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ABSTRACT

Lithostratigraphy of the Cambro-Ordovician Franklin Mountain Formation is presented for three platformal localities that form a transect perpendicular to depositional strike in NTS 96D and 96E. Previously established informal members are generally recognisable in these sections, but their contacts are ill-defined and their characteristics are not distinctive enough that they can always be identified, particularly where exposure is poor. There is a significant possibility of diachroneity or geographic variability in the development of several of the informal members, and of intraformational hiatuses. The formation was deposited under restricted conditions that limited fetch, wave-base, and biota. Storm–dominated conditions prevailed over a broad depositional area with little paleogeographic variation during accumulation of the lowermost part of the formation. Increasing restriction and differentiation into an inner, more restricted zone, a hinge zone with ooid shoals, and an outer, slightly deeper-water lagoonal area, developed during deposition of the middle and upper parts of the formation. Chert and green clay seams appear at approximately the same stratigraphic level in the upper part of the formation, and are associated with differences in diagenetic behaviour of nearby dolostones, strongly suggesting that the clays were mafic tuffs that contributed solutes (Si, Mg and Fe) to the enclosing sediment as they stabilised to clay. Field-based assessment of the diagenesis of the entirely dolomitic Franklin Mountain Formation suggests a simple post-depositional history that probably involved reflux dolomitisation either during deposition of the formation or during the hiatus that separated its deposition from that of the overlying Mount Kindle Formation. A better understanding of the Franklin Mountain Formation's depositional history east of the study area and of its lateral relationships to equivalent deep-water strata of the Misty Creek Embayment to the west and southwest would greatly enhance understanding of the region's tectonostratigraphic, paleoclimatic, and fluid-flow history.

INTRODUCTION

The Franklin Mountain Formation was established by Williams (1922) for a succession of shale and limestone that separates the Saline River and Mount Kindle formations on Mount Kindle (NTS 95O). This formation was at one time grouped with the overlying Mount Kindle Formation in the Ronning Group, but this usage has been disputed and may be misleading. This term is not used here owing to the existence of a significant unconformity between the two formations, and the stronger genetic affinity and apparently conformable contact of the Franklin Mountain Formation with the underlying Saline River Formation, which has never been included in the Ronning Group.

Working in the interior plains and front ranges of the Mackenzie Mountains, Aitken et al. (1973, Aitken and Cook (1974) and Norford and Macqueen (1975) divided the formation into four informal members based on lithologic composition. A basal "redbed" unit (ЄOf$_1$) is present only near the Mackenzie Arch, an early Paleozoic uplift in the Mackenzie Mountains (Cecile, 1982); the presence of the "redbed" unit is antithetical to that of the "cyclic" member. The "cyclic" member (ЄOf$_2$) forms the lower part of the succession east of the Mackenzie Arch wherever the formation overlies the Saline River Formation, and consists of shale, intraclast rudstone and stromatolites. The "rhythmic" member (ЄOf$_3$) gradationally overlies the "cyclic" member, "redbed" member, or Saline River Formation. It consists of alternating cycles, each typically 3 m thick, of pale grey-weathering, quartz-silty, finely crystalline dolostone and darker brown-weathering, fine- to medium-crystalline, locally oolitic or stromatolitic dolostone; this rhythmic layering is best developed in the front range of the Mackenzie Mountains. The "cherty" member (ЄOf$_4$) is characterised by conspicuous pale chert that is most abundant in the interior plains and diminishes westward into the mountains. A fifth member, the "porous dolostone" was later recognised locally at the top of the formation (Mackenzie, 1974; Pugh, 1983).

Pugh (1983) studied the Franklin Mountain Formation in the subsurface of the Peel River area of Yukon and N.W.T. and provided a thorough review of previous work. Further work in the northwestern Mackenzie Mountains and Peel Plateau and Plain was undertaken by Morrow (1999) and Pyle and Gal (2007), who recognised the presence of the three main informal members in this northwestern area.

Where the Franklin Mountain Formation overlies the Saline River Formation, the contact is placed at the top of the highest shale layer that is >1.5 m thick (Aitken et al., 1973). The upper contact of the formation with the Upper Ordovician - Silurian Mount Kindle Formation is a stratigraphically variable unconformity at which medium-brown-weathering dolostone with conspicuous, white, silicified macrofossil fragments overlies the Franklin Mountain Formation.

The (gradationally to disconformably) underlying Saline River Formation is Middle to Late Cambrian in age. The Franklin Mountain Formation represents the Sauk III sequence and is broadly Late Cambrian to Early Ordovician in age, as demonstrated by a very sparse fauna of macrofossils and conodonts from throughout the Franklin Mountain Formation's exposure area (Norford and Macqueen, 1975; Pugh, 1983). No fossils have been collected from the "cyclic" member of the Franklin Mountain Formation. Trilobite fossils from the base of the "rhythmic" member indicate a Late Cambrian depositional age. Brachiopod and echinoderm material from the lower part of the"rhythmic" member indicate a middle Late Cambrian age. Graptolites from the "rhythmic" member indicate Early Ordovician deposition. Gastropods, brachiopods, and conodonts from the "cherty" member indicate Early Ordovician deposition (Norford and Macqueen, 1975), although other conodont data suggest a Middle Ordovician age (Pugh, 1983). If the informal divisions of the formation are chronologically meaningful and lack significant diachroneity, the existing biostratigraphic data indicate that deposition of the Franklin Mountain Formation began in the Late Cambrian, that the Cambrian-Ordovician boundary is within or at the top of the "rhythmic" member, and that the upper part of the formation ("cherty" member) is Early to Middle Ordovician in age.

Field work undertaken on the Franklin Mountain Formation for the Mackenzie Corridor Project focused on producing sedimentological descriptions and a detailed lithostratigraphic transect through the formation perpendicular to strike. This part of the Mackenzie Platform was adjacent to the tectonically active Misty Creek Embayment of the Selwyn Basin, and so one objective was to identify any subtle stratigraphic features that might reflect related behaviour on the platform east of the Mackenzie Arch.

Three detailed stratigraphic sections (10-DO; 10-NR and 10-PC) were measured in NTS 96D and 96E (Figure 1). The informal member names used in previous work ("cyclic", "rhythmic" and "cherty" members) are here replaced by "unit 1", "unit 2" and "unit 3", respectively, because in many cases the previous terms do not accurately describe the unit's characteristics (cyclic member is nowhere truly cyclic; rhythmic menber is not conspicuously rhythmic at some localities; cherty member commonly contains only rare chert).

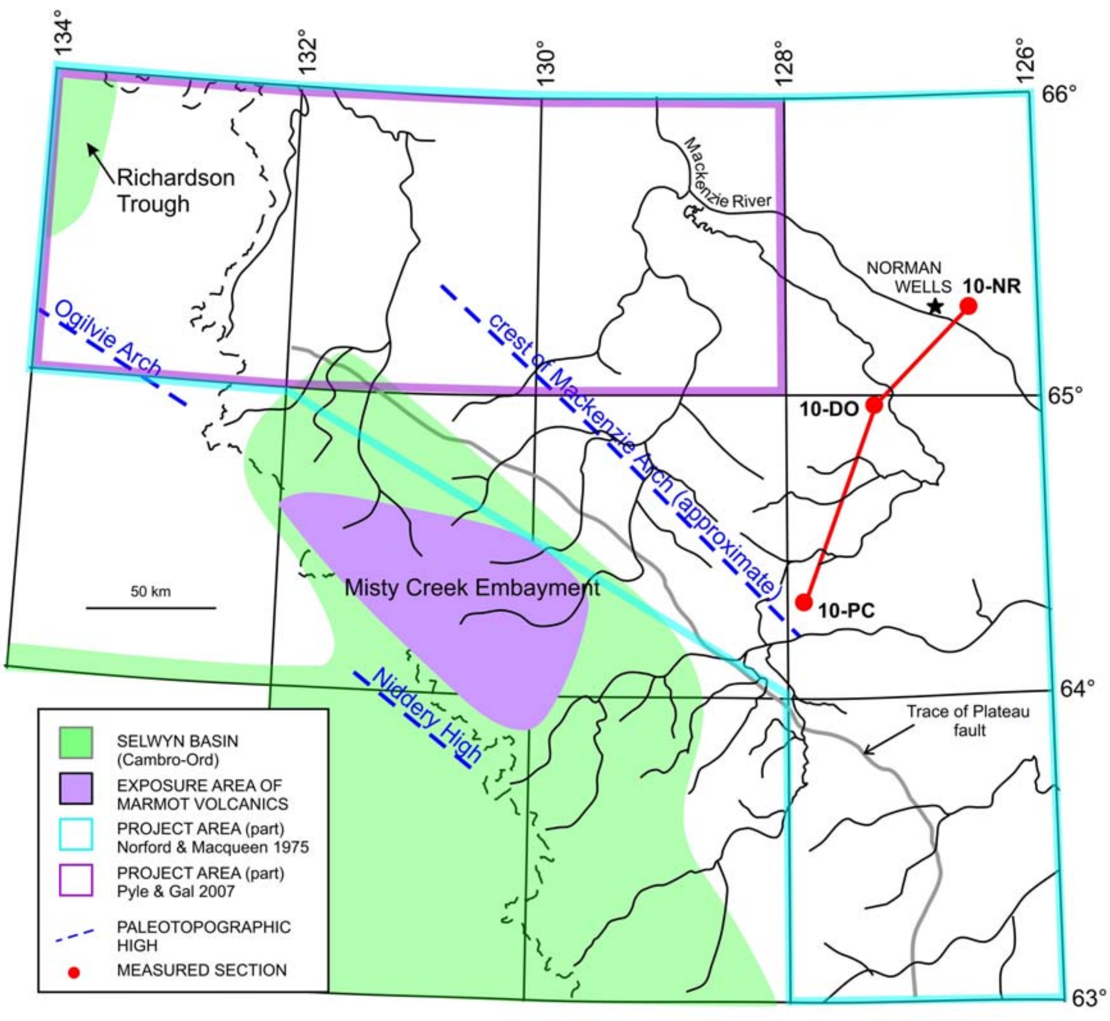

Figure 1. Location map for sections 10-NR, 10-DO, and 10-PC of this study. Parts of the study areas of previous workers are indicated. Positive paleogeographic features during deposition of Franklin Mountain Formation (blue lines), coeval shale/deep-water carbonate basins (green) and subaqueous volcanic field (purple) are also shown.

STRATIGRAPHY IN NTS 96D AND E

Dodo Canyon (10-DO)

A stratigraphically complete, well-exposed section of the Franklin Mountain Formation was measured and described in Dodo Creek as a composite of three subsections (Figures 2, 3, 4, 5A & B, 6, and 7). The lower contact with maroon mudstone of the Saline River Formation is exposed, and the upper, unconformable contact with the Mount Kindle Formation appears to be structurally modified (faulted). The Franklin Mountain Formation in Dodo Creek is approximately 535 metres thick and dips northward. The lowest 100 metres were measured up a steep talus gully on the west side of Dodo Creek (Figure 2), the middle 260 metres along the cliff base on the east side of the creek (Figure 3), and the upper 175 metres along the base of exposures on the west side of the creek (Figure 4).

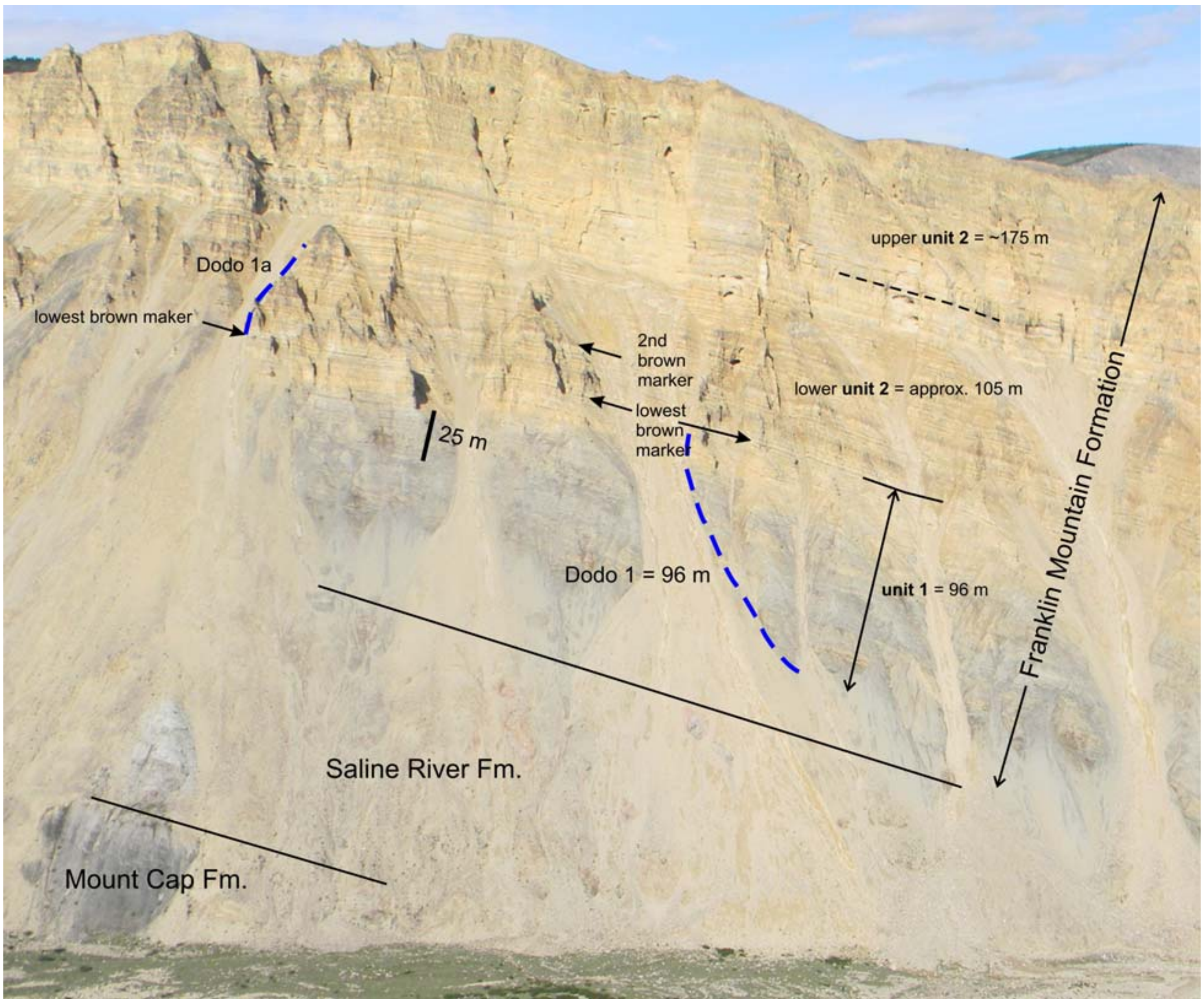

Figure 2. Outcrop photo of section 10-DO-1 (Dodo Canyon), with line of measured section and important stratigraphic units and interfaces. View to west.

Figure 3. Outcrop photo of section 10-DO-2 (Dodo Canyon), with line of measured section. View to north.

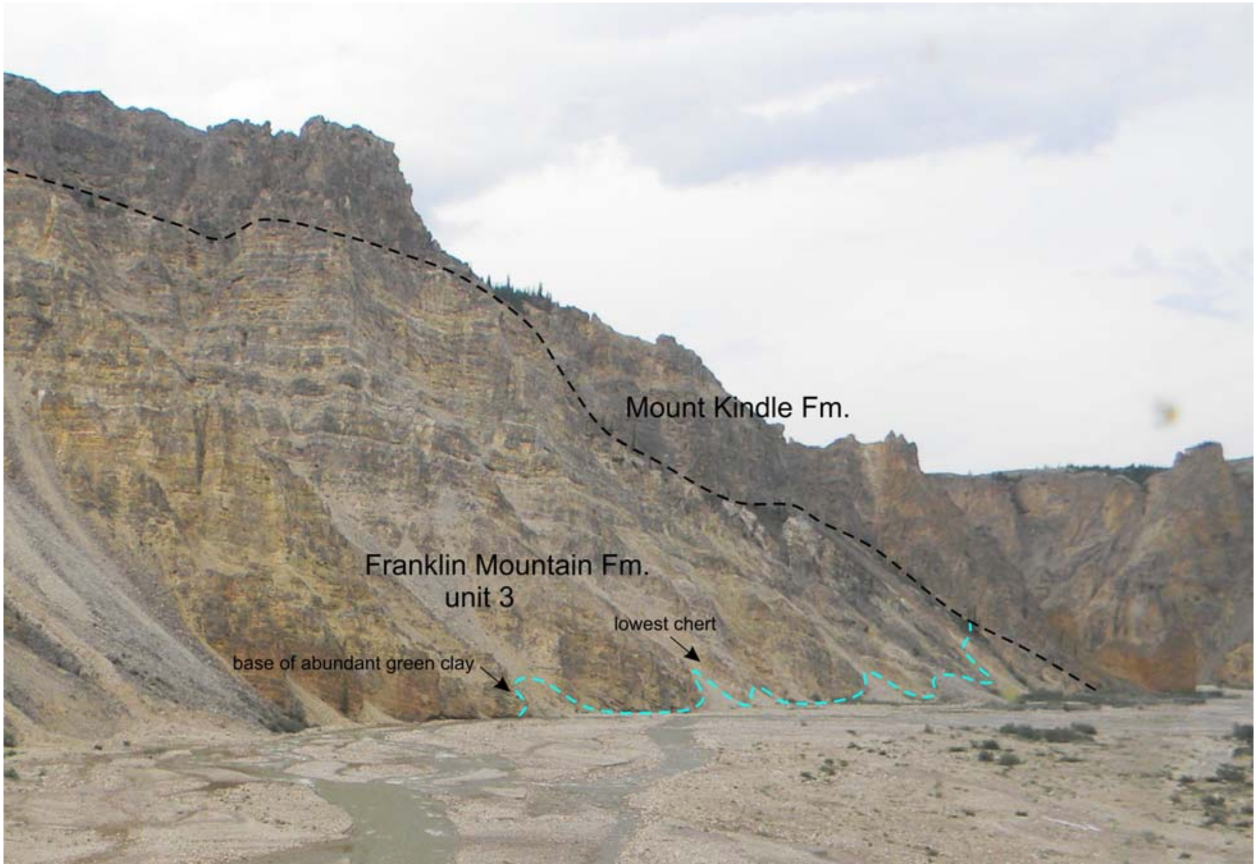

Figure 4. Outcrop photo of section 10-DO-3 (Dodo Canyon), with line of measured section. View to north.

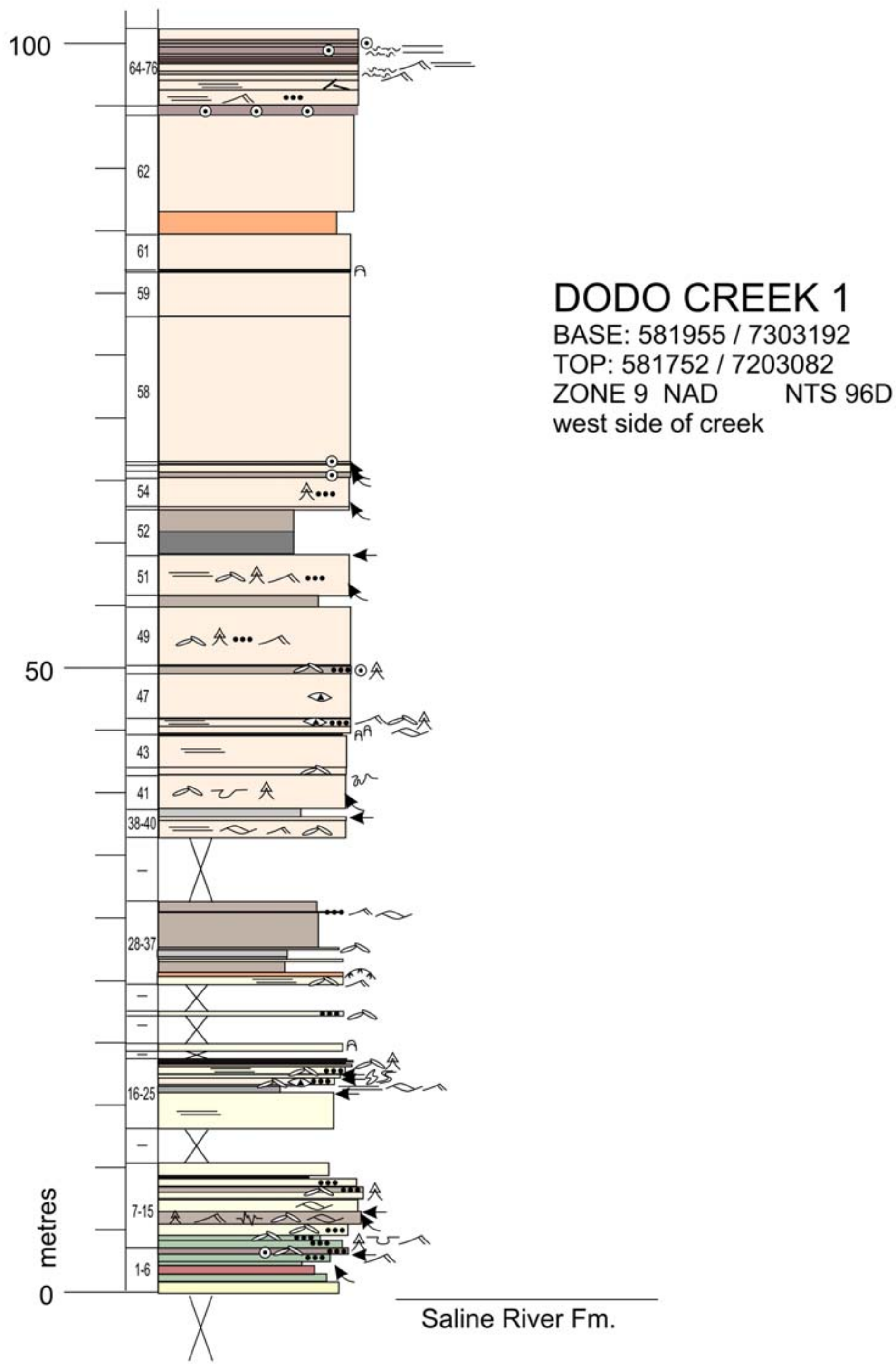

Figure 5A. Stratigraphic section 10-DO-1 (Dodo Canyon). Numbers to left of column are unit numbers.

Figure 5B. Legend for all stratigraphic sections. Weathering colours are for dry surfaces.

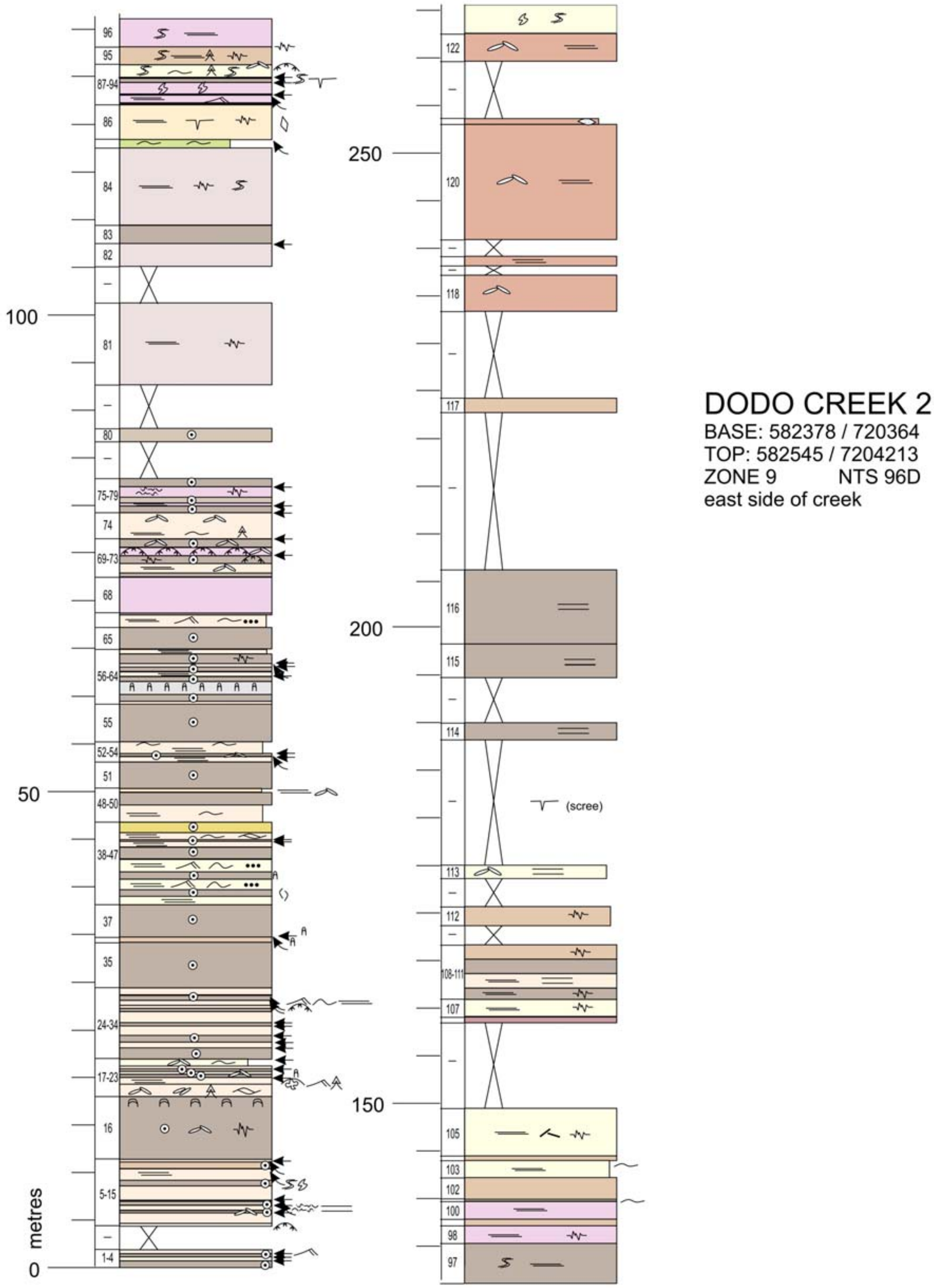

Figure 6. Stratigraphic section 10-DO-2 (Dodo Canyon). Numbers to left of column are unit numbers. For legend see Figure 5B.

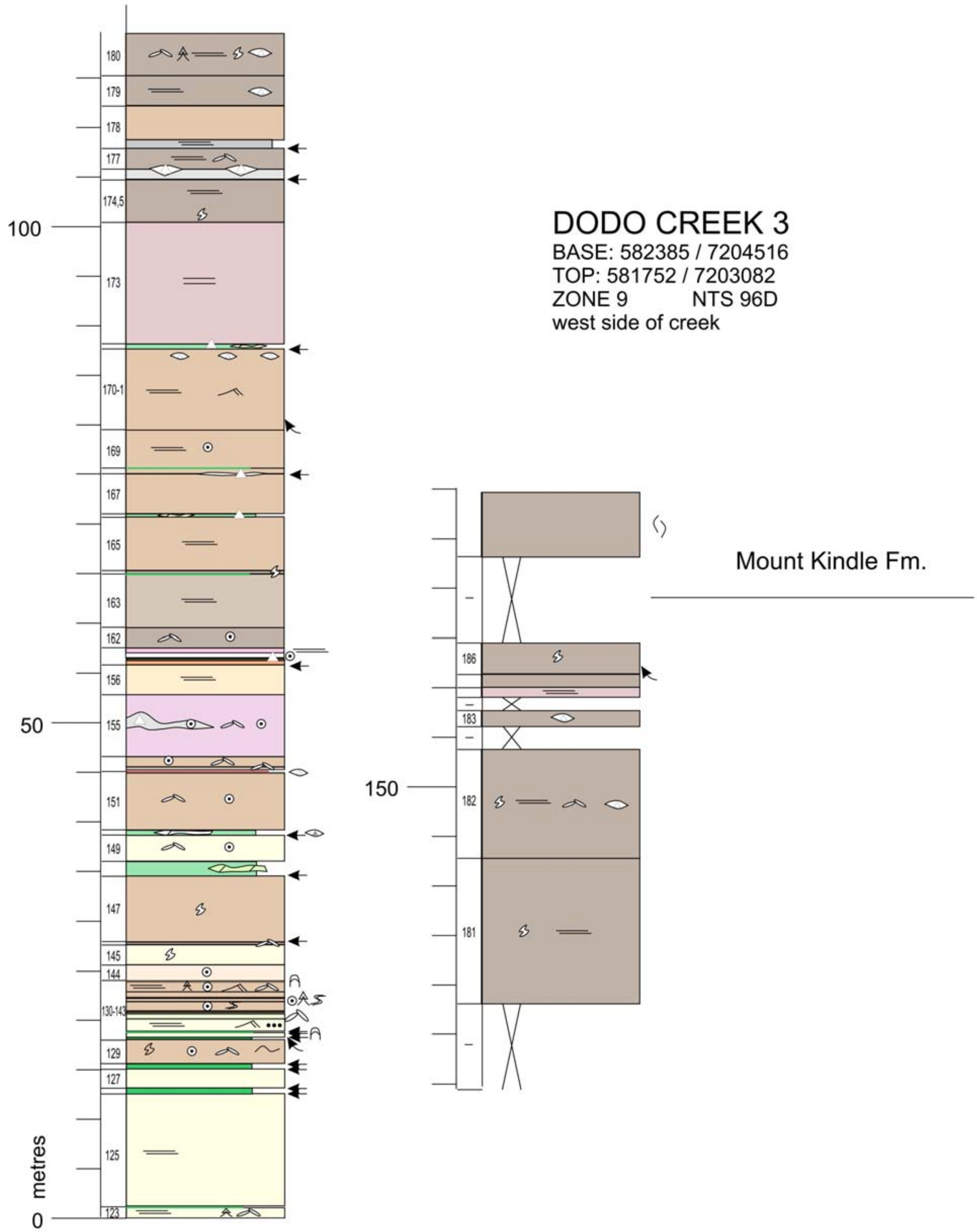

Figure 7. Stratigraphic section 10-DO-3 (Dodo Canyon). Numbers to left of column are unit numbers. For legend see Figure 5B.

At Dodo Canyon section 1, the lowermost 65 metres of the section (unit 1; equivalent to "cyclic member"; Figure 5A) are characterised by dusky grey-weathering exposures of planar-bedded carbonates and a slightly recessive profile, relative to those of the strata above. The basal 20 metres consist of interlayered quartz sandstone, maroon and green mudstone, and quartz-sandy dolostone, with intraclasts, ripple cross-lamination, hummocky cross-stratification, burrows, and one layer of ooid grainstone at 3 m. Columnar stromatolites are present 19 and 26 m above the formation's base. Graded beds are abundant. Above these basal layers, quartz sand and silt decrease in volumetric importance. Strata between 20 and 60 metres in stratigraphic elevation are characterised by graded, cross-laminated, hummocky cross-stratified, variably quartzose and intraclastic dolostone, locally with gutter casts and rarely with hardgrounds. Weak banding and parallel mechanical lamination are widespread. One layer contains stromatolites (45 m) and sparse chert nodules are present at 47 m. Above 60 metres, most of these features are absent; sparse, graded bands of fine quartz sand and silt are present, as are rare intraclast layers. Columnar stromatolites are present at 83 m. Several decimetre-thick orange-weathering argillaceous interlayers are present.

Thin, brown-weathering layers of ooid dolopackstone first appear 65 m above the section base (Figure 2) and mark the beginning of a thick succession consisting predominantly of striking metre-scale cycles of pale and dark layers (unit 2; roughly equivalent to the "rhythmic member"; Figures 3, 4, 6, and 8A-B). Each cycle generally has a lower, pale-weathering dolostone with plane lamination and locally with quartz silt, ripple cross-lamination, graded intraclasts, and (rare) hummocky cross-stratification, and an upper, brown-weathering ooid dolopackstone to dolowackestone (although the ooids are commonly next to invisible) (Figure 8A-D). Contacts within and between cycles are sharp (Figure 8B). Owing to outcrop limitations, it is not obvious whether individual units are laterally continuous, or whether individual beds may grade laterally from dolosiltstone to ooid grainstone. Columnar stromatolites with conspicuously isopachous lamination are intermittently conspicuous in the lower ~80 m of this interval.

Above the 90-metre level in Dodo Canyon section 2, the strikingly striped alternation of pale and dark layers becomes less overt. At 118 m in this section, the lowest of a series of green argillaceous layers is present (Figure 8E). This unit is associated with the appearance of burrows in the overlying ~15 m of strata (Figure 8F). In the overlying layer, conspicuous gypsum moulds are present.

Unit 2 is approximately 270 metres thick and is overlain by a succession of oolitic, intraclastic and mechanically laminated dolostones that resemble those of upper unit 2. These strata (unit 3; roughly equivalent to the "cherty member"; Figures 4, 5A & B, 6, and 7) are exposed in Dodo Canyon section 3, and consist of slightly paler brown- and yellow-weathering dolostones similar those of unit 2, with rare stromatolites (Figure 8G). What makes this unit distinctive is the presence of conspicuous, thin (centimetres to decimetres) layers of bright green clay. Such layers are especially conspicuous in the lower 40 metres of unit 3. These semi-indurated to completely unlithified clays are spatially associated with white chert nodules (Figure 8H), which are also intermittently present throughout the full thickness of unit 3, even though green clay layers are not evident above 90 metres in section Dodo Canyon 3. Clay is also spatially associated with reddening of the enclosing dolostone (Figure 8H). Some clay layers are associated with the appearance of burrows in overlying beds.

The upper contact with the Mount Kindle Formation is in a covered interval that appears to be slightly oblique to bedding and may be in part a structurally modified unconformity (Figure 4). The Mount Kindle Formation is a monotonous, brown-weathering skeletal floatstone with conspicuous, white, taxonomically diverse, silicified fossil fragments.

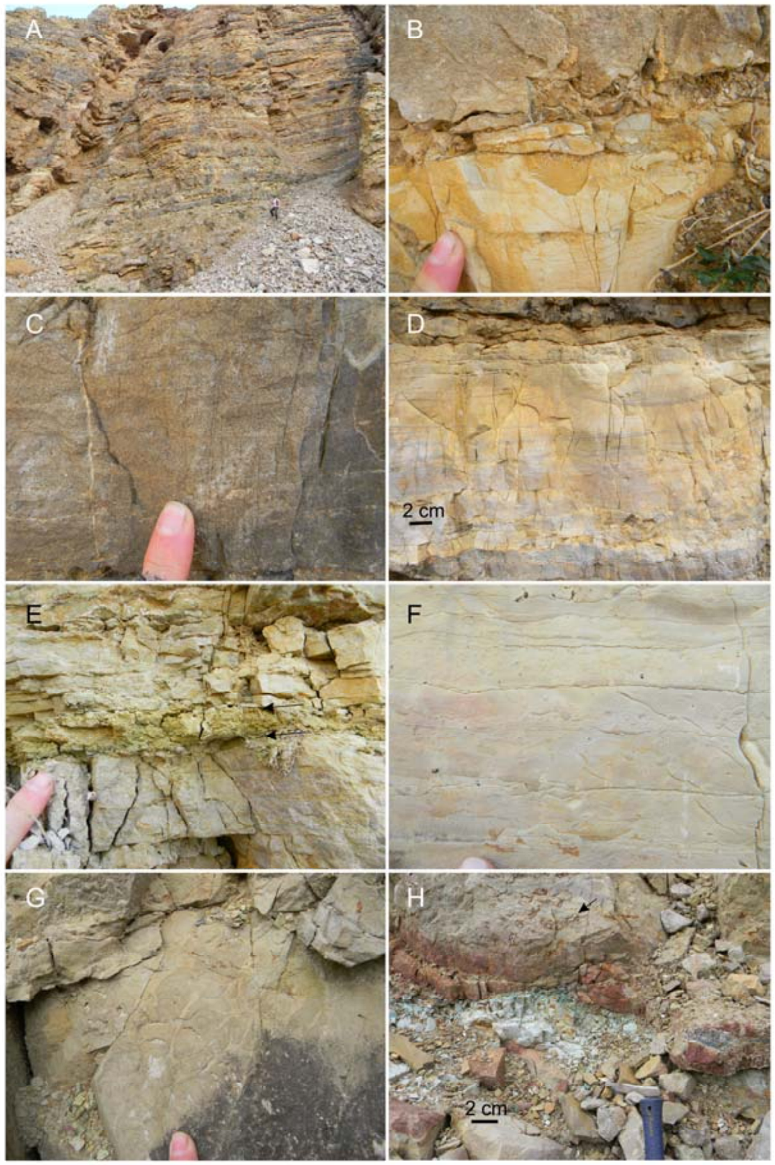

Figure 8. Lithofacies of the Franklin Mountain Formation at Dodo Canyon. Fingertip for scale unless otherwise noted. (A) Striking metre-scale colour-banding in lower unit 2 (section 10-DO-2; D.Kondla for scale). (B) Contact between banded, pale dolosiltstone (lower part of cycle) and overlying ooid dolopack/dolowackestone (upper part of cycle). Slight reworking of the dolo-silty underlying material at the contact is interpreted to record shallowing through fairweather wave-base, above which ooids formed (units 3 and 4 in section 10-DO-2). (C) Typical ooid dolopackstone, with comparatively well-preserved primary texture (unit 7 in section 10-DO-2). (D) Dolosiltstone, showing weak banding, scouring, cross-lamination, and weakly graded, centimetric storm beds (unit 40 in section 10-DO-2). (E) Lowest green clay seam (arrows) in section 10-DO-2 (unit 23). (F) Burrowing commonly appears in layers above clay seams (unit 94 in section 10-DO-2). (G) Rare stromatolite in section 10-DO-3 (unit 131). (G) Green clay seam associated with development of white chert and reddening of surrounding dolostone.
Arrow points to unusual vugs filled with white dolospar and orange calcite. Unit 152 in section 10-DO-3.

Norman Range (10-NR)

A section measured through cliffs exposed on the east flank of the Norman Range (Figures 9 and 10) contains a well-exposed, gradational lower contact, but is missing an unknown but probably significant thickness of the upper part of the formation.

The uppermost part of the underlying Saline River Formation consists of desiccation-cracked, maroon-weathering siltstone and mudstone, with sparse, thin dolostone interlayers, many of which contain columnar stromatolites with 'abiogenic' layering. This red siltstone-dominated interval passes upward to the basal Franklin Mountain Formation (unit 1; approximately 65 m thick; Figure 11A), which consists of green, cross-laminated siltstone and interlayers of 'abiogenic' stromatolitic and intraclastic dolostone (Figure 11B-C). Sedimentary structures associated with storm events include hummocky cross-stratification, grading, gutter casts, imbricated intraclasts and intraclast lenses. The top of unit 1 is marked by a conspicuous covered interval and break in slope that persists along the length of the east flank of the Norman Range in this area (Figure 9).

Strata above the covered interval (unit 2; starts at ~90 m; ~100 m thick) consist of weakly mechanically laminated dolostone. The base of the succession contains argillaceous dolostone interlayers and a conspicuous, 15 centimetre-thick bright green clay seam (stratigraphic unit 50; Figure 11E)); these are associated with burrowing (Figure 11E-F) in at least one overlying unit (unit 58). Much of this interval (from 110 to 200 metres) consists of featureless dolostone. Green and red clay seams and reddened dolostone layers are numerous between 200 and 250 metres (unit 3; >150 m thick); some are associated with burrowing in overlying units. Evidence of subaerial exposure is sparse, and sedimentary structures are dominated by plane (mechanical) lamination, with rare intraclasts, grading, and synaeresis cracks. The section ends at a broad vegetated area at the crest of the Norman Range.

Peterson Creek (10-PC)

This section was measured on a spur on the southwest flank of a range between the Keele and Carcajou rivers in southwestern NTS 96D (Figures 12 and 13). The lower contact is not exposed, but stromatolites of Little Dal Group Basinal assemblage member 1 crop out just east of the saddle where the section begins (Figure 12). The Mudcracked formation is faulted out, such that Basinal member 1 is in immediate contact with unit K7 of the Katherine Group, but the unconformity with thin basal redbeds of the Franklin Mountain Formation appears to be intact. The formation's upper contact with the Mount Kindle Formation is well exposed (Figure 12).

The lowest unit present consists of a narrow band of rubble of red sandstone in a saddle on the ridge; this is presumed to be a thin expression of the "basal Franklin Mountain redbeds". Approximately 40 metres stratigraphically above this is the lowest outcrop, consisting of 5 m of columnar stromatolites interlayered with quartz-sandy, cross-bedded, intraclastic dolostone (Figure 14A) overlain by 30 metres of quartz-sandy intraclastic dolostone (**unit 1**). The overlying 115 metres (**unit 2**; 75 m to 190 m) consist of plane-laminated to centimetrically banded dolostone (Figure 14B) with sparse ooid and intraclast layers and sparse, centimetric vugs with incomplete dolomite and quartz fills. Slightly greenish argillaceous interlayers appear 190 metres above the section base (**unit 3**) and are associated with burrowing (Figure 14C). Where depositional features are discernable, dolostones continue to be dominated by faint plane lamination and weak centimetric banding. Ooids and intraclasts are sparse. White chert first appears at 335 metres, and is conspicuous above 360 metres. Quartz sand is present between 345 and 355 metres. Scattered, centimetric, thinly crystal-lined vugs are locally present, and one 16-metre-thick, pervasively vuggy dolostone layer is present at 295 m (Figure 14D). The section ends at the contact with the Mount Kindle Formation (~378 metres; covered), a massive, brown-weathering skeletal dolofloatstone with abundant, taxonomically diverse silicified macrofossil fragments.

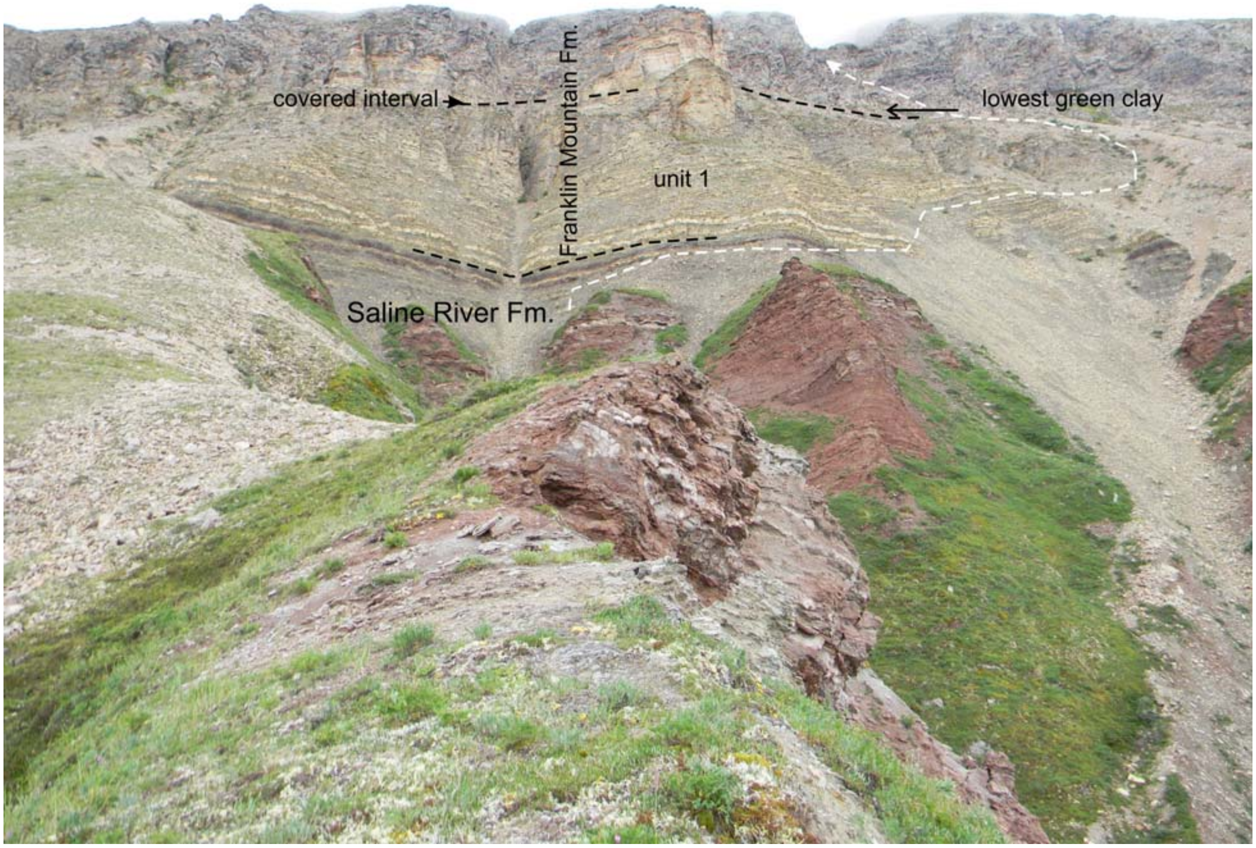

Figure 9. Outcrop photo of section 10-NR (Norman Range), with line of measured section. View to south.

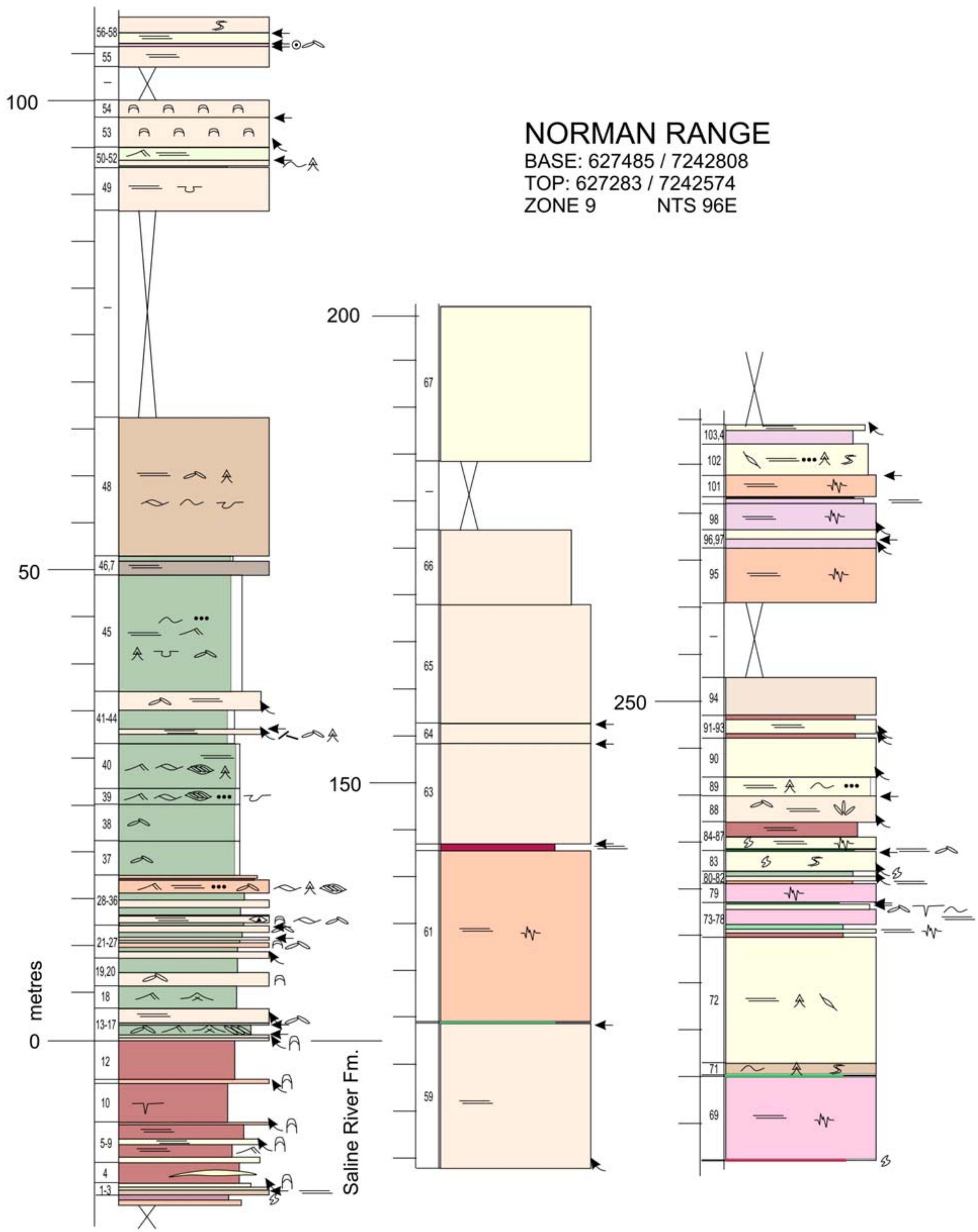

Figure 10. Stratigraphic section 10-NR (Norman Range). Numbers to left of column are unit numbers. For legend see Figure 5B.

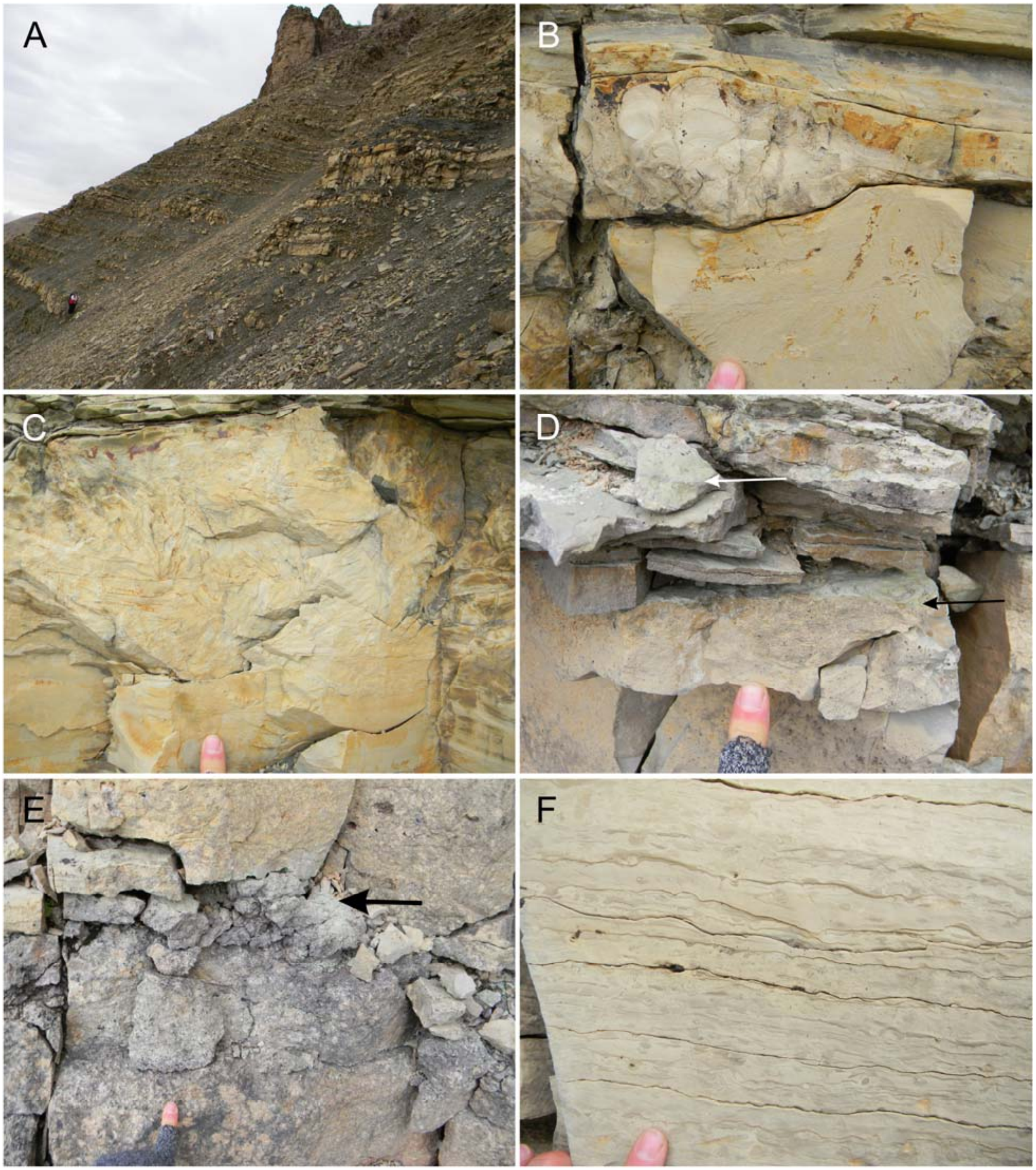

Figure 11. Exposure and lithofacies at Norman Range (section 10-NR). Fingertip for scale unless otherwise noted. (A) Interlayered dolostone and dolomitic siltstone of unit 1 (T. Chevrier for scale). (B) Margin of small mound of columnar stromatolites (unit 29). (C) Intraclast rosettes in lenses formed by storm processes (unit 39). (D) Lowest clay seam above major break in slope (base arrowed), with interlayered reddish coloured dolostone and bedding-plane burrows (white arrow) (unit 50). (E) Purple, porous dolostone associated with clay seam (arrowed) (unit 82). (F) Burrowing in dolostone above a clay seam (unit 71).

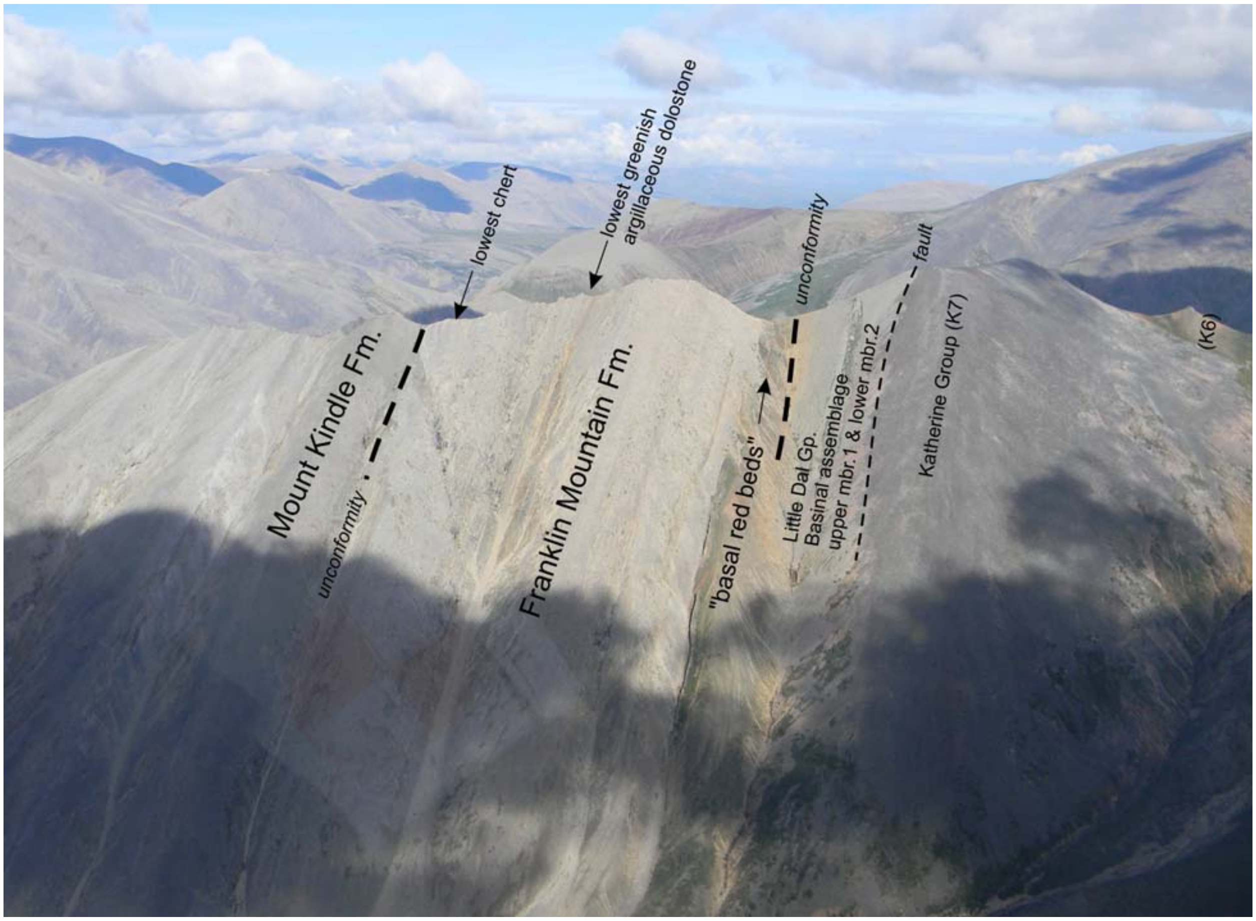

Figure 12. Outcrop photo of section 10-PC (Peterson Creek); section follows ridge-line. View to northwest.

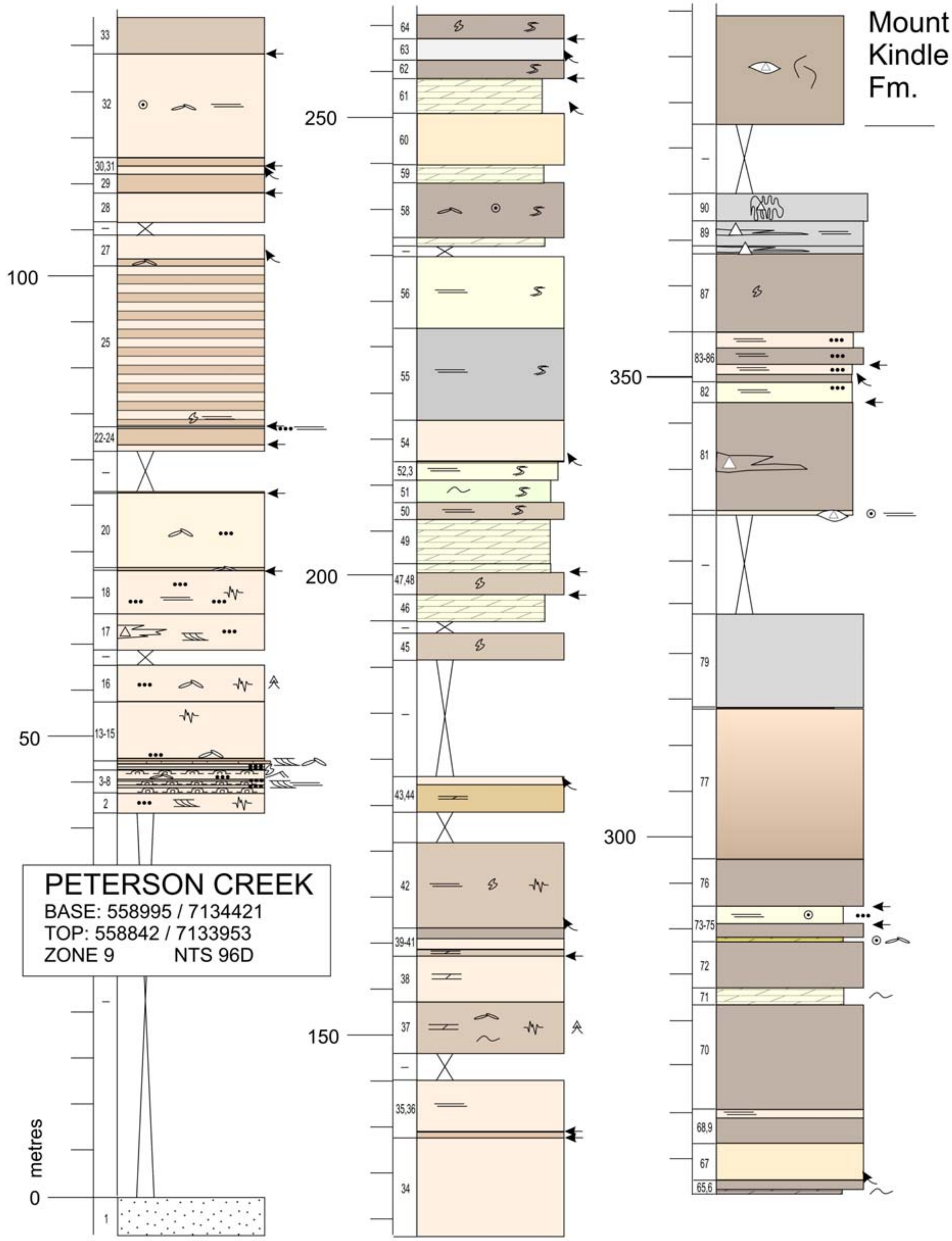

Figure 13. Stratigraphic section 10-PC (Peterson Creek). Numbers to left of column are unit numbers. For legend see Figure 5B.

Figure 14. Lithofacies at Peterson Creek. Fingertip for scale unless otherwise indicated. (A) Cross-bedded, quartz-sandy dolostone in unit 1 (unit 6; pencil is 13 cm long). (B) Faintly banded and graded dolosiltstone; stratigraphic 'up' is to left (unit 37). (C) Bedding-plane burrows in red-weathering dolostone associated with clay (unit 51). (D) Unusually vuggy dolostone (unit 77); hammer for scale.

INTERPRETATION

Informal members

The informal members of Aitken et al. (1974) and Norford and Macqueen (1975) are recognisable where the formation is well exposed in the study area, but there are significant problems with continued use of these terms. Although all previous work, and the present work, assumed by default that each “member” represents a distinct time increment, it is possible that considerable diachroneity was involved in the deposition of each member. For example, the “cyclic member” (unit 1) represents regional flooding of a very extensive surface that had some topography, at least in the area of the Mackenzie Arch. It is probable that initiation of deposition of the “cyclic” member was diachronous. Pugh (1983) suggested that regional development of chert in the upper part of the formation was diachronous, with gradual westward expansion of chert deposition through the Early and Middle Ordovician. Units 1, 2 and 3, which now replace the informal “members”, should be used and correlated with extreme caution because their contacts do not necessarily represent reliable time-lines.

The names given to the informal members are misleading: the “cyclic” member does not contain well-developed eustatically controlled cycles, but instead has storm beds, each with a standard vertical succession of tempestite features (erosional base, intraclast rudstone, graded sand- to mud-grade material, possible recolonisation by microbial mats). In contrast, the “rhythmic” member does contain regular cyclic repetition of two main lithofacies (although the cycles are of ambiguous origin). Although the informal members of Aitken et al. (1974) and Norford and Macqueen (1975) have some utility for mapping, their nomenclature is inappropriate and easily misinterpreted. Using “units 1, 2, and 3” removes the potential for misinterpretation, but does not resolve the issue of diachroneity. Work on the provenance of clay in the upper part of the formation may eventually provide real time-lines for use in regional correlation.

Intraformational correlation and paleoenvironmental interpretation

In the northeastern part of the area studied (10-NR and 10-DO), the Franklin Mountain Formation gradationally overlies an evaporative shallow-water to supratidal deposit, the Saline River Formation. In the southwestern section (10-PC), the formation has a thin basal red-bed and unconformably overlies the lower Basinal assemblage of the Little Dal Group (Neoproterozoic).

The lower part of the Franklin Mountain Formation (unit 1) consists of quartz-silty intraclastic tempestites in all three sections (Figure 15). This storm-dominated interval is of roughly equal thickness in the three locations, and, assuming minimal diachroneity, there is no indication of a paleobathymetric gradient in the area spanned by the southwest-northeast cross-section they depict (the transect may not cross the Mackenzie Arch). Quartz sand is less abundant, and quartz silt more abundant, in the eastern section (10-NR), but the meaning of this distribution is not clear. Unit 1 records a regional, energetic, shallow-water carbonate system with considerable fetch (Figure 16). The absence of macrofauna would suggest some degree of restriction of water circulation with the open ocean. Franklin Mountain unit 1 represents flooding of a broad, flat area that was previously restricted and low-energy, although water that was fully normal-marine in its chemical composition is not indicated for this unit, or for any other part of the formation.

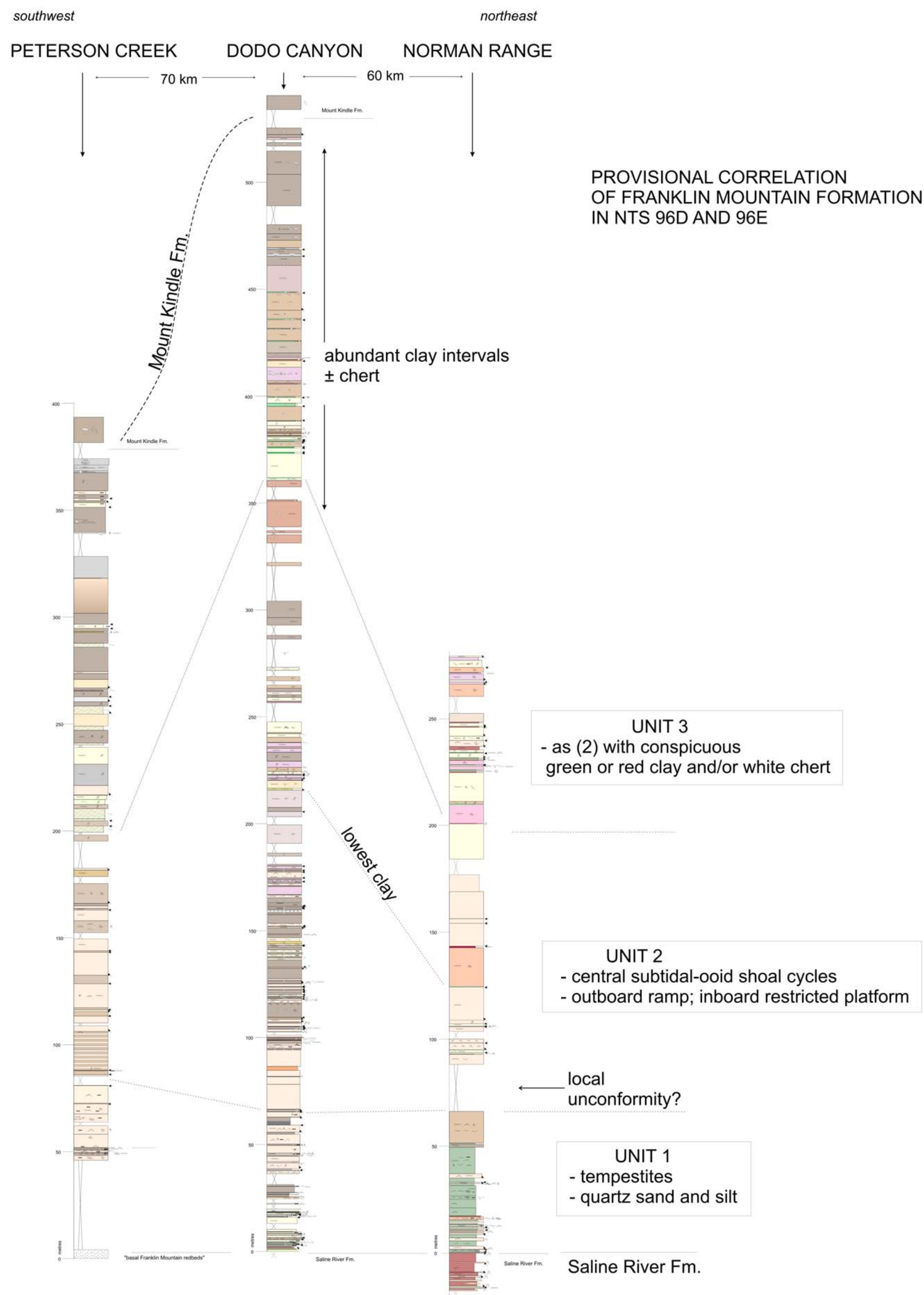

Figure 15. Provisional correlation panel for sections 10-DO, 10-NR, and 10-PC, pending further geochemical and biostratigraphic information.

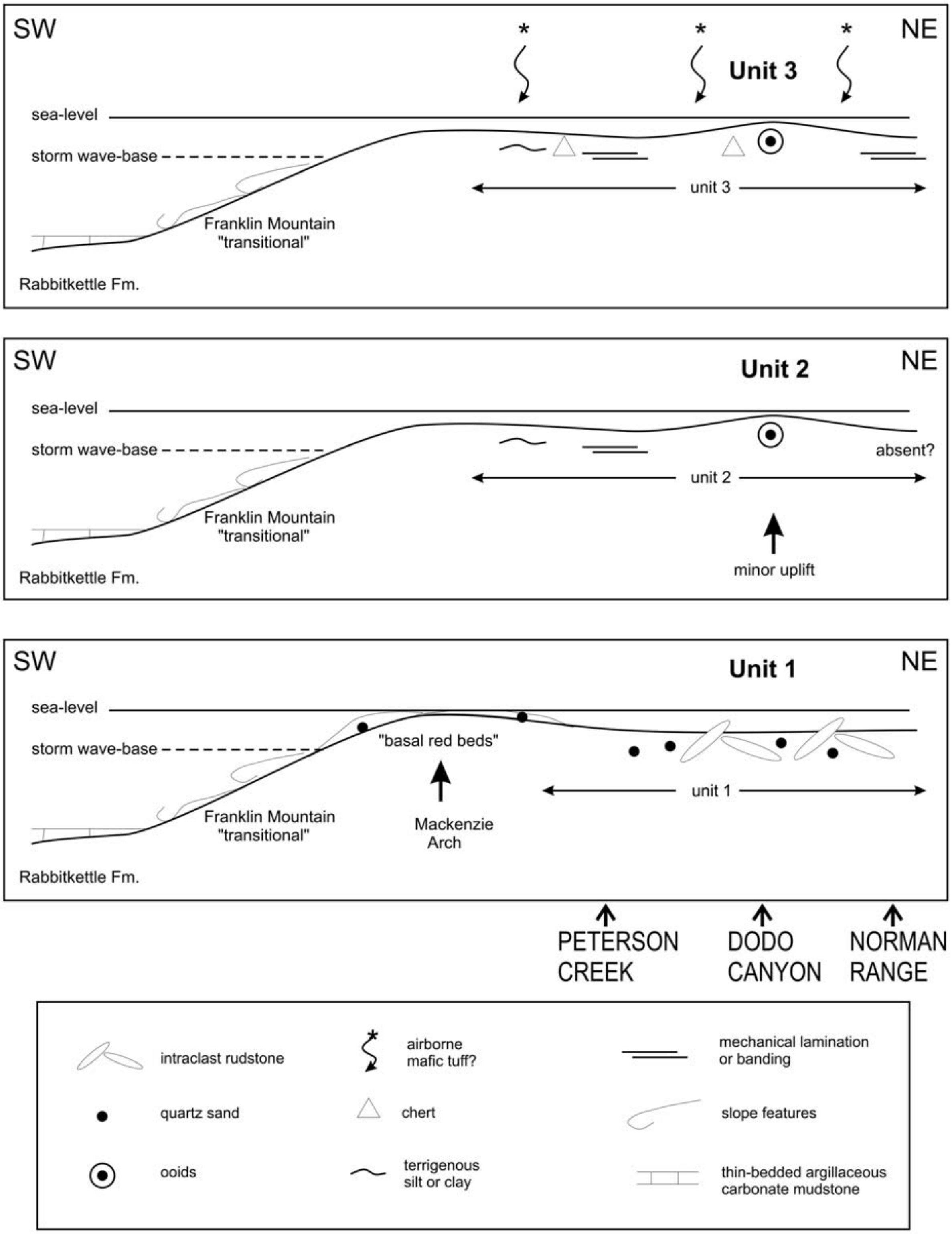

Figure 16. Strike-normal paleoenvironmental interpretation for the general area transected by sections 10-DO, 10-NR, and 10-PC.

Unit 1 is gradationally overlain by unit 2, in which the paleogeography of the area became differentiated into a slightly restricted inner ramp (Norman Range), an outboard subtidal lagoonal area or outer ramp (Peterson Creek), and a central zone (Dodo Canyon) of ooid shoals and lagoonal muds (Figure 16). The region was not as strongly influenced by a broad marine fetch, and was characterised by a shallower storm wave-base, less frequent storm influence, and more strongly chemically modified water, as suggested by the nature and abundance of storm-generated sedimentary structures, and the abundance of oolitic units (evaporative "abiogenic" carbonate precpitates) at Dodo Canyon. The exact location and extent of the ooid shoal system is unknown, but the carbonate mud content of the oolitic dolostones at Dodo Canyon suggests that ooids were locally redistributed and mixed with muddier sediment. Metre-scale cyclicity formed by sharply demarcated alternations of mechanically laminated to banded grey dolosiltstone and brown ooid dolopack-wackestone seems to be eustatic in origin (no beds were ever seen to pass laterally to a different facies), ruling out a depositional setting characterised by randomly migrating ooid shoals in a carbonate silt- to mud-dominated lagoon. Instead, the cyclic packaging both in the Dodo Canyon ooid shoal system and in the more subtle cycles of the other sections, seems to reflect high-order eustatic cycles. In the shoal system, eustatic fluctuation caused alternating development of lower-energy, lagoonal muds and silts influenced by currents (producing mechanical lamination, banding, and rare HCS) and higher-energy ooid shoals. The lack of an intermediate lithofacies (i.e., ooid wackestone, or centimetrically to decimetrically interlayered ooid grainstone and dolosiltstone/mudstone) argues against the possible lateral equivalence of these lithofacies in an ooid shoal / lagoon mosaic. Instead, each sharp-based cycle began with sea-level rise and inundation of pre-existing ooid shoal surfaces that had been at sea-level, and regional development of a subaqueous, slightly geochemically restricted lagoon. Then, once shallowing had eventually depressed fair-weather wave-base to the level of the muddy sea-floor, it scoured the sea-floor sediment to an equilibrium level, and high-energy ooid shoal development began. This interpretation explains the shart contacts both between and within cycles, but requires a non-actualistic vision of the ooid shoal system, in which ooids were produced as a regional veneer rather than in shoals that were geographically separated by subtidal areas.

The inboard area (Norman Range) contains a considerable thickness of featureless dolostone that probably records deposition of carbonate mud in a mildly restricted lagoon behind the shoal barrier. Development of facies differentiation and the ooid shoal system may reflect subtle tectonic activity that caused slight and persistent uplift in the central area.

Paleoenvironmental differentiation of the area persisted through unit 3 (Figure 16), although subtidal – oolite cycles at Dodo Canyon are less conspicuous. Both inboard and outboard areas remained salinity-stressed lagoons, and the outboard area received sparse influxes of ooids, probably transported at the outer fringes of the extensive shoal system. It is unknown whether these paleogeographic divisions of the ramp persist along strike to the southeast and northwest.

The entire region received repeated influxes of bright green clay, which may represent the settling of mafic tuffs, and thus may have potential as time-lines (Figure 15). Pugh (1983), working on core, considered that clay and red-coloured dolostone, present in the upper 40 m of the section, were caused by development of the unconformity at the top of the formation, but in the present work, these features are clearly stratigraphically intact. Clay seams remain intact in the inboard two areas, but were mixed with carbonate in the possibly more energetic, deeper, outboard zone (Peterson Creek). The clay-rich interval is commonly stratigraphically associated with the appearance of burrowing in all three sections, which probably indicates that nutrients associated with clays allowed the temporary appearance of primary producers (probably phytoplankton, rather than benthic cyanobacteria) and a non-skeletonised, stress-tolerant infauna. Clay is also intimately associated with the development of chert, supporting the possiblity that the clay consisted of particles of unstable mafic glass that reequilibrated with interstitial fluids producing dissolved silica that then replaced carbonate. In areas where no clay seams are present, it may eventually be possible to infer contemporaneous, distant volcanism based on the presence of chert as a proxy. Mafic deep-water volcanism in the nearby Misty Creek Embayment (Marmot Formation;

Figure 1) began in the early Middle Ordovician; if this volcanic event can be related to the inferred mafic tuffs and associated chert in the study area, as well as to abundant, roughly coeval cherts that are extremely abundant in the upper Franklin Mountain Formation across the interior plains (Norford and Maqueen, 1975), it would require both that some of the volcanic activity be subaerial and that eastward aeolian transport be quite pervasive and extensive.

Based on sparse biostratigraphic information, the upper Franklin Mountain Formation has hitherto been presumed to be no younger than Early Ordovician, although Pugh (1983) provided evidence of a Middle Ordovician age.

If the upper part of the formation is Middle Ordovician, the conspicuous unconformity between the Franklin Mountain and Upper Ordovician – Silurian Mount Kindle formations developed during some part of the Middle to Late Ordovician. The diverse fauna of the Mount Kindle Formation indicates normal marine conditions that are in striking contrast to the severely restricted biota and lithofacies of the Franklin Mountain Formation. The hiatal interval separating the two formations must have been a time of radical reconfiguration of the Mackenzie Platform that was associated with ongoing tectonic evolution of the Selwyn Basin; the variable stratigraphic level of the contact (rising westward; Norford and Macqueen, 1975) suggests the possibility of extensive, geographically variable post-Sauk-III uplift and erosion. A moderately restricted shelf (Franklin Mountain Formation), was later overlain by a fully normal-marine shelf (Mount Kindle Formation).

Extrabasinal correlation and comparison

As in the Mackenzie Platform of northwestern Laurentia, alternation between restricted and open-marine conditions also characterised the Late Cambrian – Early Ordovician of the Arctic Platform (northern Laurentia). The depositional age of the Franklin Mountain Formation spans the same time interval as the Cass Fiord (Late Cambrian) to Eleanor River (late Early Ordovician) succession in the Arctic Islands (and possibly the Bay Fiord Formation, if the upper Franklin Mountain Formation extends into the Middle Ordovician). The Arctic Platform succession, like the Franklin Mountain Formation, is almost uninterrupted by stratigraphic breaks. Unlike the fairly consistently shallow-water, mildly restricted environment of the Franklin Mountain Formation, however, the same time interval in the Arctic islands is represented by fairly ‘normal’ subtidal carbonates that alternate with thick lagoonal evaporites [Baumann Fiord Formation (Early Ordovician), and possibly Bay Fiord Formation (Middle Ordovician)]. Although the conditions in the two areas would seem to contrast, the main controls are shared: an arid climate, regional platformal deposition with comparatively steady subsidence, and roughly contemporaneous development of outboard zones of excessive subsidence (Selwyn Basin and its embayments in west; Hazen Formation and silled evaporite basins in north).

Cyclicity, and lack thereof

The sparse biostratigraphic constraints available indicate deposition of the formation over a time-span of as much as 35 to 40 million years, or very roughly 1.5 cm of net sediment accumulation per 1,000 years (for 10-DO, assuming minimal erosional removal at the formation’s top). The time-span of its deposition witnessed several important events, including transgression and deposition of the Sauk III sequence, the Early Ordovician surge in marine biotic diversity, and possibly a global carbon isotope excursion (the Steptoean Positive Isotope Excursion (SPICE); Saltzman et al., 1998).

Previous workers (Aitken et al., 1974; Norford and Macqueen, 1975) documented the conspicuous metre-scale cyclicity of the “rhythmic” member (unit 2) at Dodo Creek, and this pattern continues, though diminished in its visual drama, into the “cherty” (unit 3) member. In spite of this apparent higher-order cyclicity, no lower-order patterns are documented, and instead, the “rhythmic” and “cherty” intervals exhibit a startling stratigraphic monotony that is broken only by the addition of clay and chert. A similar lack of medium- to low-order cyclicity is evident in the Arctic Islands succession.

Diagenesis

The diagenetic history and economic potential of the Franklin Mountain Formation are not the immediate focus of this paper; the following remarks are broad generalisations based on field observations only. The entire Franklin Mountain Formation is dolomitised where it was studied in the course of this project. The dolomite is fine to medium crystalline; coarsely crystalline dolomite is limited to red-weathering dolostones that are spatially associated with clay seams. Few stratigraphic units exhibit conspicuously anomalous porosity. Vug- and fracture-filling carbonate phases are few: white dolospar fills minor millimetric to centimetric vugs and millimetric veinlets in the upper part of the formation, and rare orange calcite is the last phase in some vug-fills whereas white dolospar or quartz are last in others.

Depositional features of the Franklin Mountain Formation are not generally well preserved, particularly in the upper part of the formation, owing to the moderately to strongly fabric-destructive nature of the dolomitisation. Dolomitisation of the entire formation appears to have been roughly uniform in its effects, with perhaps a slight diminution in the preservational quality of depositional textures upward. Completely fabric-destructive dolomitisation does not appear to have taken place in the area studied.

The diagenetic state of the Franklin Mountain Formation in the study area may be generally consistent with its litho- and biofacies, both of which indicate restriction from open marine circulation and elevated salinity during the formation's deposition. Pale chert in the upper part of the formation preserves ooids much better than does enclosing dolostone, indicating that silicification predated dolomitisation. Poor preservation of allochems and sedimentary textures is consistent with dolomitisation that significantly post-dated sediment deposition. The slight crystal size difference between pale and dark units in the units 2 and 3 is probably a function of the original particle size of the sediment: sand-sized for ooid packstone but silt-sized for the pale-weathering dolosiltstone or dolomudstone layers.

There is no evidence in the strata studied of sabkha environments or sabkha dolomitisation in the Franklin Mountain Formation, and only sparse evidence of evaporite minerals or their former presence is visible in the field. It is possible that dolomitisation took place by reflux of brine created by mildly evaporative depositional conditions across the Mackenzie Platform during the protracted interval of deposition of the formation (possibly as much as 30-40 m.y.), or that reflux dolomitisation took place when evaporative conditions (not stratigraphically preserved) developed during part of the interval represented by the hiatus between the Franklin Mountain Formation and the Mount Kindle Formation. Fairly early dolomitisation by reflux would have stabilised the formation geochemically and preserved it from later alteration, explaining its comparatively uniform quality of preservation. The possibility of roughly syndepositional reflux dolomitisation is of interest because the depositional age of the Franklin Mountain Formation coincides with SEDEX mineralisation by venting of metalliferous brines in the temporally equivalent Rabbitkettle Formation in the Selwyn Basin (Anvil District; Goodfellow, 2007). Previous work has indicated significant porosity in the lowermost (Pyle and Gal, 2007) and uppermost (Mackenzie, 1974; Pugh, 1983) parts of the Franklin Mountain Formation elsewhere, and so it is probable that the regional diagenetic history of the formation was more complex than is suggested by this superficial assessment of diagenesis in three closely spaced stratigraphic sections.

Clay layers in the upper part of the formation contributed to diagenesis in several ways. The clays appear to have produced dissolved silica during their stabilisation below the sediment-water interface, which resulted in the replacive chert that characterises the upper part of the formation. The clay-rich layers are also immediately associated with coarser, red-weathering (presumably ferroan) dolomite and perhaps an apparent increase in porosity in the immediately surrounding dolostone.

Significance to mapping

Stratigraphic patterns, especially the appearance of minor terrigenous components, may be critical to dividing the Franklin Mountain Formation into temporally meaningful subunits (Figure 15). The combination of quartzose material and tempestites in unit 1 should be readily distinguishable during mapping, although this unit may be diachronous. The remainder of the formation contains little that is stratigraphically obvious. Nonetheless, ridge sections should permit the identification of the green or red clay (or the argillaceous dolostone equivalent in outboard areas), or the associated red-weathering dolostone or burrowing that distinguish unit 3 from unit 2. Although chert is abundant only in unit 3, its first appearance and its general abundance are not consistent; although its presence is generally synonymous with unit 3, its absence does not preclude the presence of unit 3.

Although the thickness of unit 1 is areally consistent, unit 2, as currently defined, is markedly thicker in Dodo Canyon that in the Peterson Creek or Norman Range sections. It is possible that subsidence was anomalously higher in the Dodo Canyon area during deposition of unit 2, but it is also possible that the successions at Norman Range and Peterson Creek contain a subtle erosional hiatus. It is difficult to argue for either of these possibilities without better age control. Thickness patterns in unit 3 are meaningless owing to variable loss of stratigraphic thickness by erosion between deposition of the Franklin Mountain Formation and the Mount Kindle Formation.

The presence of chert has been considered one of the more useful stratigraphic indicators in the formation, but its abundance is regionally highly variable, and it is unclear whether initiation of chert formation was contemporaneous throughout the Franklin Mountain Formation's depositional area. Until the origin of the chert is better understood, its presence should be regarded as no more than a general indication of stratigraphic position.

Future work

The results of this work point to several research topics that have the potential to elucidate a variety of scientifically and economically relevant phenomena.

(1) The existence of paleogeographic differentiation in the Franklin Mountain Formation in the transect covered here suggests that adding lithostratigraphic and paleoenvironmental data for the Franklin Mountain Formation in the plains east of the Norman Range may enable construction of a regional Late Cambrian and Early Ordovician paleogeography of northwestern Laurentia. Linking the Cordilleran, cratonic, and Franklinian depositional areas into a broad paleogeographic framework could eventually be possible. Strata deposited during this time are important not only in their geographic extent, but their depositional and diagenetic history may contribute to the understanding of regional tectonic and climatic events that contributed to the crustal fluid systems responsible for contemporaneous mineralising events in associated deep-water areas (Anvil district, central Yukon).

(2) Linking the litho/tectono/bio/chemostratigraphy of the Franklin Mountain Formation to that of contemporaneous units across the outer ramp/slope and into the deep-water Misty Creek Embayment (NTS 106A, B, C and 105P) will similarly improve the understanding of regional paleoenvironments and tectonic history, and help to resolve the base-metal potential of the deep-water basin. The potential for meaningful correlation would be greatly improved if stable isotopic analysis of Franklin Mountain strata (currently underway) can be matched with similar data from the deep-water basin, and if the geochemistry of the Franklin Mountain Formation's green clays can be tied to that of known mafic volcanic material of the Marmot Formation in the Misty Creek Embayment.

(3) Transects similar to the one presented here could be documented along strike to the northwest and southeast of this study area, to provide a regional view of the Late Cambrian – Early

Ordovician paleogepography (the results of this study provide only a limited line-transect). Similarly, documenting the nature of the formation on the northern and western (Yukon) margins of the Misty Creek Embayment could greatly enhance the understanding of the area's tectonic and paleoenvironmental evolution.

(4) The Franklin Mountain Formation is thought to be equivalent to the lower part of the Cambrian – Devonian Bouvette Formation (Yukon; Morrow, 1999). The Bouvette Formation urgently requires a detailed regional lithostratigraphic study, particularly because it is now known to host gold mineralisation (Rackla gold belt). The degree to which the two formations resemble one another and to which their depositional histories agree or differ may be critical to both the base-metal and gold prospectivity of these strata.

(5) The diagenetic history of the Franklin Mountain Formation may be important to the potential for SEDEX-type base-metal mineralisation in the Misty Creek Embayment, and so pursuing the dolomitisation history of the Franklin Mountain Formation would be a logical next step. Such a study would also focus on the contribution of possible mafic tuffs to red, porous, ferroan dolomites that may have been important aquifers at some time.

(6) The origin of chert in the Franklin Mountain Formation remains problematic. Although some of the chert is clearly spatially associated with green clay seams and red dolostone in the sections measured here, chert is clearly present in previously published sections from elsewhere, without the obvious presence of unusual clays. Was the supply of volcanic dust in other areas more distant and diffuse, and is there a geocehmical marker that could help to discern the possible influence of tuff where clays are not obvious or not present? Alternatively, were the extremely cherty areas of the interior plains simply more evaporative, and if so, is there supporting lithologic evidence? Lithostratigraphy and sampling of the Franklin Mountain Formation in inboard areas, followed by a petrographic and geochemical study of cherts from all areas, could help to determine the origin and meaning of the chert.

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