

Progress report on the stratigraphy, sedimentology and significance of the Kimerot and Bear Creek groups, Kilohigok Basin, District of Mackenzie

Project 810021

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Abstract

Some results of ongoing field investigations of the Kimerot and Bear Creek groups are summarized as they pertain to several topics, including: (1) revision of stratigraphic nomenclature for Kilohigok Basin; (2) vertical and lateral distribution of facies/fabrics of disconformities developed in the lower Bear Creek group; (3) stratigraphy and sedimentology of the Beechey Formation; (4) diagenesis studies of the Peg Formation (new name); and (5) constraints on the stratigraphy, sedimentology, and provenance of the Burnside Formation.

Résumé

Des résultats de travaux de terrain en cours sur les groupes Kimerot et Bear Creek sont colligés et comprennent les sujets d'études suivants: 1) une révision de la nomenclature stratigraphique du bassin de Kilohigok; 2) la distribution latérale et verticale des faciès et des textures des discordances générées dans la partie la plus basse du groupe de Bear Creek; 3) la stratigraphie et la sédimentologie de la formation de Beechey; 4) les études de la diagenèse de la formation de Peg (nouveau nom); 5) les effets de contraintes en stratigraphie et sédimentologie et la provenance de la formation de Burnside.

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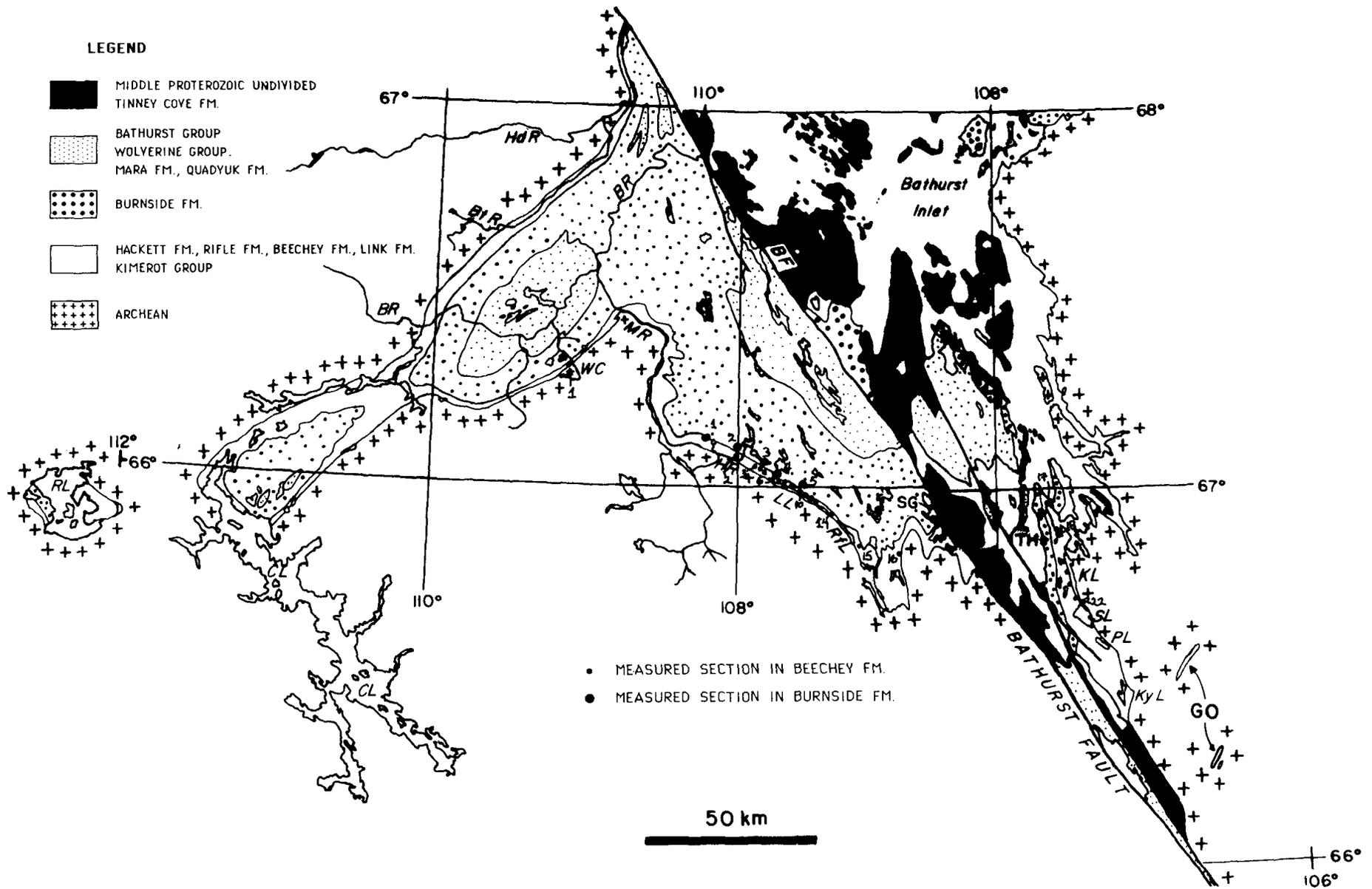


Figure 23.1 Palinspastic base map of Kilohigok Basin based on restoration of 135 km of left-lateral slip on the Bathurst Fault as recommended by Tirrul (1985). Includes location of measured sections in Beechey and Burnside formations and geographic features referred to in the text. *Note:* measured sections are intermittently numbered from northwest to southeast; numbers for unlabeled sections can be directly interpolated. *RL*, Rockinghorse Lake; *CL*, Contwoyto Lake; *BR*, Burnside River, *BtR*, Booth River; *HdR*, Hood River; *WC*, Wolverine Canyon; *MR*, Mara River; *HR*, Hackett River; *LL*, Link Lake; *RfL*, Rifle Lake; *KyL*, Kenyon Lake; *SL*, Starvin Lake; *KL*, Kathleen Lake; *PL*, Peg Lake; *SG*, Straight Gorge; *TH*, Tinney Hills. *GO*, Outliers of Goulburn Supergroup (Kimerot Group).

INTRODUCTION

Detailed stratigraphic studies of the early Proterozoic (circa 1.9 Ga) Kilohigok Basin are continuing in order to exploit the unusually advantageous circumstance that the basin fill is exposed continuously for over 250 km transverse to its depositional strike. During the field season of 1986, investigations of the Kimerot and Bear Creek groups (new names) were continued in the Beechey Lake (76G), Mara River (76K), and Tinney Hills (76J) map areas (Fig. 23.1). Work concentrated on 1:50 000 scale mapping of individual stratigraphic units (JPG, DSM), and detailed topical studies were initiated related to the nature and extent of intraformational unconformities (JPG), the stratigraphy and sedimentology of the Beechey Formation (new name) (SMP), and the stratigraphy, sedimentology and provenance of the Burnside Formation (DSM). In addition, carbonate facies and cements of the Kimerot Platform were sampled as part of a geochemical study of Peg Formation carbonate precipitation and diagenesis, including dolomitization. Studies of the Burnside Formation (DSM) will form the basis for a Ph.D. dissertation, and studies of the Beechey (SMP) Formation will form the basis for a B.Sc. thesis.

Results reported here support the tentative conclusion of Grotzinger and Gall (1986) that the Kilohigok Basin subsided in response to flexure of the lithosphere, probably associated with convergence and crustal loading along the Thelon Tectonic Zone. Stratigraphic trends in thickness and facies on the group scale were delineated during earlier work (Tirrul, 1985; Grotzinger and Gall, 1986) and indicated that downwarping of the most deeply subsiding parts of the basin was concomitant with flexure and uparching of the foreland. Similar trends can now be independently recognized on the formation scale and are discussed below. In addition, the occurrence of stratigraphic unconformities bounding individual sequences (formations) has been confirmed and indicates that although eustasy may have been the dominant control on foreland stratigraphy, formation thickness and extent of erosion of formations along sequence boundaries was localized by intrabasinal arching which persisted through all of Bear Creek Group time.

REVISION OF STRATIGRAPHIC NOMENCLATURE

The stratigraphic nomenclature of units within the Kilohigok Basin has been subjected to numerous revisions in the past as a function of increasing scales of mapping as new projects were initiated and completed. Ongoing 1:50 000 scale mapping and detailed topical stratigraphic studies form the basis for the current project and require a more refined stratigraphic nomenclature. Consequently, several new formations are proposed, and these additions, along with most of the existing formations, are organized into new groups (see Fig. 23.2). The previous Goulburn Group is elevated to supergroup status and the name Goulburn is retained. The new revisions are discussed briefly below only as they specifically pertain to units discussed in this report. A more comprehensive summary is planned for a future report designed for that purpose.

Kimerot Group. The name Kimerot Group is proposed for the units previously designated as belonging to the "Kimerot Platform" (c.f. Campbell and Cecil 1981; Tirrul 1985; Grotzinger and Gall, 1986) of the lower Western River Formation. The name Western River Formation is discarded here, and does not occur in the new nomenclature. The Kimerot Group contains two new formations, the lower Kenyon Formation and the overlying Peg Formation. These new formations correspond to the lower "siliciclastic part" and the upper "carbonate part" of the old Kimerot Platform (c.f. Grotzinger and Gall, 1986). The type areas for the Kenyon and Peg formations are in the vicinity of Peg Lake and Kenyon Lake (see Fig. 23.1 for locations), where both are well exposed.

Bear Creek Group. The name Bear Creek Group is proposed for the units previously assigned to the Western River Formation above the Kimerot Platform, plus the Burnside Formation, the Mara Formation, and the Quadyuk Formation. All those formation names are retained with the exception of Western River Formation which is abandoned. The new formations proposed all occur within the stratigraphic assemblage previously regarded as the Western River Formation above the Kimerot Platform. The four new formations approximately coincide with the previous four members of the Western River Formation described in Campbell and Cecile (1981). The new Hackett Formation, the lowest of the four, is equivalent to the old Lower member of the Western River Formation, and its type area is in the vicinity of Hackett River where it is well-developed (see Fig. 23.1 for location). The Hackett Formation consists of a lower siltstone member and an upper quartzite member.

The Rifle Formation (new name) overlies the Hackett Formation and is equivalent to the Red Siltstone member (old name) of the Western River Formation. The type area for the Rifle Formation is in the vicinity of Rifle Lake where it is best exposed (see Fig. 23.1 for location). The Rifle Formation consists almost exclusively of monotonous maroon siltstone in its type area, with uncommon sequences of unconformity-bounded(?) quartzites at its top.

The Beechey Formation (new name) overlies the Rifle Formation and is approximately equivalent to the previous Quartzite member of the Western River Formation. The type area for the Beechey Formation is between Rifle Lake and Hackett River where it is well-exposed. The Beechey Formation is a heterogeneous mixture of carbonates, quartzites, and siltstones, and is described in more detail below.

The Link Formation (new name) overlies the Beechey Formation and is approximately equivalent to the previous Upper Argillite member of the Western River Formation. The type area for the Link Formation is in the vicinity of Link Lake where it is well exposed (see Fig. 23.1 for location). The Link Formation consists of interbedded siltstones and quartzites.

Wolverine Group. The name Wolverine Group is proposed to embrace the previously defined (Campbell and Cecile, 1981) Peacock Hills and Kuvik formations. The

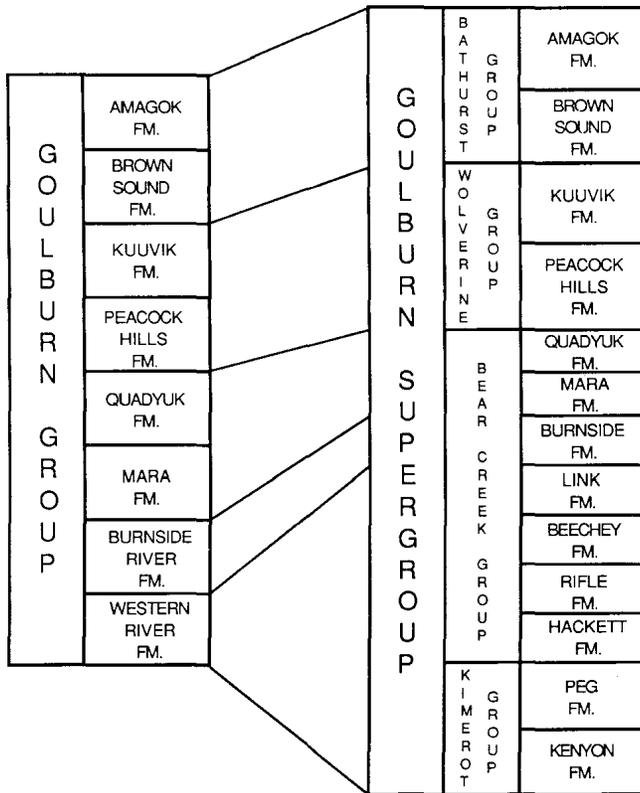


Figure 23.2 Revised Early Proterozoic stratigraphic nomenclature for Kilo Higok Basin.

Wolverine Group is well-exposed in the vicinity of Wolverine Canyon (see Fig. 23.1 for location).

Bathurst Group. The name Bathurst Group is proposed to embrace the previously defined (Campbell and Cecile, 1981) Brown Sound and Amagok formations. The Bathurst Group is best-exposed along the southeastern margin of Bathurst Inlet.

DISCONFORMITIES OF THE LOWER BEAR CREEK GROUP

Vertical and lateral distribution

Disconformities exist at several different stratigraphic levels within the Bear Creek Group (see Fig. 23.2 for review of stratigraphic nomenclature). They occur on both sides of the Bathurst Fault, but are best developed west of the fault, in the southwest part of the basin within the Beechey Lake map area. The stratigraphically lowest disconformity is developed at the top of the Kimerot Group (new name) as discussed in Grotzinger and Gall (1986). Beneath this disconformity (here termed the "sub-Hackett disconformity"), each unit of the Kimerot Group is progressively truncated from southeast to northwest. Truncation of uppermost units first occurs in the vicinity of Gordon Bay, along the east side of the Bathurst

Fault, and continues down through the remaining part of the section along the outcrop belt exposed in the Beechey Lake map area, west of Bathurst Fault. The lowest units of the platform are finally truncated in the southern parts of the large basement-involved synclines of the Beechey Lake map area. In the northern parts of the synclines, and along the rest of the outcrop belt to the northwest, the Kimerot Group is absent and the overlying Hackett Formation of the Bear Creek Group sits directly on Archean basement.

The distribution of basal conglomerate and/or regolith developed along the Archean/Proterozoic unconformity directly relates to the presence or absence of the Kimerot Group. Where the Kimerot Group is preserved, the Archean/Proterozoic unconformity is characterized by a well-developed basal conglomerate and poorly-developed or absent regolith (Fig. 23.3a). Conversely, where the Kimerot Group is absent, the Archean/Proterozoic unconformity is marked by a thick (several metres locally), carbonate-matrix regolith, and absent or poorly developed basal conglomerate (Fig. 23.3b). This correlation between the absence of Kimerot units and presence of carbonate-matrix regolith along the Archean/Proterozoic unconformity indicates that the regolith is most likely of post-Kimerot age and was produced following truncation of the Kimerot Group and subsequent re-exposure of the Archean basement surface. This relationship is important in that a method is now available to assess the width of the Gordon Bay Arch that was active during erosion of the Kimerot Group. Even though the Kimerot Group was eroded down to the level of the Archean basement, the area of basement that was exposed above sea level during sub-Hackett disconformity time can be directly estimated by evaluating the distribution of carbonate-matrix regolith that occurs to the northwest of where the sub-Hackett disconformity intercepts and becomes part of the Archean/Proterozoic unconformity. Preliminary reconnaissance data indicate that in the area of Wolverine Canyon, where the entire Bear Creek Group section thickens again after thinning in the Beechey Lake map area, the Archean/Proterozoic unconformity is devoid of any carbonate-matrix regolith and is overlain by quartzites that may be time-equivalent to the Kenyon Formation (Kimerot Group). Thus the "crest" of the Gordon Bay Arch during sub-Hackett disconformity time probably occurred near the northwest corner of the Beechey Lake map area. The trend of the arch was previously delineated by Grotzinger and Gall (1986) as running to the northeast.

A stratigraphic disconformity is also developed at the top of the Hackett Formation which overlies the Kimerot Group in the southeast part of the basin (palinspastic), and overlies Archean basement in the northwest areas where Kimerot sediments are absent. The Hackett Formation is a shallowing-upward, siltstone-to-quartzite sequence; the basal siltstone member progressively overlies (onlaps) stratigraphically lower formations of the Kimerot Group and then rests directly on basement to the northwest. The upper quartzite member is separated from the overlying Rifle Formation by a disconformity (here termed the sub-Rifle disconformity) which becomes more pronounced to the northwest, in the vicinity of the Hackett River (Fig. 23.3c,d). The contact between the

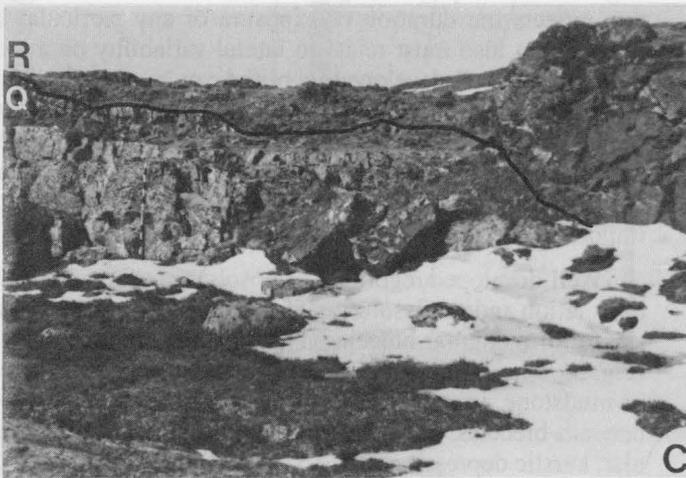
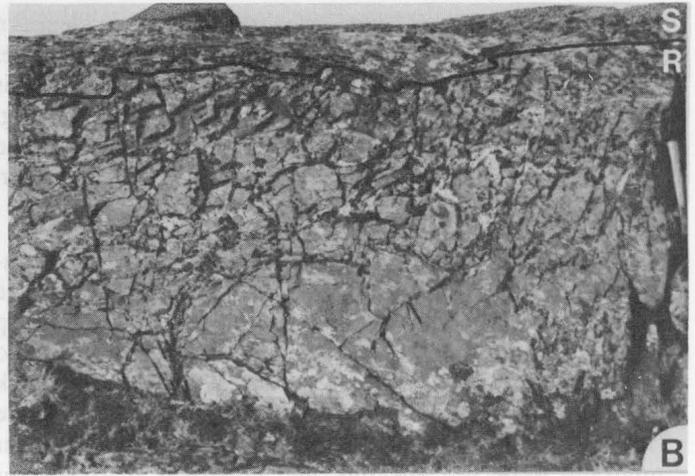
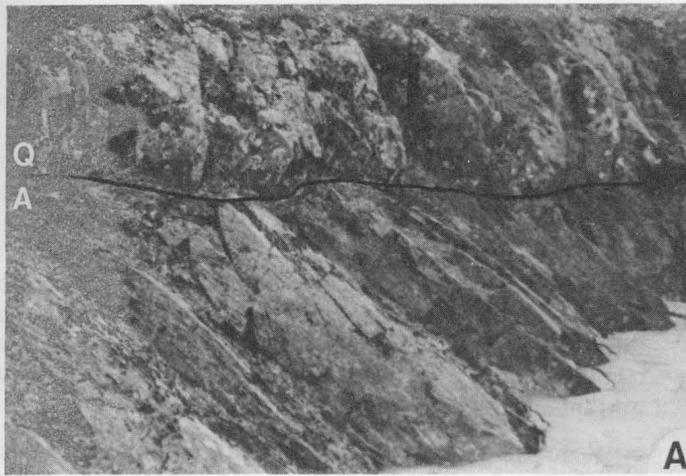


Figure 23.3 Disconformable surfaces and regoliths of Kimerot and Bear Creek Groups A) Contact between steeply-dipping Archean meta-greywacke (A) and flat-lying quartzites and basal conglomerate (Q) of Kenyon Formation (Kimerot Group). Note lack of regolith or brecciation below contact. Day-pack for scale. B) Contact between brecciated Archean meta-greywacke (R) and overlying flat-lying siltstones (S) of Hackett Formation. Note extensive brecciation of Archean meta-greywacke; breccias have well-developed "fitted" fabrics and are filled with carbonate matrix. Hammer for scale. C) Contact between quartzites (Q) of upper Hackett Formation and overlying siltstones of Rifle Formation. A thick regolith (R) is developed along the contact. Jacobs staff is 1.5 m long. D) Close-up of regolith (R) developed on Hackett Formation quartzites (Q); regolith is overlain by siltstones (S) of Rifle Formation. Arrow points to pen for scale. E) Close-up of D. Note encrustation of breccia blocks and scalloped hard-rock platform by digitate tufa. F) Similar to D. Digitate tufas were precipitated on scalloped hard-rock surfaces, possibly in the splash-zone during the early phases of transgression of the regolith surface. As such, they are analogous to the pelagosite crusts of Shark Bay.

Hackett Formation and Rifle Formation shows no evidence of disconformity east of the Bathurst Fault. Although the upper surface of the quartzite member of the Hackett Formation is locally karstic and up to several metres of section are missing, the quartzite member as a whole is regionally continuous and does not appear to be systematically truncated as is the underlying Kimerot Group.

The upper contact of the Rifle Formation is also a disconformity (here termed the sub-Beechey disconformity). The surface is conformable at the southern end of the outcrop belt east of the Bathurst Fault, becoming disconformable to the north-northwest where it truncates upper units (thick quartzites) of the Rifle Formation. Along the Beechey Lake outcrop belt to the west of the Bathurst Fault, the upper quartzite units are missing, and siltstones of the lower Beechey Formation sit directly on siltstones of the lower Rifle Formation, separated by a thick (locally several metres) sequence of pisolite and sand-rich breccia. Mapping revealed local remnants of the upper quartzite units of the Rifle Formation beneath the sub-Beechey disconformity, indicating that a significant amount of section has been removed (at least several metres). The juxtaposition of deep-water siltstones (subwave-base) of the Beechey surface that deletes a significant thickness of strata, suggests that this is perhaps the most important disconformity in the lower Bear Creek Group. Significantly, siltstones of the Rifle Formation can be traced at least as far as Wolverine Canyon where they become concretionary; this unit may correlate with the lower member of the Odjick Formation (Coronation Supergroup) in Wopmay Orogen.

A major disconformity also occurs at the top of the Beechey Formation (here termed the sub-Link disconformity). This surface is conformable at the south end of the outcrop belt, east of the Bathurst Fault, becoming disconformable to the north-northwest. Along the Beechey Lake outcrop belt, west of the Bathurst Fault, uppermost units of the Beechey Formation are truncated to the northwest and remnants of an upper stromatolitic unit are locally present. Northwest of Link Lake the upper quartzite unit is also cut out and siltstones of the lower Link Formation sit directly on the main stromatolite unit of the Beechey Formation. This relationship suggests that the sub-Link disconformity is also important.

Detailed mapping and stratigraphic studies define a distinct zone of maximum stratigraphic truncation along each disconformity in the region of the southwest part of the "basin", extending from the area of Rifle Lakenorthwest to the Mara River. In this zone, all formations thin significantly as a result of both facies changes and erosion of upper units, and fabrics indicative of subaerial exposure and erosion are best developed. Northwest of this region, in the vicinity of Wolverine Canyon, formations are thicker, additional units are present beneath disconformities, and disconformity-related fabrics are less well developed. These relationships provide evidence for continued, perhaps episodic, influence of the Gordon Bay Arch on the stratigraphy of the lower Bear Creek Group.

Facies and fabrics associated with disconformities

The sub-Hackett disconformity and those of the lower Bear Creek Group contain unique assemblages of diagnostic facies and/or fabrics that can be considered as important evidence of prolonged subaerial exposure of the underlying sequence and development of paleosols. These facies and fabrics comprise a continuum of regoliths ranging from incipient alteration of underlying facies (eg. "blotchy: carbonate cementation of quartzites) to extensive brecciation, dissolution, replacement and erosion of underlying facies. Some of these features are illustrated in Figure 23.3. In advanced stages of development, regoliths become vertically zoned with distinct facies that warrants their classification as true paleosols.

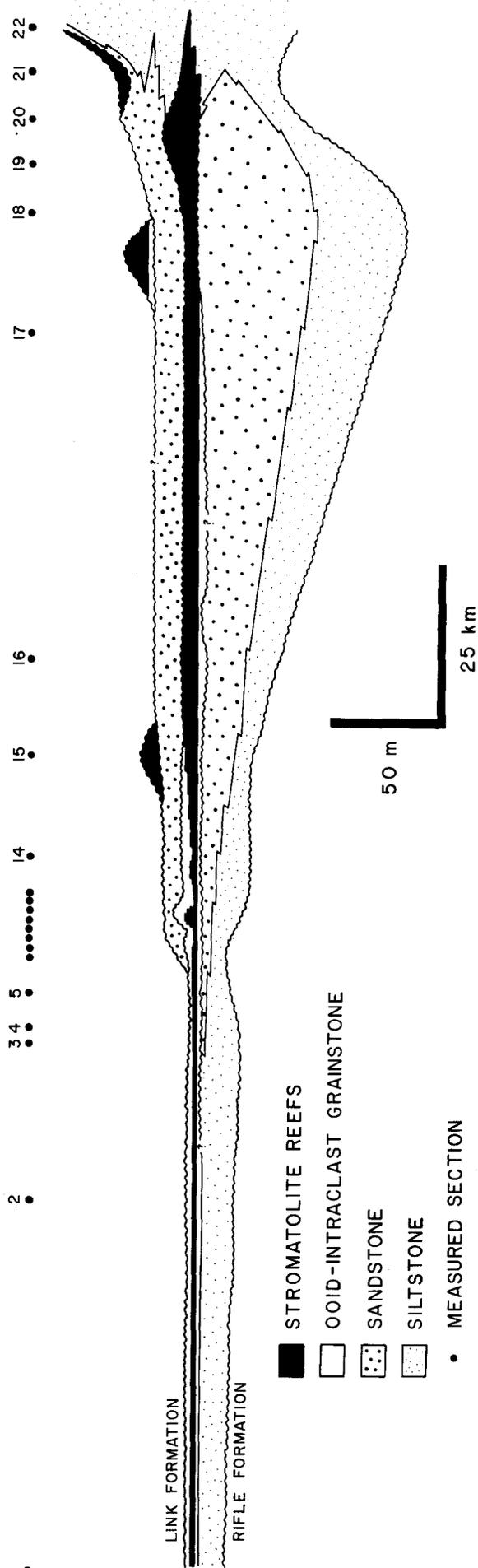
Regoliths associated with disconformities range in thickness from a few decimetres to several meters depending on degree of development (Fig. 23.3b,c,d). To a certain degree this reflects the duration of exposure of any particular sequence, but also must relate to lateral variability on a local basis in that well-developed regoliths can be traced within a few metres or tens of metres into "incipient" regoliths, and then back into pronounced regoliths. Consequently, suspected disconformable surfaces must be traced over considerable distances (tens of kilometres) in order to determine how important the disconformity is.

Well-developed regoliths (paleosols) are characterized by brecciation and/or dissolution of the underlying parent material to form angular breccias (Fig. 23.3b) or rounded blocks (Fig. 23.3d,e). Where the parent material consists of siltstone or mudstone, large tepee structures are generally developed beneath breccias. Disaggregated blocks generally fill irregular, karstic depressions up to 3 or 4 m thick. Blocks are both clast- and matrix-supported, and cavities associated with clast-constructed frameworks are generally filled with geopetal sediment including laminated dolomitic muds and pisolite. Roofs of cavities may also contain downward projecting, laminated conical structures interpreted as paleostalactites. Pisolitic units generally overlie breccias and are less than 1 m thick, although occasionally up to several metres thick; units are commonly sheets, thickening into karstic depressions and are associated with continuous layers of dolomitic fibrous cement crusts. Reverse grading may be developed.

Fibrous cement crusts consist of superimposed, isopachous layers of laminar cements, as well as upward-diverging mammillate or botryoidal structures. Individual botryoidal fans are up to 15 cm high and are defined by radiating arrays of crystal fibers up to 1 or 2 mm wide with blunt terminations. Preliminary petrographic observations suggest that these crusts may have been originally aragonitic. Individual pisoliths, as well as cement crusts, characteristically are iron-rich and contain peloids of hematite and possibly other iron-rich sedimentary minerals. These peloids also occur in local concentrations with carbonate cement.

Breccias, related cavities, and layers of pisolite show evidence for multiple generations of fracturing and renewed

Figure 23.4 Palinspastic cross-section of Beechey Formation. Note prominent NW-SE thickening and apparent paleohigh beneath sections 19-21. Section locations on Figure 23.1.



precipitation of cements and accumulation of geopetal sediments in fracture voids. Replacement of all lithologies by jasper is typical as one of the latest stages of fabric development related to exposure. This is generally associated with formation of crusts of laminated jasper silcrete which coat breccia blocks.

The last stage of fabric development commonly involves precipitation of dolomitic, colloform to digitate tufas as isopachous coatings that drape irregularities on the upper surfaces of regoliths (Fig. 23.3e,f). Although morphologically and petrographically similar to the tidal flat tufas described by Grotzinger and Read (1983) and Grotzinger (1986), these tufas are distinctly iron-rich and contain abundant hematite. In this respect they are very similar to the hematitic stromatolites and cement fans described by Grotzinger and Hoffman (1983) and Hofmann and Grotzinger (1985). This facies locally occurs capping regoliths associated with the Kimerot disconformity and overlying disconformities of the lower Bear Creek Group. Preliminary investigations reveal that similar facies also characterize parts of the Mara pisolite (Campbell and Cecile, 1981) which is related to development of a major disconformity at the top of the Mara Formation (upper Bear Creek Group). Furthermore, small digitate stromatolites and associated ferruginous pisolite interpreted as part of a paleosol has been reported from the Gibraltar Formation (Great Slave Supergroup) by Hoffman (1969). Finally, similar iron-rich peloidal pisolites occur along the contacts between shelf quartzites and overlying siltstones of some sequences in the Wilson Island Group (Great Slave Supergroup) (B. Johnson, pers. comm., 1985). Thus, it can be concluded that the distribution of this particular suite of facies (paleosols) is process-related, and independent of time. Consequently, recognition of these facies in other Proterozoic basins constitutes a method for identification of stratigraphic disconformities related to relative changes in sea level. Furthermore, the spatial distribution of such paleosols may define paleogeographic patterns useful in evaluating the relative importance of tectonic (e.g. flexure) versus eustatic effects on basin stratigraphy. If eustatic, disconformities have the added importance of being valid time markers for use in intra- and interbasinal lithostratigraphic correlation.

STRATIGRAPHY AND SEDIMENTOLOGY OF THE BEECHEY FORMATION

The Beechey Formation (Fig. 23.4,5,6a,b) was studied in the outcrop belt extending from Wolverine Canyon to Straight Gorge along the west side of Bathurst Fault, and along the Tinney Hills east of the Bathurst Fault. The study supplements initial work by Campbell and Cecile (1981) by providing new information concerning the lateral extent and diversity of carbonate facies and significance of related quartzites and disconformities. The Beechey Formation forms a shallowing-upward siltstone-to-quartzite sequence, and comprises four major lithofacies.

Siltstone lithofacies. Maroon to greyish green siltstones consist of finely- to thickly-interlaminated mudstone layers and "streaky" siltstone and very fine sandstone layers. Fine sandstones may also form ripples, and occasionally hummocky cross-laminae. Concretions and discontinuous carbo-

BEECHY FORMATION - SECTION 11

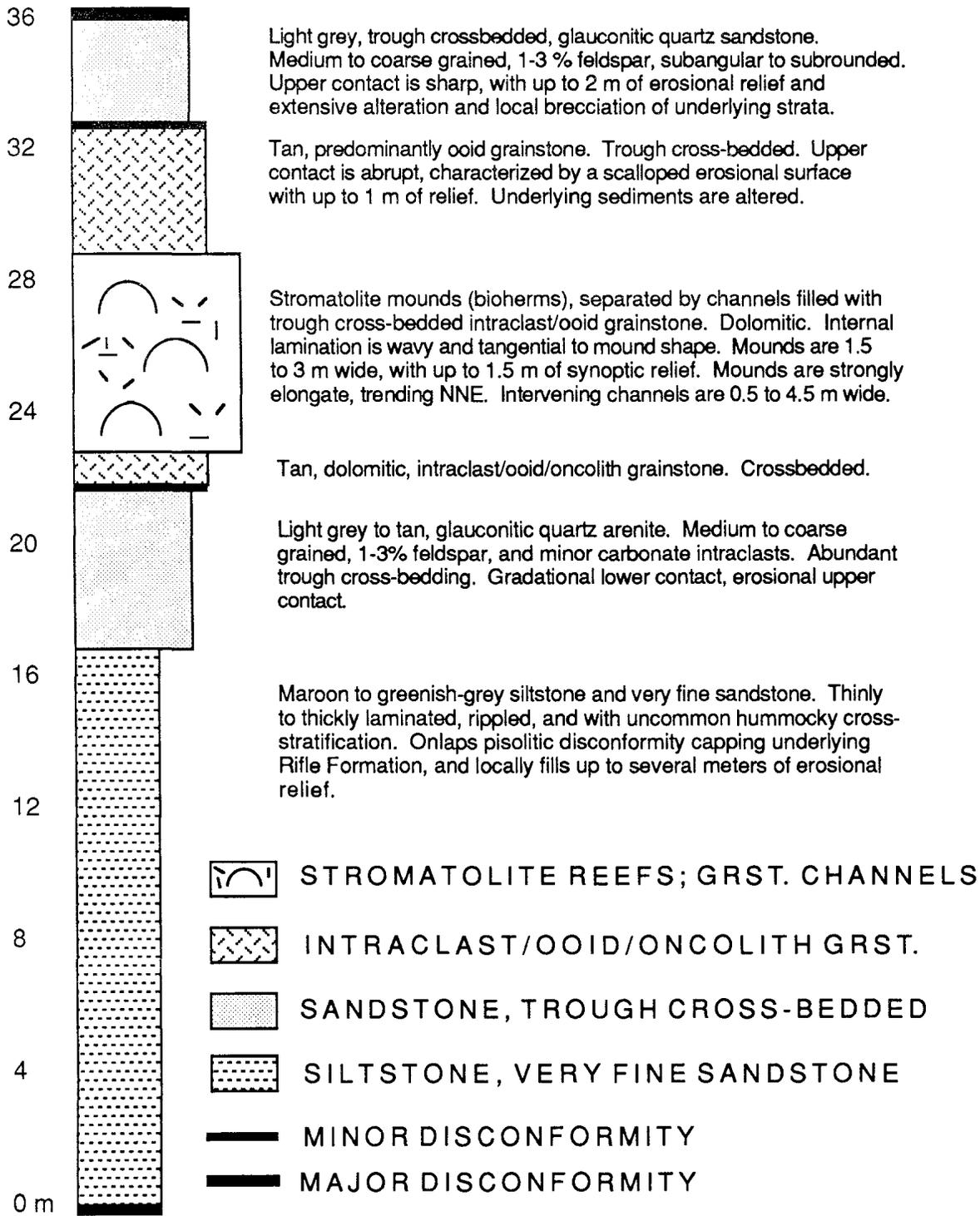


Figure 23.5 Representative measured section from type area of Beechy Formation.

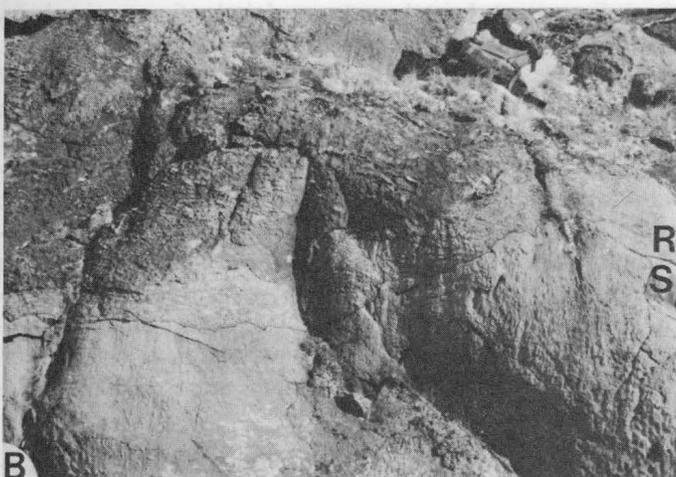
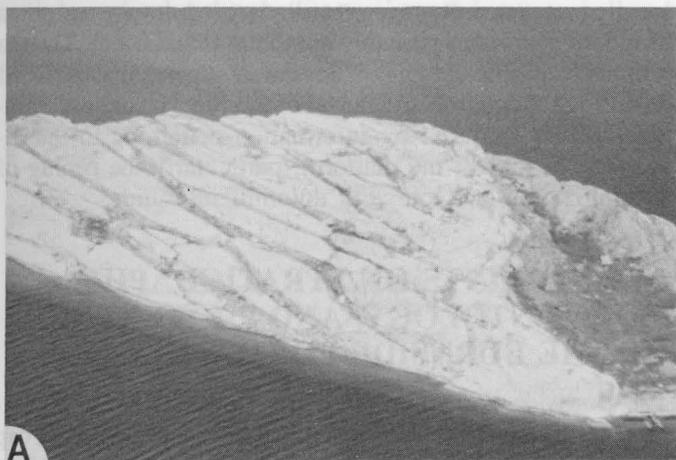


Figure 23.6 A) Stromatolitic bioherms of Beechey Formation. Note prominent elongation of bioherms and development of intervening channels. Aircraft for scale in lower right. B) Disconformity at top of main stromatolite unit (S) in Beechey Formation. Note well-developed scalloped erosional surface, overlain by intraclastic breccia and regolith (R). Day-pack at top for scale. C) Silica pseudomorphs after radial-fibrous precursor cements, probably aragonite. Pseudomorphs occur in cement-filled fractures associated with breccias in reefal facies at top of Peg Formation (Kimerot Group).

nate layers are present in southeasterly exposures. In places, mud cracks are developed near the tops of siltstone sequences.

Siltstones were probably formed in relatively deep subtidal shelf settings, perhaps near storm wave-base. They are developed as the lowermost member of the Beechey Formation and grade upward into quartzite facies. This overall transition probably reflects initial transgression of the exposure surface at the top of the Rifle Formation (sub-Beechey disconformity), followed by deepening and deposition of the siltstone facies. This was followed by progressive fall of relative sea level over the shelf to form overlying shallower-water quartzite facies.

Quartzite lithofacies. Medium- to coarse-grained quartzites occur as sheets up to 50 m thick, thinning northwestward, and extending for up to 150 km. Quartzites are composed of beds up to 1m thick, generally 20-50 cm thick, and with scoured bases. Beds pinch and swell locally, and contain trough crossbedding and uncommon planar crossbedding. Grains are generally quartz-cemented, but carbonate cements are common near disconformable surfaces. Grains are 95% quartz, with a few percent feldspar, glauconite, and opaques.

Quartzites probably represent shallow-marine sheet sands deposited during lowering of relative sea level, associated with decreasing rates of tectonic subsidence or eustatic lowering of sea level.

Ooid-intraclast grainstone facies. Carbonate (dolomitic) grainstones occur at several different stratigraphic levels within the Beechey Formation. They consist of beds 10 to 30 cm thick, which generally form sheets up to several metres thick that extend in some examples for several tens of kilometres. Other grainstones form lenses between stromatolite bioherms. Many grainstones are cross-stratified and contain oncoliths and scattered quartz grains.

Grainstones probably accumulated in shallow subtidal environments as blankets of shoal sediments that formed during periods of diminished siliciclastic influx, or as channel deposits between stromatolite biostromes. Sheet deposits are generally coarsest and thickest in the vicinity of the best-developed stromatolite biostromes suggesting that much sediment was supplied by degradation of stromatolites.

Stromatolite reef facies. Stromatolite biostromes and bioherms are best-developed at one stratigraphic interval in the Beechey Formation. However, remnants of what may have been another major stromatolitic unit are locally present beneath the sub-Link disconformity; these units were probably largely removed by erosion, although the possibility of depositional discontinuity cannot be discounted. Reefal facies consist of stromatolite mounds up to 1.5 m thick, characterized by either tangential or columnar internal structure. Component columnar stromatolites range from a few cm up to several decimeters in width. Bioherms are up to 3 m wide and separated by channels up to several metres wide (Fig. 23.6a). Both mounds and component stromatolites are elongate NNE-SSW. The main stromatolitic interval can be traced the entire distance of the Beechey Formation studied so far

(Starvin Lake to Wolverine Canyon), although it thins and passes laterally into concretionary siltstones south of Starvin Lake (off-shelf direction).

Reefal facies formed predominantly in shallow subtidal conditions, although it is not yet certain whether they developed diachronously by sheet progradation, or synchronously by vertical aggradation.

Regional stratigraphic relationships

Figure 23.4 illustrates the regional stratigraphy of the Beechey Formation. The same southeast-thickening trend observed for the entire Bear Creek Group (Grotzinger and Gall, 1976, Fig. 12.6) is displayed in the Beechey Formation. Similarly, shallow-water facies pass laterally into deeper-water facies to the southeast. Finally, individual stratigraphic units are generally bounded by erosional disconformities (Fig. 23.6b) that are best developed between sections 3 and 16, the same region inferred to represent the crest of the Gordon Bay Arch during erosional truncation of the Kimerot Group. This strongly suggests that processes influencing basin geometry and stratigraphy were probably operative on the time scale of individual formations, and that further detailed studies of other relatively thin units are warranted in that they can potentially provide important information on the subsidence and/or sea level history of the basin.

One particularly interesting feature that may have exerted a strong control on Beechey Formation stratigraphy is the apparent erosional high on top of the underlying Rifle Formation at sections 20, 21, and 22, which coincides with the shelf-to-basin transition zone. This feature has been carefully examined and all relevant contacts are well exposed. Evidence for disconformity along this surface includes brecciation of underlying siltstone, and development of autogenic pisolite, microdigitate tufa, and chert. Thus it seems likely that this surface represents an erosional high that influenced the thickness of the overlying siltstone and lower quartzite members of the Beechey Formation, consequently limiting their progradation to the southeast by restricting sediment dispersal. In turn, this probably restricted the southeastward expansion of the Beechey reefal sequence.

DIAGENETIC STUDIES OF THE PEG FORMATION, KIMEROT GROUP

Geochemical and petrographic studies of the Peg Formation, which forms the upper carbonate platform of the Kimerot Group (Grotzinger and Gall, 1986), will be undertaken by R. Creswell as part of a Ph.D. dissertation at the University of Toronto. Over 100 samples were collected from various facies of the Peg Formation including dololutes, dolarenites, cryptogalaminites, stromatolites, tufas, and dolomitic quartzites. These facies formed in a variety of depositional settings ranging from subtidal open marine to peritidal restricted (Grotzinger and Gall, 1986). The upper part of the Peg Formation was subaerially exposed and eroded to the northwest beneath the sub-Hackett disconformity, and was

locally brecciated. Breccias are filled with dolomite and silica pseudomorphs after probably aragonite (Fig. 23.6c). Thus, a range of possible diagenetic environments may have existed during sedimentation and burial of the Peg Formation. Samples will be analyzed for information pertaining to the diagenetic history of the platform, particularly the timing of dolomitization and source of dolomitizing fluids.

CONSTRAINTS ON STRATIGRAPHY, SEDIMENTOLOGY, AND PROVENANCE OF THE BURNSIDE FORMATION

The Burnside Formation (formerly Burnside River Formation) forms a thick (<1500 m) mostly nonmarine fluvial cap to the coarsening-upwards Bear Creek Group. It is underlain by green, shallow marine siltstones and sandstones of the Link Formation. It is abruptly overlain by finer-grained silty brown sandstone of the Mara Formation to the northwest, while there is a gradational, interfingering contact with stromatolites of the Quadyuk Formation to the southeast. The Burnside Formation has been interpreted as a braided stream deposit (Campbell and Cecile, 1981). The Burnside Formation is currently being studied in detail to: (1) investigate the significance of prolonged fluvial sedimentation in the subsidence history of the Kilohigok Basin, (2) determine the provenance of the Burnside Formation, (3) document regional sedimentary facies mosaics within an Early Proterozoic fluvial sequence, and (4) provide more detailed correlation of tectonic and sedimentary events between Kilohigok Basin and Wopmay Orogen.

In this section, the Burnside Formation will be characterized by lithofacies and their representative sequences. Several aspects of the Burnside Formation have stratigraphic and tectonic significance. These include the lateral variability of the lower contact, the significance and lateral facies variability in the Bd dolarenite unit, the variation of composition and lithofacies of conglomerates. Plans for future research and economic considerations are summarized at the end.

Lithofacies of the Burnside Formation

Sedimentation units within the Burnside Formation can be divided into a series of end-member lithofacies (Table 23.1) based on grain size and sedimentary structures following an interpretive classification scheme developed by Miall (1977, 1978a) and Rust (1978). Sequences of certain lithofacies repeated over hundreds of metres in the Burnside Formation suggest a hierarchy of fluvial cycles regulated by both autocyclic and allocyclic controls. These characteristic sequences allow the Burnside Formation to be divided into several mappable members.

On the largest scale (hundreds of metres), the Burnside Formation records uplift events in a southeastern source area, and changes in lithofacies sequences across depositional strike demonstrate proximal-to-distal transitions in the fluvial regime from southeast to northwest. Campbell and Cecile (1981, p. 111-115) presented a series of qualitative facies

Table 23.1 Lithofacies of Burnside Formation.

Facies Code	Lithofacies	Sedimentary Structures	Interpretation
<i>Fm</i>	silty (vf-f) sand silt, mud	massive to laminated, small rpls., mudcracks	waning flow deposits
<i>Fl</i>	silty (vf-f) sand, silt	fine lamination, small ripples	waning flow deposits
<i>Sr</i>	(vf-c) sand	ripple marks	ripples (lower flow regime)
<i>Sh</i>	(vf-vc) sand, may be pebbly	bedding-parallel lamination	plane bed flow (l. and u. flow regime)
<i>St</i>	(f-vc) sand, may be pebbly	trough cross-beds	migrating dunes (cm-dm)
<i>Sp</i>	(f-vc) sand, may be pebbly	planar cross-beds	lingoid bars (lower flow regime)
<i>Ss</i>	(f-c) sand, may be pebbly	broad, shallow scours with downlapping x-strata	scour fills
<i>Gm</i>	gravel, massive or crudely-stratified	horizontal bedding	lag deposits, longitudinal bars

Classification scheme after Miall (1977, 1978) and Rust (1978).

successions for the Burnside Formation, but did not constrain their spatial distribution. Additional lithofacies have also been interpreted. These differences are shown in measured sections and cross-sections (Fig. 23.7, 8, 9, 10).

Gm lithofacies. This lithofacies consists of massive- or horizontally-bedded clast-supported conglomerate. Bed geometry is commonly sheet-like and individual horizons can be traced laterally at least 20 km in the Tinney Hills (Fig. 23.1). Clasts are pebble to cobble size and commonly well-rounded. Matrix sand is medium to very coarse size. Basal contacts are commonly scoured <10 cm, but rarely may downcut 0.5-3 m in very coarse units. Gm units range in thickness from single clast lags to amalgamated beds up about 2 m thick. Amalgamated beds pass laterally and vertically to interbedded Gm and St lithofacies with 30-50 cm of Gm facies at the base of beds. Single clast layers are interpreted as traction carpet lags. Thicker decimetre-scale and amalgamated beds are interpreted as sheet-flood gravels, longitudinal bars, and rare channel fills.

Clasts are composed of mostly vein quartz with minor amounts of probably Archean basement lithologies and

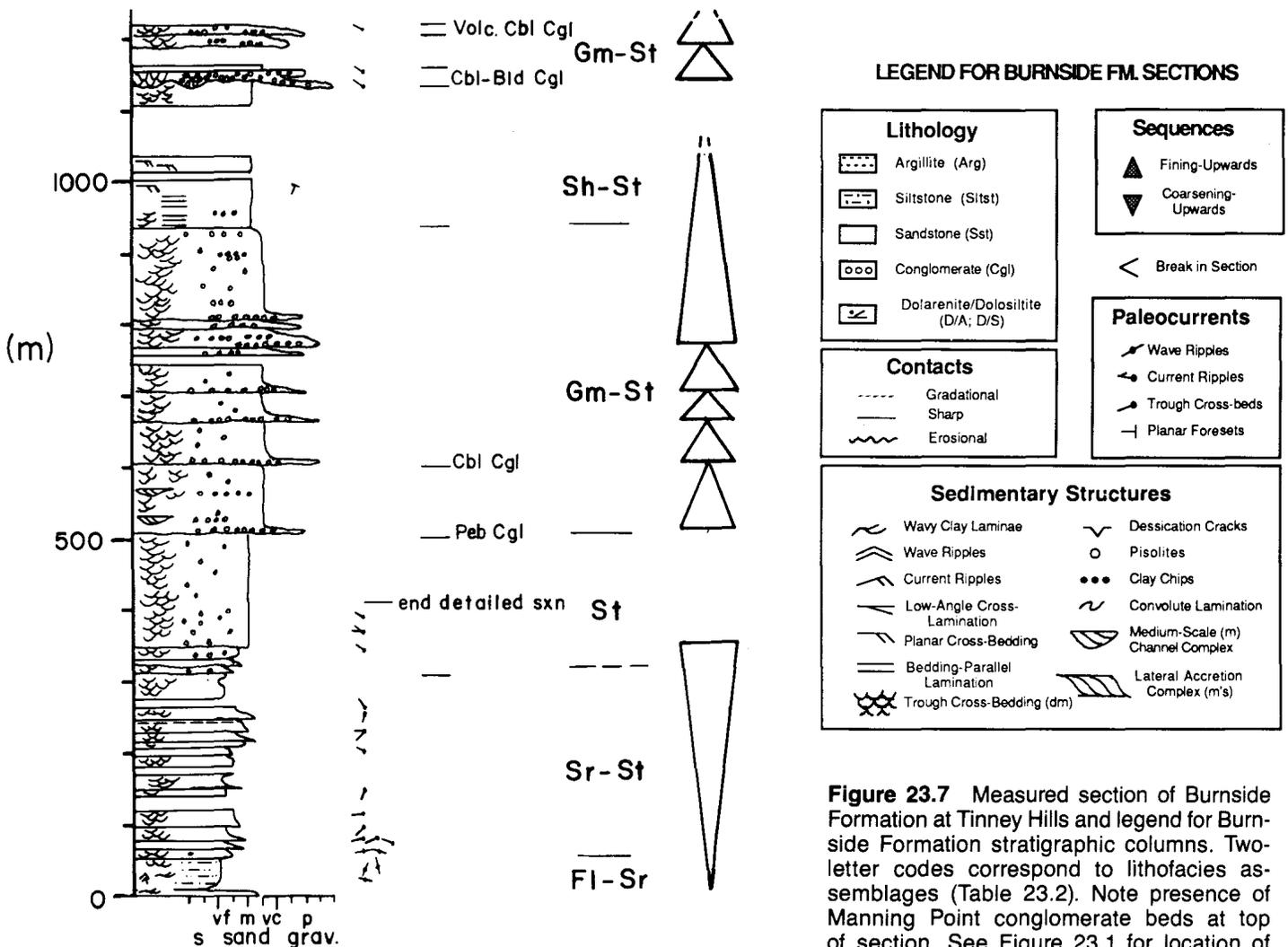


Figure 23.7 Measured section of Burnside Formation at Tinney Hills and legend for Burnside Formation stratigraphic columns. Two-letter codes correspond to lithofacies assemblages (Table 23.2). Note presence of Manning Point conglomerate beds at top of section. See Figure 23.1 for location of sections.

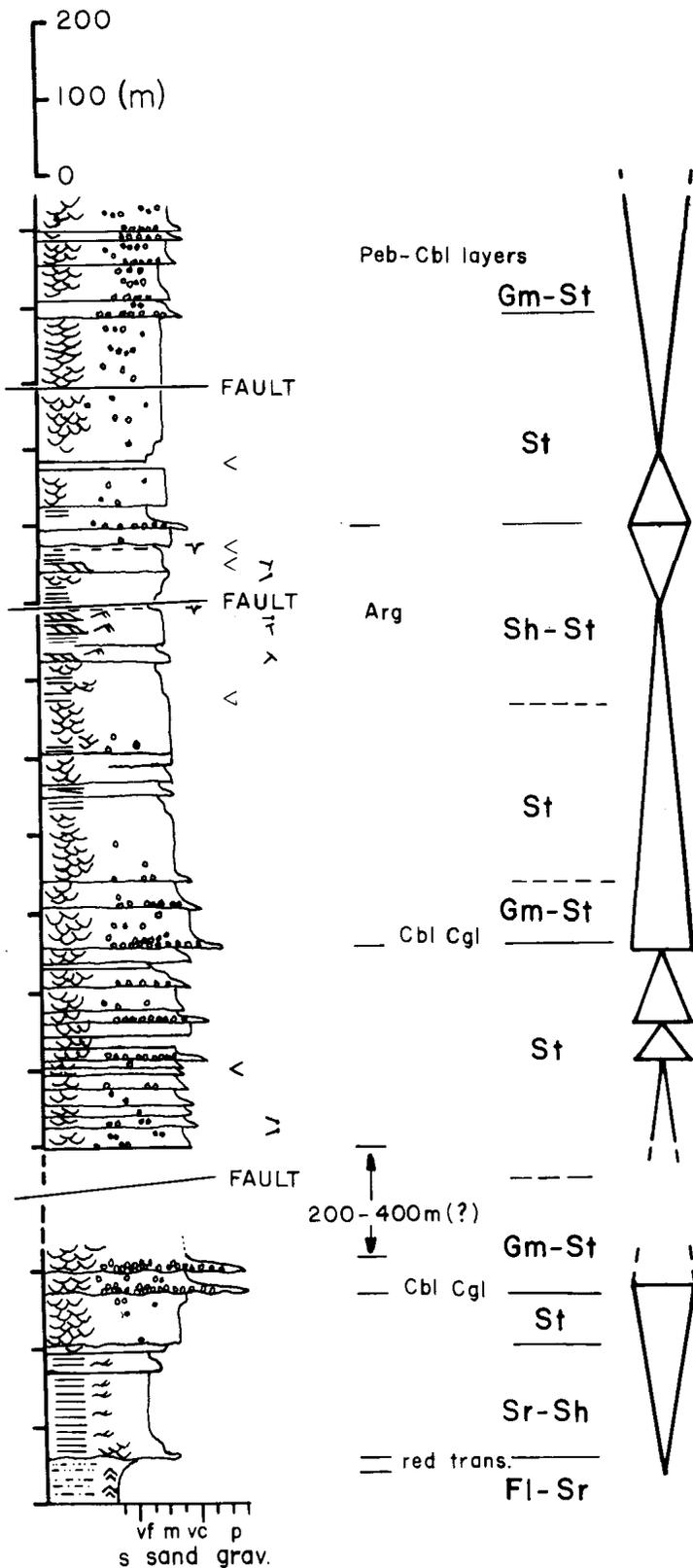


Figure 23.8 Measured section of Burnside Formation at Straight Gorge.

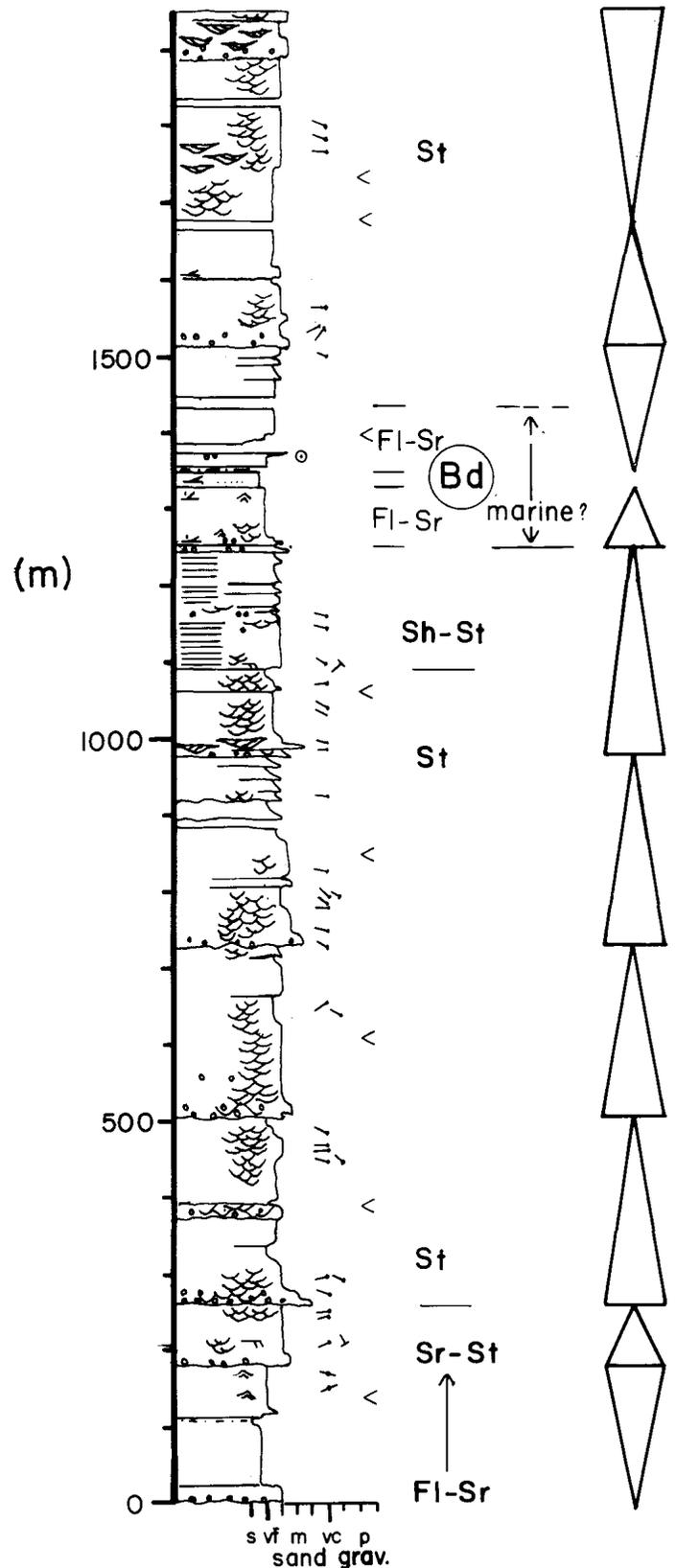


Figure 23.9 Measured section of Burnside Formation at Wolverine Canyon. Note Bd dolarenite unit and surrounding fine grained siliciclastic rocks which probably represent a marine incursion.

Lower Goulburn Supergroup clasts of jasper and sandstone. Intraformational Burnside clasts appear about two-thirds through the longer measured sections (Fig. 23.7, 8, 9).

The thickness, frequency, and maximum clast size of the Gm facies decrease to the northwest, subparallel to the predominant paleocurrent direction. Pebble to cobble conglomerate is common in the Tinney Hills and Straight Gorge areas (Fig. 23.1), whereas only granules to pebbles are found farther northwest. Individual cobbly conglomerate beds in the Tinney Hills can be mapped laterally for more than 20 km. A unique set of two Gm horizons 35 m apart are found at Manning Point at the northwest end of the Tinney Hills. Conglomerate beds contain well-rounded, boulders of intraformational Burnside clasts up to 100 cm and vein quartz up to 45 cm. The second unit consists of cobbly Gm and St lithofacies containing a large proportion of undeformed felsic volcanic clasts similar to ones described by Campbell and Cecile (1981) in the Amagok Formation. The significance of these conglomerates is discussed below.

Ss lithofacies. Ss is a minor lithofacies characterized by broad scours 60-150 cm deep and 1-5 m wide. Ss lithofacies is developed in successions with medium to very coarse sandstone. Ss is associated with St lithofacies which laps onto the scour surface. These are interpreted as scour-and-fill channels created during rising flood stage.

In the Straight Gorge section three large-scale lateral accretion complexes were identified (Fig. 23.1, 8). These are characterized by beds with sigmoidal foresets 1.5-3.0 m thick. Foreset dip directions are nearly orthogonal to the northwest-directed trough transport azimuths. One 3 m thick unit can be traced at least 200 m, the length of outcrop. These complexes are developed at the top of a gross fining-upwards cycle in fine- to medium-grained sandstone. These lateral accretion surfaces are interpreted as point bars in broad channels that may migrate across a braidplain.

St lithofacies. This lithofacies forms the majority of the Burnside Formation. It consists of fine- to very coarse-grained trough cross bedded sandstone which locally contains granules or pebbles along cross-strata and near the base of beds. Crossbed sets range from 10-80 cm thick, but are generally less than 40 cm. Thicker, coarser sets are commonly associated with Gm lithofacies, while thinner, finer sets commonly pass into Sh lithofacies. St crossbeds are generally the same scale within a given bed and bedset. The St lithofacies is interpreted as the product of migrating sinuous-crested or lignoid subaqueous dunes.

Sh lithofacies. Horizontally-laminated very fine to coarse sandstone is common. Laminae are generally 0.5-2.0 mm thick, with size differences of less than 2 phi units between laminae. Beds with Sh are commonly tabular and laterally continuous over the scale of outcrops (tens of metres). Sh is commonly associated with smaller-scale finer St lithofacies sandstone. Sh is developed in the lower transitional units and towards the top of gross (hundreds of metres) fining-upwards successions. Sh increases in abundance in more distal sections. Sh is interpreted as a lower flow regime planar bedform

as it is not commonly associated with thicker, coarser St beds. It may also represent unchanneled sheet-flow deposits on low-gradient, distal alluvial plains.

Sp lithofacies. Planar crossbedded fine to coarse sandstone is a very minor component of Burnside Formation siliclastic rocks. The occurrence of Sp is typically restricted to single sets 10-25 cm thick. Paleocurrents in this facies are mostly at a large angle to trough transport azimuths (see Fig. 23.7, 8, 9, 10). Sp is associated with Sh and finer St lithofacies. Due to small size of sets, occurrence with Sh and St, and oblique paleocurrent trends, Sp is interpreted as the product of migrating lingoid or transverse bars in the lower flow regime.

Sr lithofacies. This facies forms a minor part of the Burnside Formation. Thin (<10 cm) successions of very fine to medium sandstone with current ripples and rare wave ripples are seen. Ripples commonly have amplitudes of <2 cm and wavelengths <20 cm. They are very rarely desiccation cracked. Where recognized, Sr caps Sh and St sets. It is more common in distal sections. These are interpreted as lower flow regime migrating ripples.

Fl lithofacies. This lithofacies consists of silty, very fine- to fine-grained sandstone and rare siltstone. It is commonly a pale-greenish colour. Sedimentary structures are thin (mm) parallel to wavy laminae and small ripples with wavelengths <10 cm and amplitudes <1 cm; commonly laminae drape underlying structures. This facies rarely exceeds a few centimetres in thickness. The Fl facies forms the caps of crossbed sets and beds. Aside from clay chips, Fl is the only fine grained material in much of the Burnside Formation. It is interpreted as a waning flow deposit.

Fm lithofacies. This rarely-developed lithofacies consists of massive to laminated, reddish to purplish siltstone and argillite with mudcracks and small ripples. The thickest succession in which Fm occurs is in the middle of the Burnside Formation underlying the Bd unit (see below) in the Hackett River-Link Lake area in the southwest part of the basin. This corresponds to the Bm member mapped by Campbell and Cecile (1976, 1981); it appears to be absent from stratigraphic sections in either direction (WC and SG sections, Fig. 23.8, 9). This rarely preserved lithofacies is interpreted as a low-gradient distal fan-fringe which possibly interfingers with shallow marine siltstones to the northwest.

Lithofacies assemblages and sedimentary regimes

Five characteristic sets of lithofacies assemblages are derived from measured sections of the Burnside Formation. These are summarized in Table 23.2 and measured sections are annotated with these designations. It appears that facies assemblages persist over many tens to hundreds of kilometres through the basin. Fluvial deposits of the Burnside Formation extend a minimum of 150 km across-depositional strike as inferred from paleocurrent trends, suggesting that the alluvial plain was very extensive. In this respect, it is comparable to the scale of the paleo-braidplains documented from the middle Proterozoic Belt Supergroup of the northwest U.S.A. (cf. Winston, 1978).

Table 23.2 Lithofacies assemblages of Burnside Formation.

Major Facies	Minor Facies	Environmental Interpretation
Sr-St	Sh, Sp, Fl, Fm	fan-flat on low gradient distal alluvial plain
Sr-Sh	St, Fl	sheet-floods on distal alluvial plain
Sh-St	Sp, Sr, Fl, Fm + point bar	distal alluvial plain
St	Gm, Ss, Sp, Sh, Fl	shallow braid-plain channels
Gm-St	Sp, Sh	distal sheet-flow gravel and shallow channels on alluvial plain
Classification scheme after Miall (1977, 1978) and Rust (1978).		

Sr-St assemblage. The lower contact of the formation is everywhere transitional from wave-rippled siltstones of the Link Formation. The contact does not appear erosively disconformable as interpreted by Campbell and Cecile (1981). In the southeast part of the basin lower units consist of red Sr and St lithofacies with Sr decreasing upwards. Minor lithofacies include Sh, Sp, Fl, and rare Fm. This transitional unit thins from 300+ m in the northern Tinney Hills to 17 m at the Straight Gorge area to about 1 m in the Link Lake area (Fig. 23.8, 9, 10, 11). This sequence is interpreted as the transitional marine to fluvial unit of the Burnside Formation probably deposited on the distal part of a low-gradient alluvial plain with shallow channels and migrating dunes.

Southwest-directed paleocurrent trends in the transitional unit within the southeastern axial zone parallel trends recorded in underlying lower Bear Creek Group submarine fan turbidites and shelf deposits (Grotzinger and Gall, 1986). These paleocurrent trends shift abruptly to the northwest at the base of the overlying pink or buff-coloured St sequence. This suggests that in the axial zone the lower transitional Sr-St sequence initially developed a paleodrainage system parallel to the inferred trend of the basin axis and the Gordon Bay Arch, and probably the trend of the uplifted source terrane. Commonly, the initial phases of molasse show longitudinal dispersal patterns confined to a moat parallel to the mountain front (Miall, 1978b; 1981). However, to the northwest, initial paleocurrent trends at base of the Burnside Formation are entirely northwest-directed, suggesting that at the onset of Burnside deposition west of the Bathurst Fault, sediment dispersal was transverse to the mountain front, unrestricted, and reflects regional paleoslope. This can be extended to infer that in the axial zone, the Gordon Bay Arch influenced sedimentation by constricting paleodrainage in longitudinal systems. In contrast, to the northwest of the axial zone, initial fluvial sedimentation occurred directly over the Gordon Bay Arch which thereby could not modify dispersal patterns.

Northwestward onto the craton, Sr-St sequences of the lower transitional unit pass laterally into green silty sandstone characterized by Fl-Sr-Sh assemblage with common wave ripples (Fig. 23.8, 11) which coarsen upwards to a reddish Sr-St sequence. This silty sandstone probably represents a wave-

dominated shallow-marine shelf environment, but detailed interpretation requires further study. This facies change probably indicates that the transitional unit passes laterally from distal fan-fringe alluvial facies into a marine shelf facies reflecting proximal-to-distal expression of the initial diachronous phase of Burnside progradation. This diachroneity is also suggested by the differing thickness from the lower contact of the Burnside to the first occurrence of conglomerates in the Hackett River/Link Lake area (Fig. 23.10). Overlying nonmarine sequences comprising the majority of the Burnside Formation form a blanket extending up to 150 km to the northwest. The lower transitional unit may be correlative with the "Bg" green siltstone member of Campbell and Cecil (1976) reported only in the Rockinghorse Lake area (Fig. 23.1).

Sr-Sh assemblage. In most sections the first sandstone free of silt is a buff- or pink-coloured unit characterized by an association of St at the base, with overlying Sh-Sr with sparse wavy green clay laminae and clay chips. This facies grouping probably represents unconfined shallow sheet-flow deposits on a distal alluvial plain. As mentioned above, this facies group is laterally and vertically gradational with the red and green silty sandstone facies with increasing Sr and Fl to the northwest.

St assemblage. The most common facies group consists of almost entirely St with minor thin Gm, Ss, Sh, Sp, Sr, and Fl. Multiple crossbed sets are common. Fining-upwards cycles are developed on the scale of tens to hundreds of m. This grouping is commonly seen above the lower transitional Sr-St group. This association is interpreted as a sandy braided stream environment dominated by migrating dunes. The abundance of conglomerate layers tends to increase upwards at the base of all long sections as well as the top few hundred metres. This probably represents progradation of coarser sediment into the basin in response to uplift in the source area (Heward, 1978).

Gm-St assemblage. In the lower part of the Tinney Hills and Straight Gorge, the St group is commonly abruptly overlain by the Gm-St group. Minor lithofacies include Ss, Sh, Sp, Sr, and Fl. Thin- to thick-bedded Gm lithofacies fines upwards to large-scale St with gravel content decreasing upwards. As noted before, conglomerate beds rarely exceed 30-50 cm in thickness. In the Tinney Hills section at least five distinct pebbly to cobbly conglomerate horizons can be traced over 20 km. Similar mappable Gm-St groups are seen at Straight Gorge. These intervals probably represent distal gravelly rivers reflecting increased uplift in the source area. The lack of thick (metres to tens of metres) channelized conglomeratic intervals, their sheet-like geometry, and their lateral extent over many kilometres suggests that the area presumed to be closest to source (i.e. Tinney Hills) was always on the distal reaches of an alluvial plain subjected to sheet floods, rather than an alluvial fan or proximal alluvial plain (Andrews-Speed, 1986). The repetition of conglomeratic horizons at 50-100 m intervals could represent either discrete uplift and erosional events in the source area (allocyclic process) or the return of the focus of sedimenta-

tion which migrates over an alluvial plain (autocyclic process). The wide lateral extent of conglomerates in the Tinney Hills suggests that allocyclic control predominated.

Sh-St assemblage. Commonly St facies grades upwards over tens to hundreds of metres to a Sh-Sh association with concomitant decrease in grain size and disappearance of gravel. The scale of bedding decreases, but its lateral continuity increases. Minor lithofacies include Sp, Sr, Fl, and rare Fm. Lateral accretion complexes are found in this assemblage at Straight Gorge. In the Tinney Hills this group locally contains heavy mineral laminae along trough crossbeds. The Sh-St group probably represents a distal alluvial plain environment. However, the tabular, more continuous nature of bedding, finer grain size, and the presence of local heavy mineral laminae and interbedded stromatolites in a similar assemblage in the uppermost Burnside Formation at Tinney Cove, suggest that Sh-St may represent a shallow-marine environment as well. The vertical gradation and fining-upwards over 300-500 m from Gm-St and St assemblages suggests that the alluvial plain may have ag-

graded. This aggradation probably represents long-term denudation of the source area with little or no uplift (Heward, 1978).

At Wolverine Canyon a locally-developed assemblage of lithofacies brackets the Bd dolarenite unit (Fig. 23.9). This distinctly brown-coloured assemblage abruptly overlies a section of Sh-St. This lower unit (80 m) is characterized by Fl-Sr lithofacies with abundant wave ripples and minor dolomitic sandstone and thin (tens of centimetres) dolarenite horizons. The upper unit (about 50 m) contains a basal brown siltstone (4 m) with decimetres scale fining upward cycles. Cycles are based by intraclastic carbonate lags derived from underlying Bd dolarenite plus quartz and jasper granules. Overlying siltstones coarsen upwards to sandstone with a gradation from Fl-Sr to Fl-Sr-St assemblage. A probable pisolite horizon is present in the middle of the upper unit.

The presence in the lower unit of dolarenite resembling the overlying Bd dolarenite, finer grain size, thinner bedding and structures, and abundance of wave ripples suggests that this unit represents a shallow marine environment. As ex-

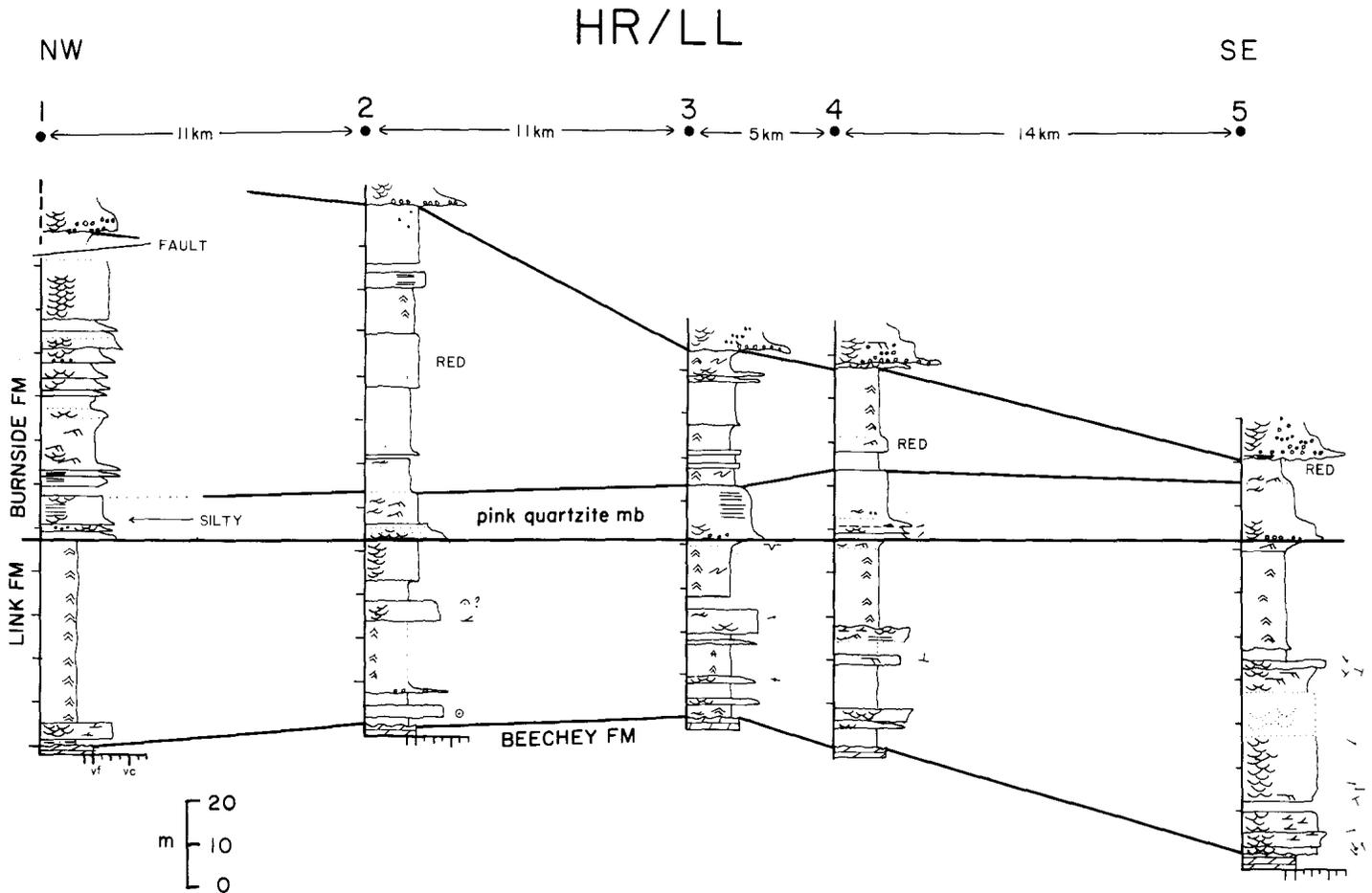


Figure 23.10 Measured sections and stratigraphic cross-section of the interval from top of the Beechey Formation through the basal Burnside Formation in the Hackett River/Link Lake area. See Figure 23.1 for location of sections. Note the fining and thinning of "pink quartzite" to the northwest and thickening of the interval to the onset of conglomerate deposition. Datum is the base of the Burnside Formation.

plained below, if the Bd unit represents a eustatic rise in sea level, the effect on the Burnside Formation should be to cause a back-stepping of fluvial facies towards the source area. This suggests that the silty to muddy Bm member of the Burnside Formation that underlies the Bd unit northeast of Hackett River may be the nonmarine facies equivalent to dolomitic sandstones underlying the Bd at Wolverine Canyon. The Bm could then represent a distal alluvial flat environment. This would discount the interpretation of Campbell and Cecile (1981) that the Bm member represents a lake environment. If such a back-stepping of fluvial facies belt did occur, then an additional allocyclic mechanism, eustasy, exerted control on the patterns of Burnside Formation sedimentation in distal areas.

Future petrographic analysis will allow more refined description of sandstone texture and composition associated with different lithofacies assemblages. Furthermore, the possible identification of petrographic trends and marker phases may provide more detailed correlation between widely separated sections. In particular, heavy-mineral bearing sandstone samples collected in 1985 near the top of the Tinney Hills section were inspected for the presence of detrital zircons. Initial results indicate that a significant population of very euhedral, probable first-erosional-cycle, detrital zircons are present (S.A. Bowring, pers. comm., 1986). Therefore, the possibility exists for detailed cross-basin correlation based on the presence, trends, and first occurrence of different zircon populations.

In every thick measured section a characteristic pattern of vertical lithofacies assemblages is observed. The first phase of sedimentation is characterized by a coarsening upwards from shallow-marine siltstones of the Link Formation to the first occurrence of conglomerates or gravels. This phase corresponds to progradation of the siliciclastic sediments from the source area. The next phase consists of several hundred metres of fining-upwards cycles. These may represent a series of uplift events that shed coarser detritus to the alluvial plains; progressive erosion probably aggraded the alluvial plain. They also may represent autocyclic meandering of the focus of sedimentation across the alluvial plain during a time of relatively steady uplift. In the distal Wolverine Canyon section (Fig. 23.9) a fining- then coarsening-upwards cycle is seen which corresponds to the Bd dolarenite and surrounding finer siliciclastic beds. This probably represents a marine incursion into the basin. The more proximal sections do not appear to have a similar pattern. The final phase of sedimentation is represented by a coarsening-upwards sequence at Straight Gorge and Wolverine Canyon (Fig. 23.8, 9). This probably reflects a second large uplift event in the source area. Interestingly, gravels seen in this coarsening upward sequence contain the first Burnside Formation intraformational clasts, suggesting that synorogenic sediments were being deformed in the hinterland. Future study of the Mara and Quadyuk formations will document the waning stages of sedimentation.

Description and significance of the Bd dolarenite unit

On the western margin of the Kilohigok Basin, a distinct westward-thickening interval of brown dolarenite and dolosiltite is developed (Campbell and Cecile, 1976, 1981). This interval is 21 m thick at Wolverine Canyon. It consists of cycles a few decimetres thick with basal intraclast lags of ripped-up dolarenite clasts overlain by wave-rippled dolosiltite grading up to dolarenite with common siliciclastic silt, sand, and rare granules. Cycles are capped by laminated dolomitic siltstone which may be brecciated. The abundance of wave ripples, clastic-textured dolomite, upward coarsening cycles, and evidence of brecciation suggest that this unit represents a subtidal to intertidal facies. The Bd unit at Wolverine Canyon resembles the shallowing-upwards lagoonal facies of the Rocknest Formation (Grotzinger, 1986). Hoffman et al. (1984) and Grotzinger (1985) have correlated the Bd unit with an interval of the Rocknest Formation in Wopmay Orogen to the west. Grotzinger (1985, 1986) postulated that the correlative Rocknest Formation interval (intraclastic member, middle non-cyclic interval) represented a eustatic rise in sea level. This suggests that the thinly-bedded, wave-rippled, silty, dolomitic units bracketing the Bd may represent a marine tongue that prograded into the predominantly fluvial succession. Thus, allocyclic sea level changes may have influenced Burnside sedimentation in the distal areas of the basin.

The Bd unit was also briefly examined in an area about 10 km northeast of Hackett River. At this location the Bd unit exhibits significantly different characteristics. The unit is underlain by several tens of metres of red silty sandstone and minor siltstone (the Bm unit of Campbell and Cecile, 1976). The Bd in the Hackett River area consists of about 1.5 m of possible caliche with a sharp upper boundary. The unit contains pink and white intraclastic carbonate cut internally by subvertical to subhorizontal cracks 1-10 cm wide which flare upward and form roughly polygonal plan patterns up to 1 m across. Probable primary carbonate material with intraclastic texture is preserved locally. At least three generations of cement-filled fractures appear to crosscut intraclastic layers and previous fractures until all continuity of bedding is lost upwards. The first two generations of cement form fibrous, isopachous linings subparallel to walls of cracks. The last generation appears to be coarse, void-filling dolomite spar. Convex-downward, concentric botryoidal carbonate fabrics are also present. The unit is capped by a few centimetres of pisolite with crudely-developed inverse grading. The unit immediately overlying consists of brown siltstone with common sand to pebble layers with intraclastic carbonate granules at the base of fining-upwards cycles.

These fabrics suggest that in the Hackett River area the Bd is a caliche, a weathering horizon subjected to vadose diagenesis in a semi-arid environment (Read, 1976; Retallack, 1981; Retallack et al., 1984; Calvet and Julia, 1983). If so, it represents the only such horizon identified in the Burnside

Formation. If it is truly correlative with the Bd dolarenite horizon at Wolverine Canyon, it implies that the northwestern part of the basin was submerged while to the east it was exposed, or at least, received little sediment at that time.

Establishing whether these two Bd units correlate and identifying their lateral equivalents is important for two reasons. According to arguments outlined above, both Bd horizons would be roughly time planes tracable through siliciclastic deposits. Lithostratigraphic correlation, which is presumably diachronous (e.g. Fig. 23.10), is the only method currently applied to the Burnside Formation. Second, if eustatic submergence occurred synchronously with exposure, an apparent paradox exists. This may be explained by a tectonic effect superimposed on the presumed eustatic effect. If this is the case, further constraints could be placed on the location of the Gordon Bay Arch and perhaps show if it migrated laterally through time. This would be an expected effect in a foreland basin where frontal deformation advances episodically toward the foreland through time (Beaumont, 1981). Thus the Bd unit could provide a good method for testing if flexure of the basin occurred during Burnside sedimentation.

Composition and significance of conglomerates

Gravel-size material is present throughout the basin, usually as isolated layers and sheet-like beds. As indicated, in the areas examined conglomerate clast size, frequency, and bed thickness decrease to the northwest, roughly parallel to paleocurrent trends. Campbell and Cecile (1981) reported that the majority of conglomerate clasts in the Burnside Formation are vein quartz plus intraformational quartzite. The remaining small proportion (<10%) of clasts were identified as "quartzite of unknown origin, and granitoid or gneissic rocks". Lithologies identified to date comprise a suite of possibly Archean basement-derived and Lower Goulburn Supergroup clasts. Tentatively-identified basement lithologies include meta-greywacke, banded iron formation (jasper plus magnetite), jasper plus chert, mylonites, and rare feldspathic and amphibolite gneisses. Goulburn clasts include jasper with detrital quartz grains probably derived from silicified disconformity surfaces within the lower Bear Creek Group. Other Goulburn clasts include white sandstones probably derived from the Kenyon Formation and sandy members in the Rifle and Link formations, and red siltstones and sandstones from the upper Link and lower Burnside formations. Clast lithologies will be identified by petrographic thin-section study during 1987.

A distinctive set of conglomerate outcrops occurs at Manning Point on the northwest end of the Tinney Hills (Fig. 23.1). The lower horizon (5-20 m thick) contains cobble to boulder size clasts in channels which down-cut up to 3 m. Intraformational Burnside clasts reach 100 cm in size (mean size locally 30-40 cm) while vein quartz clasts reach 45 cm (mean size locally 15-20 cm). Other lithologies rarely exceed

10 cm. The sharp lower contact of this unit varies up to 15 m within 50 m laterally, whereas the upper contact is planar and sharp. Two pebble counts indicate that clast populations are composed of 52-57% vein quartz, 26-27% pink intraformational Burnside clasts, 6-11% red siltstone and sandstone, and 2-3% Goulburn jasper, and minor amounts of above-mentioned Archean lithologies.

The second conglomerate unit present at Manning Point (15 m exposed) contains a significantly different clast population. Clast size does not exceed 10 cm. Most notable is the presence of a high proportion of undeformed felsic volcanic clasts. These clasts appear to be similar to red to brown crystal-rich tuffs described by Campbell and Cecile (1981) in the Amagok Formation at the top of the Goulburn Supergroup. Identical volcanic clasts were found in the upper Burnside Formation just below the contact with the Quadyuk and Peacock Hills formations at Tinney Cove 23 km to the south. Two pebble counts indicate that volcanic clasts make up 26-44% of all clasts in this conglomerate unit; vein quartz are 43-57% and Burnside intraclasts are 6-8%. The presence of the undeformed volcanic clasts in the Burnside Formation indicate that unroofing of a magmatic terrane younger than deformed Archean basement began much earlier in the Goulburn Supergroup than previously assumed. Volcanic clast samples were collected and sent to S.A. Bowring for zircon U/Pb age-dating.

It is notable that a few of the vein quartz clasts seen at Manning Point contain pegmatitic muscovite. Campbell and Cecile (1981) ascribed the origin of voluminous vein quartz clasts in the Burnside Formation to silcrete formation on alluvial plains. Vein quartz production was inferred to result from fracturing of an early-cemented flood plain associated with fluvial avulsion. If this were the case then Burnside intraformational clasts would be expected to appear in the first conglomerate layer. The first occurrence of intraformational Burnside clasts is about two-thirds through longer sections measured to date. Furthermore, the extreme bimodal size distribution of clasts in the Manning Point conglomerates and abrupt contact with finer sandstones suggests a proximal source for the larger clasts and a rapid uplift event. The introduction of intraformational clasts high in stratigraphic sections is a common feature of prograding molasse basins in which earlier deposited sediments are incorporated and uplifted in foreland-propagating thrust sheets; older parts of the formation are thereby reworked, recycled and deposited near the top of the section (Bally et al., 1966; Miall, 1978b, 1981).

Finally, none of the vein quartz clasts examined to date display any fabric or composition indicative of silcrete, such as isopachous coatings of chert or jasper around detrital quartz grains, or radial-fibrous growths of chalcedony. Vein quartz seen in the Burnside clasts appears to be uniform megacrystalline quartz, too coarse to be silcrete (cf. Summerfield, 1983; Ross and Chiarenzelli, 1985).

The conglomerates in the Burnside Formation thus provide the best indication of the unroofing history of the source area. Although no single attribute of the conglomerates is diagnostic of tectonic setting, when considered collectively, several features support a foreland basin setting for the Burnside Formation. These include the unimodal, low dispersion paleocurrent trends away from the source area; a general coarsening upwards through the entire Burnside Formation; the presence of intraformational clasts high in the stratigraphic section; and the great thickness of the formation at a distal location from the source area. Furthermore, Burnside deposits clearly prograded over and away from the zone of maximum basin subsidence (Campbell and Cecile, 1981; Grotzinger and Gall, 1986; this paper). This observation is most consistent with a foreland basin model, and argues strongly against other basin models, especially rifts and transpressional strike-slip basins in which sediment dispersal of fluvial units is almost exclusively directed away from the basin margins and into the basin center (cf. Miall, 1981; Christie-Blick and Biddle, 1985; Nilsen and McLaughlin, 1985).

ECONOMIC POTENTIAL

Disconformities of the Bear Creek Group were traversed by total-count scintillometers and measurements were taken at 1-5 km spacings. Readings appreciably greater than background were found only in one area, adjacent to the sub-Beechey disconformity. The area is located at 65° 57'N and 107° 26'W and readings of up to 50 times background were recorded.

Several Precambrian fluvial deposits contain economic concentrations of minerals, most notably detrital gold and uraninite (e.g. Witwatersrand, South Africa: Minter, 1978). The Archean basement rocks from which Burnside sediments were derived are known to contain gold, so the potential exists for remobilization and concentration of placer minerals. However, the Burnside Formation appears to lack key features associated with placer deposits. The vast majority of Burnside Formation conglomerate horizons have a thin, unchanneled sheet-like geometry (cf. Minter, 1978; Andrews-Speed, 1986). The unimodal, low-dispersion paleocurrent trends in all facies suggest that the Burnside Formation was deposited on a distal alluvial plain, not an alluvial fan. There is no indication of angular unconformities at conglomerate horizons. There are few heavy mineral laminae in sandstones. There is only one interval that indicates a possible marine transgression into the basin, i.e. the Bd dolarenite, and this occurs at the most distal location with no indication of transgressive reworking of underlying beds.

The only channelized conglomerate horizons occur at Manning Point, but these beds have an outcrop length of only a few hundred metres. Sandstones underlying these conglomerates do contain heavy mineral laminae (Sh-St assemblage), and these were beds which yielded euhedral detrital zircons. These appear to be the most promising prospects.

Perhaps another potentially more interesting prospect would be the sand-rich regoliths associated with the sub-

Hackett disconformity. As discussed above, the Archean weathering surface along the trend of the Gordon Bay Arch was exposed during flexure and erosion of the Kimerot Group. This would create a situation for reworking of earlier-formed winnowed lags, allowing for further concentration of heavy minerals. Furthermore, the Gordon Bay Arch was developed over a major iron formation in the underlying Archean rocks of the Beechey Lake area. Carbonate-matrix regolith is now developed over much of the iron formation indicating that it underwent erosion during development of the sub-Hackett disconformity. Any concentration of heavy minerals derived from the Archean during this event might be preserved in regoliths that flank the crest of the Gordon Bay Arch.

CONCLUSIONS

Investigations during the 1986 field season lead to several conclusions.

1) Formations of the Bear Creek Group are bounded by laterally continuous disconformities characterized by well-developed regoliths. Regoliths exhibit distinct suites of facies that may ultimately permit enhanced intrabasinal correlation.

2) The Beechey Formation is a shallowing-upward sequence of siltstones, quartzites, and carbonates that extends for over 150 km perpendicular to depositional strike. Its internal stratigraphy reflects the same processes that control overall basin stratigraphy.

3) Lithofacies patterns interpreted from the Burnside Formation suggest that fluvial deposition occurred on a distal alluvial plain largely in response to allocyclic controls. Proximal areas were effected by tectonic controls, whereas more distal areas may have been effected by changes in sea level. Two major phases of source-area uplift are interpreted to have created two large-scale coarsening-upwards sequences. The second phase probably records the reworking of synorogenic material. These results are consistent with the interpretation of Grotzinger and Gall (1986) that the Bear Creek Group was deposited in a foreland basin and that the Burnside Formation is a culminating molasse.

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