# Preliminary investigations of Early Proterozoic Western River and Burnside River formations: evidence for foredeep origin of Kilohigok Basin, District of Mackenzie

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**Abstract**

In the Kilohigok Basin, the Western River and Burnside River formations comprise three successively overlying tectono-stratigraphic sedimentary units of regional extent: a basal shallow water siliciclastic/carbonate platform, overlain by deepwater flysch, in turn overlain by shallow marine and fluvial molasse. This stratigraphy represents an initial stable shelf (passive margin?) whose outer, southerly edge rapidly subsided contemporaneous with arching and subaerial exposure of its interior. Shelf drowning represents the onset of foredeep subsidence subparallel to the trend of Thelon Tectonic Zone. Arching and subsidence were perpendicular to the tectonic transport direction of intrabasinal nappes, indicating that convergence and uplift along Thelon Tectonic Zone were probably responsible for foredeep subsidence within Kilohigok Basin. Following drowning, the platform was buried by deepwater deposits (flysch); with progressive uplift and basin filling, the foredeep entered the molasse phase and fluvial sediments prograded towards the foreland. The foredeep model places constraints on the origin of Thelon Tectonic Zone and provides a more comprehensive understanding of the tectonic evolution of the Slave Province and its relation to the Wopmay Orogen.

**Résumé**

Dans le bassin de Kilohigok, les formations de Western River et de Burnside River se composent de trois unités sédimentaires tectono-stratigraphiques respectivement sus-jacentes et d'étendue régionale: à la base, une plate-forme silicoclastique et carbonatée d'eau peu profonde recouverte par un flysch d'eau profonde lui-même, à son tour, recouvert par une molasse fluviale et marine peu profonde. Il s'agit, stratigraphiquement, d'une plate-forme primaire stable (marge passive?) dont l'affaisement rapide du bord externe sud a eu lieu en même temps que le bombement et la mise à nu subaérienne de sa partie intérieure. L'inondation de la plate-forme a marqué le début de l'affaisement de l'avant-fosse subparallèlement à l'orientation de la zone tectonique de Thelon. Le bombement et l'affaisement ont eu lieu perpendiculairement à la direction du transport tectonique des nappes intrabassinales, phénomène qui indique que la convergence et le soulèvement le long de la zone tectonique de Thelon auraient provoqué l'affaisement de l'avant-fosse à l'intérieur du bassin de Kilohigok. Après avoir été inondée, la plate-forme a été enfouie sous des sédiments d'eau profonde (flysch). Le soulèvement progressif et le comblement du bassin ont marqué le début d'une phase d'accumulation de molasse dans l'avant-fosse et de progradation des sédiments fluviatiles vers l'avant-pays. Ce modèle d'avant-fosse apporte certaines restrictions en ce qui à trait à l'origine de la zone tectonique de Thelon et fournit des renseignements plus complets sur l'évolution tectonique de la province des Esclaves et ses liens avec l'orogène de Wopmay.

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## Introduction

Parts of Kilohigok Basin, Northwest Territories, (Fig. 12.1) are currently being studied to document the timing and cause of basin subsidence, the relation of the basin to the contemporaneous Thelon Tectonic Zone, and the possible correlation of stratigraphic units with those in the foreland of Wopmay Orogen. The present study includes extensive measuring of detailed stratigraphic sections and limited 1:50 000 scale mapping of selected areas. This preliminary report summarizes observations and interpretations made during the 1985 field season. Further investigations are planned for the 1986 field season.

## Previous and current research

Initial reconnaissance mapping of Kilohigok Basin was done by O'Neill (1924). This was followed by a second generation of mapping, including subdivision and description of the major stratigraphic units (Wright, 1957; Fraser, 1964; Tremblay, 1967; Fraser and Tremblay, 1969; Tremblay, 1971). Subsequently, 1:500 000 scale mapping of the basin was completed by Campbell and Cecile (1976), with special emphasis on the sedimentology of specific units (Cecile, 1976; Cecile and Campbell, 1977, 1978; Campbell and Cecile, 1981). Most recently, nappes were discovered in the southeast part of the basin during detailed 1:50 000 scale mapping (Tirrul, 1985).

Hoffman (1973) interpreted Kilohigok Basin as an aulacogen. Campbell and Cecile (1981) interpreted the basin as a northwest-trending intracratonic trough, developed as a splay off of an inferred aulacogen, to the north of Kilohigok basin; the aulacogen was believed to open westward into the passive margin of Wopmay Orogen. More recently, reconnaissance work by Hoffman et al. (1984) and regional stratigraphic work by Grotzinger (1985) suggested that large volumes of siliciclastic sediment were being derived from a region east of Kilohigok Basin and entering the passive margin of Wopmay. Such an observation is inconsistent with the interpretation of Kilohigok Basin as a rift, which might have trapped sediment, preventing its transport across the stable craton. In addition, revised correlations based on more accurate time lines of Wopmay-Kilohigok strata indicate a major west-to-east thickening toward the east edge of Kilohigok Basin, and it was speculated that sediments were being derived from unroofing of the Thelon Tectonic Zone, located southeast of Kilohigok Basin. Contemporaneous work in the Thelon Tectonic Zone suggested that it might have been a site of major crustal-scale thrusting with a westerly transport component (Thompson and Ashton, 1984; Thompson et al., 1985). Support for this model was obtained independently by Tirrul (1985), who discovered northwest-verging nappes in the southeast corner of Kilohigok basin. These nappes probably represent a higher structural level of the Thelon Tectonic Zone, which contains metamorphic assemblages (staurolite-kyanite) suggesting 12 to 15 km of syn- to post-tectonic uplift (Tirrul, 1985; Thompson, personal communication, 1985).

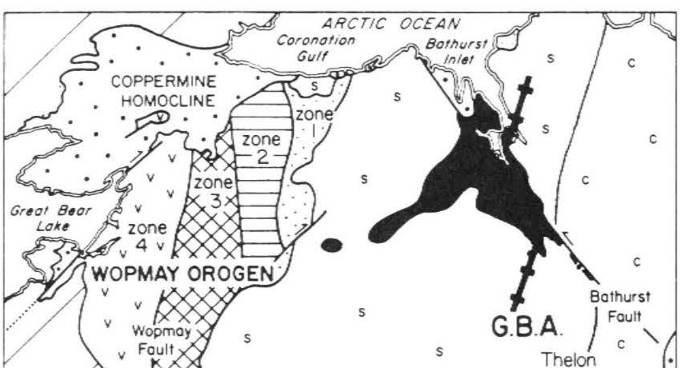


***Figure 12.1.*** *Location of Kilohigok Basin (black) relative to other tectonic elements in northwest Canadian Shield. G.B.A.; Gordon Bay Arch. "Thelon Front"; eastern edge of Thelon Tectonic Zone. Modified after Hoffman (1980).*

If sediments of Kilohigok Basin were derived from unroofing the Thelon Tectonic Zone, then basin subsidence may have been related to flexure of the lithosphere in response to convergence and crustal thickening along the Thelon Tectonic Zone, rather than extension in a region adjacent to an inferred aulacogen. The present study is designed to test this model by: 1) establishing the detailed facies relationships in key areas of the basin, 2) determining provenance of siliciclastic sediments, 3) documenting locations and trends of major depocentres and arches, and 4) evaluating the major stages of basin evolution.

Foredeeps are characteristically elongate, rapidly subsiding basins that form as "moats" adjacent to orogenic belts, where crustal thickening causes downwarping of the adjacent lithosphere (Beaumont, 1981). Facies are arranged asymmetrically so that shallow water facies near the foreland pass abruptly into deep water facies filling the basin axis. Most foredeeps display three fundamental stages of evolution: 1) initial, rapid submergence or drowning of an earlier, slowly subsiding platform (possibly passive-margin carbonates), 2) deep water sedimentation in a narrow axial trough; submarine fan and related deposits are common, and show longitudinal sediment dispersal patterns, and 3) shallow marine to fluvial sedimentation associated with final filling of the foredeep, with sediment dispersal towards the foreland. Initial foredeep subsidence may be preceded by up-arching and subaerial exposure of older platform sediments, generating an unconformity along the exposure surface. This is a consequence of the flexural origin of foredeeps, and the elastic properties of the lithosphere (cf. Beaumont, 1978). Finally, the trend of foredeep basins and related arches commonly is parallel to the trend of the load (commonly stacked thrusts) that generates the basin. Consequently, in ancient orogenic belts, foredeep basins and arches should be approximately parallel to related thrust-fold belts, and perpendicular to tectonic transport indicators (eg. stretching lineations).

Preliminary work conducted during the 1985 field season strongly suggests that the Kilohigok Basin formed by flexure of the early Proterozoic lithosphere, in response to convergence along the Thelon Tectonic Zone. Evidence for this includes identification of an early stable shelf sequence (Kimerot Platform; 500 m thick), which underwent drowning along its outer edge and up-arching within its interior to produce a karstic unconformity before it was deeply submerged. Overlying sediments (2 to 2.5 km thick) are deep water submarine fan and interfan deposits, with paleocurrents indicating sediment dispersal parallel (axial) to Gordon Bay Arch. Overlying deposits (1 to 2 km thick) are shallow marine shelf sediments with complex sediment dispersal patterns, succeeded by a major, southeastward thickening (up to 1.5 km thick) wedge of fluvial coarse sands and conglomerates. Conglomerates contain clasts of most underlying lithologies, supplementing a dominant population of intraformational clasts. Such a mixture is common in migrating foredeeps that ultimately cannibalize themselves in advanced stages of development. Paleocurrents within fluvial sediments indicate sediment dispersal across the foredeep axis and arch, toward the foreland.

### Kimerot Platform

The Kimerot Platform occurs in the southeastern part of Kilohigok Basin, where it is 0 to 500 m thick (Fig. 12.2, 12.3). Platform sediments are also preserved in several outliers, located east of Kilohigok Basin. The Kimerot Platform contains a transgressive siliciclastic part (0 to 250 m thick), and overlying carbonate part (0 to 250 m thick). Several detailed sections across the platform reveal major facies relations within the preserved outcrop belt (Fig. 12.3, 12.4). Unfortunately, most of the platform is no longer preserved within the present basin limits, so the trend of major facies belts cannot be reliably determined. However, changes in thickness and facies within the preserved outcrop belt (Fig. 12.3, 12.4) suggest that the platform probably faced southwest, south or southeast, and that the preserved cross-section is at a high angle to the trend of facies belts. This is supported by north-south elongation of platform stromatolites which were probably elongate approximately perpendicular to shelf trend.

#### Kimerot siliciclastics

Description. The siliciclastic part of Kimerot Platform (Fig. 12.3, 12.4) contains a basal transgressive lag overlain by a unit of trough crossbedded, coarse grained to pebbly

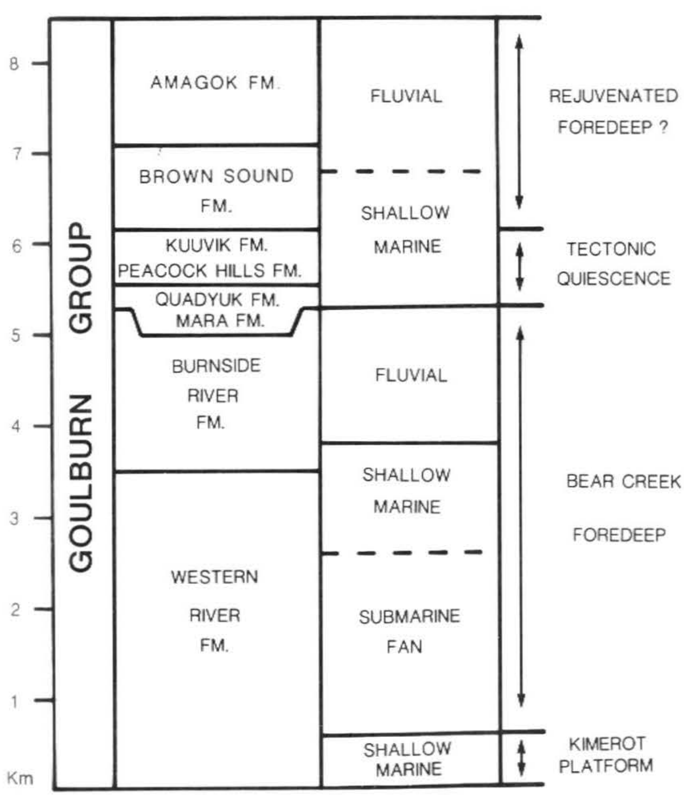


*Figure 12.2. Stratigraphy of Goulburn Group, Kilohigok Basin, in thickest (axial) part of basin. Also shown are major depositional environments and tentative tectono-stratigraphic subdivisions.*

sandstone, overlain by a unit of fine- to medium-grained hummocky cross-stratified sandstone with minor dolomites, (collectively unit 1a of Tirrul, 1985) in turn overlain by a siltstone/dolomite unit with small scale hummocky cross-stratification and interbedded stromatolitic and clastic textured dolomites (unit 1c of Tirrul, 1985). In part, the upper two units are laterally equivalent to a laminated mudstone/siltstone unit, (unit 1b of Tirrul, 1985) only developed near section 1 (Fig. 12.4). The basal lag (0 to 3 m thick) is generally a clast-supported conglomerate with sand matrix. Clasts are dominantly vein quartz, with minor amounts of metagreywacke, iron formation and granitoids, all derived locally by weathering of basement rocks. Clasts are subangular to subrounded, and units generally fine upward into overlying trough crossbedded sandstones.

Trough crossbedded sandstones (0 to 80 m thick) contain sets of troughts 5 to 20 cm thick, that form laterally continuous (> 50 m) beds with scoured bounding surfaces. Sands are medium to very coarse, locally pebbly, subrounded to well rounded, and contain 10 to 15% feldspar. Paleocurrent data (Fig. 12.4) indicate sediment transport to the northwest, southeast and southwest, and suggest that sands may have been transported along shore in some areas (data with NW/SE trends) but offshore in others (data with SW trend).

Hummocky cross-stratified sandstones form a unit 0 to 140 m thick that is typically fine- to medium-grained, and thinly bedded. Beds contain low angle truncation surfaces defining hummocks and uncommon swales, with wavelengths of 1 to 3 m, and amplitudes of 10 to 30 cm. Thicker beds up to 50 cm commonly have scoured, trough crossbedded bases which flatten upwards into hummocky strata. Between sections 3 and 6, hummocky sandstones contain biostromal mounds 1.5 m high and 150 m long (Fig. 12.5). Biostromes are composed of very irregular, dolomitic columns, separated by inter-column quartz sands which are crosslaminated. Internal stromatolitic lamination also is irregular and poorly preserved. At section 5, intermound sands are trough crossbedded channel deposits, scouring underlying hummocky cross-stratified sands and adjacent biostromes. Channel sands are overlain by hummocky cross-stratified sands. Upwards, hummocky cross-stratified sandstones pass into laminated siltstones.

The siltstone/dolomite unit (0 to 130 m thick) contains abundant small scale hummocky cross-stratification (wavelengths a few tens of centimetres, amplitudes < 10 cm), abundant clastic-textured and biohermal dolomites, and uncommon hummocky cross-stratified medium grained sandstones. Siltstones contain some thick laminae to thin beds of very fine grained sandstone with planar lamination, bundles of asymmetric wave ripples, and graded laminae. These layers may have load structures. Dolomite beds are 0.3 to 2 m thick, and increase in abundance upwards. Stromatolitic units are biohermal, but clastic-textured beds are sheets that extend for tens of kilometres.

The laminated mudstone/siltstone unit (0 to > 200 m) is only developed southeast of section 1. It is dominated by graded and nongraded laminae of mudstone and siltstone, with uncommon wave ripples and rare, scour-and-drape structures less than 20 cm wide and 1 to 2 cm deep. Also, rare, thin clastic-textured dolomite beds are present. This unit probably is laterally equivalent to the hummocky cross-stratified sandstone unit and the siltstone/dolomite unit.

Interpretation. The lower siliciclastic part of Kimerot Platform is best accommodated in a transgressive shoreface model (cf. Spearing, 1975). The sequence progresses upwards from trough crossbedded coarse and pebbly sandstones, through medium sands with large scale hummocky cross-stratification, up to siltstones with small scale hummocky cross-stratification and abundant dolomites. This is consistent with a gradual northward shift in deposition environments from upper shoreface through lower shoreface, to the offshore. The onset of carbonate sedimentation would result from decreased siliciclastic influx, as a result of continued transgression of exposed basement. Such deposits characterize the Cretaceous Gallup sandstone of western North America (Spearing, 1975). Although the Gallup is progradational, and the stratigraphy is inverted relative to that in the Kimerot, troughed sands are interpreted as upper shoreface deposits, hummocky sands are interpreted as lower shoreface deposits, and laminated siltstones represent offshore deposits.

In the Kimerot siliciclastic sequence, troughed sands are sheets that were spread over the shelf during probable longshore dune migration. There are no recognizable composite bed forms in these sheeted sandstones to suggest that they represent discrete offshore bars or sand ridges as documented by Brenner (1980), Schurr (1984) or Walker (1984). Hummocky cross-stratified sands probably formed over the deeper part of the shoreface by storm reworking and resedimentation of inner shoreface troughed sands (Hamblin and Walker, 1979). Stromatolite bioherms may have caused channeling of storm-surge return or geostrophic currents, producing trough crossbedding in an otherwise hummocky regime. As transgression continued, siliciclastic influx was decreased resulting in deposition of siltstones and carbonates. The laminated mudstone/siltstone unit probably formed on the distal shelf, generally below storm wave-base, as shown by the dominance of graded and nongraded laminae, and common lack of any hummocky cross-stratification (cf. Reineck and Singh, 1972; Soegaard, 1984). Eventually, continued transgression and/or decreased siliciclastic influx allowed a major stromatolitic reef complex to develop, as the lower unit in the overlying carbonate part of Kimerot Platform.

Kimerot carbonates

Description. The carbonate part of Kimerot Platform contains three units; a lower reef unit (0 to 80 m thick), a middle cyclic unit (0 to 130 m thick), and an upper reef/rhythmite unit (0 to 30 m) (units ld-g, Tirrul, 1985). The lower reef unit thins northward and may in part, pass laterally into siltstones and dolomites of the underlying siliciclastic part of the platform (Fig. 12.3). The overlying cyclic unit also thins northward; its upper boundary is probably isochronous, but the lower part of the unit may be laterally equivalent to the upper part of the underlying reefal unit. In the upper reef/rhythmite unit, reefal facies thin southward and pass laterally into probably time-equivalent

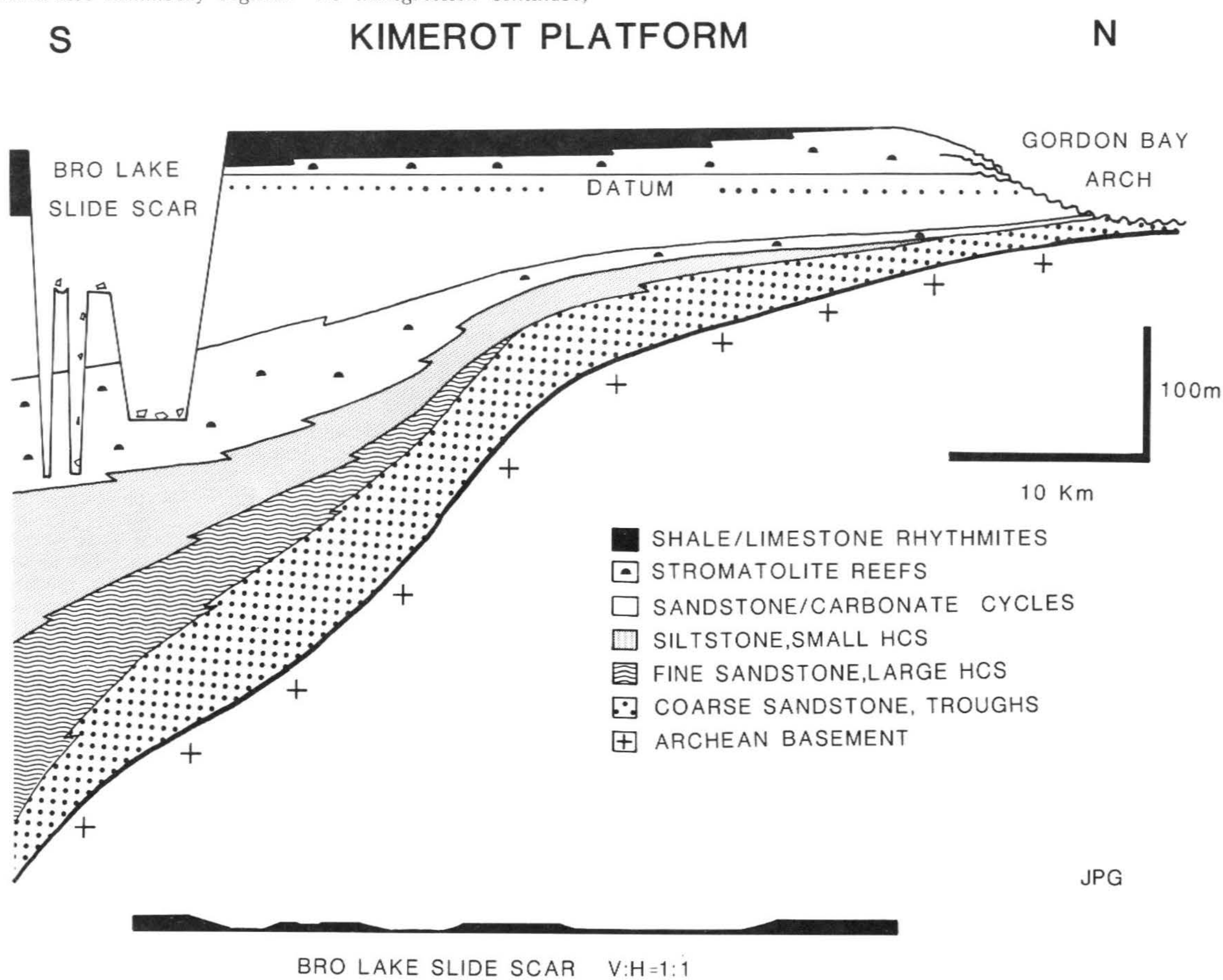


*Figure 12.3. Stratigraphic cross-section of Kimerot Platform. Datum is top of distinctive shallowing-upward cycle. Note 1:1 V:H reconstruction of Bro Lake Slide Scar at bottom of diagram. Distribution of measured sections is similar to that shown in inset of Figure 12.4.*

rhythmite facies (Fig. 12.3). Northward, reefal facies contain a few layers of tepee and tidal flat facies. The datum used in reconstructing Figure 12.3 is the top of a distinctive shallowing-upward cycle that can be correlated across the outcrop belt. Such contacts are very nearly isochronous in both Phanerozoic and Proterozoic cyclic sequences (Fischer, 1964; Anderson et al., 1984; Grotzinger, 1985, in press; Read et al., in press).

The upper part of Kimerot Platform is conformable over much of its width, but becomes a major erosional unconformity northwestward toward Gordon Bay, where underlying units are progressively cut out all the way down to Archean basement. Locally the unconformity is karstic, and residual topographic relief of several metres can be seen. "Valleys" between erosional remnants commonly are filled with rounded pebbles and cobbles of eroded lithologies. Similar relationships are observed in the northern part of Beechy Lake area, south of Bathurst Fault, where carbonates and basal clastics of Kimerot Platform are successively cut out to the northwest by an intraformational unconformity. These truncations define a northeast trend of 130-140 km if left-slip is accepted for the displacement on the Bathurst Fault (Campbell and Cecile, 1981; Tirrul, 1985). A positive area corresponding to this trend is herein termed the Gordon Bay Arch which supersedes the "Hanimok High" of Campbell and Cecile (1981) for which a trend was not confidently established (F.H.A. Campbell, personal communication, 1985).

The Kimerot Platform is everywhere mantled by dark laminated mudstone. Near section 3 (Fig. 12.4) units at the top of the platform are locally missing, probably due to sliding of parts of the platform (Tirrul, 1985). Megabreccias line the flanks and bases of possible slide scars (Fig. 12.3).

The lower reefal unit (Fig. 12.3) consists of large, strongly elongate stromatolite mounds, 0.5 to 3 m wide and 0.3 to 2 m high. Groups of mounds are separated by channels (1 to 50 m wide, 0.5 to 3 m deep containing trough cross-bedded sandstone. Mounds are composed of smaller, branching columnar stromatolites which also are strongly elongate. All stromatolites are elongate approximately north-south. Mounds become smaller northwestward and are eventually cut out over the Gordon Bay Arch. Mounds are dolomitized except for thin beds of limestone. To the southeast, penetrative strain is extremely high (Tirrul, 1985), preventing accurate facies reconstruction. It appears however, that the reefal unit passes gradually into fine grained siliciclastics, suggesting a low gradient transition

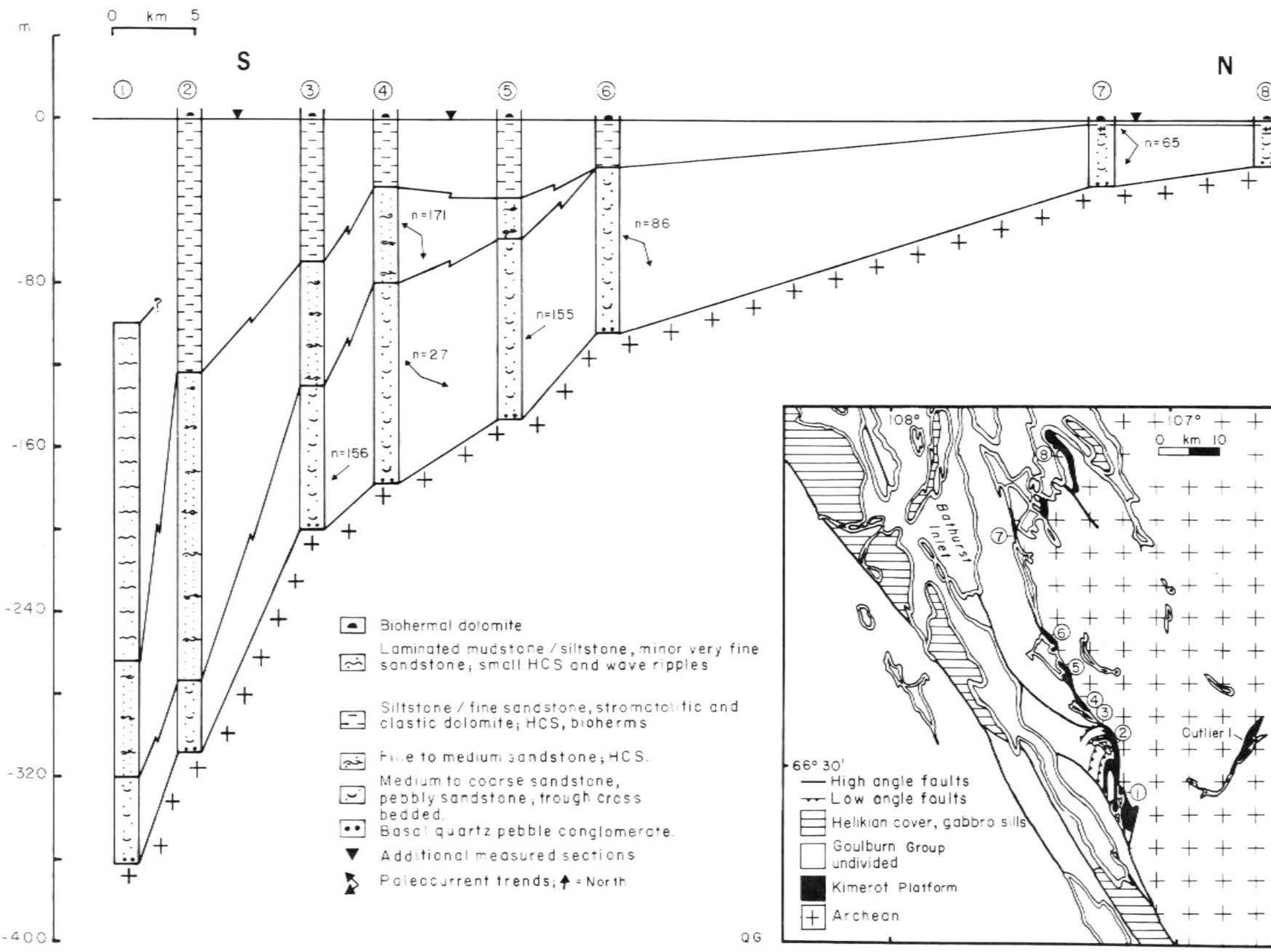


***Figure 12.4.*** *Stratigraphic cross-section of siliciclastic part of Kimerot Platform. Location of sections shown on inset map. Note that data from section 1, are not used in reconstructing cross-section of Figure 12.3. This is because of extreme strain in overlying carbonates.*

into the deeper basin (ramp?), rather than a rim which would be associated with an abrupt change into deeper water facies containing slope and allodapic breccias. In most areas the lower reefal unit is overlain by 1 to 10 m of trough crossbedded quartz-rich sandstone, which forms a regionally extensive blanket.

The overlying cyclic unit (Fig. 12.3) consists of 50 to 75 shallowing-upward cycles, 0.5 to 2 m thick. Lower parts of most cycles contain trough crossbedded siliciclastic/carbonate sands, with abundant intraclasts derived from underlying cycle caps. Upper parts of cycles contain cryptalgalaminites and tufas; stromatolites are uncommonly developed as transitional facies between the lower and upper parts of cycles. Cycle caps are commonly erosional, with well developed tepee structures and locally developed pisolite. To the southeast, troughed sands at bases of cycles pass laterally into hummocky cross-stratified fine sands, and cryptalgalaminites and tufas of cycle caps pass laterally into stromatolites. Although most of the cyclic unit lacks distinctive marker beds, several occur near the top and can be correlated for over 50 km at a high angle to depositional strike.

The upper reef/rhythmite unit is marked by a sharp lower contact, exactly parallel to underlying cycle boundaries (Fig. 12.3). On this basis, it is inferred to be approximately chronostratigraphic. Reefal facies comprise large, strongly elongate mounds (1 to 2 m wide, 0.5 to 1 m high), cored by smaller, branching columnar stromatolites, also elongate. All mounds are dolomitized. Channels are present and filled with crossbedded sands. Adjacent to Gordon Bay Arch, mounds contain brecciated horizons, associated with tidal flat facies. Some breccias are locally filled with botryoidal fibrous marine cements, that are well preserved despite pervasive dolomitization. To the southeast, reefs pass laterally into probably time-equivalent rhythmite facies that consist of thickly interlaminated dark mudstone and limestone (Fig. 12.3). Where rhythmites overlie reefal facies, the contact often contains 0.5 to 1.0 m of mounded edgewise conglomerate; clasts are derived from adjacent stromatolites.

Interpretation. The lower reefal unit was probably a ramp, deepening to the south or southeast, and may have formed during continued rise in sea level, which would have reduced siliciclastic influx. Large stromatolite mounds indicate subtidal water depths that were shallow enough to allow strong elongation by wave and/or tidal-produced currents. Channels filled with crossbedded sands may represent tidal channels. Mounds decrease in size to the north-northwest, suggesting a decrease in water depths where subsidence rates were lower (indicated by thinning of section). A relative drop in sea level may be indicated by the blanket of sandstone capping the reefal unit. On other

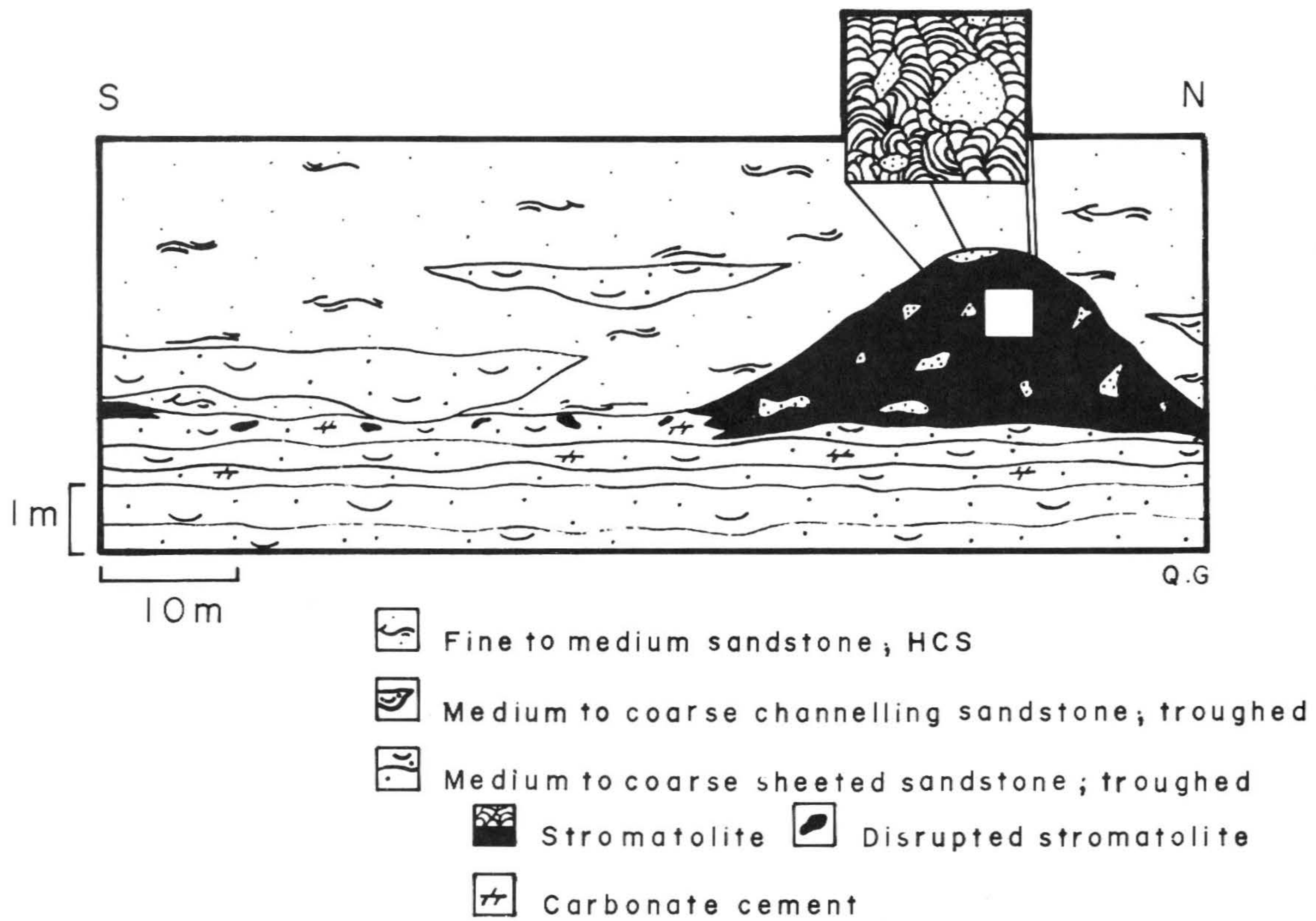


*Figure 12.5. Relationship between stromatolite biostromes and siliciclastic facies of hummocky cross-stratified sandstone unit.*

platforms, clastics were spread out as sheets during low stands in sea level (e.g. "Hawke Bay Event"; Palmer and James, 1979; Read, personal communication, 1985).

Development of the cyclic unit represents stabilization of the platform. Pinch out of tidal-flat facies within cycles to the south-southeast suggests that cycles formed by progradation of flats in that direction. Cycles probably formed in response to small changes in sea level (few metres), indicated by the brecciated, erosional cycle caps (cf. Grotzinger, 1985, in press; Read et al., in press). Siliciclastic sands forming bases of cycles (subtidal) may in part represent reworked eolian sediments which would have migrated across flats during low stands in sea level. However, sands may also have been imported by longshore transport during subtidal sedimentation. Evidence for extensive transport of subtidal sands is supported by ubiquitous trough crossbedding in sands.

The transition from cyclic unit to overlying reef/rhythmite unit represents an abrupt change to greater water depths where open-marine reefs and/or rhythmites were deposited. This transition was nearly isochronous as indicated by parallelism of the contact between the cyclic unit and reef/rhythmite unit, and underlying cycle boundaries (Fig. 12.3). This abrupt facies change at the top of Kimerot Platform is identical to the transition between cyclic sediments of the early Proterozoic Rocknest Platform and its overlying reefal veneer (Grotzinger, 1985). Initial increase in water depth over Kimerot Platform was followed by diachronous drowning of the platform, as shown by progressive northwest onlap of rhythmite facies over reefal facies (Fig. 12.3). During drowning of the outer platform, uplift of the inner platform over Gordon Bay Arch occurred (Fig. 12.3). Arching was probably synchronous with drowning because both drowning and arching postdate deposition of the cyclic unit, and predate deposition of deep water dark mudstones which cover the platform in all areas. This relationship is of great importance because it strongly suggests that drowning was caused by tectonic flexure of the platform, rather than a eustatic rise in sea level. Eustatic drowning is not likely because it does not account for simultaneous uplift of the inner shelf and drowning of the outer shelf. Support for a hypothesis of flexural tectonic drowning is found in the orthogonal relationship between the trend of Gordon Bay Arch, and the trend of finite extension lineations within nappes (Tirrul, 1985). Most likely, the northeast trend of Gordon Bay Arch is a product of northwest tectonic transport of thrust-nappes, which would have emplaced a load on the lithosphere.

Further evidence for tectonic drowning of the platform is the Bro Lake Slide, which scalloped the upper platform during drowning. Sliding and drowning probably were synchronous because both postdate deposition of the cyclic unit, and predate deposition of overlying deep water dark mudstones. Sliding of platform sediments is known to occur along the shelf break of rimmed platforms, simply due to gravitational instability (e.g. Mullins and Neumann, 1979). The Bro Lake Slide Scar however, is located well back on the platform, away from the probable shelf-to-slope transition zone. Furthermore the platform was probably a low-gradient ramp and lacked slopes that would allow sliding to occur. Thus, sliding probably occurred in response to steepening of the platform during tectonic flexure.

In sum, tectonic rather than eustatic submergence of the platform is supported by the coincidence of rapid outer platform drowning with flexural uparching of the platform interior, and simultaneous sliding of parts of the platform down tectonically steepened slopes. Diachronous southeast-to-northwest drowning of the platform is probably related to decreasing rates of tectonic subsidence (and thus relative sea level rise) towards the Gordon Bay Arch; such a systematic decrease in subsidence rate would be a direct consequence of flexural downwarping (e.g. Beaumont, 1978). Drowning of Kimerot Platform heralds the onset of foredeep subsidence and sedimentation in Kilohigok Basin.

At this stage in the study, it is not possible to determine whether Kimerot Platform formed on a passive continental margin, or in an intracratonic basin. If it did form on a passive margin, then it was destroyed at a very early age; subsidence rates should have been large, and this is not in agreement with the unusually thin cycles of the cyclic unit.

### Bear Creek Foredeep

The "Bear Creek Foredeep" includes sediments of the Burnside River Formation and parts of the Western River Formation that overlie the Kimerot Platform (Fig. 12.2). These sediments are superbly exposed in the Bear Creek Hills area, east of Bathurst Inlet. The foredeep sequence (5.5 km thick) is subdivided spatially into a thicker axial sequence (3.0 to 5.5 km) developed above the outer part of Kimerot Platform, and a thinner shelf sequence (1.5 to 3.0 km) developed over the Gordon Bay Arch (Fig. 12.6). The axial sequence consists of submarine fan and related deposits (up to 1.5 km thick), that pass up into continuous mudstones (1 km thick), overlain by shelf sandstones and mudstones (up to 1.5 km thick), in turn overlain by an upper sequence of fluvial sandstones and conglomerates (1.5 km thick).

The shelf sequence was developed synchronously with the axial sequence, but generally under much lower subsidence rates (Fig. 12.6). Shelf sediments (0.5 to 2 km thick) are dominated by shallow marine sandstones and mudstones, with minor carbonates, and pass upwards into fluvial sandstones and conglomerates (0 to 1 km thick). Most shelf sands contain unconformities which pass into conformable contacts southeastward, toward the basin axis (Fig. 12.6). Shelf sands are generally laterally separated from deep water axial sands by a zone devoid of sands, probably representing the slope and area of bypassing.

Because of the great thickness and aerial extent of Bear Creek Foredeep deposits, only a limited number of sections were measured during the 1985 season. Of sections measured in marine deposits (Western River Formation), most were in the axial sequence, and only two were measured in the fluvial sequence (Burnside River Formation). Enough data however, were collected so that when used in combination with documentation by Campbell and Cecile (1981), it allows a preliminary cross-section of the foredeep to be constructed (Fig. 12.6).

#### Axial sequence, lower part

Description. The lower part of the axial sequence consists of interbedded dark mudstones and fine to coarse sandstones (10-15% feldspar), locally containing carbonate blocks (units 2a-f, Tirrul, 1985). Sandstones occur as large lenses, tens of kilometres wide and hundreds of metres thick. The lowermost lens (unit 2b, Tirrul, 1985) consists of amalgamated sand layers, separated by occasional mudstones. Sands are massive or normally graded, rarely trough crossbedded, and occasionally contain large blocks of clastic-textured or stromatolitic dolomite and limestone. Dolomite blocks appear to be derived from the siltstone/dolomite unit of the siliciclastic part of Kimerot Platform, but limestone blocks are of uncertain origin. Where present, blocks are reverse graded.

Overlying sandstone lenses are composed of interbedded sandstones and dark mudstones. These may be arranged in thinning-upward fining-upward sequences, 30 to 70 m thick. Sandstones are fine- to very coarse-grained, and beds commonly are trough crossbedded or massive, and pinch out within 50 to 100 m along strike. Rarely, sandstone beds contain classical Bouma sequences, and many beds consist of a single set of trough foresets. Beds are 0.1 to 3 m thick, with scoured bases and flute casts. Thin mudstones may separate sand beds that are otherwise amalgamated. Paleocurrent measurements of crossbed foresets and flutes show longitudinal transport to the southwest, parallel to the basin axis and Gordon Bay Arch.

Interpretation. A deep water submarine fan origin for sandstone lenses in the lower part of the axial sequence is supported by several features that compare with other well documented submarine fan sequences (cf. Howell and Normark, 1982). These are: large sand lenses on the scale tens of kilometres by hundreds of metres, completely enclosed in finely laminated dark mudstones; individual sand beds that are channelized and discontinous over 50 to 100 m; sand beds form thinning-upward fining-upward sequences; sand beds contain trough crossbedding, graded bedding, massive bedding, rare Bouma sequences, and have scoured or channeled bases with flute casts; sediment transport is strongly unimodal, consistent with transport in a narrow trough. In the lower sand lens, coarse, amalgamated sands containing blocks with inverse grading may reflect a setting on the inner-fan channel or channelized portion of suprafan lobes (Eriksson, 1982; Howell and Normark, 1982; Walker, 1984). In the upper sand lenses, discontinuous sand beds form thinning-upward fining-upward sequences which may reflect deposition on the channelized or braided portion of suprafan lobes.

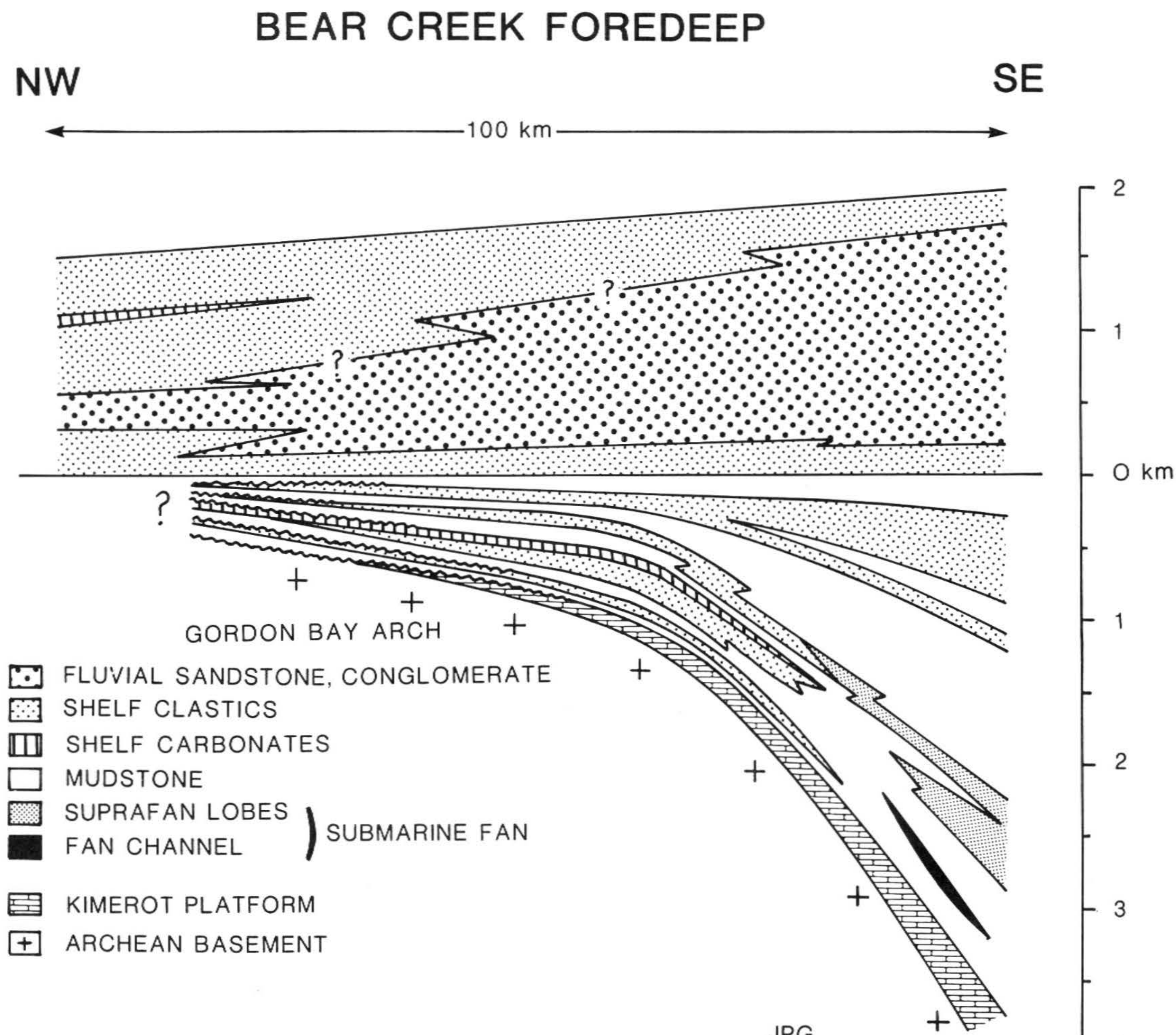


*Figure 12.6.* *Stratigraphic cross-section of Bear Creek Foredeep. Note systematic increase in thickness to southeast, which reflects differential subsidence; location of submarine fan facies (axial zone) over outer part of Kimerot Platform; progressive shallowing of foredeep axis with time. Lower "shelf carbonate" unit is Beechy Platform; upper "shelf carbonate" unit is Bd member of Burnside River Formation.*

In the stratigraphically highest sand "lens", apparent submarine fan facies in the axial sequence pass laterally into shelf sands of the shelf sequence. The reason for this is not yet clear, although it may have to do with the evolving geometry of the foredeep allowing lateral migration of fan deposits toward the foreland, at the same time the basin was filling.

Paleocurrents in sand beds with troughs and/or flutes show remarkably unimodal sediment dispersal, parallel to the basin axis and Gordon Bay Arch. Longitudinal sediment dispersal is a classical feature of foredeeps (McBride, 1962; Potter and Pettijohn, 1963; Mutti, 1985), and is a product of the narrowly confined and linear geometry of the basin.

Axial sequence, middle part

Description. The middle part of the axial sequence is dominated by shallow marine shelf sandstone and mudstone units (units 3a-$B_1$, Tirrul, 1985). All units are within the Western River Formation, except for the uppermost shelf sand unit, which forms the lowermost member of the Burnside River Formation. Sandstone units are 70 to 600 m thick, and laterally continuous for over 100 km, unlike underlying fan deposits. Intervening mudstones are 30 to 300 m thick. Internally, sandstone units contain sequences dominated by trough crossbedded sheet sands with polymodal paleocurrent patterns, that pass laterally and vertically into units dominated by hummocky cross-stratification, and then into units dominated by mudstone with uncommon thin sand layers. Some sand units are maroon, with abundant mudchips within crossbeds, and rare possible desiccation cracks.

Interpretation. The middle part of the axial sequence represents filling and shallowing of the foredeep, and the onset of widespread shallow shelf sedimentation. Variations in relative sea level probably produced alternation of shallow shelf sandstones (with hummocky crossbedding and trough crossbedding) with deeper shelf mudstones. Maroon, trough crossbedded sandstones with mud chips may be shallow subtidal to lowest intertidal sediments, or possibly even fluvial. However, in the absence of fossils, distinguishing trough crossbedded shallow marine facies from braided fluvial facies is difficult. Well documented fluvial sequences (Campbell and Cecile, 1981) in the upper part of the axial sequence, however, have strongly unimodal paleocurrent patterns, unlike inferred marine units described here which have complex polymodal patterns.

Axial sequence, upper part

Description. This unit was examined during reconnaissance, and descriptions rely heavily on those already published (e.g. Campbell and Cecile, 1981). The unit (Burnside River Formation) generally consists of fluvial sandstone and conglomerate in a thick wedge that thins northwestward. A characteristic feature is the development of fining-upward cycles (0.2 to 2.5 m thick) which have conglomeratic scoured bases that pass upward into trough crossbedded sandstones, overlain by planar-laminated sandstones, and capped by mudstone layers. Conglomerates are dominated by clasts of vein quartz and intraformational quartzite, but also contain clasts of many underlying lithologies, including granitic and metasedimentary basement. All paleocurrents indicate sediment dispersal to the northwest (Campbell and Cecile, 1981), across and perpendicular to the trend of Gordon Bay Arch.

Interpretation. Fluvial facies of the upper part of the axial sequence have been interpreted as braided river deposits (Campbell and Cecile, 1981). In the foredeep model presented here, they represent final basin filling, and transport of sediment across the basin, directly towards the foreland. Campbell and Cecile (1981) interpreted conglomerate composition to reflect intrabasinal processes. The abundance of intraformational quartzite clasts and vein quartz clasts was inferred to represent early, synsedimentary cementation of clastics and silcrete development on floodplains, throughout deposition of the unit. Vein quartz was believed to have been precipitated in fractures related to shallow dewatering and compaction. Subsequent rapid subsidence in the basin would have fractured the early cemented floodplains, resulting in instantaneous fluvial capture and production of intraformational boulders by rapid channel downcutting (Campbell and Cecile, 1981).

The interpretation presented here differs significantly from that of Campbell and Cecile (1981). Burnside sediments were examined for evidence of early cementation or silcrete development and, if present, it is not abundant. Fractures filled with vein quartz are rare in general, and most occurrences could be related to a system of conjugate transurrent faults which postdates the Burnside River Formation (Tirrul, 1985). Furthermore, most vein quartz is formed during deep burial to levels much greater than floodplains. Finally, many intraformational quartzite boulders contain fractures not present in the host rock, indicating fracturing at depth prior to resedimentation.

Foredeeps migrate in front of prograding thrust-fold belts (Beaumont, 1978, 1981). Thus, initial foredeep deposits may be incorporated into thrust wedges advancing toward the foreland. Sediments are delaminated by propagating thrusts, uplifted, eroded and recycled back into the foredeep. Such cannibalization of the Jurassic/Cretaceous foredeep adjacent to the Cordilleran thrust wedge occurred during deposition of the Paleocene Paskapoo Formation (Bally et al., 1966). In the Bear Creek Foredeep, intraformational quartzite boulders in fluvial facies probably reflect a similar history of early foredeep sedimentation, cannibalization during progressive migration of the thrust wedge, and recycling of quartzites back into the foredeep. Vein quartz would have been formed during fracturing associated with thrusting. Other clast lithologies indicate that the early axial part of the foredeep, as well as basement were also being reworked.

Shelf sequence

Description. The shelf sequence in Bear Creek Foredeep contains a lower shallow marine part, and upper fluvial part (Fig. 12.6). All marine units except for the uppermost shelf sand (Burnside River Fm.) are in the Western River Formation. Fluvial sediments (Burnside River Fm.) are distal equivalents of facies described above and are not discussed here.

The lower marine sequence contains alternating sequences of sandstones (40 to 100 m thick) and mudstones (10 to 80 m thick), with uncommon carbonates (1 to 30 m thick). Most shelf sandstones are dominated by hummocky cross-stratification, but some contain abundant trough cross-stratification, and one unit is dominated by large scale, tabular-planar crossbedding with sets up to a few metres thick. The tabular-planar crossbedded sands are overlain by 1 to 30 m of stromatolitic carbonate (Beechy Platform; Fig. 12.6). The Beechy Platform contains large stromatolite mounds that are locally up to 3 m wide, 1 to 2 m high, and 100 m long.

The Beechy Platform and many sand units within the foredeep shelf sequence have unconformable upper contacts, some erosional (Fig. 12.6). Unconformities are marked by scoured surfaces overlain by layers containing pebbles or cobbles of underlying sands; siliciclastic mudstones and siltstones may contain layers of patchy carbonate cementation and poorly developed tepee profiles. Locally, zones of complex brecciation several metres thick are developed below unconformities, particularly where clastic carbonate was deposited in addition to siliciclastic sands. Above the Beechy Platform, well developed pisolitic profiles are locally developed on scalloped solution surfaces. Tepees and breccias are also present, as are layers (10 to 100 cm thick) of fibrous dolomite cement. Cements are composed of botryoids (originally aragonite?) up to several centimetres wide, and have well preserved prismatic crystals with square terminations.

Interpretation. Shelf sandstones and mudstones were deposited over the Gordon Bay Arch, where subsidence rates were greatly reduced relative to the axial part of Bear Creek Foredeep. Consequently, water depths were generally much shallower, as shown by the abundance of hummocky cross-stratification, wave ripples, and crossbedding with complex polymodal patters.

The presence of unconformities capping shelf sand and carbonate units indicates large fluctuations in relative sea level. Because these sequences are, in part, located over the Gordon Bay Arch, it is not yet possible to determine whether relative sea level oscillations were tectonic- or eustatic-induced. A eustatic origin, however, is suggested by their possible lateral extent beyond the influence of arching, as well as the direct juxtaposition of deep water mudstone facies on many of the surfaces, without intervening paralic sediments. If eustatic, sea level oscillations would have been third- to fourth-order cycles (cf. Vail et al., 1977).

If the Bear Creek unconformities separate offlap-onlap sequences, then they are sequence boundaries and time lines in the sense that the unit below the surface is everywhere older than the unit above the surface (Vail et al., 1977). This has important implications for the Bear Creek Foredeep as well as other Precambrian siliciclastic sequences where, in the absence of fossils, only tuff beds (easily reworked in shelf settings) are presently available for time correlation. Therefore, Bear Creek unconformities must be thoroughly investigated during future research in order to ascertain whether they are tectonic or eustatic, and if they extend into the Coronation Supergroup of Wopmay Orogen.

### Regional correlations

Preliminary correlations between the Western River and Burnside River formations of Bear Creek Foredeep, and Coronation Supergroup of Wopmay Orogen suggest that Bear Creek Foredeep may have initiated and culminated during the rift and passive margin stages of Wopmay Orogen, respectively. At this point in the study, the best time line used in making correlations is the lateral extension of the Rocknest Formation (intraclastic member) from Wopmay Orogen into Kilohigok Basin. The Rocknest Formation correlates with the K4 member of Cecile and Campbell (1978) in the Peacock Hills area, which in turn correlates with the Bd member of Campbell and Cecile (1981), a regionally extensive carbonate unit in the central and western parts of the Burnside River Formation. The Rocknest K4-Bd unit probably formed during a eustatic sea level high, an event that was probably nearly isochronous over the Rocknest Platform (Grotzinger, 1985). These relations indicate that Burnside sedimentation was coeval with Rocknest sedimentation, and thus the Bear Creek Foredeep was in an advanced stage of development during the carbonate phase of passive margin sedimentation in Wopmay.

Another possible time line may be the correlation of deep water shales at the base of the Odjick Formation (lowermost passive margin strata, Wopmay Orogen) with one or more of the possible sequence boundaries in the shelf sequence of Bear Creek Foredeep. It should be emphasized that this correlation is speculative, although easily testable due to excellent exposures. If correct, then it suggests that Kimerot Platform and overlying marine sequences in Bear Creek Foredeep may have been deposited during rifting in Wopmay Orogen.

### Possible foredeep reactivation

Development of a regional carbonate platform up to 600 m thick (Peacock Hills and Kuuvik formations; Fig. 12.2) over Bear Creek Foredeep clastics probably signifies the end of convergence and uplift along Thelon Tectonic Zone. However, reactivation of Thelon Tectonic Zone at a later time may be indicated by deposition of the Brown Sound and Amagok formations. These units comprise an eastward-thickening wedge (up to 2 km) of mudstones, immature sandstones and conglomerates, in which fluvial facies (Amagok Fm.) have unimodal westward-directed paleocurrents.

Unlike the underlying fluvial wedge of Bear Creek Foredeep (eastern facies of Burnside River Fm.), the Brown Sound/Amagok wedge contains a significant volume of felsic to intermediate volcanic and hypabyssal plutonic clasts with minor coarser grained diorite clasts (Campbell and Cecile, 1981). These clasts may be undeformed, which contrasts with other vein quartz and quartzite clasts, granitic and gneissic clasts, and mylonites. Significantly, the undeformed suite of clasts may comprise a consanguineous arc-related volcanic-plutonic suite, that developed on top of, or adjacent to, the Thelon Tectonic Zone. This hypothetical arc may have been a high level equivalent of some intrusive rocks in the Thelon Tectonic Zone (Thompson, personal communication, 1985). If so, then the arc has been subsequently completely eroded. This hypothesis has an obvious testable prediction in that the age of volcanic clasts in the Amagok Formation should agree closely with the ages of some granites in the Thelon Tectonic Zone. Arc volcanism should predate an inferred collision at about 1.9 Ga along the Thelon Tectonic Zone. However, this would not explain why volcanic clasts are limited to the Brown Sound/Amagok wedge and absent from the underlying foredeep strata, as high level volcanic rocks should be the first to be eroded. Alternatively the volcanism might be related to crustal melting consequent to the collision, in which case their stratigraphic restriction could be explained and their predicted age would fall between about 1.9 and 1.85 Ga.

### Initial conclusions

Preliminary investigations during the 1985 field season permit several tentative conclusions. These will be scrutinized during future research.

1. The Kilohigok Basin is probably a major foredeep, related to convergence along the Thelon Tectonic Zone. Apparent stages of development mimic those seen in younger foredeeps and include tectonic drowning of a stable platform (Kimerot Platform) and formation of a flexural "outer swell" (Gordon Bay Arch). This was followed by rapid subsidence of the platform and depositon of axial submarine fan sediments followed by shallow marine shelf sands and muds, overlain by fluvial sands and gravels shed toward the foreland. The composition of fluvial conglomerates suggests foreland-directed migration of the foredeep axis with time.
2. The trend of Gordon Bay Arch is perpendicular to finite extension lineations in nappes described by Tirrul (1985). Nappes are probably the highest preserved structural level of the Thelon Tectonic Zone, which suggests that flexure of the lithosphere to produce Bear Creek Foredeep was caused by crustal-scale thrusting in the Thelon Tectonic Zone. More generally, the development of Gordon Bay Arch indicates that the early Proterozoic lithosphere was capable of elastic flexure in response to emplacement of crustal-scale thrust loads.
3. Intrabasinal unconformities are developed within shelf sequences proximal to the foreland. Unconformities may relate to flexure over the Gordon Bay Arch, or alternatively, to eustatic fluctuations in sea level.

If eustatic, unconformities are probably time lines, and provide a superb opportunity to precisely correlate events in Bear Creek Foredeep with those in Wopmay Orogen.

4. Preliminary regional correlations suggest that Bear Creek Foredeep subsidence probably was synchronous with rifting in Wopmay Orogen. If so, then it suggests that rifting in Wopmay occurred during convergence along the Thelon Tectonic Zone. A Phanerozoic analogue of this is present in north Alaska where, during the Jurassic to Cretaceous, convergence in the Brooks range (foredeep) occurred synchronously with rifting and initial passive margin subsidence of the Beaufort shelf (Grantz and May, 1982). The two zones are separated by approximately 300 km, and a flexural high (Barrow Arch) intervenes. Not surprisingly, the Prudhoe Bay giant oil fields are located over the Barrow Arch.


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