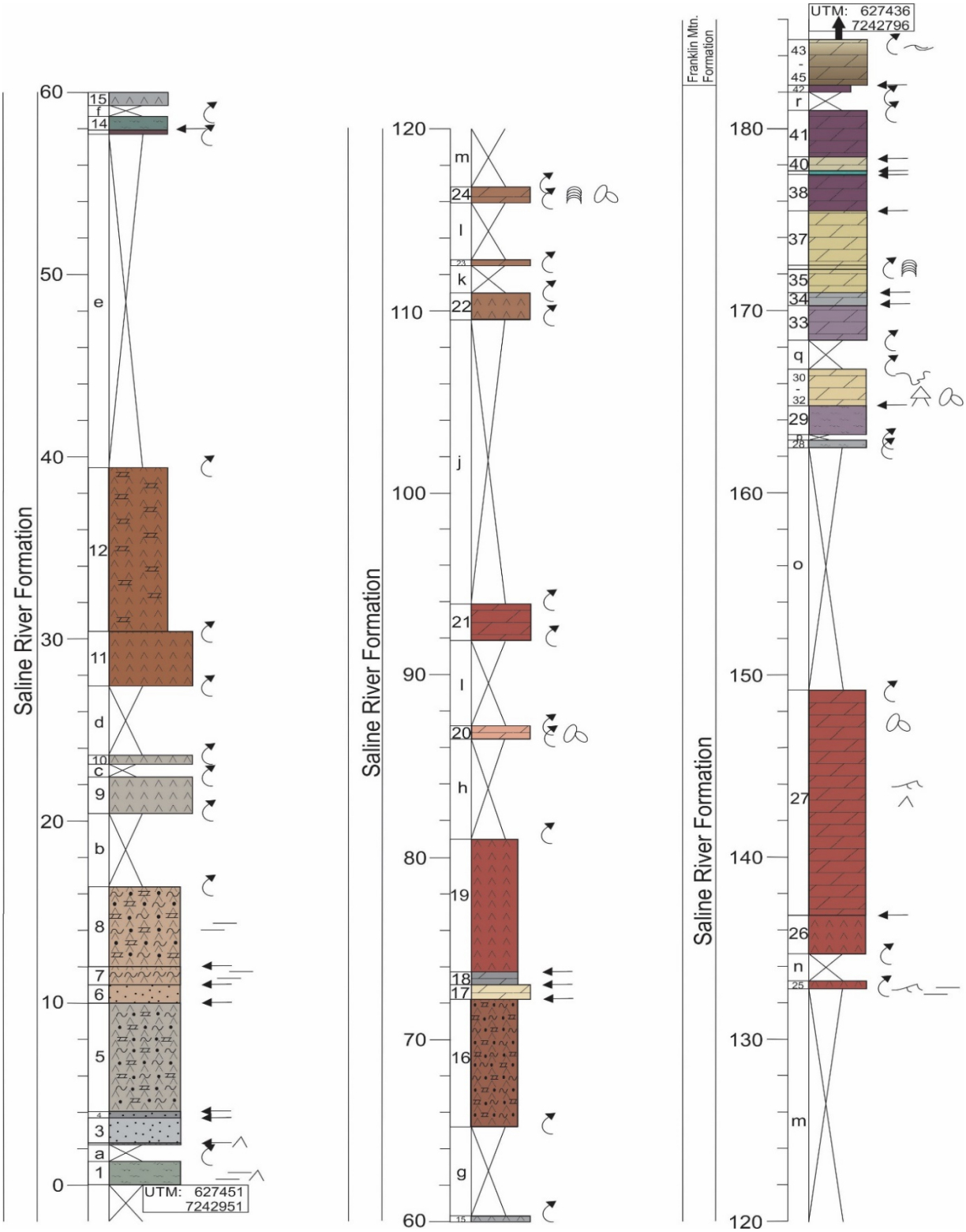

Figure 10. Stratigraphic section 3, Norman Range section, of the Saline River and Franklin Mountain formations measured in the Norman Range. Exposed units are numbered and covered intervals designated with lower-case letters. Column widths indicate weathering profile and coloured fill indicates weathering colour.

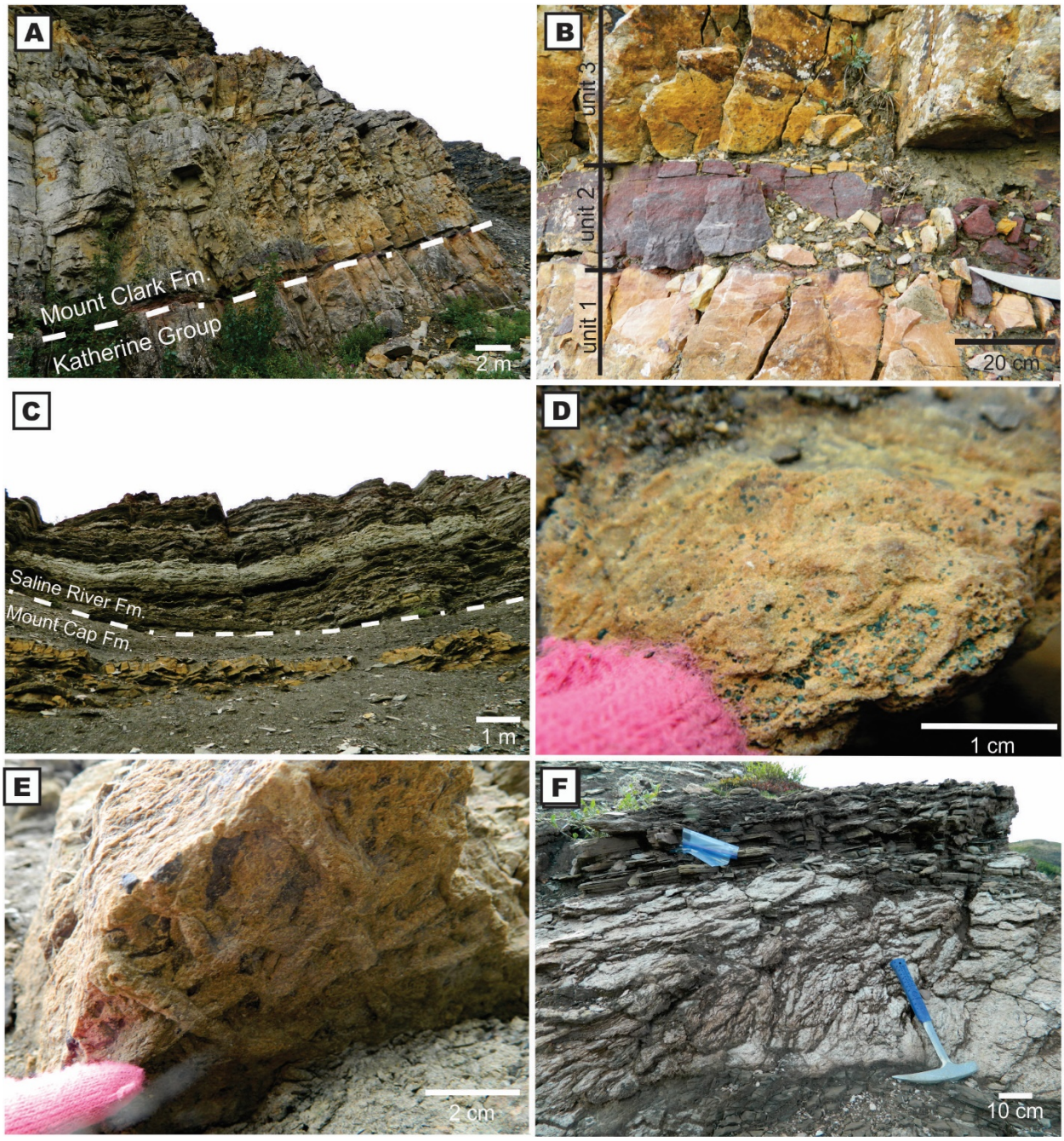

Figure 11. Characteristics of the 'Bearpaw Creek' measured section (section 1, Fig. 8). (A) Upper units of the Abraham Plains Formation of the Katherine Group unconformably overlain by lowermost units of the Mount Clark Formation. (B) Abrupt contact between quartz-cemented quartz arenite of the Abraham Plains Formation (unit 1) and hematite cemented quartz arenite of the Mount Clark Formation (units 2 and 3). (C) Uppermost units of the Mount Cap Formation overlain by lowermost units of the Saline River Formation. (D) Glauconite grains in unit 10 of the Mount Cap Formation (black arrow). (E) Trace fossils in unit 10 of the Mount Cap Formation. (F) Contorted gypsite of the interval ("m"; Fig. 8) of the Saline River Formation.

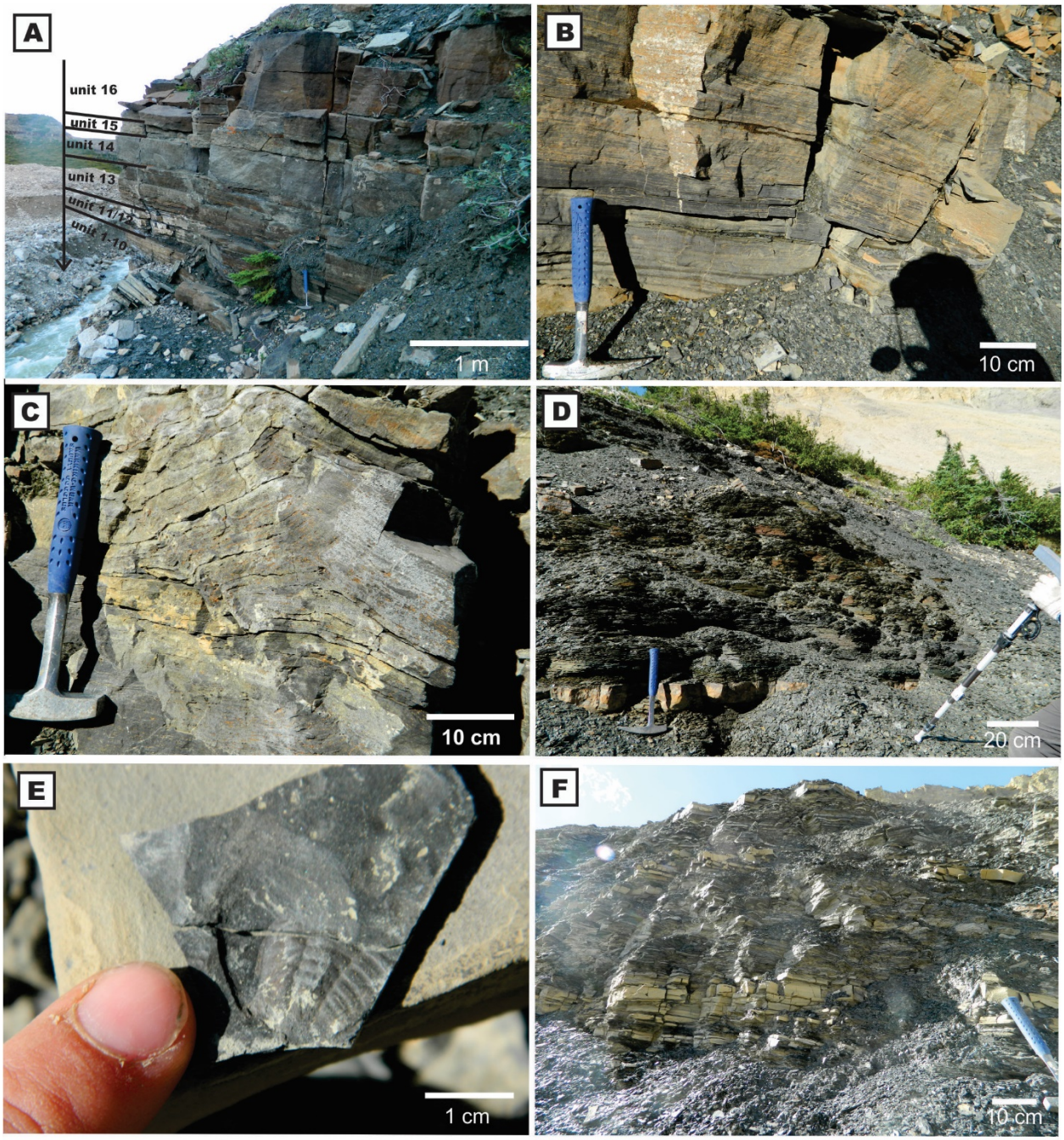

Figure 12. Characteristics of the Mount Cap Formation in the Dodo Canyon measured section A and B (section 2A and B, Fig. 9). (A) Basal units showing abrupt contacts between layers. (B) Parallel laminations in limestone of unit 18. (C) Cuspate syn-sedimentary folds in limestone of unit 23. (D) Shale (or siltstone) interval (unit 27) with minor interbeds of limestone (unit 26). (E) Trilobite fragment from shale in unit 28. (F) Upper part of unit 5 showing resistant dolostone interbedded with recessive shale (or siltstone).

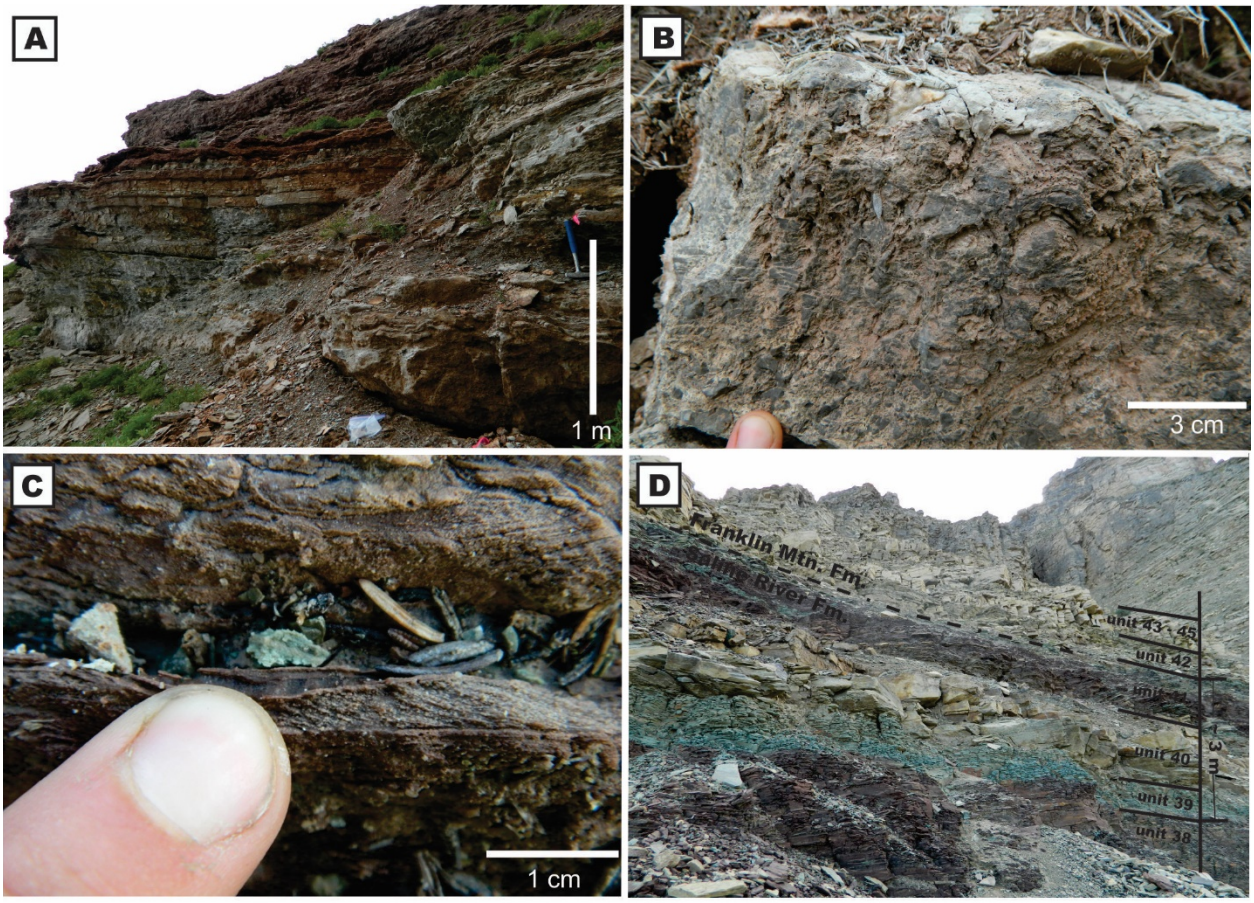

Figure 13. Saline River Formation in the Norman Range measured section (section 3, Fig. 10). (A) Unit 11 gypsite with minor massive medium-crystalline dolostone and fine-grained sandstone beds (B) Stromatolitic dolostone in unit 24. (C) Minuscule ripple in unit 25. (D) Units 38 to 45 (black lines); dolostone, dolomudstone, and mudstone, and gradational contact between Saline River Formation and Franklin Mountain Formation (black dashed and dotted line).