SEDIMENTOLOGY AND SEQUENCE STRATIGRAPHY OF THE BAKER LAKE SUB-BASIN, NUNAVUT: EVOLUTION OF A PALEOPROTEROZOIC RIFT BASIN

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Department of Earth Sciences

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ABSTRACT

The northeast-trending Baker Lake sub-basin was a volcanically active half-graben during deposition of ca. 1.85-1.78 Ga Baker Lake Group. Transverse streamflow-dominated alluvial fans were concentrated along the southern margin of the sub-basin. These fed gravel- and sand-bed braided streams that merged with an axial drainage system. Alluvial dynamics were characterized by channel aggradation and abandonment. Abandoned channel belts were sites of floodplain and eolian deposition. Braided streams fed northeast and southwest to a depocentre located near Christopher Island, where eolian, playa, and lacustrine environments were intimately linked. Paleoflow patterns indicate that the sub-basin was hydrologically closed.

A model is derived for the alluvial sequence stratigraphy and is applied to the Baker Lake Basin. Discharge and sediment supply are considered boundary conditions. Primary control on alluvial facies changes is attributed to alluvial gradient. Graded profile is defined as the topographic profile of a graded stream linking a sediment source region to a subaqueous basin. It is proposed that coupled source uplift and basin subsidence exert primary control on alluvial systems at relatively large scales.

In Baker Lake Basin, high accommodation alluvial, low accommodation alluvial, and mixed fluvial-shallow-lacustrine sequences are interpreted as 3^{rd}-order depositional sequences of tectonic origin. The succession of 3^{rd} order sequences illustrates basin evolution from rift initiation, rift climax accompanied by widespread volcanism, to immediate post-rift. These comprise the 2^{nd} order Baker Sequence, representing a tectonic stage of intracontinental rifting.

The high accommodation stage of basin development may have been the result of intracontinental retro-arc extension during ca. 1.85-1.84 Ga formation of the Kisseynew back-arc basin of the Trans-Hudson orogen. The Baker Lake Basin probably marked the northeastern extent of a series of basins that trended along the Snowbird Tectonic Zone, correlative with the Martin Group in northwestern Saskatchewan. Closure of the Kisseynew basin and collision of the Superior Province with the Western Churchill Province coincided with a change to strike-slip dominated faulting in the Baker Lake Basin. This low accommodation stage of basin development probably was a response to lateral tectonic escape adjacent to the Saskatchewan-Manitoba and Baffin Island-Committee Bay foci of the Superior collision.

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I would like to thank my parents Attima and Elisabeth Hadlari, and the rest of my family especially Ann and Ed Rempel in Brampton, and Jen Galloway for providing solace.

ORIGINAL CONTRIBUTIONS

During the summers of 1998,1999, 2000, and 2001 I mapped lithofacies and measured stratigraphic sections at Thirty Mile Lake and northern Christopher Island on Baker Lake, Nunavut. Additional observations were made during mapping elsewhere in the Baker Lake Basin as a seasonal employee of the Geological Survey of Canada, primarily with Rob Rainbird, but also with Al Donaldson. This includes mapping at Aniguq River, southern Christopher Island, the Kazan River south of Baker Lake, and near Pitz Lake.

Based on this basin analysis, and by modifying existing alluvial sequence stratigraphic models, I formulated a model for alluvial sequence stratigraphy that aims to rationalize not only my observations but also related outstanding issues in the stratigraphic literature.

A model of basin evolution was constructed through geological mapping and stratigraphic analysis, building upon previous work in concert with new findings from a recent synthesis of the Western Churchill Province. This new perspective led to a new tectonic model for the Baker Lake Basin.

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CHAPTER 1

GENERAL INTRODUCTION

This research was undertaken as part of a multi-disciplinary regional study, the western Churchill NATMAP Project of the Geological Survey of Canada. The project provided contextual information for the Baker Lake Basin by highlighting contemporaneous magmatic, metamorphic, and structural events. It also included further refinement of the Dubawnt Supergroup stratigraphy by Rainbird and Hadlari (2001) and Rainbird et al. (2003), in addition to improving geochronologic control (Rainbird et al., in press).

The Baker Lake Basin comprises 5 sub-basins. This study focuses on one of these, the Baker Lake sub-basin and is limited to the ca. 1.84-1.78 Ga Baker Lake Group, or Baker second-order sequence (Rainbird et al., 2003). This study represents the first detailed sedimentological analysis of the Baker Lake Group in Baker Lake sub-basin. An emphasis on constructing a sequence stratigraphic framework for the Baker Lake Group, through detailed measurement of stratigraphic sections and targeted detailed mapping, has led to a new and better understanding of basin evolution. These results in concert with other results from the western Churchill NATMAP project have facilitated a better understanding of the tectonic evolution of the Western Churchill Province.

The next three chapters are formatted as separate papers to better facilitate submission to scientific journals, resulting in certain redundancies.

CHAPTER 2

ALLUVIAL, EOLIAN, AND LACUSTRINE SEDIMENTOLOGY OF A PALEOPROTEROZOIC HALF-GRABEN, BAKER LAKE BASIN, NUNAVUT, CANADA

Abstract

The northeast-trending Baker Lake sub-basin was a volcanically active half-graben during deposition of ca. 1.85-1.76 Ga Baker Lake Group. Drainage was oriented along transverse and axial directions with flow to playa lake and deeper perennial lacustrine depocentres. Basin margin, streamflow-dominated alluvial fans were concentrated along the southern margin, and provided sediment from Archean crystalline basement rocks. These fed transverse gravel- and sand-bed braided streams. Alluvial dynamics were characterized by channel aggradation and abandonment. Abandoned channel belts were sites of floodplain and eolian deposition. Basin axial braided streams fed northeast and southwest to a depocentre near Christopher Island, where eolian, playa, and lacustrine environments were intimately linked. Felsic minette flows were initially erupted from localized centres; contemporaneous sedimentary deposits typically contain minor volcaniclastic components that increase in abundance basinward. Voluminous and widespread younger minette flows prograded outward from volcanic centres, contributing significant additional basin-infill.

2.1 Introduction

This research is part of an integrated study of the Baker Lake Group emphasizing sequence stratigraphy and chronostratigraphy for the purpose of constructing a tectonostratigraphic model for Baker Lake Basin. Utilization of non-marine sequence stratigraphic methods to elucidate the relationship between sedimentation and tectonism requires an understanding of the depositional environments throughout the basin. This paper describes the sedimentology of the ca. 1.83 Ga Baker Lake Group from well-exposed key stratigraphic-sections from margin to inferred depocentre of the Baker Lake sub-basin, as an aid to reconstruction of its paleogeography. In addition, the remarkable preservation and absence of bioturbation from these Paleoproterozoic rocks provides sedimentological insight into alluvial environments in certain instances generally not available from the Phanerozoic. Thick alluvial fan deposits are exposed on large, glacially polished outcrops. Floodplain deposits are associated with braided stream deposits, a relatively undeveloped topic of study (e.g. Bristow et al., 1999), but observed elsewhere in Precambrian deposits (Sønderholm and Tirsgaard, 1998). It has been speculated that eolianites should be more prevalent in Precambrian deposits than in the Phanerozoic due to lack of terrestrial vegetation (e.g. Eriksson and Simpson, 1998). While this generally hasn't been reported in the literature, eolian deposits do occur throughout the Baker Lake Basin, reworking fluvial deposits and forming thin sandsheets to large ergs (Rainbird et al., 2003; Simpson et al., 2004). This research, representing the first regional lithofacies analysis of the Baker Lake sub-basin, incorporates previously completed fieldwork by the Geological Survey of Canada.

2.1.1 Regional geology and previous work

Greater Baker Lake Basin extends from Dubawnt Lake northeast to Baker Lake (Nunavut, Canada) and comprises a series of northeast-trending intracontinental basins, including the Baker Lake sub-basin (Rainbird et al. 2003; Fig. 2.1; Fig. 2.2). Basin fill comprises the faulted but unmetamorphosed, siliciclastic and volcanic rocks of the Dubawnt Supergroup (Wright, 1955; Donaldson, 1967; LeCheminant et al., 1979b, Gall et al., 1992; Rainbird and Hadlari, 2000; Rainbird et al., 2003; Fig. 2.3). The ca. 1.85-1.70 Ga Baker Lake Basin occupied a unique location in space and time with respect to the evolution of the Western Churchill Province. Deposition of the ca. 1.85-1.76 Ga Baker Lake Group appears to have closely followed deformation and metamorphism in underlying crystalline basement rocks, which in some cases were at lower crustal levels at ca. 1.9 Ga (Sanborn-Barrie et al., 1994). Contemporaneous collisional tectonics were taking place in the ca. 1.9-1.8 Ga Trans-Hudson Orogen, 500 km to the south and southeast (e.g. Lucas et al, 1999).

The Dubawnt Supergroup is subdivided into three unconformity-bounded stratigraphic units that correspond to, from oldest to youngest: the Baker Lake, Wharton, and Barrensland groups (Donaldson, 1967; Gall et al., 1992; Rainbird and Hadlari, 2000); or the Baker, Whart, and Barrens second-order sequences (Rainbird et al., 2003; Fig. 2.3). These groups or equivalent second-order sequences have been interpreted to represent the tectonic stages of rift, modified rift, and thermal sag respectively (Rainbird et al., 2003).

The Baker Lake Group comprises the South Channel, Kazan, Christopher Island, and Kunwak formations (Donaldson, 1965, LeCheminant, 1979b) and ranges in cumulative thickness from 500 m to over 2 km. These lithostratigraphic sub-divisions have provided the framework for regional mapping within Baker Lake Basin. Chronostratigraphic control on these formations is quite poor, but recent studies suggest that they time-equivalent, reflecting lateral facies boundaries (Rainbird et al. 1999; Rainbird et al., 2003).

The South Channel Formation comprises boulder to cobble conglomerate interpreted as alluvial fan deposits. It typically overlies crystalline basement rocks at the basin margin and is composed of locally derived clasts of granite, amphibolite, and gneissic lithologies. For this reason it appears to be the oldest formation, although volcanic rocks of the Christopher Island Fm also unconformably overlie basement (Rainbird and Hadlari, 2000), and occur as clasts within the South Channel Fm (Hadlari and Rainbird, 2001).

The Kazan Formation consists of arkosic sandstone, siltstone, and mudstone, representing a variety of sedimentary environments including eolian, fluvial, and playa lake (Donaldson, 1965, LeCheminant, 1979b; Rainbird et al., 2003).

The Christopher Island Formation comprises alkaline volcanic rocks interbedded with volcaniclastic and siliciclastic sedimentary rocks. Volcanology of the Christopher Island Fm from Baker Lake sub-basin has been described in detail (LeCheminant et al., 1979a; 1979b; Blake 1980). A generalized volcanic stratigraphy for the greater Baker Lake Basin, from oldest to youngest, consists of: felsic minette flows; minette flows; and felsite flows (Peterson et al., 1989; Hadlari and Rainbird, 2001; Rainbird et al., 2003). The felsic minette flows and equivalent volcaniclastic deposits are less areally extensive than younger minette flows, and have been observed to overlie the basal unconformity of the Baker Lake Group. Mantle-derived minette flows record voluminous extrusion throughout the entire basin, and represent the largest known ultrapotassic volcanic province (LeCheminant et al., 1987; Peterson et al., 1989; Peterson et al., 1994; Cousens et al., 2001). Felsite flows are the youngest and most areally restricted volcanic rock. Analyses of phlogopite phenocrysts from a flow, and a syenite intrusion that intrudes the lower Baker Lake Group yield $^{40}Ar/^{39}Ar$ ages of 1845 ± 12 Ma and 1810 ± 11 Ma respectively (Rainbird et al., 2002; see discussion by Rainbird et al., in press). A more precise U-Pb zircon age of 1833 ± 3 Ma has been obtained from a felsic minette flow from the western end of Baker Lake Basin, providing the best constraint on basin formation (Rainbird et al., in press). This age is within error of an $^{40}Ar/^{39}Ar$ age of 1837 ± 8 Ma obtained from a minette flow at Aniguq River (Rainbird et al., in press). This is consistent with an age of 1832 ± 28 Ma obtained from a lamprophyre dyke southeast of Baker Lake Basin that is considered to be co-magmatic with the Baker Lake Group volcanic rocks (Pb-Pb apatite; MacRae et al., 1996).

The Kunwak Formation (LeCheminant et al., 1979b) consists of conglomerate composed primarily of Christopher Island Fm volcanic clasts as opposed to basement rock types in the South Channel Fm. It is differentiated from the Christopher Island Fm by its stratigraphic position above volcanic rocks and below the unconformity at the top of the Baker Lake Group. This formation primarily occurs in the interior of the Baker Lake sub-basin, located proximal or downstream from volcanic centres.

In the Thirty Mile Lake area of the Baker Lake sub-basin (Fig. 2.4) steeply inclined, east-northeast-striking units of conglomerate, sandstone, and volcanic strata of the Baker Lake Group unconformably overlie intrusive rocks adjacent to the MacQuoid-Gibson belt (Tella et al. 1997). Previous mapping in this area identified South Channel Fm conglomerate, Kazan Fm sandstone and mudstone, and Christopher Island Fm volcanic rocks (Donaldson, 1965, 1967; Miller, 1980; and LeCheminant et al., 1979b). The Kunwak Formation is exposed to the northwest, along the Kunwak River, where it contains felsite clasts and is unconformably overlain by the Wharton Group (LeCheminant, 1979b; Hadlari and Rainbird, 2001).

At Christopher Island (Fig. 2.5) the South Channel Formation unconformably overlies the MacQuoid-Gibson supracrustal belt (Tella et al. 1997; Hanmer et al. 1999) and the 1.9 Ga Kramanituar metamorphic complex (Sanborn-Barrie, 1994; Sanborn-Barrie et al., 2001). The Kazan Formation comprises eolian, playa, and braided stream deposits (Donaldson, 1965, 1967; Rainbird et al. 1999). The Christopher Island Fm locally comprises volcanic flows, pyroclastic and volcaniclastic deposits.

2.2.0 Lithofacies Associations

From the principal study areas at Thirty Mile Lake and eastern Baker Lake, and other select locations within Baker Lake sub-basin (Fig. 2.2), the sedimentary rocks of the Baker Lake Group are here subdivided into facies associations (FA) more detailed than those presented in previous formational descriptions. Individual facies are outlined in Table 2.1. In general, FA 1 corresponds to the South Channel Fm, FA 2 and 3 correspond to the Kazan and Kunwak formations, and FA 3 to 7 correspond to the Kazan Formation.

2.2.1 Facies Association 1: Alluvial Fan

Lithofacies description:

Clast-supported disorganized conglomerate (Gcd) contains cobble- to boulder-grade angular to subrounded clasts within 1-5 m thick tabular beds with erosional basal contacts. Diffuse horizontal stratification grades laterally into a more massive framework, which is intact to condensed with slight to no imbrication (Fig. 2.6d). The matrix is typically moderately to very poorly sorted, fine to coarse sandstone. Atypically, the matrix exhibits both horizontal stratification and small-scale (less than 5 cm thick) cross-stratification adjacent to cobble- to boulder-grade clasts. Randomly distributed within sub-tabular conglomerate beds, mound-shaped accumulations of granules and coarse sand overlie certain framework clasts (Fig. 2.6c). Rare examples of reverse grading in the matrix was observed in some beds.

Clast-supported organized conglomerate facies (Gco) contains pebble- to cobble-grade, sub-angular to sub-rounded clasts within an intact to condensed, imbricated framework. The matrix is moderately well-sorted medium to coarse sandstone. Tabular beds, 0.5-2 m thick, generally fine upward, and may form composite conglomerate sheets. A typical occurrence would consist of multiple beds consisting of 30 cm of cobble- to 20 cm of pebble-conglomerate comprising a composite thickness of 2-3 m. Other occurrences include horizontally stratified (Fig. 2.6b) and less common cross-stratified tabular beds. Horizontal stratification marks the boundaries of rare, thin, lenticular beds of trough cross-stratified sandstone.

Trough cross-stratified conglomerate facies (Gt) is predominantly pebble-grade with a condensed framework and consists of lenticular units up to 2 m thick and 10 m wide that fine upward and laterally. The lower surfaces of these beds are erosional.

Trough cross-stratified sandstone facies (St) consists of fine- to pebbly cross-stratified sandstone in sets typically ranging in thickness from 5 cm to 20 cm. Facies St occurs at the top of lenticular conglomerate units or as lenticular units overlying conglomerate sheets. It may be overlain by parallel-stratified mudstone facies (Fl), consisting of laminated mudstone and minor siltstone or fine sandstone, with rare mud curls. These layers are overlain by erosional surfaces that are laterally continuous for more than 100 m.

Lithofacies interpretation:

The clast-supported framework, absence of inverse grading, and weak stratification of the disorganized conglomerate facies (Gcd) suggests a streamflow origin as opposed to deposition by debris flows (e.g. Sohn et al., 1999; Blair 2000a). A similar facies has been described by Jo et al. (1997), in which an erosional lower boundary, weakly developed clast imbrication, crude stratification, and lack of inverse grading were considered to be streamflow characteristics. The tabular morphology of similar facies has been attributed to deposition by bedload sheets forming low-relief longitudinal bars (e.g. Reid and Frostick, 1987; Todd, 1989). Because these conclusions are consistent with our observations, this facies (Gcd) is considered to have been rapidly deposited (intact framework, poor sorting, and non-imbrication) by unconfined high-magnitude stream flood flows. Sandstone cross-laminae adjacent to clasts indicate that deposition of the sand occurred within an intact gravel framework as "shadow deposits" by sediment-laden currents. Where coarse to granular sand mounds occur atop clasts, the sediment is interpreted to have been transported downward through a gravel framework to rest upon upper clast surfaces. Rare inverse grading of the matrix is considered to be formed by a process of sieving, or mechanical sorting through the framework (Hooke, 1967).

The organized conglomerate facies (Gco) is generally interpreted as longitudinal gravel bars deposited by gravel sheets (e.g. Reid and Frostick, 1987; Todd, 1989). Weak internal stratification within these deposits probably represents waxing and waning of individual flood flows. Well-stratified units are similar to a facies of alternating coarse-fine conglomerate "couplets" described by Blair (2000b) from the Hell's Gate alluvial fan in Death Valley. These "couplets" were interpreted to have been deposited under upper-flow regime conditions during the washout stage of the standing-wave cycle based on similarities with documented features of supercritical sheetflood events (Blair and McPherson, 1994). Blair (2000b) surmised that the "autocyclic growth and destruction of standing waves during a single sheetflood produces 50-250 cm thick sequences of multiple couplets". These features are identical to some of our observations, and thus we consider that for the well-stratified conglomerates, deposition occurred by bedload processes during high-magnitude unconfined stream flow conditions, possibly due to the washout of standing waves. Whereas this process describes part of the Gco facies, it may not extend to the entire facies where stratification isn't well developed. The development of bedforms differentiates this facies from the clast-supported disorganized conglomerate facies (Gcd), which lacks well developed stratification.

Lenticular trough cross-stratified conglomerate (Gt) is interpreted to have in-filled trough-shaped channels following periods of incision between flood events. This facies is commonly observed within alluvial fan deposits (Jo et al. 1997; Rhee et al., 1998; Blair, 1999, 2000a, b) and is considered to represent secondary, non-catastrophic processes that occurred between infrequent sheetfloods.

Cross-stratified sandstone (St) and laminated mudstone (Fl) indicate that low-energy streamflow conditions prevailed over a laterally continuous gravel substrate, infilling pits and gullies with sand and mud. Mud curls record subaerial exposure and desiccation between streamflow events.

Since the coarsest (up to boulder grade) conglomeratic facies exhibit streamflow indicators, we must consider the reason for streamflow to prevail over debris flow depositional processes. Blair (1999) has described adjacent alluvial fans in Death Valley, one streamflow-dominated, the other debris flow-dominated. The debris flow-dominated alluvial fan was fed by a source region of sedimentary rocks; the streamflow-dominated alluvial fan had a source region of crystalline rock. Therefore, the difference was neither the gradient of the valley wall nor discharge, but simply the type of sediment supplied. Clast lithologies from the alluvial fan deposits at Thirty Mile Lake and South Channel match the underlying crystalline basement rocks, consistent with Blair's (1999) theory for streamflow predominance to be a function of derivation from weathered crystalline rock in the source region.

Facies successions:

Two typical bedset end members consist of: (1) 1-3 m of disorganized cobble- to boulder conglomerate (Gcd) overlain by metre-scale channel-fill conglomerate facies (Gt) and/or trough cross-stratified sandstone; or (2) a few metres of organized cobble- to pebble conglomerate (Gco), incised by channel fill facies (Gt), trough cross-stratified sandstone (St), and/or overlain by parallel laminated mudstone and siltstone (Fl). Coarse, tabular sheetflood deposits (Gcd; Gco) represent the main accretion units.

Bedsets are commonly arranged in pairs that have a composite upward-fining character over 5-10 m (Fig. 2.6a, Fig. 2.7). Although stratal surfaces within the paired bedsets are discontinuous, the erosional surfaces above ubiquitous sandstone caps that bound the couplets are laterally continuous (>100 m) where viewed transverse to inferred paleoflow. Whereas bedsets represent sheetflood deposition and subsequent reworking, coupled bedsets have a higher order of genetic significance. The upward decrease in clast size may be a function of upstream aggradation of the alluvial fan, widening of the active lobe, or a decrease in gradient as the toe migrated forward. The inactive lobe is marked by low-energy streamflow and suspension deposition indicated by stratified sandstone and laminated mudstone.

Blair (2000b) has described similar stratigraphic units from Death Valley alluvial fans and noted that generally 2 to 8, 50-250 cm sheetflood deposits capped by gully-fill or eolian facies were bound by "progressive tectonic unconformities". These are on the scale of the 5-10 m paired bedsets of this study; however Blair (2000b) was able to observe a bedding discordance over the intrafan unconformity, concluding that faulting had caused a down-drop of the fan. Therefore this type of stratigraphic unit may be considered to represent a fault-generated increment of accommodation, where the succession records the characteristic alluvial response: aggradation of the fan surface.

Alternatively, Mack and Leeder (1999) have described 3-10 m thick "alluvial fan cyclothems". These were considered to form primarily due to the combined effects of vegetative cover and precipitation (minimum sediment yield would correspond to peak precipitation due to the binding of sediment by vegetation, and vice versa). This model obviously would not apply to alluvial fan deposits from the Baker Lake Basin, because of an absence of vegetative cover in the Paleoproterozoic.

Commonality suggests that this nested upward-fining stratal pattern is intrinsic to the alluvial fan depositional environment in fault-bounded basins from the Precambrian through the Phanerozoic. Since alluvial fans aggrade via lobe accretion and abandonment, this punctuated process superimposed on a gradual fault-induced subsidence, though unrealistic, would result in the observed succession. Thus, these units do not necessarily indicate specific fault motions but that subsidence was sufficient to provide the grade required for alluvial fan formation.

2.2.2 Facies Association 2: Gravel-bed braided stream

Lithofacies description:

Clast-supported massive conglomerate facies (Gcm) is pebble- to cobble-grade with rare boulders in a coarse- to granular sandstone matrix. Clasts form a condensed, imbricated framework that is moderately to well sorted. Tabular beds range in thickness from 10 cm to several metres. Sheets of massive conglomerate are continuous for 10s of metres but are discontinuous over 100s of metres perpendicular to the inferred paleoflow direction.

Rare lenticular beds of trough cross-stratified conglomerate (Gt), 30 cm to 50 cm thick incise into the massive conglomerate, but are less prominent than in the alluvial fan FA. Angular mudstone clasts are common.

Medium- to thick-bedded, trough cross-stratified sandstone beds occur as solitary sets or compound sets up to a metre thick, above thick beds of massive conglomerate. Rare laminated mudstone (Fl) occurs at the tops of 10 m-thick, upward-fining packages.

Lithofacies interpretation:

The gravel-bed braided stream FA is distinguished from the alluvial fan FA by a more homogeneous, better sorted, imbricated, and more condensed framework conglomerate. Clast imbrication in facies Gcm suggests bedload transport. The condensed framework and better sorting indicate a more sustained streamflow and less rapid aggradation than inferred for conglomeratic facies from the alluvial fan FA. Massive texture makes it difficult to differentiate gravel-sheet from longitudinal gravel bar deposits, a common characteristic of gravel-bed braided stream deposits (Miall, 1977). The lateral discontinuity of lithofacies perpendicular to the inferred paleocurrent direction indicates that deposition occurred in channels smaller than a few hundreds of metres in width.

Cross-stratified channel-fill conglomerate (Gt) probably represents reworking of abandoned-channel gravel sheets prior to deposition of sandstone. Mudstone rip-up clasts within conglomerate sheets attest to intermittent suspension deposition, although these deposits were subsequently eroded and transported, between flood events.

Trough-cross stratified sandstone was deposited in abandoned channels. The laminated mudstone (Fl) and trough cross-stratified sandstone that sharply overly conglomerate probably represent low energy deposition following avulsion and channel abandonment (Miall, 1977), similar to gravel-bed abandoned channel deposits from the Waimakariri River in New Zealand (Reinfelds and Nanson, 1993). Alternatively, where non-erosional contacts exist between successive beds of conglomerate, sandstone, and mudstone, the upward-fining pattern may reflect deposition from waning flood (Miall, 1977).

Facies successions:

Upward-fining packages of the gravel-bed braided stream FA are considered to be deposits of superimposed bars (Miall, 1977). Bedsets are arranged in 5 to 10 m aggradational to mildly upward-fining successions of massive conglomerate (Gcm), capped by sandstone (St) or cross-stratified pebble conglomerate (Gt). Such packages are considered to represent vertical aggradation followed by channel belt switching (Miall, 1977), represented by sandstone deposition in abandoned channels.

2.2.3 Facies Association 3: Sand-bed braided stream

Lithofacies description:

Massive, clast-supported conglomerate (Gcm) is a minor component of the sand-bed braided stream FA, occurring as thin beds at the base of upward-fining bedsets. Sets of fine-grained to pebbly, trough cross-stratified sandstone (St) range in thickness from 10 cm to 1 m, bedforms of 3-dimensional dunes are apparent in certain outcrops. These bedsets commonly have a pebble lag and abundant mudstone clasts at the base. Horizontally stratified sandstone facies (Sh) consists of planar, horizontally laminated, well sorted, fine- to medium-grained sandstone that commonly displays primary current lineation. Bedding geometry is predominantly tabular, and large-scale lateral accretion surfaces appear to be absent.

Fine- to medium-grained ripple cross-stratified sandstone (Sr) infrequently occurs at the top of upward-fining bedsets dominated by medium to thick sets of trough cross-stratified sandstone (St).

Laminated mudstone (Fl) occurs at the top of upward-fining successions. Trough cross-stratified sandstone (Ste) with inversely graded foresets and pinstripe lamination is also at the top of upward-fining successions. These sets are typically 10 to 50 cm thick, but locally are 1 m thick. In thin sets (5-10 cm) the foreset angle is as low as about 5 degrees; thick beds commonly overlie symmetrical ripples (Sw).

As a sub-association occurring over 10s of metres in thickness, rippled sandstone (Sr) may be exclusively interbedded with horizontally stratified sandstone (Sh) that displays prominent primary current lineation (Fig. 2.8a). Mudstone drapes are ubiquitous above lenticular ripple bedforms.

Lithofacies Interpretation:

Thin conglomerate beds at the base of upward-fining bedsets indicate that coarse sediment load was deposited at the base of braided channel-fill, perhaps as braid bars.

Trough cross-stratified sandstone is a result of three-dimensional dune migration, particularly evident where dune bedforms are exposed. Horizontally stratified sandstone with primary current lineation is interpreted to have been deposited under upper-flow regime-conditions (Allen, 1964; Southard and Boguchwal, 1973). The tabular geometry, lack of lateral accretion surfaces, predominance of trough cross-stratification, presence of upper-flow-regime plane beds are consistent with deposition by shallow sand-bed braided streams (*cf.* Miall, 1977).

Rippled sandstone (Sr) capped by mudstone at the top of upward-fining bedsets is inferred to represent waning of flood flow followed by suspension deposition. Where rippled sandstone and upper-flow regime plane beds are the dominant lithologies in fine-grained sandstone successions, this represents sheetflood deposits for which the grain size was too small to form dunes (*cf.* Southard and Boguchwal, 1990), and so linguoid ripples transformed directly into upper-flow regime plane beds in response to increasing stream velocity (Baas, 1994). Mudstone records waning flood or abandoned-channel deposition.

Cross-stratified sandstone with inversely graded foresets record wind ripple migration during eolian reworking of abandoned channel deposits (cf. Hunter, 1977).

Facies Successions:

Upward-fining bedsets, 0.5-5 m thick, typically consist of an erosive base with pebble lag, overlain by predominantly trough cross-stratified sandstone that passes gradationally upward into horizontally stratified sandstone, current-rippled sandstone, and laminated mudstone (Fig. 2.9). However, there is a spectrum of heterolithic to sandstone-dominated deposits. The most proximal deposits contain conglomerate at the base of metre-scale cycles that fine upward to sandstone, deposited by a waning flood flow that carried a load of sand and gravel. Medial deposits consist predominantly of cross-stratified sandstone. Less proximal deposits typically consist of less than metre-scale upward-fining cycles of sandstone with abundant mud drapes, capped by laminated mudstone deposited by waning streamflows that carried a mixed load of sand and mud. This variation is interpreted to reflect a spectrum of facies from shallow braided stream to mixed-load, ephemeral sheetflood (e.g. Sønderholm and Tirsgaard, 1998). In deposits rich in mudstone, desiccation cracks are common, indicating that between flood events at least part of the river bed was subaerially exposed. Inversely graded sandstone laminae, characteristic of wind transport, typically occur at the top of upward-fining cycles where mudstone is absent, indicating eolian reworking of dry river beds (Fig. 2.8b).

Single bedsets represent flood events and deposition-abandonment of small braided channels. Multiple bedsets comprise 5-15 m thick composite, upward-fining successions capped by prominent, laterally continuous (up to 50 m at least) mudstone or eolian sandstone (Fig. 2.9); these are interpreted as multiple channels in a larger channel tract. The upward-fining trend indicates that within the channel tract, aggradation was accompanied by a decrease in stream competency. Aggradation would result in a reduction of slope, channel switching and abandonment, to produce upward-fining patterns in fluvial deposits capped by fine-grained or eolian deposits (cf. Miall, 1977; Hjellbakk, 1997). These thicker upward-fining successions therefore likely represent aggradation and abandonment of a braided channel complex (Fig. 2.9).

2.2.4 Facies Association 4: Floodplain

Lithofacies description:

The floodplain FA is typically composed of the lithofacies Fl, Sr, Sh, St, and Ste. Rippled sandstone (Sr) with nearly ubiquitous mudstone drapes is typically interstratified with 5 to 20 cm thick laminated mudstone (Fl). Sedimentary structures and bedforms include, ripple cross-lamination, symmetrical and asymmetrical ripples, and V-shaped polygonal cracks in mudstone. Thin intervals (generally less than 2 m) of upward-fining, trough cross-stratified sandstone (St) occur within mudstone-dominated sections. Cross-sets are less than 50 cm thick and typically contain up to 5 cm angular mudstone clasts. Cross-stratified sandstone with inversely graded foresets (Ste; Fig. 2.8c), occurs at the top of upward-fining intervals, typically as single cross-sets up to 1 m thick. Bedding geometries are typically tabular-horizontal; however, low-angle inclined cosets, cumulatively less than 1 m thick, overlying and overlain by horizontally laminated mudstone, occur locally (Fig. 2.8d). These inclined strata consist of thin beds of parallel-laminated, fine- to medium-grained sandstone overlain by mudstone drapes, some of which display desiccation features such as mudcracks and mud curls.

A sub-division within this FA is an association of wavy bedded sandstone and mudstone (SFw) with subordinate trough cross-strata (St) and laminated mudstone (Fl). Either symmetrical or asymmetrical ripples may dominate metre-scale intervals of predominantly interlaminated sandstone and mudstone. The occurrence of desiccation structures is variable; desiccation cracks are generally absent where symmetrical ripples are common.

Lithofacies Interpretation:

The FA of current ripples, mudstone, and desiccation cracks suggests periodic overbank flooding followed by suspension deposition and subaerial exposure within a floodplain setting. Current ripples and planar laminae lacking primary current lineation are indicative of lower-flow-regime deposition, and wave ripples mark periods when water remained pooled on the floodplain after floods. Thin intervals, less than 2 m thick, of upward-fining cross-stratified sandstone represent small crevasse channels that traversed the generally mudstone-dominated substrate (*cf.* Rhee et al., 1993). Deposits of eolian sandstone (Ste) indicate subaerial sand dune migration over the floodplain where flooding was insufficient to inhibit dune formation.

The low-angle inclined sets of parallel-laminated sandstone contain mudstone laminae, discounting an eolian origin. Desiccation features indicate intermittent subaerial exposure. The low angle of inclination is inconsistent with formation by dune migration, but too steep to have been deposited as upper-flow-regime plane beds. The lack of a vertical progression of structures, for example from dune to ripple-scale cross-sets, suggests that this wasn't a fluvial channel. Additionally, the absence of cross-lamination, ripple forms and primary current lineation are inconsistent with deposition as plane beds under upper-flow-regime streamflow. The horizontal laminae are therefore considered to have been deposited during lower-flow-regime conditions on an inclined sand surface that migrated over floodplain mud. This is similar to crevasse splays described from the sand-bed braided Niobrara River (Bristow et al., 1999), in which ~1 m thick inclined sets of parallel lamination and ripple lamination overlie floodplain fines. We therefore interpret such inclined sets of laminated sandstone as crevasse splay deposits that emanated from the thin laterally equivalent units recognizable as trough cross-stratified sandstone-dominated (St) crevasse channels.

Intervals dominated by the wavy bedded facies are inferred to represent prolonged periods where pools of water remained on the floodplain, perhaps due to a fluctuating near-surface water table. Such deposits have been described from recent braided fluvial floodplain deposits by Bristow et al. (1999) and ephemeral streams by Martin (2000). Floodplain deposits with wave ripples and an apparent absence of desiccation features have also been described from a Mesoproterozoic braided fluvial system in East Greenland by Sønderholm and Tirsgaard (1998).

Current understanding of the relationship between gradient, sediment grain size, and stream type is based mainly on systems that include sediment-binding vegetative cover. In the absence of vegetation, braided streams probably can exist at lower gradients, lower discharge regimes, or finer sediment grain sizes. Therefore, heterolithic braided streams and associated floodplains may be the pre-vegetative equivalent to meandering streams and floodplains with respect to these factors. However, the predominance of braided streams, even in the finest deposits and hence lowest gradients, could alternatively be due to ephemeral flash-flooding that resulted in episodic high-discharge streamflow. In contrast to recent floodplain deposits, such as along the Waimakariri River which generally preserves very few depositional structures (Reinfelds and Nanson, 1993), floodplain deposits from the Paleoproterozoic Baker Lake Basin contain a diverse array of structures due to the absence of bioturbation or root growth.

Together with other Precambrian deposits, such as the Mesoproterozoic braided fluvial system described by Sønderholm and Tirsgaard (1998), they provide a perspective on floodplain deposits generally not available from the Phanerozoic.

2.2.5 Facies Association 5: Eolian

Lithofacies description:

The eolian FA is typified by up to 10 m thick accumulations of trough cross-stratified sets, 20 cm to 2 m thick, of fine- to medium-grained, well-sorted sandstone (Ste). Basal foresets are typically reverse-graded fine- to medium-grained sandstone (Fig. 2.8c), and most exhibit pinstripe lamination (cf. Fryberger, 1988). Upper foresets are wedge-shaped, taper downward, normally graded, locally coarse- to medium-grained sandstone. The tops of cross-sets are typically truncated by horizontal surfaces. These may be associated with granule or pebble layers, or cross-stratified pebbly sandstone (St). Overlying these erosional surfaces are 10-20 cm thick intervals of wave-rippled sandstone (Sw) and/or inter-laminated mudstone (SFw), which are succeeded by metre-scale cross-sets.

Lithofacies interpretation:

Pinstripe lamination and reverse-graded foresets are interpreted as sub-critically climbing translatent stratification resulting from the migration of wind-ripples over subaerial dune slipfaces (cf. Hunter, 1977). Wedge-shaped, normally graded foresets are interpreted as grainfall deposits. Intervals of wave rippled sandstone (Sw) and/or inter-laminated mudstone (SFw) at the base of eolian cross-sets are considered to be wet-condition interdune deposits indicating a near surface water table (Kocurek and Havholm, 1993). The occurrence of minor pebbly sandstone indicates that interdune areas were subject to streamflows because the pebbles are too large to have been transported by wind. The original fluvial deposits are inferred to have been reworked, resulting in pebble layers interpreted as lags. The large-scale cross-sets are therefore considered to be formed by the migration of eolian dunes, with wind-ripple lamination preserved on lower slipfaces, and interdune areas characterized by standing water with infrequent streamflow influx from surrounding alluvial plains. This is characteristic of a wet condition eolian system (Kocurek and Havholm, 1993).

Simpson et al. (2004) consider eolian deposits from the Baker Lake Basin to consist of two general types: thin sandsheets dominated by wind ripple lamination associated with ephemeral lacustrine and fluvial deposits, and thicker (up to 100 m) erg deposits dominated by large-scale cross-sets (up to 6 m thick). The eolian FA described herein is primarily based upon observations from northern Christopher Island, where it is represented by up to 10 m thick accumulations of large scale (up to 2 m) cross-sets of sandstone associated with ephemeral lacustrine and fluvial deposits. The presence of interdune deposits between individual cross-sets indicates that these were not compound dunes and therefore are equivalent to the thin sandsheet sub-division of Simpson et al. (2004).

Facies Successions:

There are two types of bedset within the eolian FA (Fig. 2.10). The first is relatively simple and consists of large-scale trough cross-stratified sandstone (Ste) with wave-rippled sandstone bottom sets (Sw) or cross-stratified sandstone (St), considered to probably represent dune and interdune strata, respectively (Kocurek, 1981).

The second type of bedset is more complex. A complete vertical facies succession consists of: thin (~10-20 cm) cross-stratified pebbly sandstone (St); pebble or granule lag; approximately 10-20 cm thick interstratified sandstone and mudstone with prominent wave ripples (SFw; Sw); overlain by metre-scale eolian cross-sets. The pebbly sandstone is rarely preserved, and so bounding surfaces for multiply stacked bedsets are commonly the horizontal erosional surfaces. The interpreted succession of depositional events is: fluvial influx of pebbly sand; erosion to produce the lag; intermittent wave currents and suspension deposition; followed by metre-scale eolian dune migration. These bedsets occur as multiply stacked sets, and so fluvial sandstone overlies eolian cross-sets, representing streamflow flooding of the eolian dune field prior to erosion.

Two potential processes for producing the horizontal erosional surfaces are wind deflation and wave-induced erosion. In the first case, deflation of the eolian dune field would be accompanied by streamflows, accounting for fluvial sandstone overlying the eolian cross-sets. The surface of deflation may have been controlled by the groundwater table as a Stokes surface (Stokes, 1968; Fryberger et al., 1988; Kocurek and Havholm, 1993). Subsequent erosion following fluvial deposition may have been inhibited by formation of an armoured pebble lag, as observed in periglacial eolian deposits of Iceland (Mountney and Russell, 2004). This would be followed by shallow subaqueous conditions with intermittent wave currents and suspension deposition recorded by the interstratified wave rippled sandstone and mudstone laminae. In the absence of streamflows, and eolian dune field was re-established.

With respect to wave-induced erosion, initial groundwater table would be steady or low during eolian dune field formation. A rise in groundwater table would be accompanied initially by an influx of fluvial streamflows, then by shallow standing water as adjacent playa lakes expanded. Wave currents would rework the substrate resulting in a horizontal erosion surface, pebble lag, and overlying wave rippled sandstone. The latter part of this process is analogous to a transgressive surface of erosion. Contraction of the playa lakes would be accompanied by re-establishment of the eolian dune field.

It is difficult to determine whether the pebble lags record wind deflation or transgressive erosion; although association with the overlying SFw/Sw facies is consistent with the latter, a combination of processes is probable. Sweet (1999) rationalized a rising water table and wind deflation by supposing that during lake expansion sediment supply from lake margins was cut off. Winds blowing off the playa margin were undersaturated with respect to sand and therefore effective at deflating dunes. In the Baker Lake Basin, subsequent to removal of eolian sediment supply and deflation, shallow lacustrine inundation may have been accompanied by wave erosion and additional planation.

Both models involve rising groundwater table: If base level controls the erosion surface, then base level fluctuations control the accommodation increment in eolian systems, consistent with existing theories for preservation of eolian accumulations

(Stokes, 1968; Kocurek and Havholm, 1993; Carr-Crabaugh and Kocurek, 1998; Simpson et al., 2004).

This FA therefore probably represents an environment without significant fluvial sediment flux where eolian dunes fields were able to develop, but were subject to episodes of flooding during expansion and contraction of adjacent playa lakes in response to groundwater table fluctuations.

2.2.6 Facies Association 6: Playa/mudflat

Lithofacies description:

This FA is dominated by 5-20 cm thick layers of mudstone (Fm) interstratified with 5-20 cm thick trough cross-stratified sandstone (St) and ripple cross-stratified sandstone (Sr; Fig. 2.8e). Within mudstone, V-shaped cracks up to 5 cm deep filled with sandstone from the overlying bed are prominent.

Lithofacies interpretation and succession:

Thick mudstone layers indicate sustained periods of suspension deposition; deep v-shaped desiccation cracks indicate subaerial exposure; thin cross-stratified sandstone beds overlain by mudstone indicate that bedload deposition preceded a resumption of suspension deposition. The depositional environment was characterized by playa lake expansion due to episodic flooding, leading to sustained suspension deposition to form a mud flat environment (5-20 cm of laminated mudstone), followed by subaerial exposure representing playa lake contraction and desiccation of the mudflat.

The basic depositional unit of this association is an upward-fining 10-40 cm cycle of sandstone to mudstone, which represents playa lake expansion followed by contraction and desiccation, likely recording climatic fluctuations. Successions of these cycles are generally less than 5 m thick, but locally are greater than 50 m thick (Rainbird et al., 1999). Since this facies association is typically intercalated with eolian and lacustrine facies, we interpret it to have been deposited in a playa lake-mud flat environment.

With respect to the association with eolian deposits, a prevalence of playa over eolian environment could be due to a relatively higher water table that periodically dampened the substrate sufficiently to inhibit eolian dune growth, or there may have been a higher proportion of fine sediment. Considering the proximity of a vegetation-free sandy braidplain, the playa environment was more likely a product of a relatively high water table.

At southern Christopher Island the playa facies is dominated by mudstone with desiccation cracks, and it reaches a maximum thickness of 50 m (Rainbird et al., 1999). This implies a significant source of mud-grade sediment. Macey (1973) identified detrital phlogopite in the Kazan Formation from southern Christopher Island and proposed that Christopher Island Formation volcanic and volcaniclastic deposits had supplied volcaniclastic sediment. These chocolate brown, volcaniclastic rocks contain abundant ash-sized particles (Blake, 1980; Rainbird et al., 1999), which indicates the availability of a large volume of fine sediment to an ephemeral lacustrine environment.

2.2.7 Facies Association 7: Lacustrine delta

Lithofacies description:

This FA is diverse comprising St, Sw, Fl, and normally graded Sh. The St facies primarily occurs as 0.2-0.8 m trough cross-sets that form 1-2 m thick cosets. Mudstone clasts are common at the base of these cosets. Mudstone drapes are common at the top of cross-stratified sets and on foresets. These units have lenticular bases incised into underlying deposits, which may include facies Fl or St.

Laminated mudstone and siltstone facies (Fl) is interstratified with starved symmetrical ripples and beds of sandstone generally less than 5 cm thick. Pebble lags occur at the base of mudstone-dominated intervals that overlie pebbly sandstone (Fig. 2.8g). Desiccation features are absent. These intervals of Fl reach thicknesses up to 50 cm and are commonly incised by the 1-2 m thick St units.

Conversely, mudstone drapes are less common in the symmetrical-rippled sandstone facies (Sw). Ripple types include symmetrical ripples that cap reworked cross-set tops, and climbing ripples, locally supercritically climbing (Fig. 2.8f). Together with thin (5-10 cm) cross-stratified sandstone (St) sets with symmetrical-rippled tops, the rippled sandstone comprises tabular sheets 1-2 m in thickness.

An uncommon facies within this FA is normally graded, horizontally laminated sandstone (Sh; Fig. 2.8h) that may overlie a 5-15 cm massive sandstone bed. This occurrence of Sh is typified by upward-fining and upward-thinning laminae comprising beds 10-15 cm thick. Basal laminae are medium-sand grade; upper laminae are fine to very fine sand. Angular mudstone clasts of mm-scale are common in the thicker laminae. Very thinly laminated siltstone and mudstone overlie upper graded sandstone laminae; locally these thin laminae are composed almost entirely of horizontal mudstone microclasts. Individual laminae can be traced laterally over a few metres, to the extent of outcrop (and lichen) limitations, and beds are continuous for more than 100 m. Trough cross-bedded sandstone with up to 10 cm thick inverse to normally graded foresets is associated with this facies, as well as with ripple cross-laminated sandstone (Sr).

Lithofacies Interpretation:

Upward-fining bedsets of trough cross-stratified sandstone (St) forming sets that incise into underlying deposits are considered to be channel deposits. Mudstone drapes, including those on foresets, indicate suspension deposition within channels between streamflow events. Angular mudstone clasts are interpreted as mudstone rip-ups. Braided stream deposits (FA 3) are characterized as an ephemeral, high-discharge fluvial system. The channels within this FA record streamflows alternating with standing water suspension deposition, perhaps reflecting seasonal discharge within distributary channels in a lacustrine environment.

The association of facies Fl with wave ripples and thin beds of sandstone indicates an environment dominated by suspension deposition, but subject to wave currents and occasional bedload deposition of sand. The lack of desiccation features, as in the playa deposits (FA 6), and brief periods of wave currents and bedload sedimentation, would be consistent with deposition in a protected bay. The pebble layer at the base is interpreted as a lag, and together with wave ripples is suggestive of a preceding phase of wave erosion. Subsequent incisement by channels that record inter-streamflow slack water conditions is consistent with deposition in an inter-distributary bay (cf. Elliot, 1974).

Within the rippled sandstone sheets, the dominance of symmetrical ripples indicates the prevalence of oscillating currents and therefore wave processes. In-phase climbing ripples indicate high rates of sedimentation. Ubiquitous wave-ripple reworked cross-set bed-tops indicating that unidirectional currents were consistently followed by wave currents, are suggestive of sand bars subject to shoaling waves. These features and the sheeted geometry are consistent with deposition at a lake margin delta front mouth bar (cf. Plint and Browne, 1994; Marshall, 2000).

The graded horizontal lamination is identical to Bouma division T_d, which is characterized by fine parallel lamination and textural sorting (Bouma, 1962). Oaie (1998) described an Neoproterozoic occurrence of mudstone microclasts from the T_3 subdivision (distinctly laminated sandstone, equivalent to T_d; Stow and Shanmugan 1980), and also noted features such as continuous or discontinuous parallel lamination due to the orientation of microclasts parallel to bedding planes. Ripple cross-laminated sandstone associated with graded laminae correspond to Bouma division T_c. These packages of Bouma T_{c-d} divisions locally have wave-ripple reworked tops, and closely overlie cross-sets that have wave-ripple reworked tops, indicating that they were deposited above storm wave base. 5-15 cm thick massive beds that underlie some graded laminae intervals are interpreted at Bouma division Ta. Packages of Bouma division Ta and Td, without well developed ripples of Tc are considered identical to A1 (crudely stratified to massive) to A3 (upward-thinning, upward-fining graded laminae) successions for sand-rich turbidite deposits associated with deltaic facies (Mutti et al., 2003). Mutti et al. (2003) interpret these as being deposited first from the dense base of a sediment gravity flow due to frictional freezing, and second near-bed suspension from a less dense, turbulently mixed part of the flow. These upward-thinning and upward-fining units with ripple cross-stratified sandstone or massive sandstone beds are interpreted to be turbidites, reflecting delta front sediment gravity flow processes. These flows may have originated as sediment-charged, hyperpycnal streamflows or slope instability due to earthquakes or explosive volcanism.

An alternative interpretation of the normally graded Sh is oscillatory flat-bed sedimentation. However erosional processes in the foreshore environment that produce lenticular beds or low and cross-stratification (e.g. Clifton, 1969) are inconsistent with the lateral continuity of the laminated Sh in the Baker Lake sub-basin, as are field observations and experimentally produced oscillatory flat-bed laminae that, when graded, display reverse-grading (Clifton, 1969).

In the absence of tidal features, the turbidites are the best indication of a lacustrine environment. Together, the association of turbidites, distributary channels, inter-distributary bays, and rippled sandsheets comprise an assemblage best interpreted as a perennial lacustrine deltaic environment.

Facies successions:

There are two types of generally upward-coarsening successions (Fig. 2.10). In the first, the base is sharp and erosion is typically indicated by a transgressive lag overlain by laminated mudstone (Fl). This is succeeded by an upward-coarsening interval of cross-stratified sandstone with abundant mudstone clasts, which is truncated and incised by an upward-fining interval of cross-stratified sandstone. Employing the distributary/inter-distributary bay model presented by Elliott (1974), we interpret this as a prograding mouth bar overlain by an upward-fining distributary channel. Such distributary channel deposits generally display wave-reworked tops, as indicated by wave ripples or a lag. This is likely because an abandoned distributary channel will be a positive feature, and subject to wave erosion at the delta edge until inter-distributary bay sedimentation "catches up" and buries the sand bar.

The second type of upward-coarsening succession is similar to the first, with a sharp base overlain by mudstone and upward-coarsening sandstone. Turbidites locally form the base of these upward-coarsening intervals. Sheets of wave-rippled sandstone (Sw) and the sub-facies of thin cross-stratified sandstone beds with wave-rippled tops occur at the top, instead of a distributary channel deposit, reflecting lobe abandonment prior to channel incisement of the mouth bar. Similar associations of upward-coarsening successions with thin cross-stratified sets capped by wave-rippled tops have been described by Plint and Browne (1994) from a Phanerozoic strike-slip basin, and interpreted to represent the lake margin bay mouth bar of a lacustrine delta. We similarly interpret this succession as a bay mouth succession capped by progradation of a mouth bar at the lake margin. The rippled sandsheet is overlain by eolian deposits, so continued progradation of the delta system was interrupted by relative lake level fall and eolian reworking of the delta top (Fig. 2.10).

2.3.0 Depositional Model

Examination of stratigraphic contacts and areal distribution of the various facies associations enables reconstruction of the paleobasin through a model of linked facies tracts. The alluvial fan FA is preserved at kilometre- scale thickness adjacent to the southeastern basin margin (Fig. 2.11). Evidence of local derivation includes bouldersized angular clasts, similar to the underlying crystalline basement, even though contemporaneous volcanic centres were locally active within the basin. Paleocurrent data indicate alluvial transport was transverse to the basin margin (Fig. 2.4), which suggests that the present-day basin margin approximates the paleobasin margin.

The gravel-bed braided stream FA occurs in gradational stratigraphic contact with the alluvial fan FA. This, in turn grades into the sand-bed braided stream FA. The gradational transition indicates that these facies are linked and represent lateral transitions. The change in grain size and inferred depositional gradient therefore is representative of a proximal to distal fluvial system; proximal alluvial fans fed gravel-bed braided streams at their base which, with decreasing gradient and competence, graded into sand-bed braided streams. The braided streams were distributed throughout the basin from the inferred paleomargin (Thirty Mile Lake; Fig. 2.12) to the depocentre (Christopher Island). Paleocurrent data define two drainage patterns for these braided streams: (1) near the basin margins the trend is transverse to the margin (Fig. 2.4); and (2) along the centre of the elongate Baker Lake sub-basin an axial drainage system (Fig. 2.2; Fig. 2.5). Together with asymmetry of stratigraphic thickness of the Baker Lake Group from the northwest to the southeast, ~500 m and > 2000m respectively, the drainage patterns are consistent with deposition in a half-graben, the bounding fault of which was adjacent to the southeast margin (Fig. 2.2).

The floodplain FA is associated with the sand-bed braided stream FA, but also occurs in stratigraphic contact with eolian, playa, and lacustrine FAs. Prominent within the floodplain depositional environment are indications of standing water, such as abundant wave ripples and local paucity of desiccation features. Similarly, wet-condition interdune deposits characterize the eolian facies, where thin sandsheet-type eolian deposits are interstratified within most facies of the Baker Lake Group throughout the basin. Thicker eolian deposits, dominated by large-scale cross-sets primarily associated with lacustrine, floodplain, and to a lesser degree braided stream FAs, are most common near the inferred basin axis along Kazan River (Simpson et al., 2004) and the main depocentre at Christopher Island (Rainbird et al., 1999, Simpson et al., 2004; Fig. 2.5). The playa-mudflat FA is primarily in stratigraphic contact with the eolian FA on Christopher Island, indicating a close spatial relationship near the main depocentre of the Baker Lake sub-basin (Rainbird et al., 2003). The lacustrine delta FA has a small areal extent, exposed only at Christopher Island. The stratigraphic transition from fluvial to lacustrine (though rarely complete) passes through eolian, playa, and floodplain FAs, indicating that mud flats and eolian dunes occupied lake margins adjacent to deltas, depending on lake expansion or infilling, respectively. Paleocurrent data from northwestern Christopher Island (Fig. 2.4) indicate southwesterly streamflow. Therefore, northwestern Christopher Island marked the eastern edge of the basinal depocentre. Deltas prograded south and west, into the lake basin, and were fed by braided streams that originated to the northeast. The preserved basin margin ends at the north shore of Baker Lake and it is likely that the paleobasin originally extended farther northeast, because these paleocurrent data indicate that in the upstream direction sand-bed braided streams extend to the present margin instead of conglomerate that would be expected, if the preserved northeast margin coincided with the paleobasin margin.

Paleocurrent data from delta-top eolian cross-sets (Fig. 2.10) indicate southwesterly wind flow, assuming that dune crests were oriented transverse to the primary wind direction. This appears to be a valid assumption, because the paleocurrent directions are perpendicular to the trend of wave ripple crests within the delta complex. Other northwestern Christopher Island eolian paleocurrent data that indicate northwesterly aerial transport (Fig. 2.5) are similarly perpendicular to wave ripple crest trends from interdune intervals, suggesting that waves were generated by a similar prevailing wind direction as the eolian dunes. These paleocurrents are associated with braided stream deposits that display southeast-directed paleocurrents, distinct from the eolian paleocurrent direction.

Thus, a model of linked facies tracts for the Baker Lake sub-basin is set within an elongate half-graben basin. From the margins, a transverse drainage system of alluvial fans to braided streams, with floodplains and eolian dunes, fed an axial fluvial system. Axial drainage was primarily directed northeasterly and less extensively southwesterly culminating at a depocentre near Christopher Island (Fig. 2.2). This pattern indicates that the Baker Lake sub-basin was a hydrologically closed system: primary drainage was endemic rather than directed to an adjacent basin. At the depocentre, deltas fed into a lake that was surrounded by floodplains, mudflats, and eolian dunes with prevailing wind directed northwest and southwest (relative to present geography).

2.4.0 Discussion

2.4.1 Volcanic stratigraphy and sedimentary relations

The facies tract model is based on the sedimentary record within the Baker Lake sub-basin; however, a large component of basin fill comprises volcanic rocks. Relations between the volcanic and sedimentary environments are best illustrated by comparing sedimentary and volcanic-dominated sections such as at Thirty Mile Lake on the south side of the Baker Lake sub-basin (Fig. 2.2, 2.11).

Near central Thirty Mile Lake, a succession of felsic minette (k-feldspar-phyric) flows, approximately 200 metre thick, overlies the basal unconformity (Fig. 2.11). To the east and west, alluvial fan deposits unconformably overlie crystalline basement (Fig. 2.2). At the western side of Thirty Mile Lake, felsic minette clasts locally occur within the South Channel Formation. K-feldspar porphyry dykes, inferred to be the intrusive equivalent to felsic minette flows, have intruded the lower part of the alluvial fan deposits. These volcano-sedimentary relations indicate that felsic minette flows were erupted from localized volcanic centres adjacent to alluvial fans, near the basin margin (Fig. 2.11). Felsic minette flows are overlain by minette flows near central Thirty Mile Lake. At the west end of Thirty Mile Lake, minette flows overlie either felsic minette flows or a distinctive conglomerate marker that contains felsic minette clasts and a minor component of minette clasts. In clastic-dominated sections, such as at the far western end of Thirty Mile Lake, an interval of fluvial sandstone occurs between the conglomerate marker and the minette flows. These stratigraphic relations between the conglomerate marker and minette flows indicate that the flows originated at volcanic centres, which progressively expanded outward to eventually blanket most of the basin. The volcanic centres would have been positive topographic features that supplied volcaniclastic sediment, altered drainage patterns by diverting streamflow, and replaced sedimentary processes as a basin-infilling mechanism. Stratigraphically above the minette flows are either felsite volcanics, volcaniclastic conglomerate that contains felsite clasts (e.g. the Kunwak Formation at the Kunwak River) or the unconformably overlying Wharton Group. Therefore, within the threefold subdivision of the volcanic stratigraphy, the lower section of felsic minette was less areally extensive than the voluminous outpouring of middle-section minette flows. The upper unit of felsite was yet more restricted.

At the northern basin margin (near Aniguq River), felsic minette volcanism is represented by a K-feldspar crystal tuff near the base of the Baker Lake Group (Rainbird and Hadlari, 2000). This is succeeded by minette flows, and is laterally equivalent to conglomerate and sandstone interstratified with minette volcanic rocks. The stratigraphic thickness of the Baker Lake Group at the northern margin (~ 500 m) is significantly less than at the southern margin (~ 2000 m). This basin asymmetry was due to normal faulting on the south side of the half-graben. Less volcanic material was therefore required to create volcanic edifices that were sources of volcaniclastic sediment supply rather than locations of sedimentary deposition (hence the higher proportion of volcanic rocks along the northern margin).

On Christopher Island and surrounding islands (not shown on Fig. 2.5), volcanism was primarily explosive, as indicated by bomb and accessory-clast sag structures, normal and reverse grading, and cross-stratification within extensive volcaniclastic deposits

(Rainbird et al., 1999). These structures indicate deposition, in part, by turbulent pyroclastic surges (*cf.* Fisher and Schmincke, 1984; Cas and Wright, 1987). Crudely stratified, cognate volcanic clast-rich deposits reflect deposition close to interpreted volcanic centers, presently indicated by topographic highs. Due to the combination of island exposure and shallow dips, stratigraphic relationships are not clear, and the upper unconformity bounding the Baker Sequence is not exposed. Where apparent, the volcaniclastic strata overlie the alluvial strata, indicating that the lacustrine, eolian, and playa deposits predate widespread explosive volcanism in this area. However, mudstone from the playa lithofacies contains phlogopite, a characteristic phenocryst in the CIF volcanic rocks (Macey, 1973). The playa deposits also are the same colour as the volcaniclastic rocks, and therefore likely are composed of a high proportion of ash (Rainbird et al., 1999). In addition, thin conglomeratic layers within the braided stream deposits from northwest Christopher Island contain minette clasts. These features suggest that minette volcanism was active throughout the depositional history in this area, and similar to the Thirty Mile Lake area, culminated in voluminous extrusion that likely blanketed most of the basin.

The three-fold volcanic succession spans the entire Baker Lake Basin from Kamilukuak sub-basin to the Baker Lake sub-basin. This petrological correlation appears to be confirmed at the base of the succession by a U-Pb zircon age of 1833 ± 3 Ma from Kamilukuak sub-basin and a $^{40}Ar/^{39}Ar$ age of 1837 ± 8 Ma from the Baker Lake sub-basin (Rainbird et al., in press). The sedimentary facies associations representing alluvial fan, braided stream, and lacustrine characterize the Baker Lake sub-basin, and are also present within the Angikuni sub-basin (Aspler et al., 2004), highlighting the lateral continuity of facies within the greater Baker Lake Basin.

2.4.2 Eolian deposits and paleoclimate

Sedimentology of the Baker Lake Group reveals a variety of climatic indicators. Eolian deposits, which are a measure of aridity, are primarily associated with lacustrine, floodplain, and to a lesser degree braided-stream facies (Fig. 2.10), and are most common near the inferred basin axis along Kazan River (Simpson et al., 2004) and the main depocentre at Christopher Island (Rainbird et al., 1999; Fig. 2.12). In very thick deposits (30 to 100 m) of eolian sandstone, some cross-set bounding surfaces indicate dry interdune conditions (Rainbird et al., 1999; Simpson et al., 2004). However, thinner sandsheet-type accumulations in association with lacustrine and floodplain facies, in particular at the inferred depocentre (Christopher Island), contain a greater proportion of interdune deposits composed of inter-laminated, wave-rippled sandstone and mudstone, indicating flooding of interdune areas (*cf.* Kocurek and Havholm, 1993). Almost every facies association includes an eolian component: eolian reworking of abandoned channels; eolian sandstone sheets associated with playa-mudflat environments; and eolian sandstone interstratified with floodplain deposits. However, wave ripples and mudstone laminae within floodplain deposits record periods where standing water was relatively common. Deltaic deposits indicate that a perennial lake existed at the main depocentre. These features confirm that the water table was close to the surface, inconsistent with an arid climate. Climatic fluctuations occur at vastly shorter time scales than the ~ 45 Ma span of time represented by the Baker Lake Group. For example, the hyper-arid Rub Al

Khali eolian system of the Arabian Peninsula is presently the world's largest erg; however, lacustrine and paleogroundwater deposits such as travertine suggest that the climate was humid at 35-25 ka and 10-6 ka, coincident with precessional orbital parameters (Bray and Stokes, 2004). Furthermore, eolian systems are not restricted to hot-climate environments, as exemplified by the cold-climate Askja region periglacial sandsheet of Iceland (Mountney and Russell, 2004). These relatively recent, biologically hostile environments are analogous to those of the Baker Lake Basin in that they developed on a non-vegetated landscape with sufficient sediment supply for eolian accumulation. In the absence of sediment-binding vegetative cover in the Paleoproterozoic, it is possible that eolian deposits are not necessarily an indication of an arid climate, but rather a mobile substrate adjacent to a viable sediment source (e.g. active fluvial channel belts). Therefore, the Baker Sequence deposits broadly suggest a variably semi-arid to semi-humid paleoclimate. With respect to lacustrine deposits, related evaporite minerals, and chemogenic lake beds within the Angikuni sub-basin, Aspler et al. (2004) has similarly suggested a wet paleoclimate with local arid intervals for the Baker Sequence.

2.5.0 Conclusion

The alluvial fan FA consists of upward-fining stratal units 5-10 m thick. These indicate that the alluvial fan developed by a succession of lobe accretion and abandonment events. The main lobe accretion units are represented by upward-fining, tabular units of the facies Gcd and Gco respectively, which record rapid deposition of gravel sheets during high-magnitude streamflows followed by incisement during secondary low-magnitude streamflows. Inactive lobes were characterized by sand and mud deposition analogous to overbank processes on alluvial plains. The predominance of streamflow processes was probably due to weathering and erosion of crystalline rock in the source region, as indicated by granitoid and gneissic clast lithologies.

Alluvial fans were primarily located along the southeastern margin of the basin, and combined with regional paleocurrent and stratigraphic thickness variations indicate that the primary basin-bounding fault of the Baker Lake sub-basin was adjacent to its present southeastern margin.

The gravel-bed braided stream FA also preserves upward-fining bedsets, 5-10 m thick, which record aggradation and lateral channel-belt switching. These are differentiated from the alluvial fan facies by better sorting and condensed framework, with imbricated clasts indicating more sustained streamflow and less rapid deposition. Conglomerate facies are discontinuous at scales over 100 m, indicative of approximate channel widths. The gravel-bed FA is gradational between the alluvial fan and sand-bed braided stream FAs, and distributed from the basin margin through the basin axis.

The sand-bed braided stream FA comprises 5-15 m thick upward-fining, stacked bedsets interpreted as channel complex successions. Aggradation of mixed-load ephemeral sheetflood and shallow, sand-bed braided streams was followed by upstream channel-belt switching. The abandoned channels were sites of suspension deposition of overbank fines and eolian reworking.

The floodplain FA primarily consists of interstratified sandstone and mudstone representing alternating bedload and suspension deposition in an overbank setting.

Locally abundant wave ripples record standing water subsequent to flood events, suggesting a shallow and fluctuating water table. Thin sandstone intervals represent crevasse channels, and inclined sandstone sets represent crevasse splays. Eolian dunes indicate subaerial reworking of abandoned fluvial channels.

The eolian FA includes thin sandsheets located adjacent to floodplains, playas, and deltas. Cross-sets up to 2 m thick record eolian dunes bounded by wet-condition interdune intervals indicative of a near surface water table, which controlled accumulation of eolian deposits. This description is in addition to previously documented erg deposits at the Kunwak River (Simpson et al., 2004), and lesser erg deposits at southeastern Christopher Island associated with playa deposits (Rainbird et al., 1999; Simpson et al., 2003).

The playa FA is dominated by laminated mudstone with desiccation cracks and subordinate trough cross-stratified sandstone, representing alternating suspension deposition and desiccation of a lacustrine mudflat, punctuated by bedload flood events. This facies is associated with the eolian and lacustrine FAs, and represents a lake margin setting where expansion and contraction due to base level fluctuations inhibited eolian sandsheet formation.

The lacustrine delta FA consists of prodelta turbidites, rippled sandsheets that accumulated in bay mouth bars, distributary channel sandstone, and interdistributary bay laminated, rippled sandstone-mudstone. The deltaic deposits of northwestern Christopher Island record progradation toward a depocentre to the southeast.

In a three-fold subdivision of the volcanic stratigraphy, the lower sub-division comprises felsic minette flows and volcaniclastics erupted at volcanic centres adjacent to basin-margin alluvial fans. This was followed by voluminous minette extrusion, in which flows and volcaniclastic sediments spread from the volcanic centres to blanket most of the basin. Flows are common at Thirty Mile Lake, but rare at Christopher Island where volcaniclastics constitute most of the volcanic deposits. Areally restricted felsite domes comprise the upper part of the volcanic succession. Where the basin was not entirely filled or overfilled due to minette volcanism, gravel-bed braided streams transported felsite clasts basinward.

The sedimentology of the Baker Lake Group indicates a transverse drainage system of alluvial fans to braided streams, with floodplains and eolian dunes adjacent to inactive channels. This transverse system fed an axial drainage system that primarily was directed northeast and less extensively southwest to a depocentre near Christopher Island, defining the pattern of a hydrologically closed basin. At this depocentre, deltas fed into a lake that was surrounded by floodplains, mudflats, and eolian dunes deposited when the prevailing wind was directed northwest and southwest. Sedimentological features such as ephemeral, flash flood-type alluvial deposits, playas, and eolian sandsheets and ergs record indicate a level of aridity moderated by wet-condition eolian inter-dune deposits and floodplain deposits indicative of a near surface water table, and thus a semi-arid to semi-humid paleoclimate.

Table 2.1: Lithofacies, modified from Miall (1977) and Jo et al. (1997).

Lithofacies	Description	Interpretation
Gcd: framework-supported, disorganized conglomerate	Cobble- to boulder-grade clasts; coarse to fine sandstone matrix; poorly to very poorly sorted; crude and irregular stratification; tabular geometry; erosional base.	Gravel sheets emplaced by high magnitude flood flows.
Gco: framework-supported, organized conglomerate	Pebble- to cobble-grade clasts; granule to medium sandstone matrix; moderately sorted; organized framework; erosional base; wedge-shaped and tabular units; predominantly horizontally stratified.	Gravel sheets emplaced by bedload processes during flood events.
Gcm: framework-supported, massive conglomerate	Pebble- to cobble-grade clasts; coarse to medium sandstone matrix; moderate to well sorted; imbricated; intact framework; tabular geometry.	Gravel bars in high-energy braided streams.
Gt: trough cross-stratified conglomerate	Pebble- to cobble-grade clasts; granule to medium sand grade matrix; fine upward; cross-stratified; lenticular units with erosional base.	Filling of channels, scours and channel pools by gravel during flood flows.
Sh: horizontally stratified sandstone	Fine- to medium-grained sandstone; well sorted; planar-horizontal lamination; +/-primary current lineation on bedding planes.	Planar bed flow (upper and lower flow regime).
St: trough cross-stratified sandstone	Medium to coarse-grained sandstone; trough cross-stratification.	Migration of 3-dimensional dunes.
Ste: trough cross-stratified sandstone with pinstripe lamination	Fine- to medium-grained sandstone; inversely graded foresets; pinstripe lamination; up to 2 m thick.	Migration of eolian 3-dimensional dunes.

Table 2.1 (concluded)

Sr: sandstone with asymmetric ripples	Laminated sandstone with predominantly asymmetric ripples; +/- mudstone drape; linguoid bedforms common.	Bedload deposition/migration of current ripples.
Sw: sandstone with symmetrical ripples	Laminated sandstone; symmetrical ripples; +/- mud drapes; bifurcating crests; sheet-like geometry.	Wave-formed ripples; lacustrine shoreface, or delta mouth bar.
SFw: wavy bedded sandstone and siltstone/ mudstone	Inter-stratified sandstone and siltstone/mudstone; asymmetric and/or symmetric ripples.	Overbank, abandoned channel, or waning flood deposits.
Fl: parallel-stratified mudstone	Mudstone, siltstone, with parallel-laminated and/or cross-stratified sandstone.	Prolonged periods of quiet-water suspension deposition.

AMZ - Amer Mylonite Zone
BF - Bathurst Fault
CBB - Committee Bay Belt
CFZ - Chesterfield Fault Zone
EAMT - East Athabasca mylonite triangle
FF-GD - Flin Flon-Glennie Domain
GSLSZ - Great Slave Lake Shear Zone
GBA - Great Bear Magmatic Arc
KCX - Kramanituar Complex
KD - Kisseynew Domain
SAMZ - Striding Athabasca Mylonite Zone
STZ - Snowbird Tectonic Zone
THO - Trans-Hudson Orogen
TM - Talston Magmatic Zone
TTZ - Thelon Tectonic Zone
TuFZ - Tulemalu Fault Zone
TySZ - Tyrrell shear zone
UCX - Uvauk Complex
WB - Wathaman Batholith
WBG - Woodburn Group
WBSZ - Wager Bay Shear Zone
WG - Wollaston Group

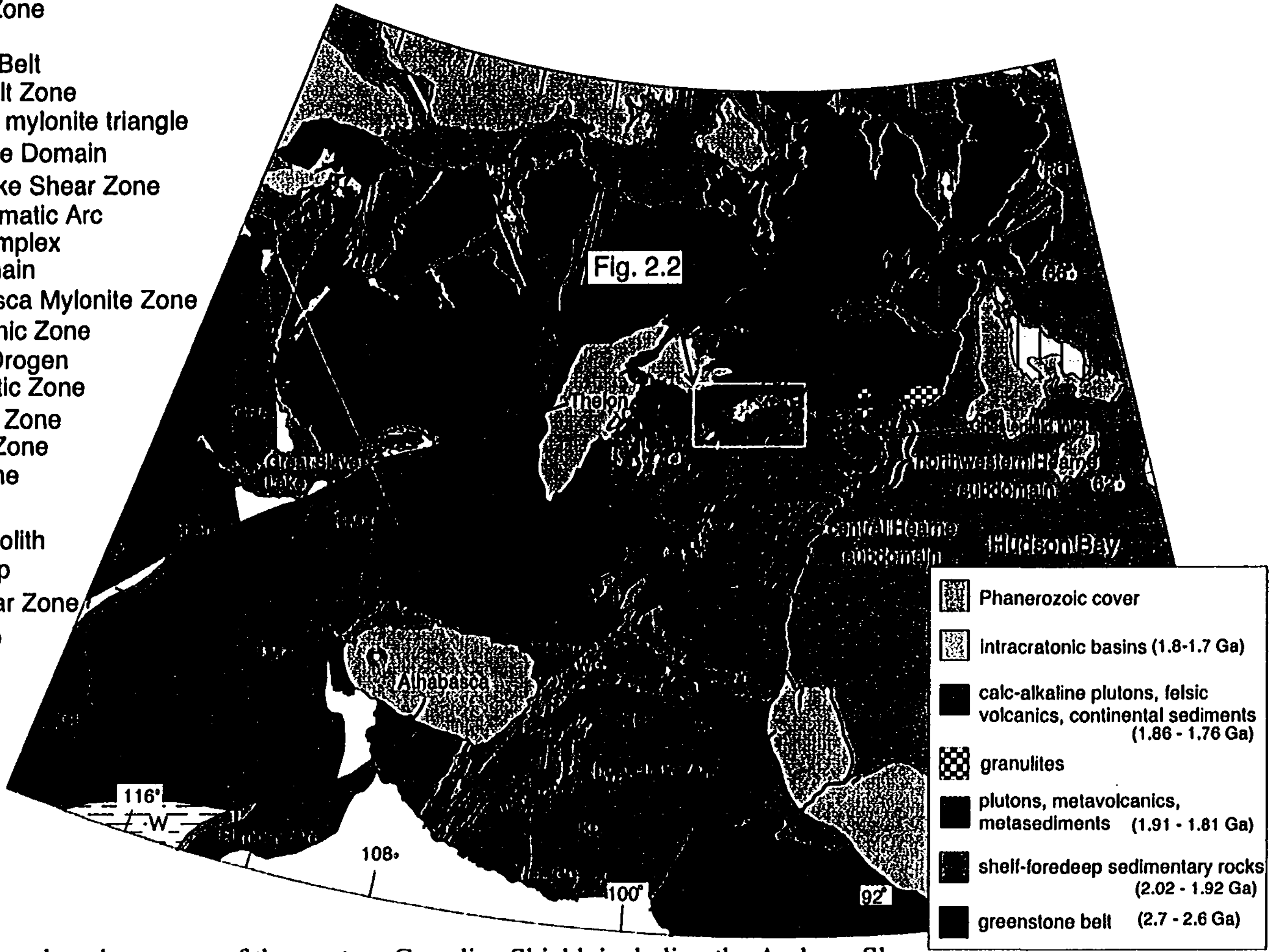


Figure 2.1: Regional geology map o f the western Canadian Shield, including the Archean Slave, Western Churchill (Rae-Hearne), and Superior provinces (after Wheeler et. al, 1997).

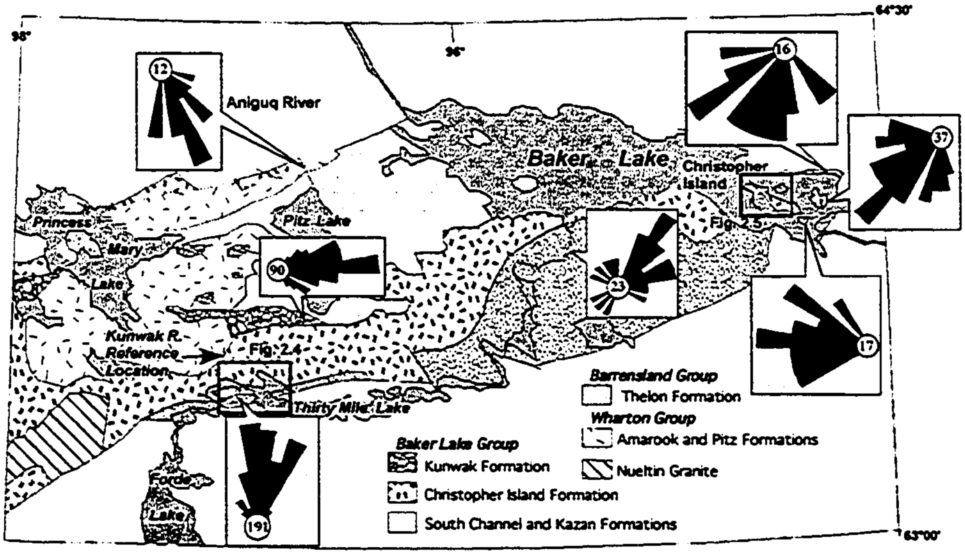


Figure 2.2: Geology of the Baker Lake sub-basin, including paleocurrent data derived from cross-set and primary current lineation measurements. Note Thirty Mile Lake, Kunwak River, Aniguq River, and Christopher Island study areas.

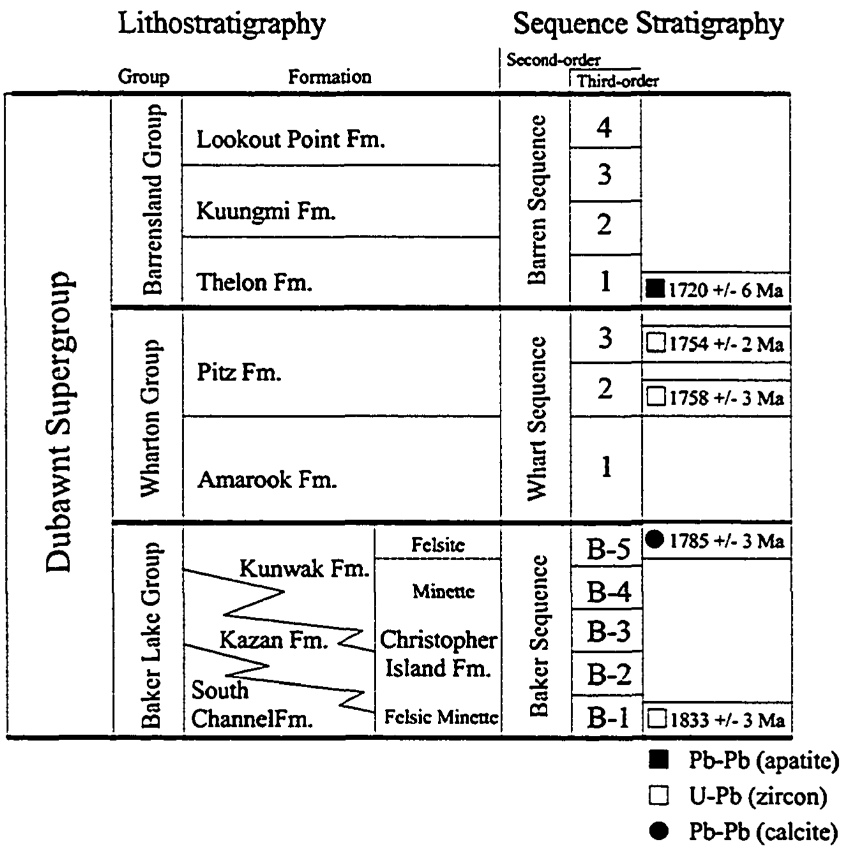


Figure 2.3: Litho- and sequence stratigraphy of the Baker Lake Basin. Geochronology sources: Thelon Fm., 1720 +/- 6 Ma (Miller et al., 1989); Pitz Fm., (Rainbird et al., 2001); Baker Lake Grp.,1785+/-3 Ma (Rainbird et al., 2002), 1833+/-3 Ma (Rainbird et al., in press).

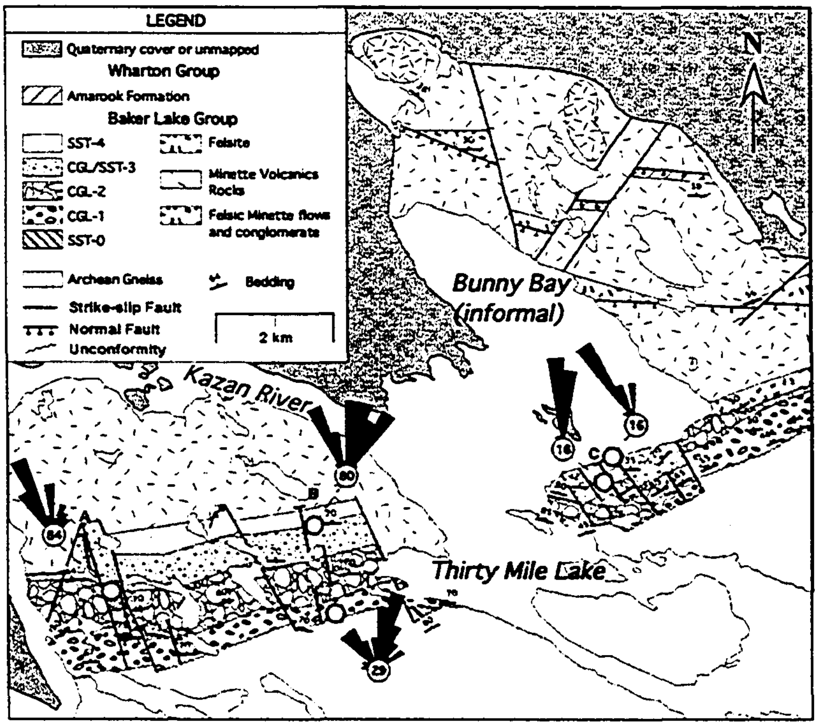


Figure 2.4: Geologic map of the Thirty Mile Lake study area. Paleocurrent data were derived from cross-set measurements. CGL = conglomerate and SST = sandstone.

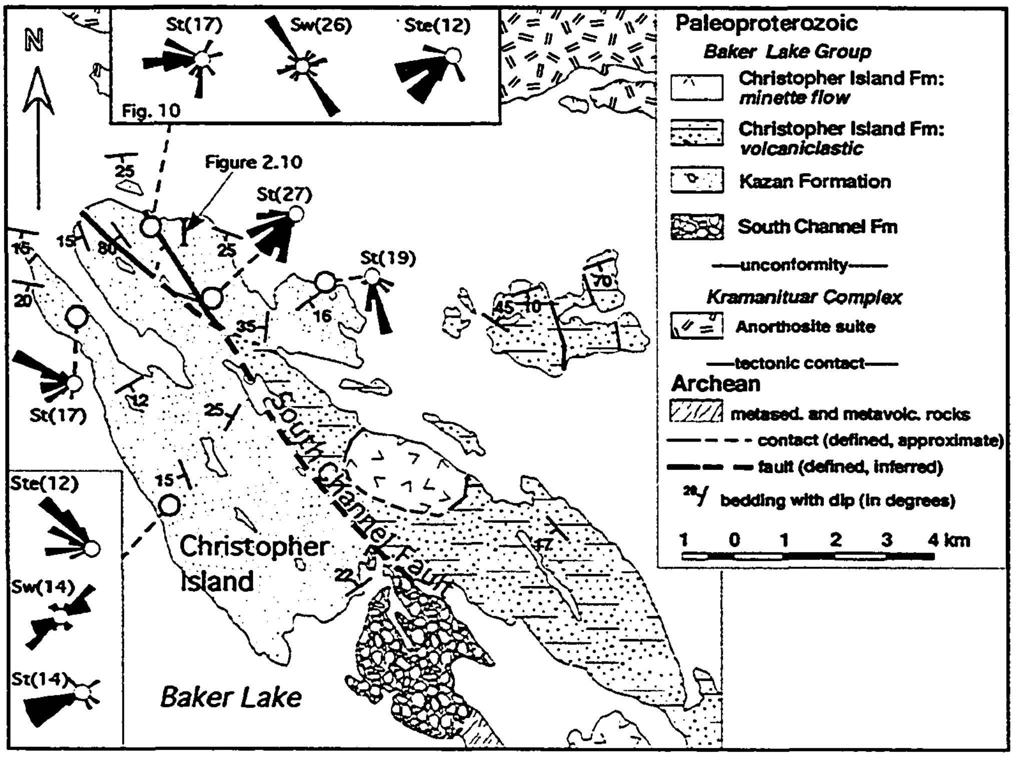


Figure 2.5: Geologic map of the Christopher Island study area including paleocurrent data (St = fluvial; Sw = wave ripple crests; Ste = eolian cross-sets). Note location of section displayed in Figure 2.10.

Figure 2.6: Sedimentological features of the alluvial fan facies association (FA), Thirty Mile Lake area. **(a)** Three upward-fining bedsets in the alluvial fan FA; top of first beneath rock hammer (centre); two more to left of hammer. **(b)** Organized framework cobble conglomerate with alternating tabular cobble and pebble layers, similar to conglomeratic "couplets" described by Blair (2000b). Lens cap diameter is 5 cm. **(c)** Disorganized framework, cobble conglomerate, showing a granular sand accumulation above a framework pebble. Coin is 2.5 cm in diameter. **(d)** Disorganized framework, cobble conglomerate from the alluvial fan FA. Notebook for scale is 20 cm long.

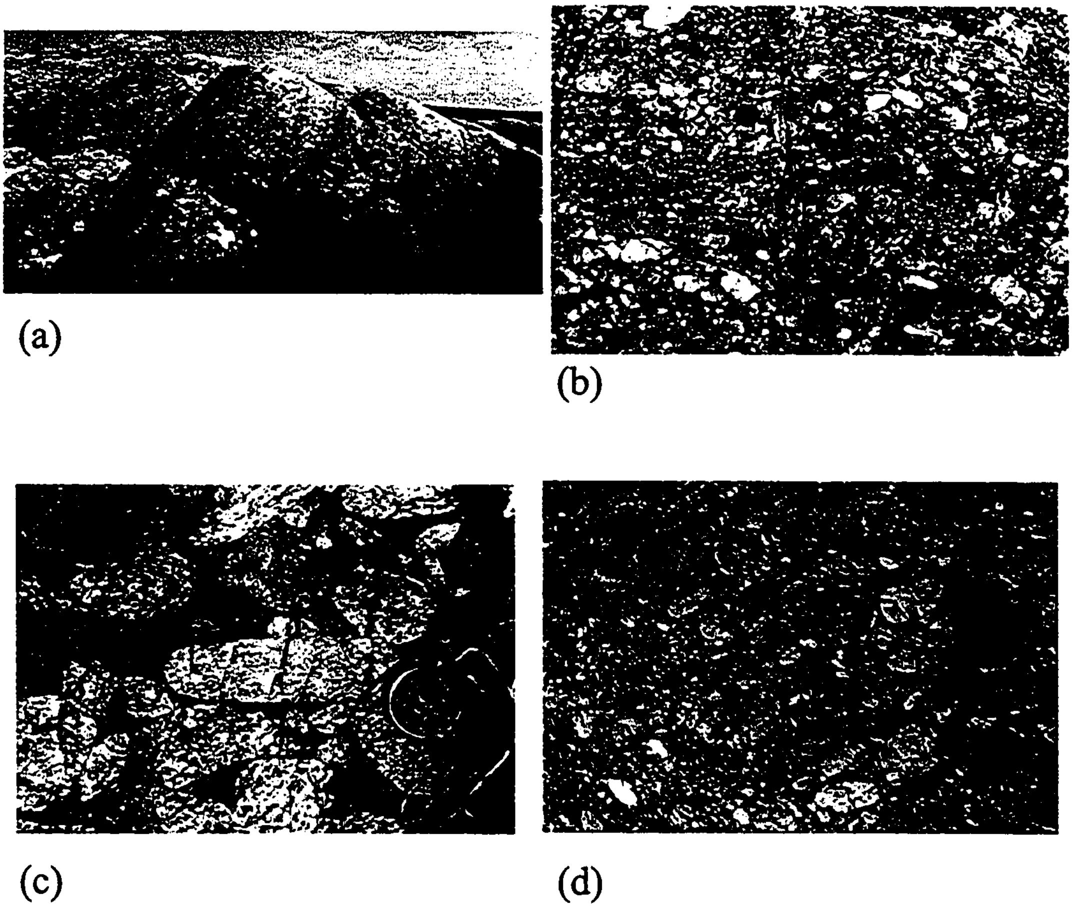


Figure 2.6a-d

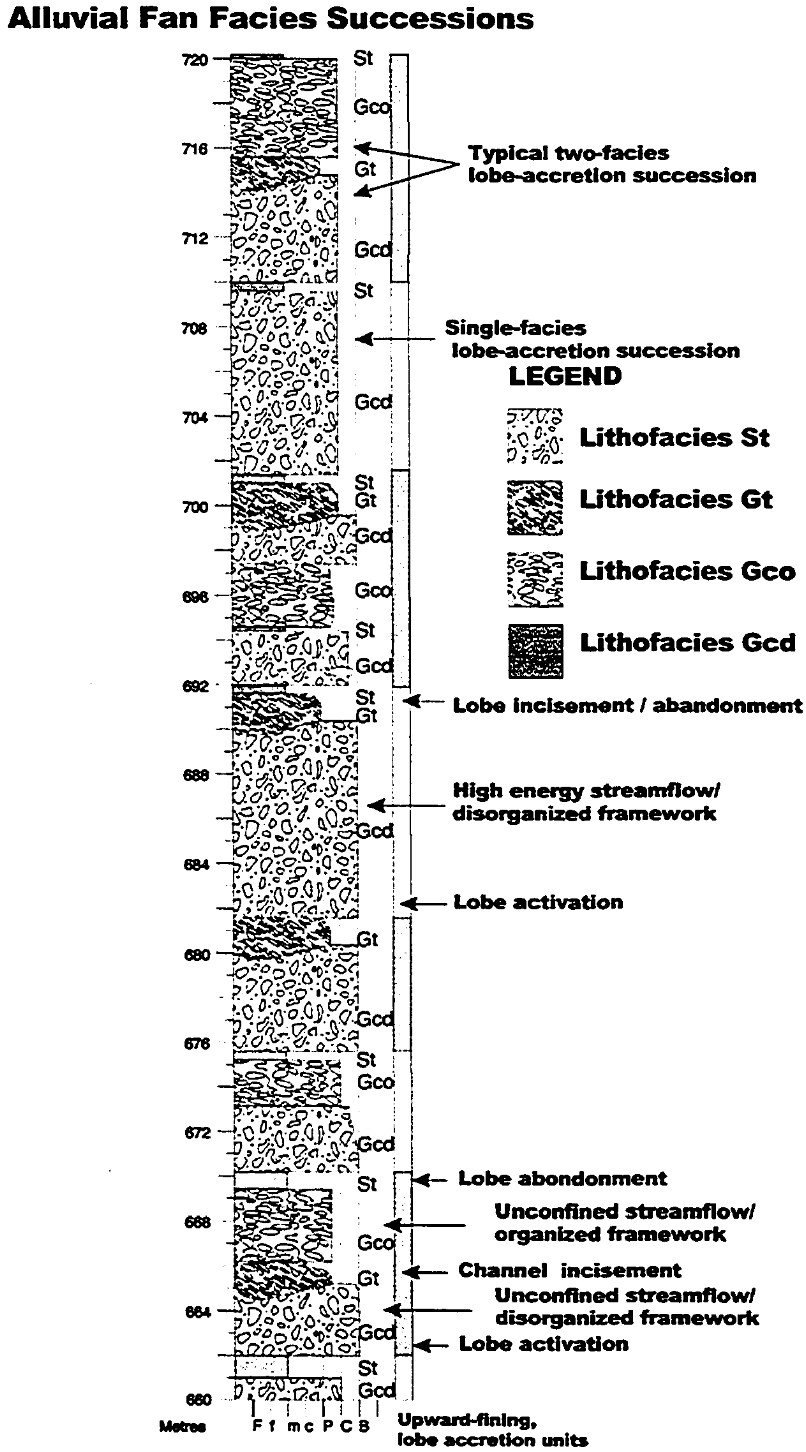


Figure 2.7: Stratigraphic section from Thirty Mile Lake study area (section B; Figure 2.4) displaying upward-fining intervals of the alluvial fan facies association. Lithofacies abbreviations from Miall (1977) and Jo et al., (1997), see Table 2.1.

Figure 2.8: Sedimentological features from facies associations (FA) 3-7. Lens cap is 5 cm. **(a)** Linguoid ripples above primary current lineation from the sand-bed braided stream FA; knife is 10 cm long. **(b)** Erosional surface marked by granule lag truncating medium-grained, cross-stratified sandstone and overlain by inversely graded sandstone laminae, of the sand-bed braided stream FA. The overlying laminae, interpreted as eolian, suggests that this is a deflation lag formed by winnowing of fluvial deposits. **(c)** Inversely graded lower foresets of a 1.5 m thick eolian cross-set, interpreted as sub-critically climbing wind ripple lamination. Faint cross-laminae are visible within these foresets. **(d)** Floodplain FA, in which an inclined planar-laminated sandstone (Sh) interval lies between units of horizontally laminated mudstone-siltstone-sandstone (Fl). Some inclined sets are interlaminated with mudstone and form mudstone dishes indicative of subaerial exposure (inset). To the right side of the photograph, on an oblique exposure, arrows highlight inclined surfaces. This is interpreted as a crevasse splay that prograded onto a mud-rich floodplain, was abandoned and subsequently overlain Fl facies. Rock hammer is 75 cm long. **(e)** Playa FA, showing alternating cross-stratified sandstone grading upward into laminated mudstone with abundant desiccation cracks. **(f)** Wave-ripple lamination from a rippled sandstone sheet from the lacustrine FA, interpreted as a mouth bar deposit. **(g)** Erosional surface and lag truncating cross-stratified sandstone overlain by mudstone. This is interpreted as a wave-ravinement surface overlying an interdistributary channel in a deltaic environment. **(h)** Normally graded, upward-thinning and upward-fining laminae, containing mudstone clasts: interpreted as delta-front turbidite deposits. Pen is 1 cm wide.

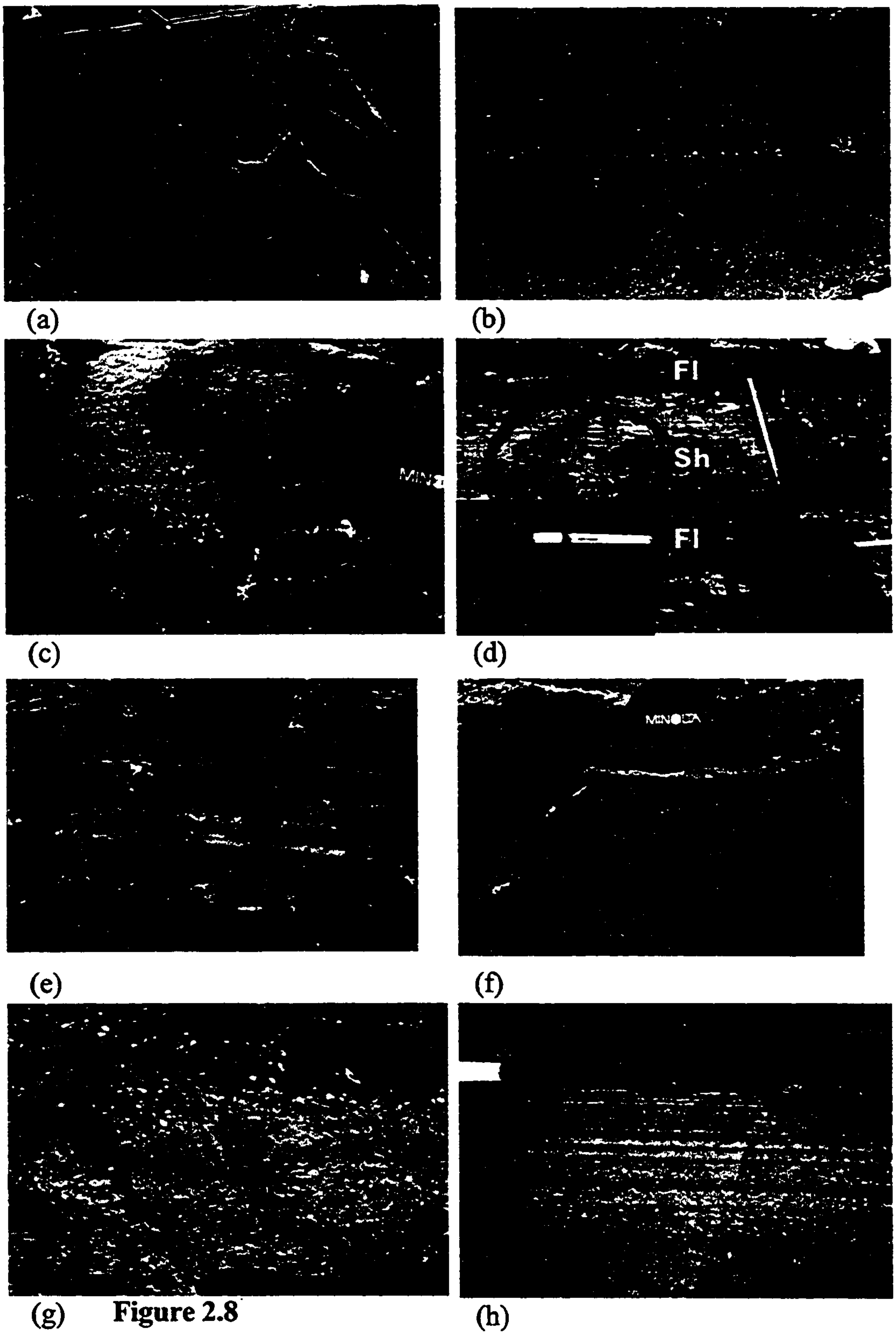


Figure 2.8

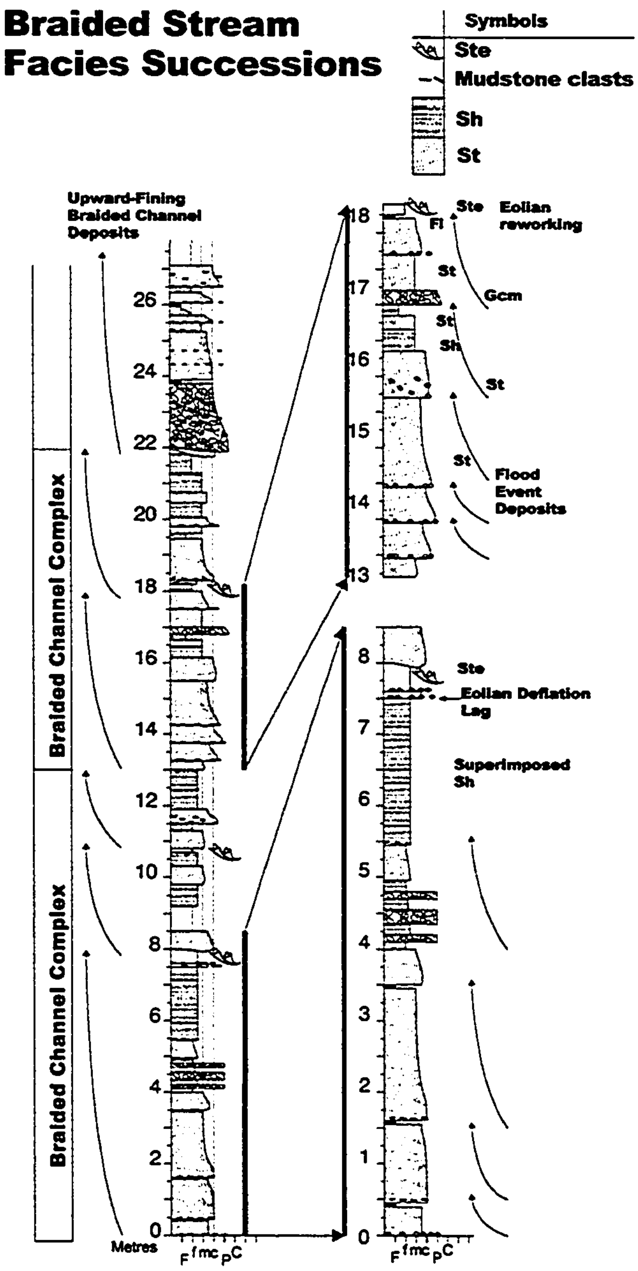


Figure 2.9: Stratigraphic section from Thirty Mile Lake study area displaying facies successions from braided stream and floodplain facies associations. Lithofacies abbreviations from Miall (1977); see Table 1. Section derived from Thirty Mile Lake section C.

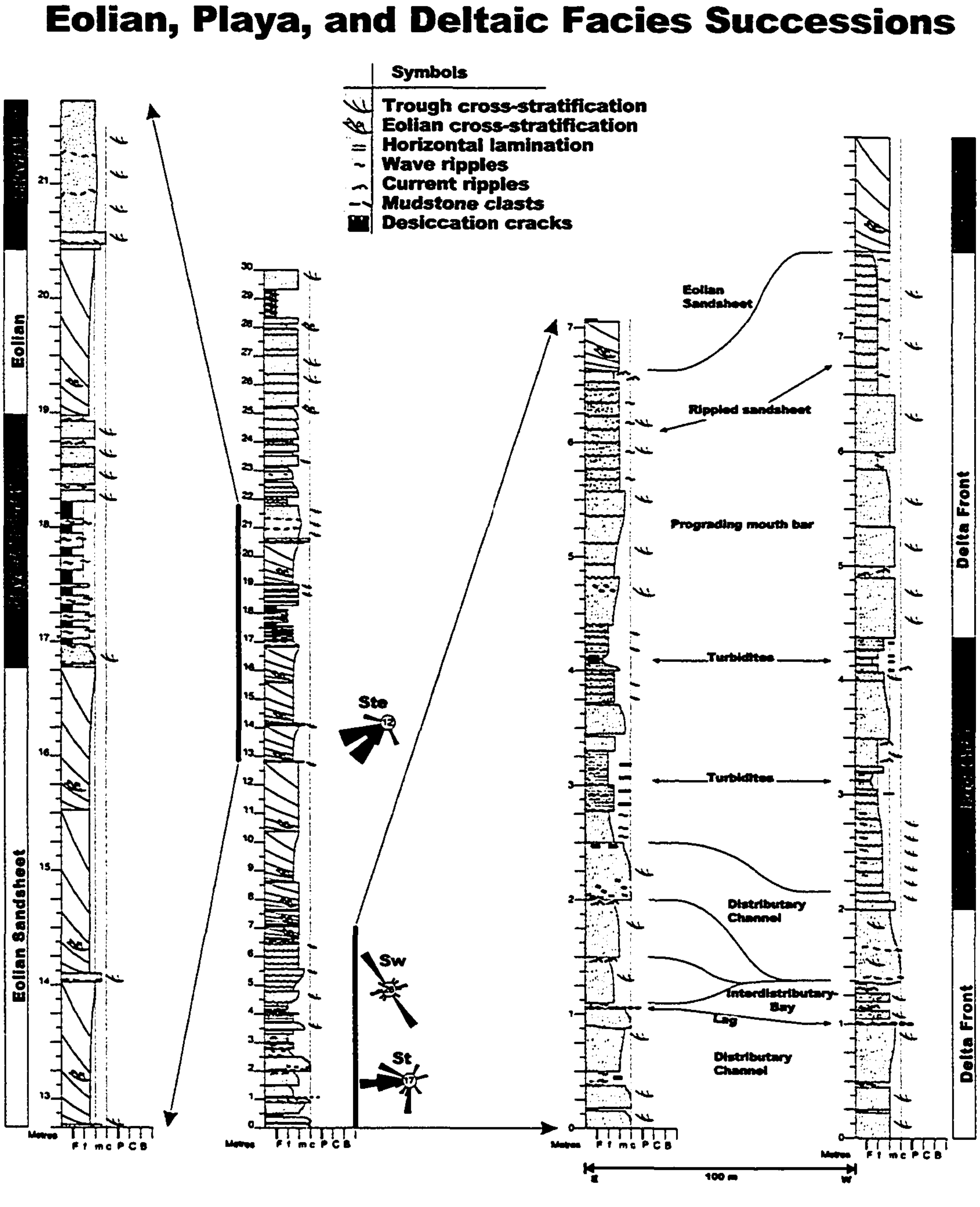


Figure 2.10: Stratigraphic section from northwest Christopher Island study area, showing lacustrine, eolian, and playa facies assemblages. Section location is shown in Figure 2.5. Paleocurrent data are derived from cross-sets (St), wave ripple crests (Sw), and eolian cross-sets (Ste).

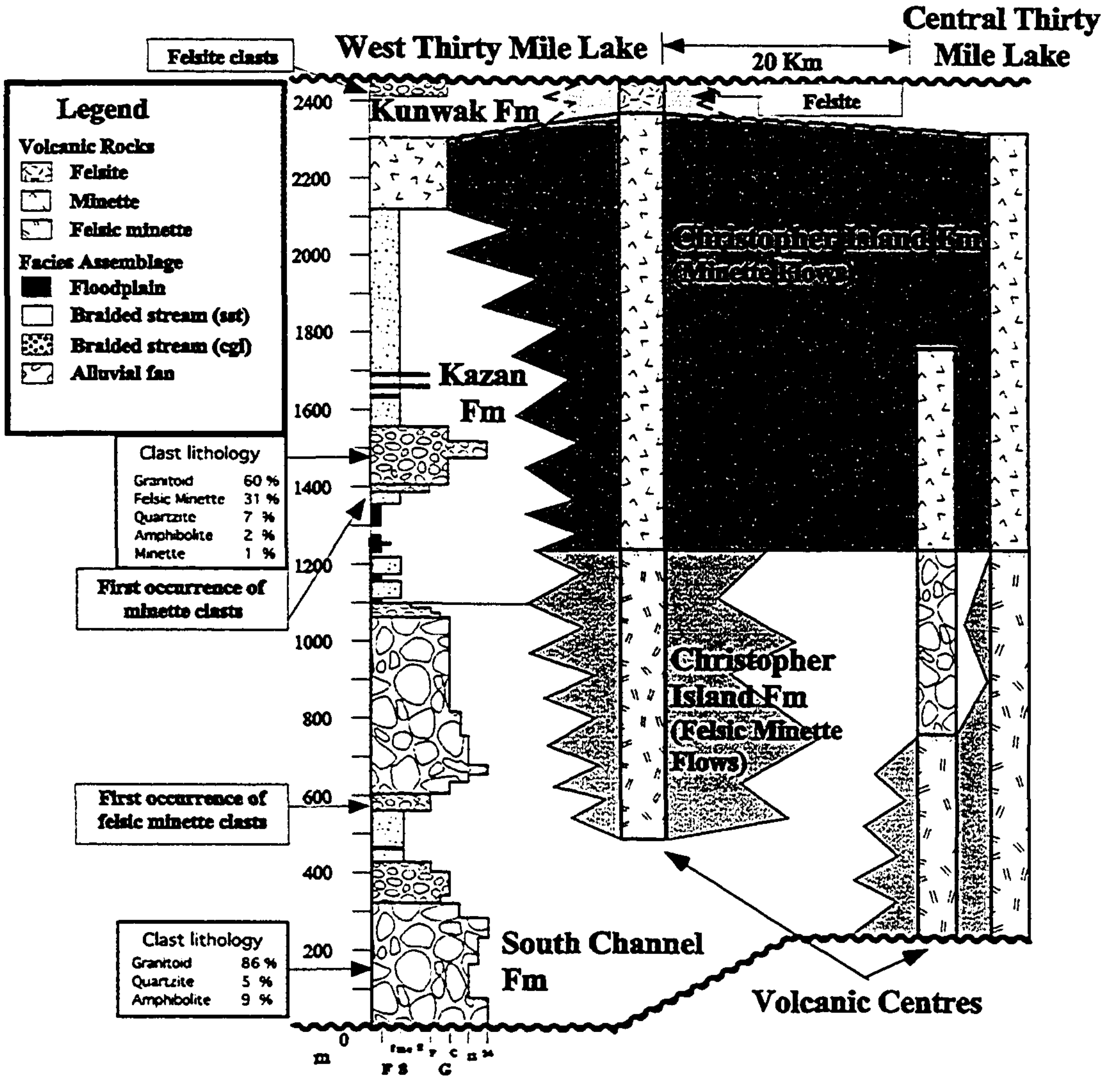


Figure 2.11: Volcanic and sedimentary relations between west Thirty Mile Lake and central Thirty Mile Lake.

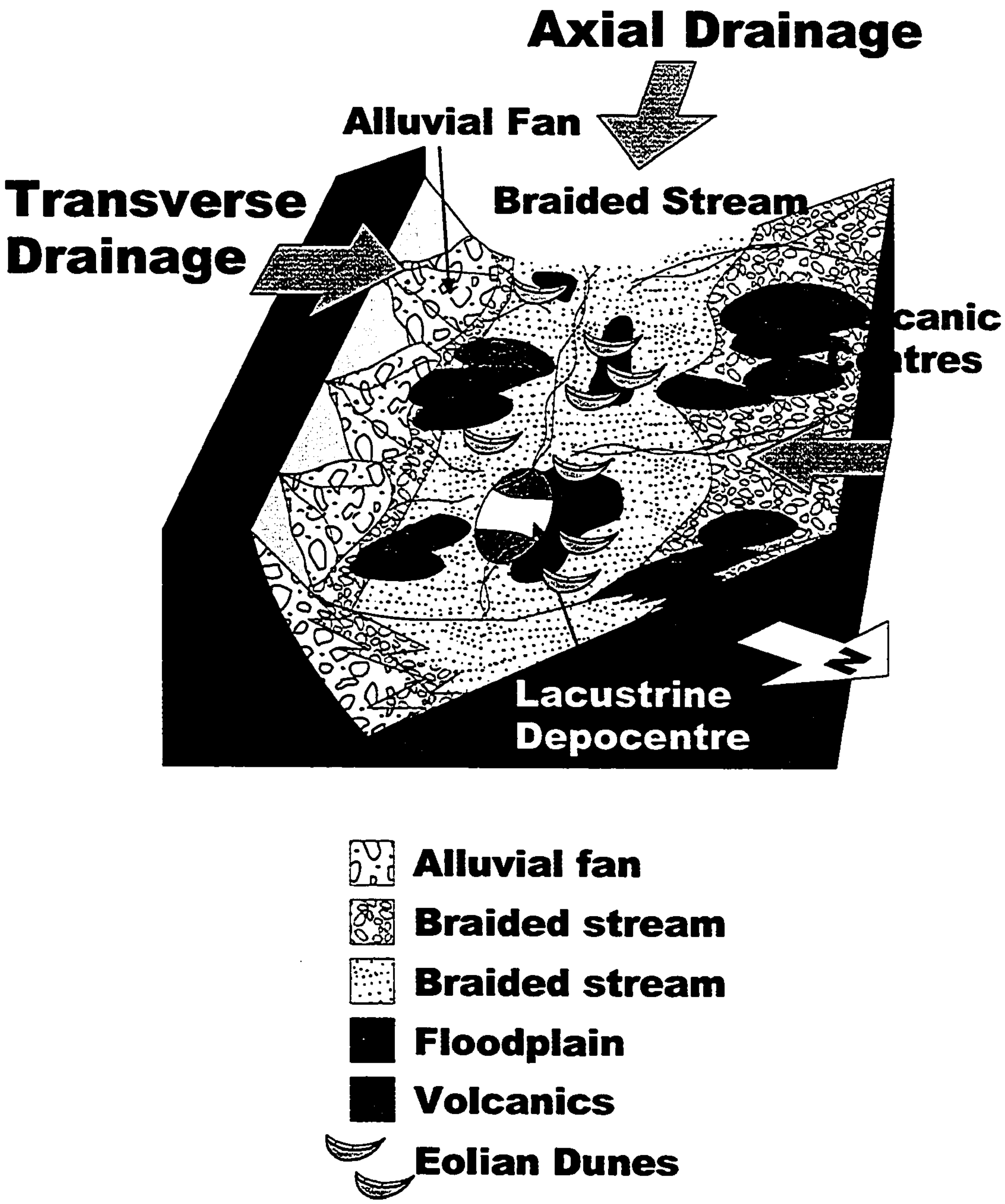


Figure 2.12: Schematic block diagram of half-graben and facies tracts from the Baker Sequence. View facing southwest.

<u>CHAPTER 3</u>

SEQUENCE STRATIGRAPHY OF THE NON-MARINE BAKER LAKE GROUP, BAKER LAKE BASIN, NUNAVUT, CANADA

Abstract

A model is presented here for alluvial sequence stratigraphy and applied to the non-marine, Paleoproterozoic Baker Lake Basin. Discharge and sediment supply are considered boundary conditions, subject to feedback effects. Primary control on alluvial facies changes is attributed to the gradient of the alluvial plain. This gradient is determined by the "graded profile", a topographic profile defined by a graded stream linking a sediment source region to a subaqueous basin. It is argued that coupled source uplift and basin subsidence provide feedback on sediment supply, -grade, and –flux that reinforce expected facies changes, in part providing justification of initial assumptions. The model provides a rationalization for a generally upward-fining alluvial sequence that is coeval with a general upward-fining to –coarsening nearshore sequence. It also provides an interpretation of basin-scale stratigraphy based on the tectonic evolution of sedimentary basins, in keeping with the models for how they form.

Third-order depositional sequences of tectonic origin from the Baker Lake Basin are subdivided into high accommodation alluvial, low accommodation alluvial, and mixed fluvial-shallow-lacustrine sequences. The succession of 3rd order sequences illustrates basin evolution from rift initiation, rift climax accompanied by widespread volcanism, to immediate post-rift that comprises the 2nd order Baker Sequence, representing a stage of intracontinental rifting from ca. 1.84-1.79 Ga.

3.1.0 Introduction

There has been much debate as to the stratigraphic character and architecture of subaerial depositional sequences and how they relate to subaqueous depositional sequences (Vail et al., 1997; Posamentier and Vail, 1988; Miall, 1991; Westcott, 1993; Wright and Marriott, 1993; Shanley and McCabe, 1994; Olsen et al., 1995).

Fluvial deposits were initially incorporated into sequence stratigraphic models (Posamentier et al., 1988; Posamentier and Vail, 1988) by employing the concept of *stream equilibrium profile*, based on the graded stream concept (Mackin, 1948), to link fluvial and marine systems. These models predicted that alluvial accommodation requires seaward migration of the bayline during relative sea level high- or lowstand, implying that alluvial accommodation was inversely related to marine accommodation. This may be accurate with respect to alluvial deposition at nearshore locations, where fluvial deposition would occur during sufficiently low relative sea level in contrast to marine deposition during high relative sea level, but does it apply to fully non-marine successions deposited landward of nearshore environments?

In general, most workers consider a fluvial/alluvial depositional sequence to comprise an upward-fining succession (e.g. Westcott, 1993; Wright and Marriott, 1993; Shanley and McCabe, 1994; Olsen et al., 1995; Plint et al., 2001; Atchley et al., 2004), based primarily on the occurrence of paleosols within floodplain deposits at the top (Wright and Marriott, 1993; Shanley and McCabe, 1994), but including other types of sequence boundary criteria (Miall, 2001), thought to correlate with unconformities at shelf locations (Vail et al., 1997). This functional definition incorporates low- and high-accommodation systems tracts (Shanley and McCabe, 1994; Olsen, 1995; Plint, 2001) reflecting low and high depositional rates that are correlated to established low- (LST/HST) and high- (TST) accommodation, marine systems tracts.

The Baker Lake Basin was a tectonically active, terrestrial, and hydrologically closed basin during deposition of the Baker Lake Group (Donaldson, 1967; LeCheminant et al., 1979b, Gall et al., 1992; Rainbird and Hadlari, 2000; Rainbird et al., 2003), or equivalent Baker second-order sequence (Rainbird et al., 2003). Thus it provides an opportunity to filter out the effects of sea level in order to examine the relationship between sedimentary dynamics and tectonic parameters. In order to interpret the stratigraphy from a basinal perspective, a model is presented for the sequence stratigraphy of alluvial systems wherein the concepts of fluvial accommodation space and the graded stream are revisited, and which is subsequently applied to the Baker second-order sequence (*sensu* Krapez, 1996).

3.2.0 Terrestrial Sequence Stratigraphy: *conceptual model*

3.2.1 Factors

A terrestrial sequence stratigraphic model must be based upon the fundamental concepts of established sequence stratigraphy. These include the parameters sediment supply (S), sediment flux (SF), base level, accommodation space (AS), and accommodation (A). Sediment supply is the sediment available to the system; it is a function of erosion in the source region or along the course of the river. Non-marine sediment flux is primarily through fluvial pathways. The upper boundary to subaqueous accommodation space is sea or lake level. In the application of sequence stratigraphy to fluvial systems, the definitions of base level and accommodation space require a more complex definition than relative sea or lake level.

As proposed by Posamentier and Vail (1988), a reasonable way to define fluvial accommodation space is to employ the concept of the graded river (Gilbert 1977; Davis 1902; and Mackin 1948) to define the upper boundary of subaerial accommodation space. Thus subaerial accommodation space can be considered the space between substrate and a graded profile, or potential graded profile, which can be positive, negative, or zero. Note that Posamentier and Vail (1988) use the term *equilibrium profile* after the state of dynamic equilibrium that the graded stream is thought to exist. Quirk (1996) noted that this term is unnecessary, since the definition is equivalent to (and based on) that proposed by Mackin (1948) for *graded profile*. Also, Posamentier and Vail (1998) posited that the graded profile ends at a bayline whereas Miall (1991) suggested that the shoreline would more properly take into account sediment flux.

Mackin (1948) defined the *graded stream* as, "one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for the transportation of the load supplied from the drainage basin... readjustment is effected primarily by appropriate modification of slope by up building or down cutting..." A graded stream is characterized by zero net deposition or erosion along its length. Slope is inversely proportional to discharge and positively proportional to grain size, hence a graded profile decreases in slope downstream.

3.2.2 Facies

To apply the graded profile-accommodation space concept to interpretation of stratigraphic successions, facies must be incorporated. Well-established characteristics of streams are:

1. Downstream fining due to grain abrasion and selective deposition of coarse fractions (Paola and Seal, 1995);
2. Abrupt transitions in grain size and slope (Sambrook-Smith and Ferguson, 1995); for example the transition of gravel to sand accompanied by a decrease in slope, corresponding to a change in transport mode from bedload to mixed load and therefore a different Shields parameter (Dade and Friend, 1998);
3. Commonly identified stream types, such as braided and meandering, are discharge- and gradient-dependent (Schumm, 1985).

The observed trend of downstream fining accompanied by abrupt transitions in grain size and slope should provide lithological sub-divisions of proximal to distal facies.

The empirical relation (Lane, 1955) between water discharge, Q, channel slope, S, sediment discharge, Q_s, and median particle size, d_{50}, can be expressed as:

$$QS \sim Q_s d_{50} \qquad \text{(Lane, 1955)}$$

Consider that a stream at grade is characterized by zero net deposition and erosion, therefore downstream sediment flux per unit channel width is constant (Dade and Friend, 1998). By this proposition, complications associated with converging channels and increasing total discharge are avoided, and a two-dimensional profile is sufficient to represent the potential graded profile (Dade and Friend, 1998). Now, if for a given fluvial system SF (or Q_s) and water flux (Q) remain relatively constant, then slope (S) is proportional to grain size (d_{50}). This is a suitable assumption because recent studies suggest that sediment yield is stable over geologic time scales either due to tectonic control or because the fluvial sediment system is inherently dynamically stable (Phillips, 2003). Thus, changes in grain size can be broadly attributed to changes in paleoslope, and combined with downstream fining trends and the gradient dependency of stream types (e.g. braided to meandering), should yield predictable downstream facies transitions. Schumm and Khan (1972) have demonstrated gradient control of facies experimentally, concluding that for a given discharge, as slope is progressively increased a straight river becomes sinuous and then braided. Based on these principles, a graded profile can be sub-divided into proximal to distal facies zones of decreasing grain size and inferred gradient (i.e. gravel-bed to sand-bed braided stream).

As a hypothetical exercise, assuming that the required grain sizes are available, a graded profile can be constructed with respect to facies for a given discharge regime (Fig. 3.1) by considering that each facies is stable within a gradient range (e.g. Schumm, 1985). If the net gradient between the sediment source point and the shoreline (or end-of-stream) were to fall within the range of the lowest gradient facies A, then the graded state would be defined by that facies (Fig. 3.1a). Establishment of grade would involve deposition beginning near the sediment source, initial selective deposition of coarse grain size fractions, and therefore an upward-fining succession. In a second case, if the net gradient exceeds the range of facies A, then a higher gradient facies B be established starting at the sediment source point, and comprise the minimum length required as part of the graded profile (Fig. 3.1b). With increasing net gradient (or "set up") this process would continue until a maximum gradient facies is determined by the sediment supply, grain size, or discharge. For example, if cobbles and boulders comprise a small proportion of the sediment available, then only a small component of the graded profile can be alluvial fan facies regardless of the net gradient set up, and the head of the alluvial fan will abut against the presumably uplifted area. Alternatively, since the transition from meandering to braided stream can occur at the same gradient but with increasing water discharge (Schumm, 1985), in high discharge, or ephemeral flash-flood type regimes, braided streams are the predominant stream type even at relatively low gradients.

In accordance with the approach to subaqueous and nearshore deposits, it is not necessary to estimate exact paleoslope (e.g. Paola and Mohrig, 1996), but simply to identify relative changes, for a given fluvial system, with respect to basinward or sourceward facies migrations. In this context a basinward migration of facies would result in a coarsening-upward or progradational succession and vice versa. Now it is possible to interpret and predict relative facies changes based on graded profile evolution. Quirk (1996) has reviewed how a graded profile would react to various factors including relative sea level (RSL), uplift, and subsidence; this is expanded upon in Fig. 3.2. Note that the Baker Lake Basin was a terrestrial system, and so the upper boundary to subaqueous AS is referred to as relative lake level (RLL), but in the general model RLL and RSL are interchangeable.

3.2.3 Dynamics of the Graded Profile

The graded profile is the upper limit of subaerial accommodation space in much the same way that sea level is the upper limit of accommodation space in marine or lacustrine systems – both represent potential space available, only realized when deposition occurs. Therefore, deposits are a function of the relationship between sediment flux and accommodation.

The depositional relationship between graded profile and sediment flux is inherently dynamic because a graded river is defined by zero net deposition; therefore the resulting deposits are a direct result of adjustments made by a river in a non-graded state. Furthermore, even if other factors remain constant, then through positive feedback effects fluvial sediment flux will tend to result in additional subaerial accommodation. This is illustrated in Fig. 3.2(a), the initial state is a graded profile intersecting subaqueous base level at the shoreline. If all relevant factors are positive (SF, discharge, base level), then fluvial sediment flux will result in subaqueous deposition at the shoreline (i.e. delta), and accordingly progradation. Basinward migration of the shoreline will decrease the net gradient of the graded profile and a small amount of fluvial accommodation space will have been created and filled between the initial graded profile and the resultant graded profile. Although not shown on the diagram, erosion of the sediment source region will tend to lower the elevation of the sediment source point, decreasing the gradient further (Nummedal et al., 1993). The decrease in gradient over the course of alluvial deposition will result in a retrogradational succession of fluvial facies concurrent with progradation of nearshore facies. Opposing trends between river-mouth and upper valley locations were also envisaged by Nummedal et al. (1993), who suggested that "aggradation characterizes the lower alluvial valley in response to river-mouth progradation, and that the upper valley reaches degrade." This represents the dynamics of the fluvial system during relatively static conditions, and illustrates the nature of the graded profile concept as a state of dynamic equilibrium.

The response of the graded profile to changes in relative lake level is more complex, and is directly related to the ratio of SF to A (rate of accommodation space creation), as incorporated into shelf sequence stratigraphic models (Vail et al., 1977). If subaqueous base level rises and accommodation exceeds sediment flux, then the rate of deposition *along* the graded profile *and* at the shoreline is exceeded by base level rise and the shoreline will retreat landward (Fig. 3.2b). From Fig. 3.2b, if other factors remain unchanged, then base level rise will result in a decrease in gradient of the graded profile, hence retrogradation of both fluvial and nearshore subaqueous facies. If SF = A, then fluvial and nearshore deposition will fill new accommodation space and nearshore facies will aggrade; however, the fluvial gradient will decrease and therefore fluvial facies will retrograde. If SF > A, then fluvial and nearshore deposition will exceed accommodation and original AS will be filled as nearshore facies prograde; the fluvial gradient will decrease and fluvial facies will retrograde. If, for a given fluvial system sediment flux is approximately constant, then we can restate these SF/A relations as high to low accommodation systems representing transgressive and highstand/lowstand systems tracts. Relative lake level fall (Fig. 3.2c) will result in a basinward migration of the shoreline, and subaerial erosion starting at the old shoreline, and an increase in gradient of the graded profile and thus stream calibre. Basinal facies will prograde in response, and when RLL fall ceases, coarse fluvial deposits will overlie an erosional surface. Note that within the model, lake level rise, exclusively, does not result in an increase in net gradient of the graded profile; in each of the three cases described, alluvial facies are expected to retrograde, a point that would be reinforced if source region denudation were considered.

Thus far, changes in relative lake level have been addressed. These changes could be the result of lake level fluctuations, and/or basin subsidence/uplift; however, the type of subsidence considered would be quite specific, affecting the source and basin uniformly, a relation that is expected to breakdown toward basin margins due to differential subsidence and source uplift. Fig. 3.2d and Fig. 3.2e address tectonic factors. Fig. 3.2d considers the effect of source region uplift, which is assumed to be the result of faulting and not a general tilting of the basin margin. The result is an increase in gradient of the graded profile as the alluvial system aggrades to match uplift of the sediment source region. This results in progradation of fluvial facies, and deposition between the initial graded profile and the new graded profile. The progradation of facies is highly dependent upon sediment flux and the ability of the alluvial system to aggrade in response to source uplift. Note that, primarily as a function of the calibre of sediment supplied, the profile would have an upper gradient limit, in which case the depositional part of the stream would abut against the uplifted area. Also, in consideration of the amount of potential alluvial accumulation, nearshore environments may be characterized by low rates of sediment flux. Or, due to selective deposition of coarse fractions upstream, characterized by fine-grained sediment (e.g. Paola and Seal, 1995); unless source uplift dramatically increased S and SF thereby oversupplying the alluvial plain and transporting sediment to nearshore locations.

In the case of differential subsidence increasing toward the basin centre, the effects will be more complex than for lake level rise. This is because differential subsidence results in dynamic topography. The land surface, and hence the graded profile, will become tilted toward the basin. The result is a forced increase in gradient, producing a more competent streamflow, and thus promoting progradation of alluvial facies and increase in grain size. Nearshore locations will experience relative lake level rise, and lacustrine facies will retrograde.

In tectonically active basins, subsidence and marginal uplift are genetically linked. For example, subsidence in a foreland basin is a response to tectonic loading and crustal thickening in the adjacent orogen (Quinlan and Beaumont, 1984). Similarly, normal fault motion in a rift basin provides relative basin subsidence and coeval marginal uplift (e.g. Leeder, 1995). The result for a graded profile is concurrent source uplift and basinal subsidence (Fig. 3.2e). This will have the simultaneous effects of an increase in gradient of the graded profile and a relative rise in subaqueous base level. The high fluvial accommodation and net increase in gradient will result in progradation of fluvial facies. The high potential for fluvial deposition will result in low nearshore sediment flux, thereby increasing the probability of retrogradation of nearshore facies in response to relative lake level rise. Indeed, there are expected to be feedback effects upon sediment supply and flux which have been omitted for the sake of simplicity. For example, source uplift would be expected to increase the grain size of sediment supply. Within the context of the model this will tend to reinforce the expected progradation of fluvial facies (Fig. 3.2d and e). Upon cessation of uplift/subsidence, denudation of the source region would tend to decrease grain size and sediment flux enhancing the expected retrogradation of fluvial facies, in concert with nearshore progradation as in Fig. 3.2a. Since every sedimentary basin is characterized, indeed defined, by some form of tectonic subsidence and that changes in base level will only be recorded in deposits when superimposed on a subsidence curve (e.g. Nummedal et al., 1993), the most relevant models are those that incorporate subsidence (Fig. 3.2a, c, d, and e). Successional patterns in proximal alluvial and nearshore subaqueous environments are thus decoupled throughout the accommodation cycle: tectonic subsidence such that A>SF leads to progradation and retrogradation, respectively (Fig. 3.2e); stillstand or SF>A (tectonic or subaqueous base level) leads to retrogradation and progradation, respectively (Fig. 3.2a); and finally base level fall likely leads to erosion in both (Fig. 3.2c), transporting coarse detritus to more basinal locations. This model concludes that fluvial accumulation occurs mostly during relative lake or sea level rise and during periods of tectonism and source uplift as suggested by Miall (1991).

3.3.0 Sequence Stratigraphy of Baker Lake Basin

3.3.1 Regional Geology

Greater Baker Lake Basin extends from Dubawnt Lake northeast to Baker Lake (Nunavut, Canada) and comprises a series of northeast-trending intracontinental basins, including the Baker Lake sub-basin (Rainbird et al. 2003; Fig. 3.3; Fig. 3.4). Basin fill comprises the faulted but unmetamorphosed, siliciclastic and volcanic rocks of the Dubawnt Supergroup (Wright, 1955; Donaldson, 1967; LeCheminant et al., 1979b, Gall et al., 1992; Rainbird and Hadlari, 2000; Rainbird et al., 2003; Fig. 3.5).

The Dubawnt Supergroup is sub-divided into three unconformity-bounded lithostratigraphic units that correspond to, from oldest to youngest: the Baker Lake, Wharton, and Barrensland groups (Donaldson, 1967; Gall et al., 1992; Rainbird and Hadlari, 2000); or the Baker, Whart, and Barrens second-order sequences (Fig. 3.5; Rainbird et al., 2003; sensu Krapez, 1996; 1997). These groups or corresponding second-order sequences have been interpreted to represent the tectonic stages of rift, modified rift, and thermal sag respectively (Rainbird et al., 2003).

The sedimentology of the Baker Lake Group (Rainbird et al., 2003; see Chapter 2) indicates a transverse drainage system of alluvial fans to braided streams, with floodplains and eolian dunes adjacent to inactive channels. This transverse system fed an axial drainage system that was directed northeast and less extensively southwest, culminating at a depocentre near Christopher Island. At this depocentre, deltas fed into a lake surrounded by floodplains, mudflats, and eolian dunes with prevailing wind from the southeast and northwest. The drainage system pattern and distribution of facies are consistent with deposition within a volcanically active half-graben.

The Christopher Island Formation comprises alkaline volcanic rocks inter-bedded with volcaniclastic and siliciclastic sedimentary rocks (Donaldson, 1966; LeCheminant et al., 1979a; 1979b; Blake, 1980). A generalized volcanic stratigraphy for the greater Baker Lake Basin, from oldest to youngest, consists of: felsic minette flows; minette flows; and felsite flows (Peterson et al., 1989; Hadlari and Rainbird, 2001; Rainbird et al., 2003). The felsic minette flows or equivalent volcaniclastic deposits overlie the basal unconformity of the Baker Lake Group and were erupted less extensively than the younger minette flows. Mantle-derived minette flows record voluminous extrusion throughout the entire basin and represent the largest known ultrapotassic volcanic province (LeCheminant et al., 1987; Peterson et al., 1989; Peterson et al., 1994; Cousens et al., 2001). Felsite flows are the youngest and most areally restricted volcanic rock.

Geochronological information has been primarily derived from volcanic or coeval intrusive rocks and bracket deposition of the Baker Sequence between ~1.84-1.79 Ga (see Rainbird et al., in press).

3.3.2 Methodology

The sequence stratigraphic method utilized herein follows Krapez (1996), after Vail (1977), Van Wagoner et al. (1990), and Posamentier et al. (1993), with respect to the reconstruction of sedimentary environments and interpretation of successions. Various orders of sequences in the Baker Lake Basin are described from basic metre-scale sedimentary cycles to kilometre-scale tectonic stages. For clarity during description, it is necessary to refer to the stratigraphic order each unit represents; these have been determined according to the framework outlined in Krapez (1996; 1997) after Vail (1977): First-order sequences correspond to the opening or closing of ocean basins - couplets of these correspond to the Wilson Cycle; Second-order sequences represent tectonic stages of basins (e.g. passive margin, foreland basin, or rift basin); Third-order sequences, or basin-filling rhythms, record pulses of accommodation and are a function of basin type (e.g. clastic wedges in foreland basins); and fourth-order sequences correspond to sediment flux patterns or relatively minor base level fluctuations.

With respect to unconformities, basin paleogeography and volcanic signature, the Baker Sequence represents a distinct tectonic stage within the Dubawnt Supergroup, and is therefore considered to be second-order (Rainbird et al., 2003). Within the thickest preserved sections (> 2 km thick), alternating coarse alluvial fan and fine braided stream / floodplain deposits hundreds of metres in thickness have been interpreted as third-order sequences, which are composed of lower-order progradational, aggradational, and retrogradational sequence sets (Hadlari and Rainbird, 2000; Rainbird et al., 2003). Following the hierarchical sequence concept these lower-order sequences are considered to be fourth order. They are not intended to be equivalent to fourth-order sequences from basins of different tectonic setting. These interpretations are based on sections from three locations in the Baker Lake sub-basin, Aniguq River, Christopher Island, and Thirty Mile Lake – primarily the latter two (Fig. 3.4).

3.3.3.1 Thirty Mile Lake

Baker sequence rocks near Thirty Mile Lake generally dip more than 45°, allowing sections measured to be from this area that are relatively thick. The stratigraphic thickness is much greater on the south side (Thirty Mile Lake) than on the north side of the basin (Aniguq River), reflecting proximity to the main bounding fault of the half-graben (Fig. 3.6). A volcanic section is correlated to the predominantly sedimentary section based on lateral facies transitions and conglomerate clast lithologies (Fig. 3.6). Alluvial fan, braided stream, floodplain, eolian, and volcanic facies comprise three sections from the western end of Thirty Mile Lake (Fig. 3.7). Although stratigraphic analysis here focuses on the sedimentary sections, basinal correlations largely depend on the volcanic sections.

Stratigraphic sections from Thirty Mile Lake are composed of alluvial fan, braided stream, and floodplain deposits, sub-divided into four distinct intervals hundreds of metres thick that can be correlated within the western Thirty Mile Lake area (Fig. 3.8). These represent the next hierarchical subdivision down from the Baker second-order sequence, interpreted as third-order sequences termed B-1, B-2, B-3, B-4, and considering the felsite bearing conglomerate at Kunwak River, B-5. B-1 is stratigraphically equivalent to felsic minette flows. B-3 is dominated by felsic minette clasts, but also contains minette clasts, indicating that minette volcanism had initiated during or immediately after sequence B-2. Sequence B-5 contains minette and felsite clasts, indicating that it is younger or equivalent to the felsite volcanic sub-division.

The 3rd-order sequences are composed of distinct upward-fining intervals approximately 5-15 m thick, interpreted as 4th-order sequences (Fig. 3.9) which are composed of sedimentary elements. Fourth-order sequences from the alluvial fan facies association consist of multiple conglomerate sheets that generally fine-upward, are alternately incised by channel-filling conglomerate, and capped by sandstone or laminated mudstone (Fig. 3.9). These are considered to be units of lobe accretion, and the punctuated succession to be a product of alluvial fan lobe activation and abandonment (see Chapter 2). Fourth-order sequences from the braided stream facies association are also upward-fining, and interpreted as 5-15 m thick channel complexes (see Chapter 2).

Fourth-order sequences from the floodplain facies association also fine-upward, with intercalated sandstone- and mudstone-dominated intervals representing small crevasse-type channels within an overbank setting. Floodplain deposits from Thirty Mile Lake display wet-condition features such as an abundance of wave ripples, indicating a near surface water table. Similarly, the eolian deposits from Christopher Island tend to contain wet-condition interdune intervals; their preservation appears to be linked to water table fluctuations (see Chapter 2).

3.3.3.2 Third-order sequences

Third-order sequence B-1 unconformably overlies crystalline basement rocks (Fig. 3.7). It comprises a thin (< 50 m) to absent progradational set of 4th-order alluvial fan sequences at its base. These pass upward into an approximately 300 m thick aggradational set of 4th-order alluvial fan sequences including boulder-grade conglomerate, overlain by a 100-200 m thick retrogradational set of 4th-order sequences from alluvial fan through gravel-bed to sand-bed braided stream deposits. The top of sequence B-1 is placed at the point of maximum retrogradation, marking the point of lowest depositional gradient.

At the base of sequence B-2, a progradational set of 4^{th}-order sequences grade from sand-bed braided stream through gravel-bed braided stream to alluvial fan deposits that demarcate a significant upward increase in depositional gradient. An aggradational set 300-400 m thick records the maximum gradient. This is succeeded by a set that retrogrades from alluvial fan to gravel-bed, to sand-bed braided stream, and finally to floodplain deposits from 10 to 100 m thick. The top of sequence B-2 is determined by maximum retrogradation. This is represented by eolian deposits within the floodplain facies. Above the eolian deposits, fluvial sandstone progressively dominates the floodplain facies, which then grades upward into sand-bed braided stream facies.

The base of B-3 is a progradational set of 4^{th} –order sequences, from floodplain through sand-bed to gravel-bed braided stream facies. At outcrop scale and between sections, thickness of the conglomerate and its stratigraphic level relative to the underlying floodplain mudstone are laterally variable over hundreds of metres, consistent with channelized flow as opposed to the steep unconfined flow of alluvial fans. Aggradation of coarse conglomerate is not as pronounced as it is in sequences B-1 and B-2; a retrogradational set of 4^{th}-order sequences defines the upper part of B-3. The facies that define the retrogradation differ slightly between sections. In section C (Fig. 3.8), gravel-bed braided stream facies grade upward into sand-bed braided stream, and then into approximately 100 m of floodplain-rich facies. At the top, floodplain fines are sharply overlain by sandstone and pebbly sandstone. In sections A and B, floodplain fines are less abundant, and laterally equivalent deposits comprise coarser, more proximal facies, consistent with thicker and coarser progradation-maximum deposits of sequence B-3 in sections A and B, and therefore a mark long term, more channel- proximal location.

Sequence B-4 has a very thin progradational component, from floodplain to thin gravel-bed braided stream deposits. This passes upward into > 200 m of sand-bed braided stream deposits. This sequence is interrupted at the top by minette flows (Fig. 3.8, section B).

At the west end of Thirty Mile Lake (Fig. 3.8), minette flows are overlain by felsite flows. On the Kunwak River, approximately 15 km north-northeast of section A, Baker Sequence conglomerate that contains both minette and felsite clasts is unconformably overlain by the Whart Sequence, and therefore is considered to be the youngest Baker Sequence siliciclastic deposit in the area. This conglomerate is considered to overlie the sandstone of B-4, and is therefore assigned to sequence B-5.

3.3.3.3 Application of the terrestrial sequence stratigraphic model:

The first step in applying the terrestrial sequence stratigraphic model to the Baker Sequence is to define the sedimentary facies tracts. Based on gradational facies boundaries within the sections at Thirty Mile Lake, linked facies of decreasing depositional gradient from proximal to distal are: alluvial fan, gravel-bed braided stream, to sand-bed braided stream and floodplain facies associations (see Chapter 2). Since this is an alluvial system and the location is inferred to have been adjacent to the basin margin, with respect to Fig. 3.2 these sections, illustrated in Fig. 3.8, are considered to lie in the proximal alluvial zone.

Fourth-order sequences represent accumulation-abandonment episodes of alluvial fan lobes, braided channel complexes, and floodplain channels. Thus, within the alluvial deposits, 4^{th}-order sequences represent lateral shifting of sediment flux pathways, and the upward-fining character does not necessarily indicate large-scale sediment flux/accommodation (SF/A) relations, and therefore basin scale correlation is inappropriate (Krapez, 1996). However the vertical succession of these 4^{th}-order sequences does reflect changes that can be interpreted with respect to basin-scale sediment flux and accommodation.

Third-order sequences B-1 and B-2 are composed of similar facies and 4^{th}-order sequence sets. The progradational component of B-1 consists of upward-coarsening alluvial fan deposits that are thin and discontinuous, reflecting infill of paleotopography on the basal unconformity. The progradational 4^{th}-order sequence set of B-2 grades from sand-bed braided stream, through gravel-bed braided stream, to alluvial fan deposits. This represents increasing depositional gradient during alluvial accumulation as shown in Fig. 3.2e, in response to basin subsidence and coeval marginal uplift. At Thirty Mile Lake near the master fault of the half-graben, this increase in gradient resulted in the formation of alluvial fans. The aggradational 4^{th}-order sequence set represents the maximum gradient determined by the maximum grain size of sediment supply. Note that the central "aggradational" component of each sequence actually fines-upward or coarsens-upward and that this is complementary between sections of the same sequence (e.g. B-2 coarsens-upward in section A and fines-upward in section B, Fig. 3.8). Since the coarsest grain size of each sequence, or the progradation-maximum, occurs at different points within the vertical succession between sections, kilometre-scale lateral sediment flux patterns have a significant effect upon the succession, and therefore the exact point of maximum grain size is non-unique, in contrast to a maximum flooding surface.

The upper component of sequences B-1 and B-2 consists of retrogradational 4^{th}-order sequence sets, from alluvial fan to sand-bed braided stream, or floodplain facies respectively. This represents a decrease in depositional gradient over the course of alluvial accumulation, and signifies a decrease in accommodation such that sediment accumulation in the basin was able to infill new and old accommodation space, thus decreasing the net gradient through vertical end-of-slope aggradation and lateral, basinward migration of the shoreline as in Fig. 3.2a. The retrogradational 4^{th}-order sequence set of sequence B-2 culminates in floodplain facies that represent the lowest depositional gradient, and a phase of a high proportion of sediment throughput. When relating fluvial deposits to a graded profile and inferred paleoslope, it is important to note that floodplain fines are overbank deposits. Since overbank processes selectively deposit the finest fraction of the sediment load, floodplain deposits do not reflect the competency of streamflow within associated channels, nor do they indicate the calibre of the sediment load. Therefore floodplain deposits represent the lowest gradient, but the nature of the bypassing sediment is unknown. The sequence boundary is placed at the point of maximum retrogradation of facies, for example eolian facies within the floodplain deposits. However, because the point of maximum progradation is non-unique, the point maximum retrogradation may be non-unique too. Therefore it is possible that the sequence boundary should be placed at the floodplain – braided stream facies contact. Due to the overall high accommodation setting, this contact is gradational and difficult to place.

Sequence B-3 comprises a lower 4^{th}-order sequence set that progrades from floodplain to gravel-bed braided stream facies, and an upper set that retrogrades to floodplain facies. The gravel-bed braided stream deposits vary in thickness and grain size between sections, and the thickness of floodplain facies is complementary to this variation. Coarse fluvial conglomerate is prominent within section B and floodplain mudstone prominent within section C. This likely reflects the position of the "main" alluvial channel belt, a topographically lower area of greater subsidence and therefore higher accommodation. That section B was the location of greater subsidence is consistent with the greater total thickness of section B, and with paleocurrent measurements from sequences B-3 and B-4 within sections A and C that trend toward section B. With respect to graded profile, the progradation represents an increase in gradient over the course of alluvial accumulation, likely as a response to basin subsidence and coeval marginal uplift. The retrogradation is interpreted to represent infilling of accommodation space, a decrease in the depositional gradient and a culminating phase of a high proportion of sediment throughput.

Sequence B-4 is similar to B-3 except that the conglomerate is much thinner and finer grained. Although the upper part of sequence B-4 is interrupted by minette flows, the implications with respect to graded profile and accommodation are the same.

A similar analysis can be applied to the succession of 3rd-order sequences as to the succession of 4th-order sequences. At Thirty Mile Lake, the succession B-1 to B-4 is overall upward-fining, defining a retrogradational 3rd-order sequence set. Sediment flux was exceeded by accommodation, the basin was underfilled, and facies retreated to the basin margin as the system was unable to infill the new accommodation space. By implication, closer to the paleobasin margin, though not preserved, sequences B-3 and B-4 would have progradation-maximum alluvial fan deposits. Sequence B-5 is coarser grained than sequence B-4, and located at the top of the Baker 2nd-order sequence, it marks a progradational top to the succession of third-order sequences, indicating that sediment flux, including volcanic flux, exceeded accommodation at the basin scale likely as a result of decreased subsidence. Although volcanism was active throughout, voluminous minette volcanics virtually blanketed the basin during sequences B-3 and B-4, the period of inferred maximum subsidence and contributed volcanic flux such that the succeeding siliciclastic sequence indicated a basinal overfilled state. The tectonic stage of rifting represented by the Baker 2nd-order sequence is thus illustrated by the upward-fining then upward-coarsening succession of 3rd-order sequences, indicating increasing rates of accommodation, flood volcanism, subsidence cessation, and finally an overfilled stage overlain by a basin-wide unconformity.

At Thirty Mile Lake contacts between all facies and particularly between sequences are gradational, due to high accommodation in proximity to an inferred basin-bounding normal fault.

3.3.4.1 Christopher Island

Baker sequence rocks at Christopher Island have low dips, generally <15°, and the topography is subdued. As a result, the measured thickness of stratigraphic sections is much less than at Thirty Mile Lake. However, there is sufficient thickness from northwest Christopher Island (Fig. 3.10), where the volcanic component is smaller than eastern Christopher Island, to reconstruct a third-order sequence from this paleodepocentral location (Fig. 3.11).

Linked facies from proximal to distal are gravel-bed to sand-bed braided stream, floodplain, eolian, playa-mudflat, and shallow lacustrine (see Chapter 2). Fourth-order sequences in braided stream deposits from Christopher Island are similar to the sand-bed braided stream units from Thirty Mile Lake. Lacustrine bearing 4^{th}-order sequences are similar to marine sequences. In Fig. 3.12, deltaic distributary channel and interdistributary bay deposits are succeeded by delta front turbidites recording relative base level rise. This is succeeded by a prograding delta front, rippled sandsheet, and metre-scale eolian cross-sets that record relative base level fall. The eolian deposits pass upward into playa, eolian, then to fluvial deposits recording another pulse of relative base level rise and fall. These sequences are relatively thin, occurring over 10-15 metres. Thus, 4^{th} order sequences that include lacustrine deposits (deltaic or playa) are a function of lacustrine base level fluctuations.

3.3.4.2 Third-order sequences

The succession of 4th-order sequences over a few hundred metres from northern Christopher Island consist of (Fig. 3.11): a retrogradational set (TST), culminating at delta front turbidites; a progradational set (HST), with braided stream facies sandstone at the top; another retrogradational set (TST), with a thin basal conglomerate passing through braided stream facies sandstone and overlying eolian sandstone; which passes upward into fluvial sandstone, possibly the upper HST. The 3rd –order sequence boundary is an erosional surface at the base of the conglomerate. Across this boundary there is a shift in paleocurrent directions from southwest- to south-directed (Fig. 3.11), indicating a change in the drainage regime likely related to tectonic parameters (cf. Miall, 2001). This succession represents two incomplete depositional sequences, which actually constitute a genetic sequence.

3.3.4.3 Application of the terrestrial sequence stratigraphic model:

With respect to regional paleocurrent patterns (Fig. 3.4) and braided stream, eolian, and lacustrine facies, Christopher Island represents the depocentre of Baker Lake sub-basin and is therefore located at the basinal or nearshore zone in Fig. 3.2. Although the base of the lower 3rd order sequence is not exposed (Fig. 3.11), the lower part consists of a retrogradational 4th order sequence set of fluvial, eolian, and shallow lacustrine deposits, indicating that SF<A (TST; e.g. Fig. 3.2e). Thin delta front deposits record the maximum flooding of the basin. The succession of facies subsequently prograde through eolian and playa facies to sand-bed braided stream deposits, defining a progradational set of 4th order sequences indicating that SF>A (HST; Fig. 3.2a).

The sequence boundary is at the base of conglomerate, ~5 m thick, sharply overlying sandstone (Fig. 3.11). This is interpreted to reflect a relative base level fall (e.g. Fig. 3.2c) resulting in a basinward migration of the shoreline, subaerial erosion initiating at the old shoreline, and an increase in gradient of the graded profile and thus stream calibre. Alternatively, if relative base level fall resulted in basinward migration of the shoreline at the same gradient as the graded profile then alluvial environments would be characterized by non-deposition. In either case coarse detritus was transported basinward, and when relative base level fall ceased, coarse fluvial deposits were deposited on the erosion surface. Across the sequence boundary, paleocurrent directions change from westerly to southerly (Fig. 3.11), this is attributed to renewed subsidence and tilting of the half-graben. The <5 m conglomerate is succeeded by sand-bed braided stream deposits, indicating that coarse detritus no longer reached the basin centre, as coarse sediment fractions were deposited upstream as the alluvial plain began to aggrade. The braided stream deposits of the upper 3rd order sequence are succeeded by eolian deposits defining a high accommodation, transgressive systems tract. Note that, within the present facies tract, eolian deposits are intimately related to lacustrine deposits, and so the alternation of fluvial and eolian facies can be treated similar to the alternation between fluvial and lacustrine. The top of the upper 3rd order sequence is not exposed, but the transition from eolian to fluvial may indicate the transition from transgressive to highstand systems tract.

These two incomplete depositional sequences are inferred to record base level fluctuations with equivalent componentry of marine shelf sequences, namely that of lowstand, transgressive, and highstand systems tracts. Therefore, in limited sections from Christopher Island, at the inferred depocentre of Baker Lake sub-basin, a third-order sequence has the same architecture as nearshore sequences in other basins, including rift basins (Embry, 1989; Changsong et al., 2001; Benvenuti, 2003). These 3rd-order pulses of accommodation are attributed to subsidence via normal faults that bounded the half-graben, in essence a "tectonic cyclothem" *sensu* Blair (1988).

3.3.5.1 Aniguq River

The Aniguq River study area is located at the northwestern margin of the Baker Lake sub-basin (Fig. 3.4), where the Baker 2nd-order sequence is ~ 500 m thick (Rainbird and Hadlari, 2000; Rainbird et al., 2003). A volcanic-dominated section consists of K-feldspar porphyry tuff at the base succeeded by minette flows (Fig. 3.6). A sedimentary-dominated, laterally equivalent section consists of conglomerate and sandstone that interfingers with the volcanic succession (Fig. 3.6). This latter section is segmented by strike-slip faults along the course of the Aniguq River, but there is sufficient outcrop to discern the lower unconformity overlying crystalline basement, the upper unconformity between the Baker and Whart sequences, and unconformities within the Baker sequence that bound 3rd-order sequences. The locations of these unconformities, with respect to 100 m-scale coarse-fine alternations interpreted as 3rd-order sequences, are below conglomerate units that fine upward to sandstone. This is similar to alluvial 3rd-order sequences described elsewhere (Westcott, 1993; Shanley and McCabe, 1994; Olsen et al., 1995; Plint et al., 2001; Atchley et al., 2004).

3.3.5.2 Application of the terrestrial sequence stratigraphic model

With respect to graded profile and accommodation, the coarse base to the 3rd-order sequences is interpreted to record an increase in depositional gradient at the basin margin as it responded to basin subsidence as in Fig. 3.2e. The upward-fining trend is inferred to record a decrease in depositional gradient due to basinward infilling of AS. The development of unconformities within the Baker sequence at Aniguq River, in contrast to their absence at Thirty Mile Lake at the southeastern basin margin, is attributed to location on the hinged side of the half-graben and therefore less accommodation. This is further indicated by the thinner Baker 2nd-order sequence at Aniguq River (~500 m vs. >2000m at Thirty Mile Lake.), and the accordingly scaled thickness of 3rd-order sequences (~100-150 m vs. 400-600 m at Thirty Mile Lake; Fig. 3.6).

There are 4 sequences at Aniguq River and probably 5 at Thirty Mile Lake (Fig. 3.6). According to the volcanic stratigraphy, from the base, the second sequence at Aniguq River correlates to sequence B-3 at Thirty Mile Lake. This indicates that deposition did not occur initially at the hinged margin, but proceeded as the basin expanded; and therefore the B-1/B-2 conformable sequence boundary transforms into an unconformity toward Aniguq River that onlaps onto the basal unconformity near Aniguq River.

3.4.0 Discussion

The basic unit of a rift basin is a half graben (e.g. Leeder, 1995). It has a high length to width ratio and is sub-divided into axial and transverse drainage systems. A cross-section parallel to the basin axis will result in a graded profile for the axial system. In the simplest case this terminates at a lacustrine depocentre and is identical to the graded profile of Fig. 3.2. So a cross-section perpendicular to the basin axis at the lacustrine depocentre traces a graded profile for the transverse drainage system that terminates at the lake, each side identical to Fig. 3.2. A perpendicular cross-section not centred on the lake results in two graded profiles that meet near the centre. Note that this point is not free to migrate independently in the same way as a shoreline, since sediment transport and deposition along one profile will influence the other, and so these profiles are coupled. Furthermore, the basin-axial graded profile intersects the two transverse profiles at the topographic low point, transporting sediment toward a regional depocentre, and thus all three are linked. This approach provides a dialectic for basin-scale correlation.

3.4.1 Fourth-order sequences

Third-order sequences are composed of sets of 4th-order sequences. Lacustrine 4th-order sequences, 5-15 m thick preserved at the inferred basin depocentre (Fig. 3.12), directly record base level fluctuations. Sequences of this scale have been observed in other extensional basins (e.g. Changsong et al., 2001; Benvenuti, 2003) and are generally attributed to fault-subsidence. For example, high-resolution seismic data from the Rukwa Rift in Tanzania identified wedge-shaped lacustrine sequences, 6 to 65 m thick, some bounded by angular truncations, and therefore attributed to pulses of fault activity (Morley et al., 2000).

It is possible that 4^{th}-order alluvial sequences are correlative (Fig. 3.9), recording fluvial infilling of accommodation increments generated by basin-margin normal-fault-induced subsidence. Infilling of this accommodation would then record a decrease in gradient as new accommodation was filled, resulting in the upward-fining succession. The tops of alluvial sequences indicate a stage of sediment bypass, suggesting the reinstatement of a graded profile. Deposition or incisement will occur if a change takes place, such as autogenic infilling of basinal AS, which will result in a further upward-fining trend as part of the same sequence, or renewed subsidence and the initiation of new lacustrine and alluvial sequences. Blair (2000b) observed bedding discordance over intra-fan unconformities bounding 5-10 m intervals of upward-fining alluvial fan deposits, and concluded that fault activity had periodically caused a down-drop of the fan thus prompting renewed aggradation.

This proposition should be considered with caution, because lateral shifting in an alluvial setting is an abrupt and episodic process that will necessarily lead to successive self-similarly stacked stratal packages. Thus the fluvial system will aggrade in punctuated units as accommodation is more gradually filled within the lacustrine system. It is therefore possible that the alluvial plain is in a state of constant aggradation throughout the accommodation increment recorded by 4^{th}-order lacustrine sequences, and that the 4^{th}-order alluvial sequences are simply a product of channel tract aggradation/avulsion processes.

It is also possible that a combination of channel aggradation-avulsion and accommodation-gradient processes contributed to the development of 4^{th}-order alluvial sequences. Krapez (1996) postulated that 4^{th}-order sequences from an Archean strike-slip basin represent relatively short-term processes that were chaotic composites of intrinsic (systemic redistributions of energy) and extrinsic (climate change or tectonic factors) rhythms, which is compatible with the previous discussion. Considering the number of factors (e.g. local faulting, aggradation-avulsion, or discharge variations as a function of climate) and thus the uncertainty involved, one-to-one correlation of fourth-order sequences between nearshore and proximal alluvial settings from this study is equivocal, in addition to exceeding the dataset for the Baker Lake Basin. Since the vertical succession of 4^{th}-order sequences occurs over a larger scale than lateral channel switching processes, 4^{th}-order sequence sets should yield reliable SF/A relations relevant to the trends upon which these units were superimposed.

3.4.2 Third-order sequences

Geochronology of the Baker Lake Basin (Rainbird et al., in press) suggests that 3^{rd}-order sequences of the Baker second-order sequence span approximately 10 Ma. They occur across the Baker Lake sub-basin from conformities to correlative unconformities, and also between sub-basins across the greater Baker Lake Basin. Stratigraphic analysis indicates that they record pulses of accommodation and infilling by the sedimentary system. The succession of 3^{rd}-order sequences documents the tectonic history of the basin, and thus these regional pulses of subsidence are basin-filling rhythms in the genetic sense (Embry, 1989; Krapez, 1996).

Third-order sequences from the Baker 2^{nd} order sequence comprise a spectrum of forms from depocentral lacustrine-bearing at Christopher Island, to low accommodation alluvial sequences at Aniguq River, to high accommodation alluvial sequences at Thirty Mile Lake. The present data set for the Baker Lake sub-basin does not enable direct correlation of these sequences, but speculation with respect to a model can perhaps be tested against similar basins for which seismic data and/or extraordinary outcrop are available.

As indicated from other extensional basins, depositional sequences from more basinal settings are similar to marine shelf sequences with respect to high and low accommodation systems tracts (Embry, 1989; Changsong et al., 2001; Benvenuti, 2003), consisting of retrogradational to progradational components separated by maximum flooding surfaces, and bounded by erosional surfaces. More proximal alluvial sequences have an overall upward-fining character with a lower section that may initially coarsen upward. In low accommodation settings these sequences are bounded by erosional surfaces, as exemplified by paleosols at Aniguq River. Even more proximal alluvial sequences in high accommodation settings, such as at Thirty Mile Lake, which contain alluvial fan facies deposited adjacent to inferred basin-margin normal faults, contain a thicker progradational base, and aggradational centre. If we consider that these sequences represent a continuum from the centre to the margin of the basin (Fig. 3.13), then we can explore the factors that produce this trend. It is not intended that specific sequences be correlated, but that the forms from different locations be compared.

With respect to a unified sequence model (Fig. 3.14), below the sequence boundary, proximal and medial locations record the lowest gradient facies (e.g. floodplain) and are generally characterized by high proportion of sediment throughput.

Nearshore locations are characterized high SF/A, and lake contraction through infilling with detritus.

The base of a 3rd order alluvial sequence is conformable in high accommodation settings and unconformable in low accommodation settings. In areas of high accommodation, initiation of accommodation in proximal locations resulted in an increase in gradient during alluvial accumulation, and thus a progradation of facies and increase in grain size (Fig. 3.14a). This also occurred in medial locations, although the rate of accumulation is presumed to have been less since the gradient-response to accommodation is expected to begin near the sediment source, effectively localizing deposition upstream. In basinal locations, renewed accommodation and fluvial deposition was initially marked by deposition of gravel. This lag is overlain by finer deposits indicating that coarse sediment no longer bypassed proximal locations. As accommodation increased and lake expansion occurred, basinal facies retrograded, and was recorded by upward-fining (Fig. 3.14a).

With increasing rates of accommodation, at proximal locations a maximum gradient determined by boundary conditions may be achieved, which would lead to an aggradational succession. In basinal settings, relative base level rose and lake expansion approached a maximum, equivalent to the maximum flooding surface in the marine realm.

As accommodation decreased, new accommodation space was filled and old accommodation space began to be filled. In proximal locations this led to a decrease in gradient, retrogradation of facies and decrease in grain size. Rates of alluvial accumulation also decreased, and therefore more sediment was available for transport into basinal locations. This also occurred in medial locations, a decrease in gradient and retrogradation of facies, and lower rates of deposition. With minimal subsidence, as the basin infills and the margins denude, the grade of sediment supply if not the flux is expected to decrease, thereby accentuating the rate of proximal and medial retrogradation. As the locus of deposition migrated basinward, the lake contracted and nearshore facies prograded, resulting in a nearshore upward-coarsening succession that completed the depositional sequence (Fig. 3.14b).

Subsequent upland erosion and relative base level fall may lead to alluvial and nearshore erosion resulting in basinal nearshore or alluvial deposition (Fig. 3.14c).

There are a few notable implications of this model:

1) A perspective on floodplain deposits as minimum-gradient, minimum accommodation facies within alluvial successions, which is opposite to the model of Wright and Marriott (1993).

Wright and Marriott (1993) suggested that preservation of floodplain fines is a result of rapid aggradation of the alluvial plain. This raises a number of notable points. First, considering grain size of the deposits (floodplain fines vs. channel sand) the sediment transported through the channels must have had a very high volume of mud, and also a high ratio of mud to sand. Second, to accumulate a significant amount of fine-grained floodplain sediment, associated channels must have not traversed these locations – implying that channels were relatively stable and that their locations were long-lived.

Now if an aggrading river primarily deposits its load within-channel (otherwise channel deposits would be rare and floodplain deposits the norm) then a rapidly aggrading channel would quickly rise above surrounding areas and therefore be more likely to avulse. Thus high aggradation rates should be accompanied by frequent channel switching events, thereby aggrading the alluvial plain through channel-aggradation. This is not consistent with the model of Wright and Marriott (1993).

An alternative view of floodplain preservation would be that channels or channel tracts are relatively stable in their location due to low rates of aggradation. This allows for thick deposits of laminated fines to accumulate in adjacent areas through overbank flooding. This describes a fluvial system characterized primarily by a high proportion of sediment throughput, whereby most of the sediment load is transported through channels with little deposition. Aggradation of the alluvial plain occurs primarily when water discharge exceeds the capacity of the channel system, but even after these events the channel system does not change location, suggesting that there is no gravitational impetus for a lateral channel shift to occur. Thus, the floodplain and the channel aggrade at the *same* rate. The result is selective deposition of the finest sediment fraction, and bypassing of an unknown quantity and grain size of sediment, allowing for transport of sand and gravel to locations downstream from the floodplain.

2) With respect to clastic wedge inundations of basinal settings, an upward-fining trend at the top of alluvial sequence, and the indication from the nearshore sequence that new and old accommodation space is being filled: as the locus of deposition migrates basinward and distal locations aggrade, the gradient of the graded profile decreases and

alluvial facies migrate headward / sourceward. Accordingly, as a clastic wedge approaches basinal locations, the sourceward reaches of that wedge are characterized by a decreasing gradient and facies therefore retreat sourceward, resulting in a proximal alluvial upward-fining succession and a coeval upward-coarsening succession in the subaqueous basin.

3) In lower accommodation regimes, for example on the hinged margin of a half-graben (Aniguq River), the progradational base of the alluvial sequence is thinner than in high accommodation regimes. Thus with lower levels of accommodation, alluvial accumulation therefore responds primarily to basinal infilling of existing accommodation space, punctuated by brief increases in gradient corresponding to new, low-magnitude accommodation. Positive feedback between accommodation and sediment flux (coupled uplift/subsidence) is expected, leading to low rates of sediment flux. Since the alluvial deposits at Thirty Mile Lake are interpreted to have been deposited during an underfilled stage, headwall erosion did not lead to erosion on the alluvial plain. But at the less underfilled (but perhaps overfilled due to volcanic flux) Aniguq River location, sourceward erosion led to erosion of the alluvial plain, promoting regolith development and a sharp break in facies.

4) The opposite gradational character of sequences between proximal and distal is similar to the gradational trend across the shelf to basin facies boundary, and is an extension of this trend. Major basinal accumulations occur during RLL highstand/lowstand when high proportion of sediment bypasses alluvial and nearshore shelfal locations, but basinal locations are characterized by low to non-deposition during

RLL rise as the locus of deposition migrates sourceward. Proximal alluvial accumulation is minimal during lowstand as a high proportion of sediment bypasses basinal and/or nearshore locations. Uplift and subsidence lead to increasing alluvial gradients and accumulations, whereas facies transgression characterizes nearshore locations and focusses deposition sourceward. Decreasing accommodation leads to progradation of nearshore facies, source denudation and lower alluvial gradients and accumulations. Over an accommodation cycle, the locus of deposition migrates from basin to source and back through nearshore to basin.

3.4.3 Second-order sequence

If the succession of 3rd order sequences is treated from a basinal perspective, then the trend of retrogradational to progradational represents high to low accommodation phases. Thus, the basin history is illustrated by the upward-fining then upward-coarsening succession of 3rd-order sequences, indicating increasing rates of accommodation, flood volcanism, subsidence cessation, and finally an overfilled stage overlain by a basin-wide unconformity. This is comparable to the framework outlined by Prosser (1993): the upward-fining succession would be equivalent to the rift initiation and rift climax stages; and the upward-coarsening cap is equivalent to the immediate post-rift stage.

On the hinged side of the basin (Aniguq River) the succession is predominantly progradational with unconformities/paleosols developed at sequence boundaries reflecting the low tectonic accommodation. On the opposite side of the basin (Thirty Mile Lake), the succession has a larger retrogradational component, and sequence boundaries are gradational facies boundaries reflecting the high level of tectonic accommodation.

The Baker second-order sequence records the formation of a half graben rift basin at approximately 1833 +/-3 Ma (Rainbird et al., in press) and its subsequent infilling before diagenesis at 1785 +/-3 Ma (Rainbird et al., 2002). This is equivalent to a primary, approximately 45 Ma, second-order sequence as defined by Krapez (1996; 1997).

3.5.0 Conclusion

An alluvial sequence stratigraphic model is derived through modification of existing non-marine sequence stratigraphic concepts. Alluvial accommodation space is based upon the graded profile, a topographic profile defined by a graded stream connecting a sediment source to a subaqueous basin. Sedimentary facies are incorporated by considering common characteristics of streams: downstream-fining; downstream decrease in slope; and gradient dependency of stream types. It is suggested that if conditions of sediment supply and discharge are considered boundary conditions specific to individual basins, then relative facies changes can be interpreted with respect to basin dynamics. Because sedimentary basins are an expression of tectonic setting, accommodation is presumed to be driven primarily by coupled source uplift and basin subsidence, which have feedback effects on sediment supply, sediment flux, and along-stream and end-of-stream deposition. The interpretation of alluvial successions is therefore based on grain size and alluvial facies with respect to the effect of tectonic accommodation on the graded profile. Within this context, the model is able to rationalize previously published alluvial and nearshore sequence forms, specifically an inversion of grain size, within a coherent flexible framework. Within this model, the transition between proximal alluvial and nearshore environments appears to be like the facies boundary between shelf and basin with respect to facies evolution and sediment accumulation.

This model is applied to the non-marine, Paleoproterozoic Baker Lake Basin during a stage of intracontinental rifting represented by the Baker 2nd order sequence. The basin is interpreted to have been a half-graben with alluvial fans at the margins transversely feeding a longitudinal drainage system of braided streams that culminated at a depocentre composed of eolian and lacustrine facies. Measured sections from three locations within the basin provide stratigraphic signatures from the lacustrine depocentre, the low accommodation hinged margin, and the high accommodation margin adjacent to the master normal fault.

The ca. 1.84-1.78 Ga, 2nd order Baker Sequence comprises a retrogradational succession of 3rd order sequences, flood volcanism, and progradational top. This indicates increasing rates of accommodation, flood volcanism, and subsidence cessation equivalent to the stages of rift initiation, rift climax, and immediate post-rift, respectively. Third-order sequences are correlated to a basinwide tripartite volcanic succession and are composed of ~100-500 m thick progradational, aggradational, and retrogradational 4thorder sequence sets. These basin-filling rhythms represent basin-scale accommodation accompanying pulses of normal faulting during development of a half-graben.

Three types of 3^{rd} order sequences have been identified:

1) mixed fluvial-shallow-lacustrine sequences which are retrogradational-progradational in form, composed of high accommodation, transgressive systems tract-equivalent deposits and low accommodation, highstand systems tract-equivalent deposits;
2) high accommodation proximal-alluvial sequences that record the graded profile response to subsidence, which are characterized by a high accommodation, progradational or aggradational base and a low accommodation, retrogradational top; and
3) lower accommodation alluvial sequences that have a less pronounced progradational base and therefore generally fine-upward and display paleosol horizons near the sequence boundary.

Fourth-order sequences, ~5-15 m thick, are composed of sedimentary units representing small-scale base level (lake level) fluctuations possibly related to fault-displacements combined with autogenic alluvial processes.

Because the Baker Sequence was deposited in a hydrologically closed non-marine basin, the effects of sea level can be discounted. Therefore Ma-scale sequences of 2^{nd} and 3^{rd} order can be confidently attributed to tectonic processes. Comparison with other basins reveals that 3^{rd} order pulses of accommodation are an essential characteristic by which basins evolve throughout a 2^{nd} order tectonic stage.

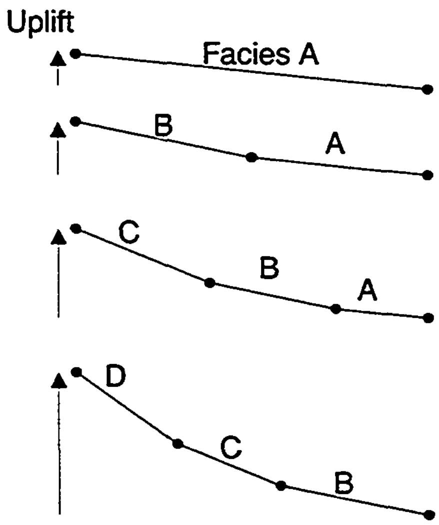


Figure 3.1: Subdivision of the graded profile into sedimentary facies, where each facies is defined by a gradient range. Hypothetical facies A, B, C, and D are stable at progressively higher gradient ranges.

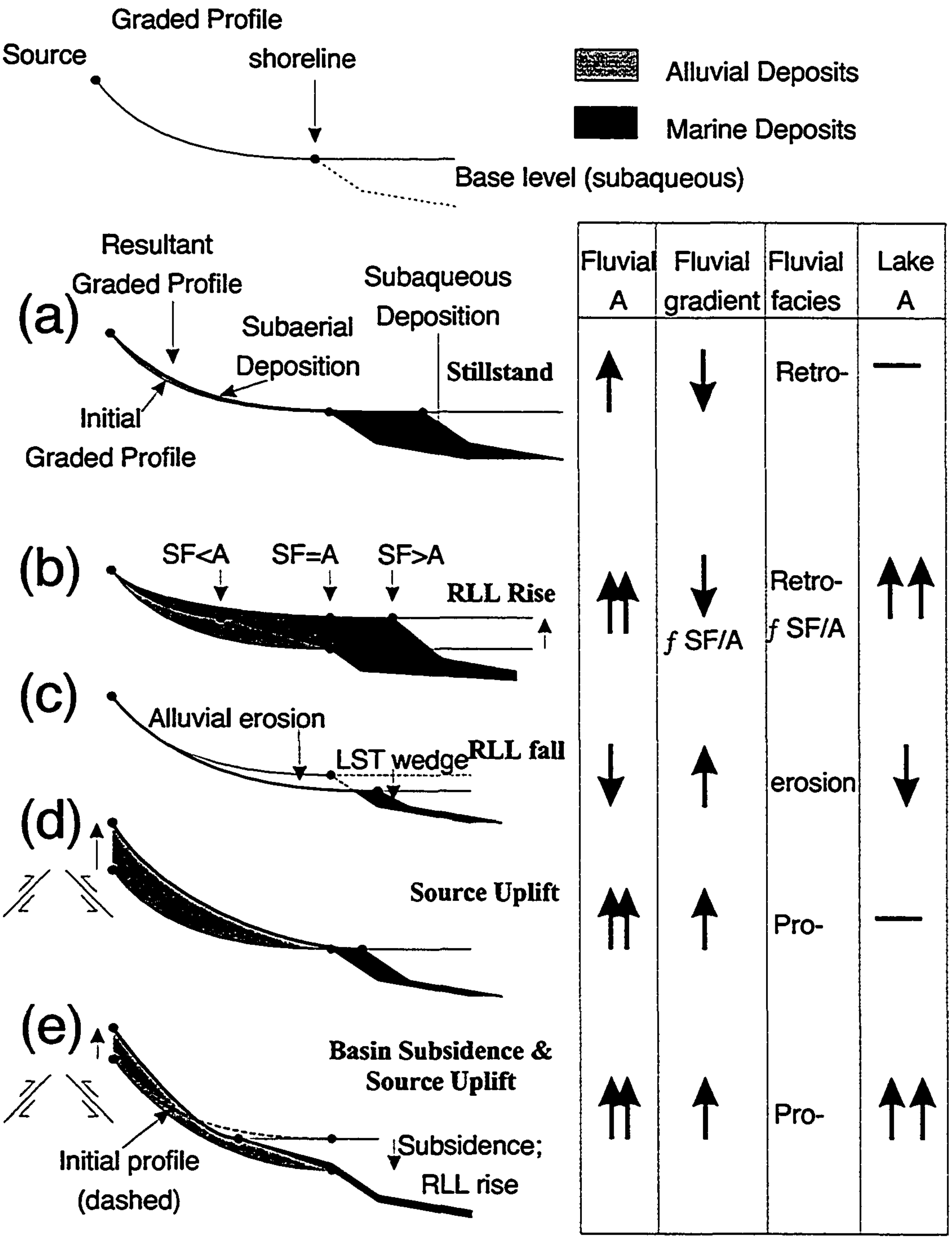


Figure 3.2: The graded profile. Dynamics of the graded profile with respect to changes in base level, subsidence, and source region uplift or erosion. SF = sediment flux, A = accommodation, RSL = relative sea level (base level), Retro- = retrogradation, and Pro = progradation. Note that certain elements, particularly the subaqueous environments have been exagerrated for clarity.

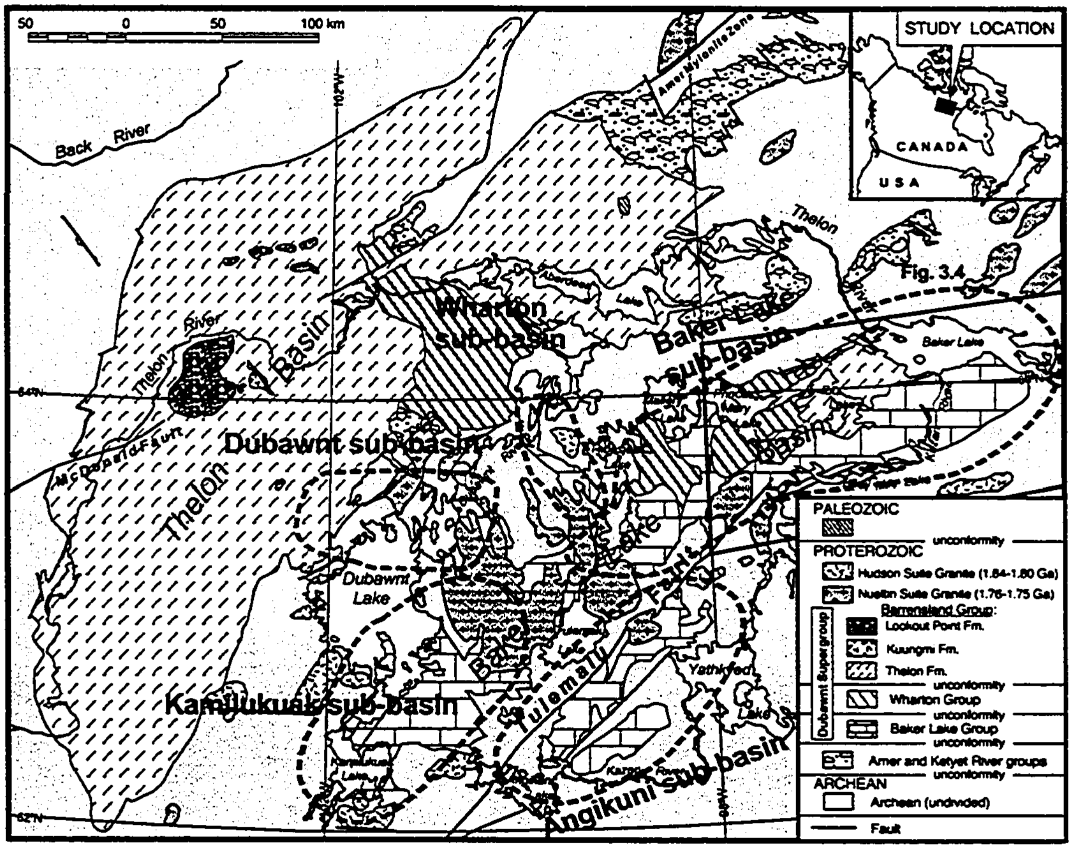


Figure 3.3: Geologic map of the greater Baker Lake Basin highlighting the distribution of sub-basins (after Rainbird et al., 2003).

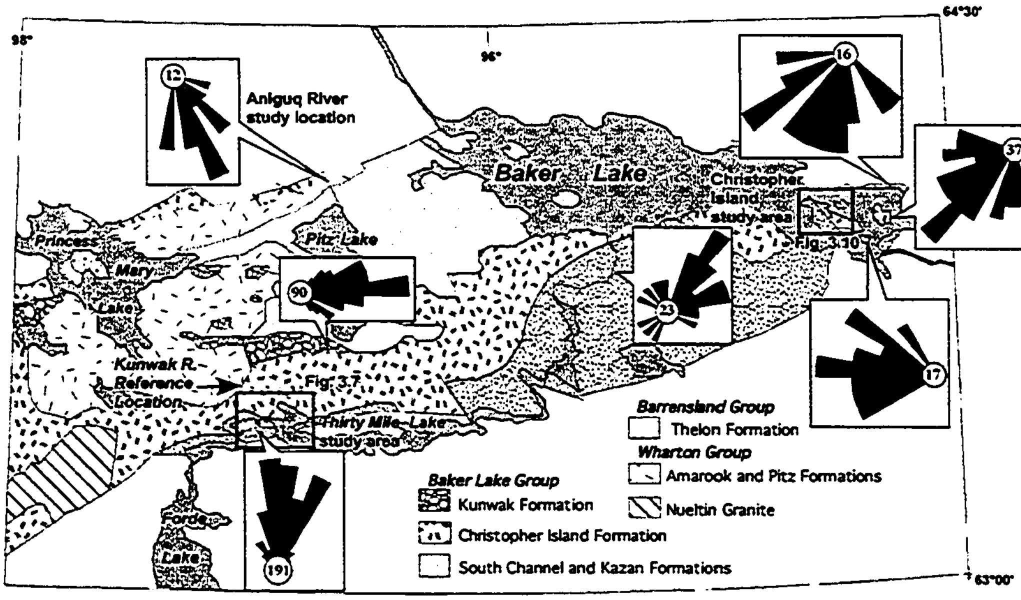


Figure 3.4: Geology of the Baker Lake sub-basin, including paleocurrent data derived from cross-set and primary current lineation measurements. Note that boxes outline Thirty Mile Lake and Christopher Island study areas, whereas Kunwak River and Aniguq River are indicated by arrows.

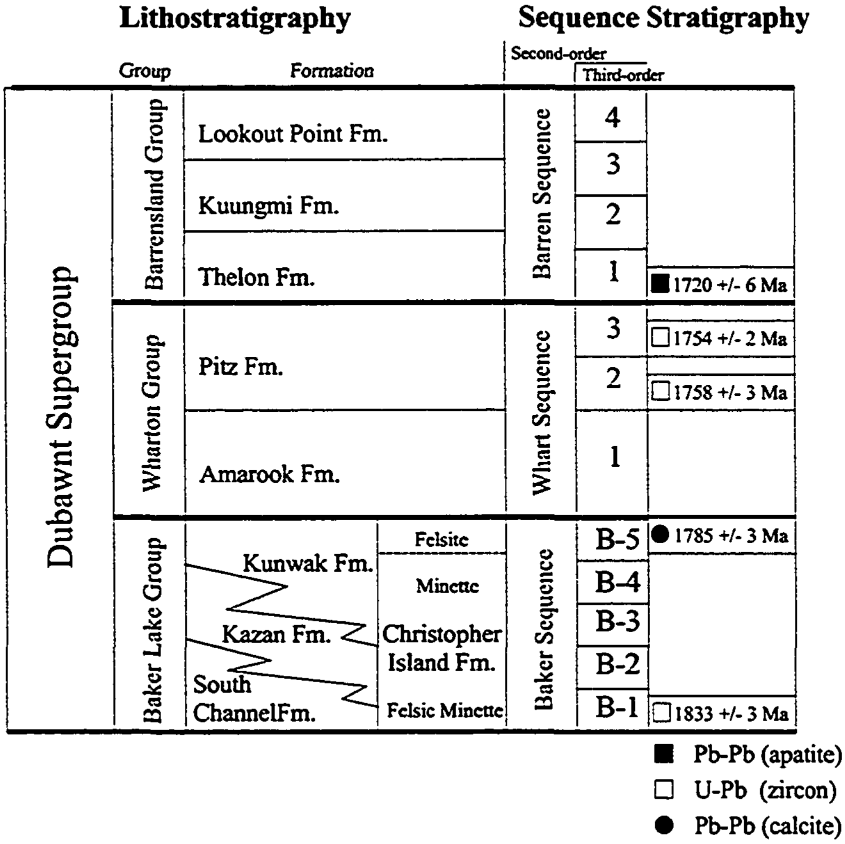


Figure 3.5: Litho- and sequence stratigraphy of the Baker Lake Basin. Geochronology sources: Thelon Fm., 1720 +/- 6 Ma (Miller et al., 1989); Pitz Fm., (Rainbird et al., 2001); Baker Lake Grp., 1785+/-3 Ma (Rainbird et al., 2002), 1833+/-3 Ma (Rainbird et al., in press).

Figure 3.6: North-south cross-section of the Baker Lake Basin from Aniguq River to Thirty Mile Lake. The sedimentary and complementary volcanic-dominated sections are lateral equivalents. The Thirty Mile Lake volcanic section is composite. Note that the Kunwak River outcrop contains felsite clasts, equivalent to the youngest volcanic rocks at Thirty Mile Lake. The Aniguq River and Kunwak River sections are from the reference locations shown in Fig. 3.4. Thirty Mile Lake section is section B from Fig. 3.7.

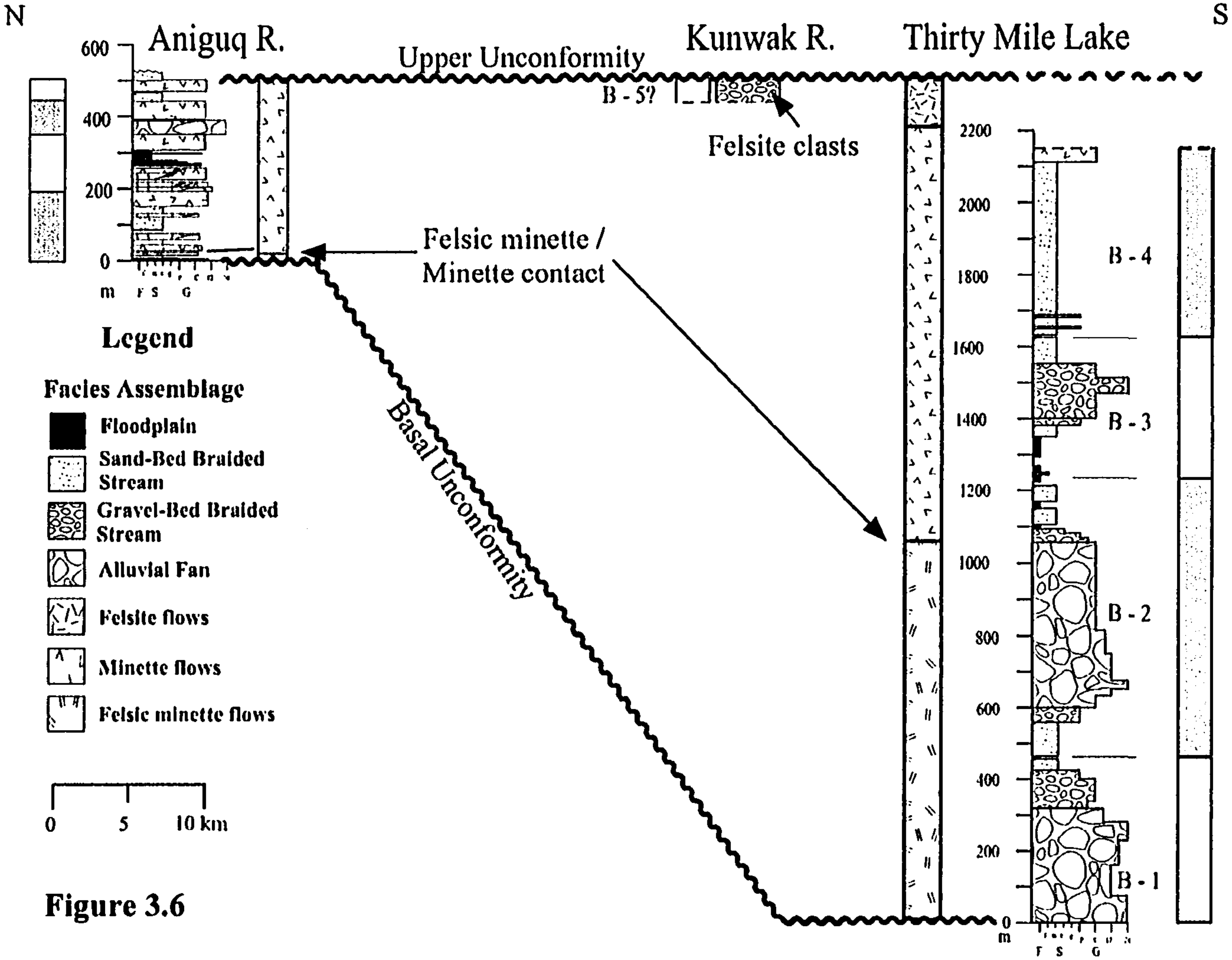

N
S
Aniguq R.
Upper Unconformity
Kunwak R.
Thirty Mile Lake
B - 5?
Felsite clasts
Felsic minette /
Minette contact
Basal Unconformity
B - 4
B - 3
B - 2
B - 1
600
400
200
0
m
F S G
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
m
F S G
Legend
Facies Assemblage
Floodplain
Sand-Bed Braided Stream
Gravel-Bed Braided Stream
Alluvial Fan
Felsite flows
Minette flows
Felsic minette flows
0
5
10 km

Figure 3.6

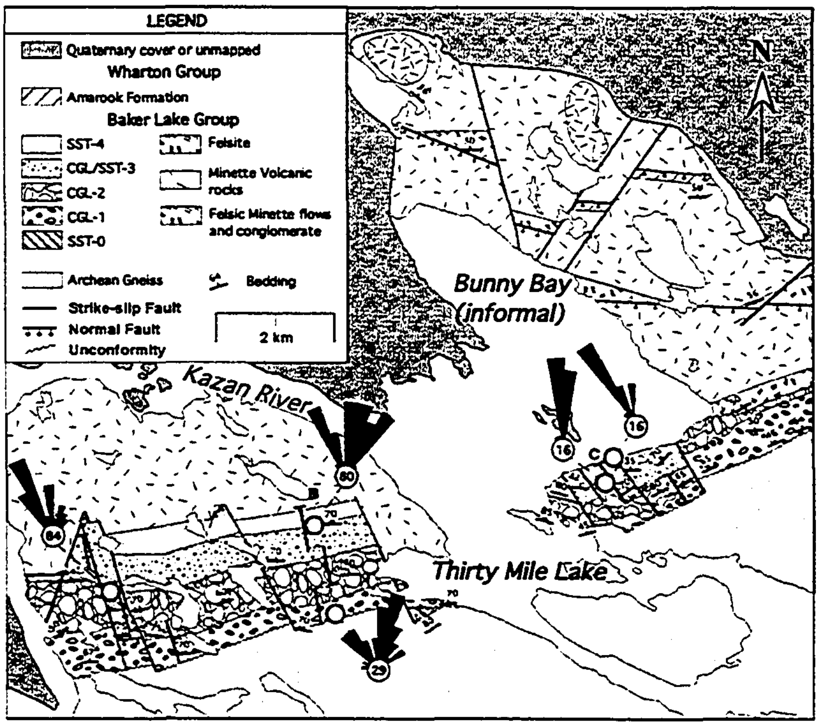


Figure 3.7: Geologic map of the Thirty Mile Lake study area. Paleocurrent data were derived from cross-set measurements. CGL = conglomerate and SST = sandstone. Note location of sections A, B, and C of Fig. 3.8.

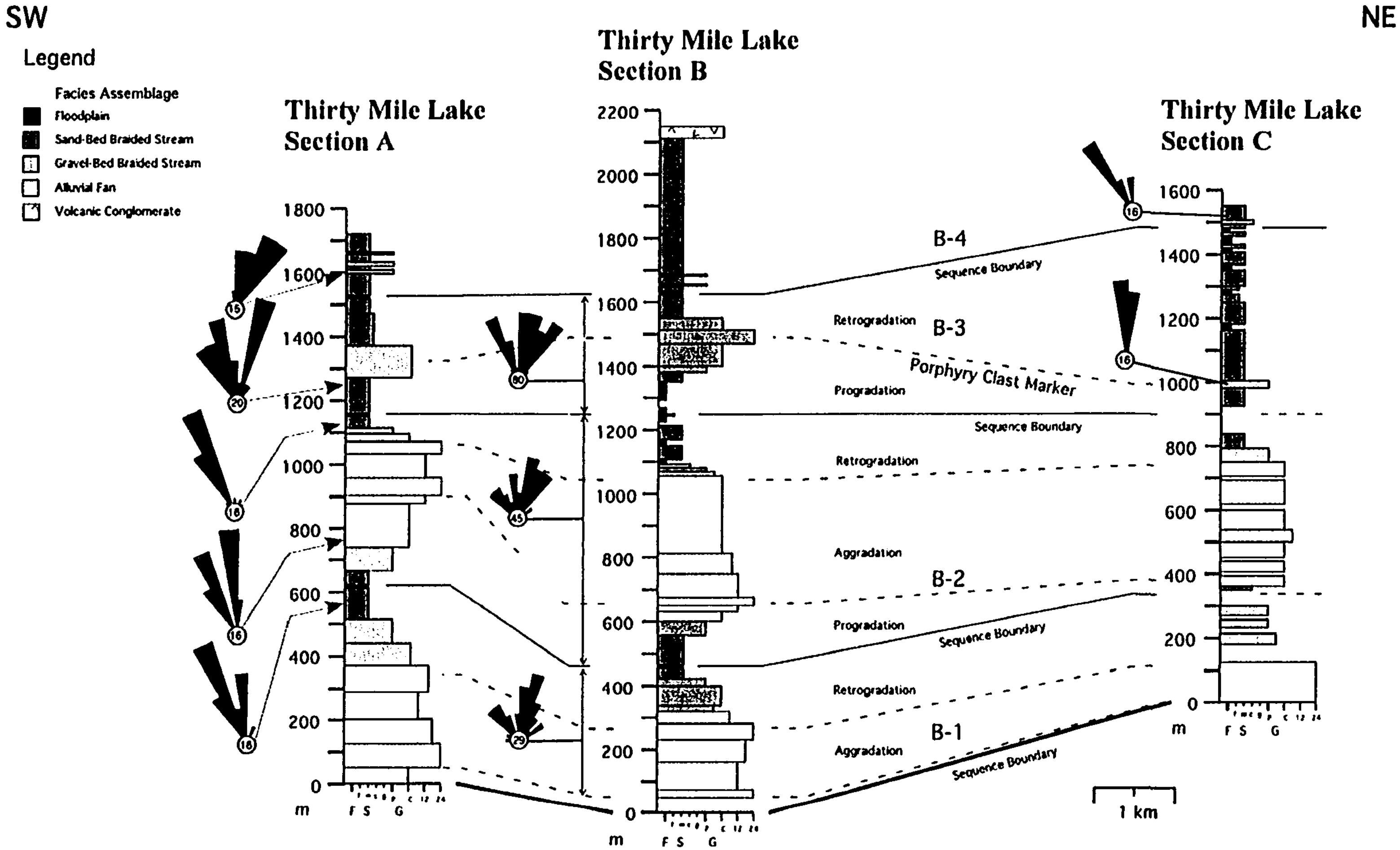


Figure 3.8: Correlated sections from the Thirty Mile Lake study area displaying 3rd-order sequences, B-1 to B-4, partially comprising the Baker 2nd-order Sequence. F = mudstone, S = Sandstone, and G = conglomerate. Section locations are indicated on Fig. 3.7.

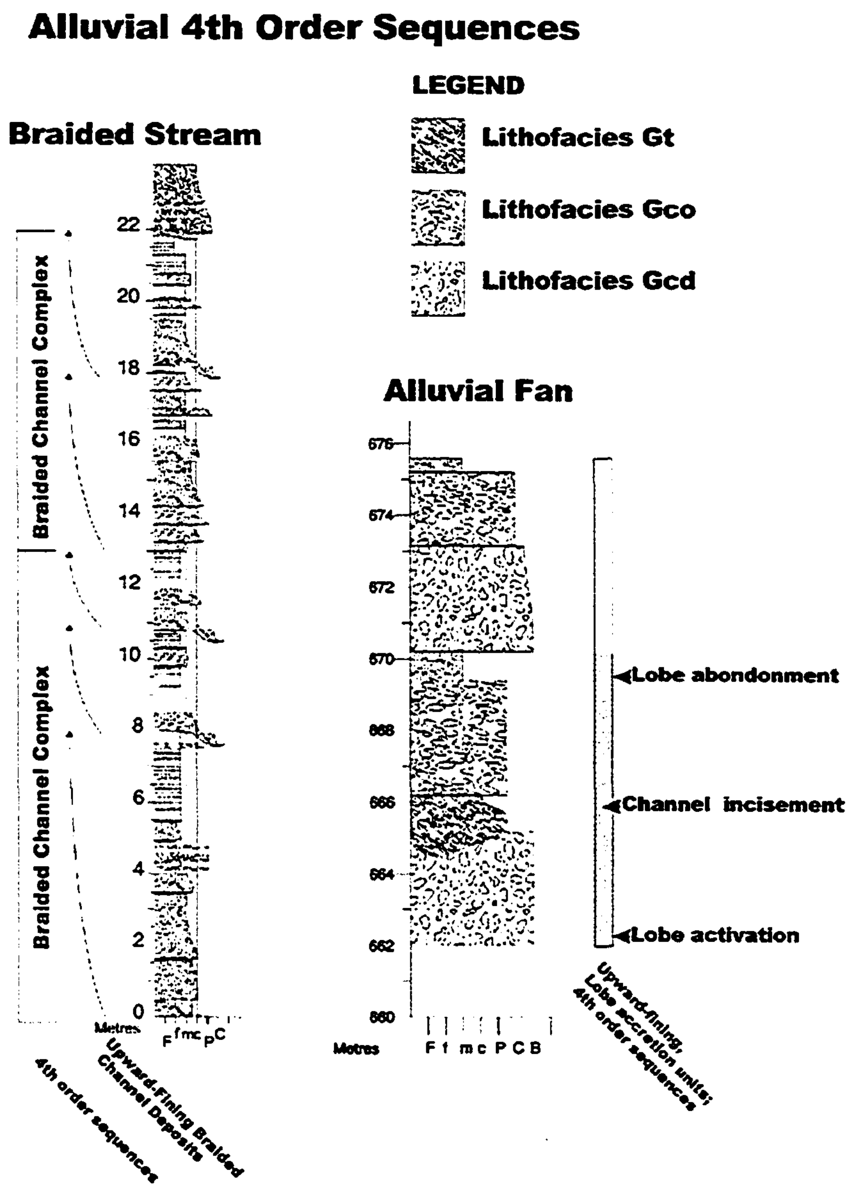


Figure 3.9: Fourth-order sequences of the alluvial fan, braided stream, and floodplain facies assemblages. Alluvial fan and braided stream sections are from Thirty Mile Lake sections B and C respectively, Fig. 3.7.

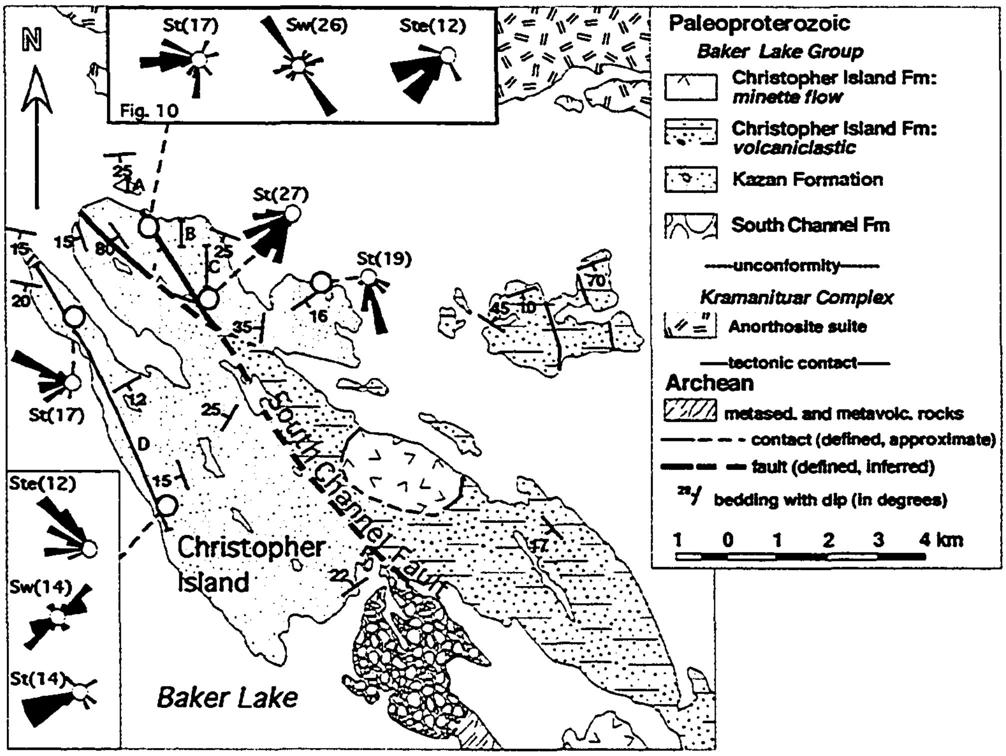


Figure 3.10: Geology map of the Christopher Island study area including paleocurrent data (St = fluvial; Sw = wave ripple crests; Ste = eolian cross-sets). Note locations of sections A, B, C, and D displayed in Figures 3.11 and 3.12.

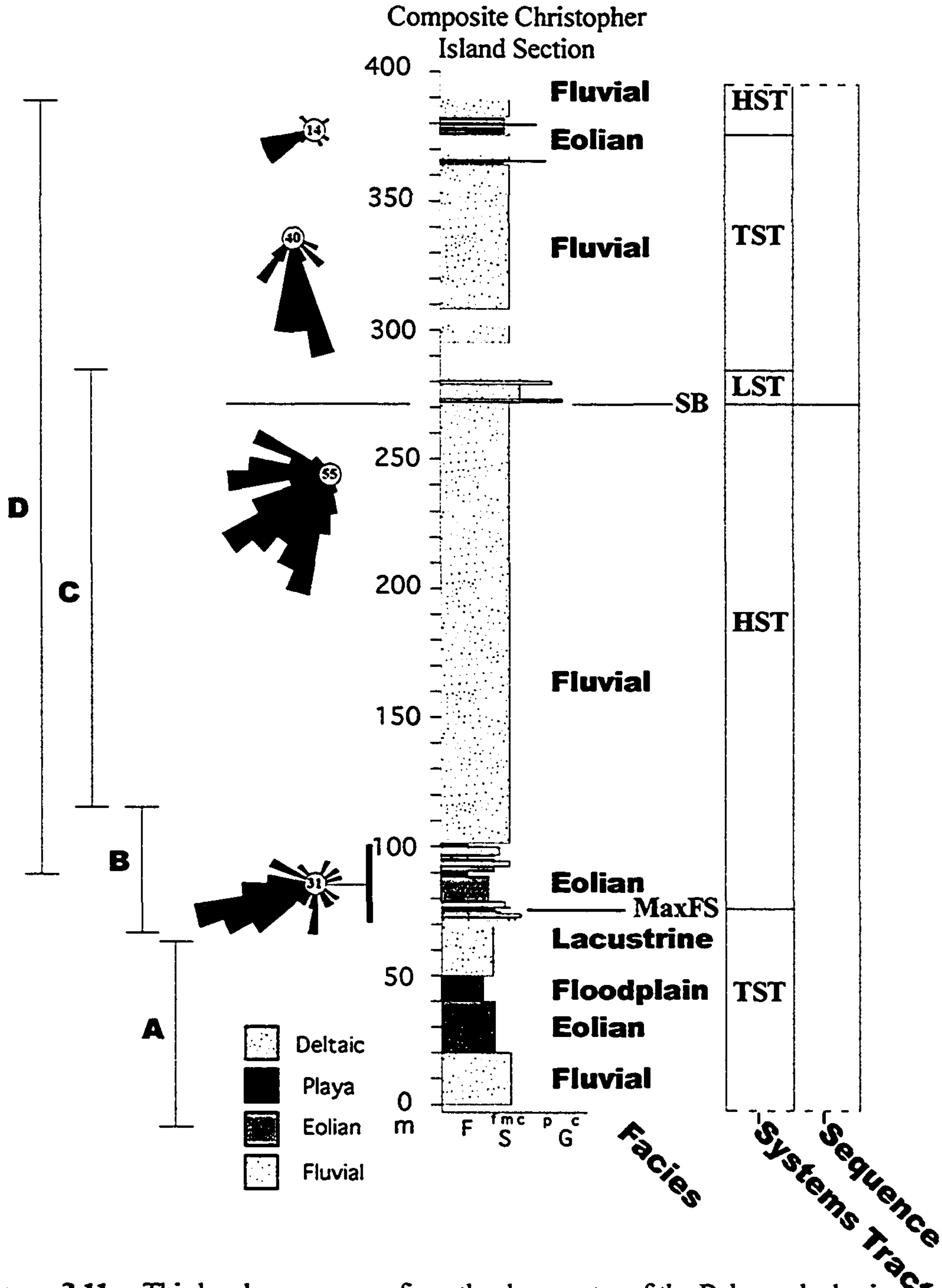


Figure 3.11: Third-order sequences from the depocentre of the Baker paleobasin, at Christopher Island, that are composed of fourth-order sequence sets. Composite section composed of sections A, B, C, and D from Figure 3.10. LST = lowstand systems tract, TST = transgressive systems tract, HST = highstand systems tract, and SB = sequence boundary.

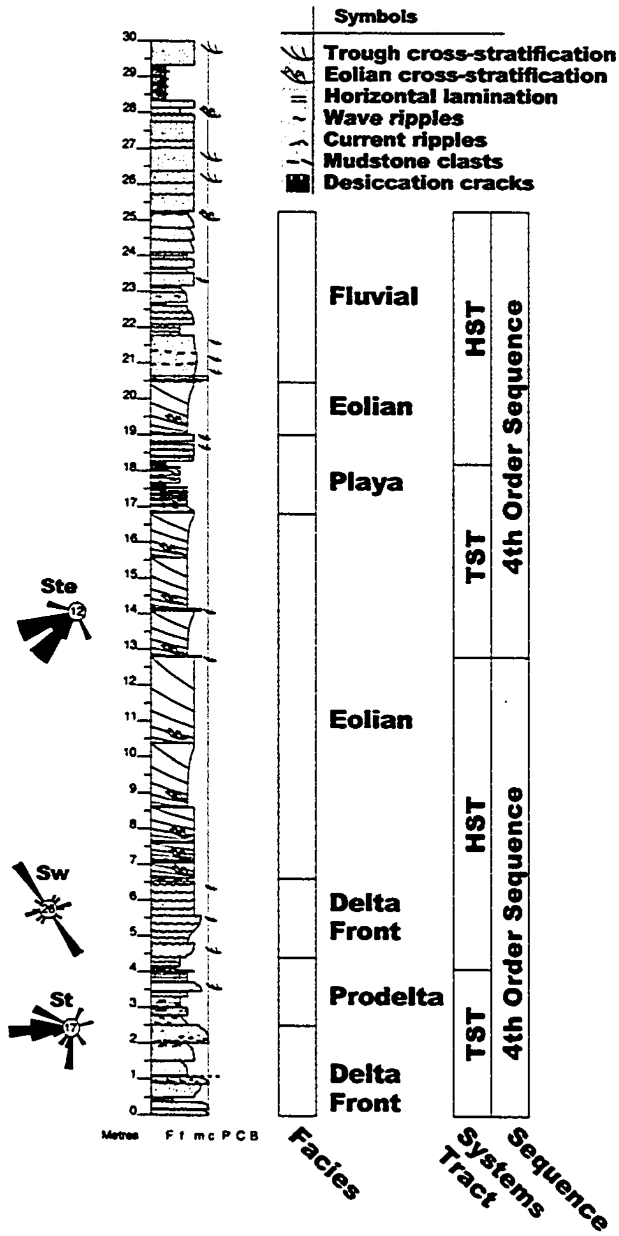


Figure 3.12: Fourth-order sequences composed of eolian, playa, and deltaic facies. Section corresponds to section B in Fig. 3.10, 3.11.

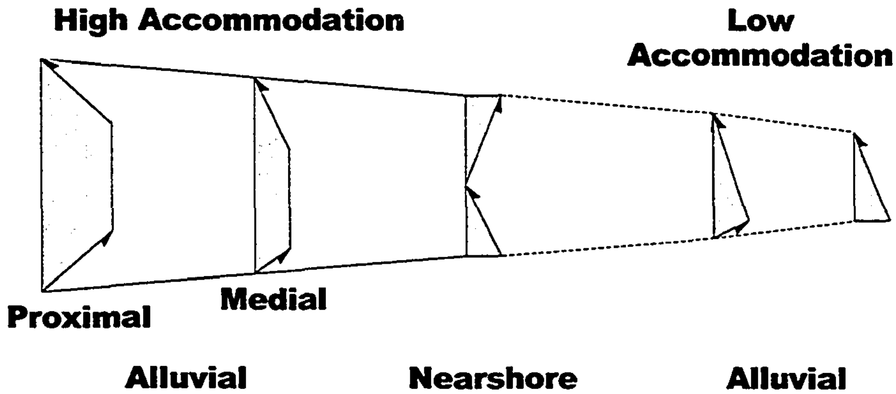


Figure 3.13: Architectural comparison of sequence forms from the basin depocentre to the basin margin. High accommodation alluvial settings with high sediment flux are characterized by thick sequences and upward-coarsening to upward-fining successions. Low accommodation alluvial sequences are predominantly upward-fining with a sharp or erosional base. A mixed alluvial-lacustrine depositional sequence typically has an upward-fining to upward-coarsening character,consisting of lowstand, transgressive, and highstand systems tracts.

Figure 3.14: Resultant depositional sequence with respect to alluvial and nearshore locations. (a) Initial conditions of graded profile intersecting base level. Concurrent source uplift and basin subsidence result in an increase in alluvial gradient and a relative base level rise. Alluvial deposits coarsen-upward and nearshore deposits fine-upward during this phase. (b) Cessation of subsidence/uplift leads to a high proportion of alluvial sediment throughput and nearshore deposition, resulting in nearshore progradation, net alluvial gradient decrease and therefore alluvial facies retrogradation. The alluvial system may still build upward through deposition to match source uplift, or if caught up, source erosion may contribute to a further decrease in alluvial gradient. (c) Alluvial erosion and relative base level fall may contribute to establishment of a widespread erosional surface. (d) Resultant stratigraphic signatures are upward-coarsening to –fining in alluvial settings, upward-fining to –coarsening in nearshore settings, and upward-coarsening dominated in deeper, basinal settings. LST = lowstand systems tract, TST = transgressive systems tract, HST = highstand systems tract, and RLL = relative lake level (base level). Shades of light and dark are used to differentiate deposits between sucessive time intervals, light shades are alluvial deposits and dark shades are lacustrine deposits.

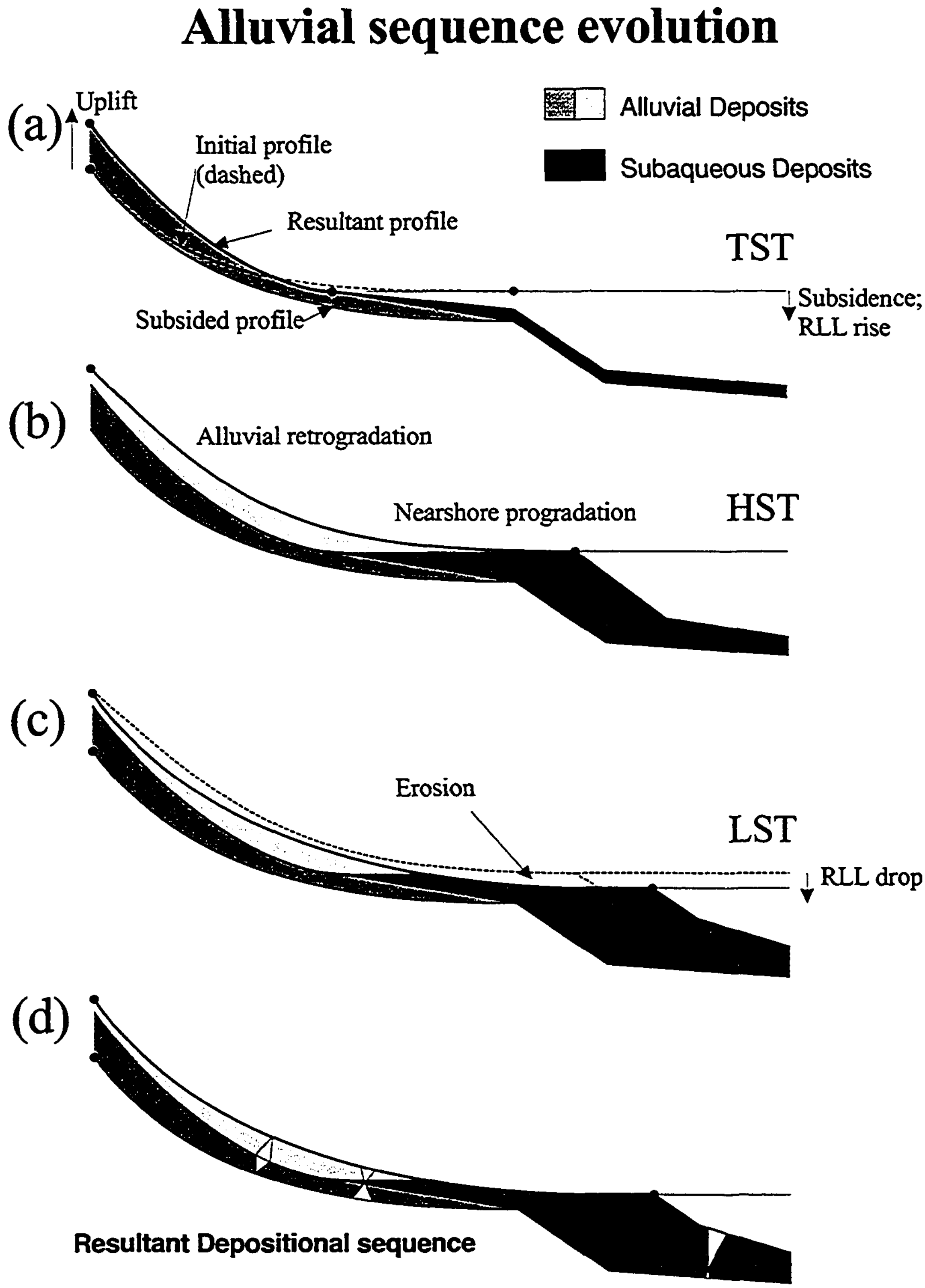

Alluvial sequence evolution
(a)
Uplift
Initial profile
(dashed)
Resultant profile
Subsided profile
Alluvial Deposits
Subaqueous Deposits
TST
Subsidence;
RLL rise
(b)
Alluvial retrogradation
Nearshore progradation
HST
(c)
Erosion
LST
RLL drop
(d)
Resultant Depositional sequence

Figure 3.14

CHAPTER 4

TECTONIC EVOLUTION OF BAKER LAKE BASIN WITH REGIONAL IMPLICATIONS

Abstract

Within the Baker Lake sub-basin, the ca. 1.84-1.78 Ga Baker Sequence formed in two general stages. During rift initiation, half-graben were host to siliciclastic alluvial, eolian, and lacustrine deposits and localized felsic minette volcanics. Leading to rift climax, increased extension resulted in areal expansion and high accommodation recorded as both back-stepping of facies and coeval extrusion of voluminous minette volcanics, which eventually covered most of the basin. Post-rift deposits are thin, and coeval felsite domes areally restricted. Because volcanic rocks and some siliciclastic units correlate between sub-basins, this interpretation is extended across the greater Baker Lake Basin, which implies that the basin formed in response to regional north-south extension and crustal thinning. Associated strike-slip faulting contributed to formation of the Dubawnt sub-basin.

The high accommodation stage of basin development probably was the result of intra-continental retro-arc extension during ca. 1.85-1.84 Ga formation of the Kisseynew back-arc basin of the Trans-Hudson orogen. The Baker Lake Basin marks the northern extent of a series of basins that trend northeastward along the Snowbird Tectonic Zone, from an inlier of the correlative Martin Group in northern Saskatchewan. On closure of the Kisseynew back-arc basin and collision of the Superior Province with the Western Churchill Province, the Baker Lake Basin was characterized by strike-slip faulting. The second, low accommodation stage of basin development coincided with lateral tectonic escape adjacent to the Saskatchewan-Manitoba and Baffin Island-Committee Bay foci of the Superior Province collision.

4.1.0 Introduction

The Baker Lake Basin overlies the boundary between the Rae and northwestern Hearne sub-domains within the Western Churchill Province (Fig. 4.1). The greater Baker Lake Basin comprises 5 sub-basins that are host to continental siliciclastic, volcaniclastic, and volcanic deposits (Fig. 4.2).

In this chapter, sedimentology and stratigraphy of the Baker Lake sub-basin are examined in relation to intra-basinal and extra-basinal faulting. Relations between stratigraphic signatures and previously established magmatic evolution of the Baker Sequence are explored. Together with previous studies from the greater Baker Lake Basin (e.g. LeCheminant et al., 1981; Peterson and Rainbird, 1990; Rainbird and Peterson, 1990, and Rainbird et al., 2003) this has enabled construction of an integrated model of basin evolution.

Results from the western Churchill NATMAP project have provided boundary conditions for the Baker Lake Basin. In combination with tectonic models for the Trans-Hudson Orogen (e.g. Lewry et al., 1994), tectonic models for the Baker Lake Basin are proposed.

4.2.0 Regional Geology

4.2.1 General geology of the Western Churchill Province

The Baker Lake Basin overlies the Archean Western Churchill Province, comprising the Rae and Hearne domains (Davis et al., 2000) (Fig. 4.1), referred to by Hoffman (1988) as the Rae and Hearne provinces. These domains are separated by the Snowbird tectonic zone (STZ), and the Western Churchill Province is bounded to the west and east by Proterozoic orogenic belts, the 2.02-1.91 Ga Thelon and 1.9-1.8 Ga Trans-Hudson orogens (THO), respectively (Hoffman, 1988).

The Rae domain is differentiated from the Hearne by the presence of komatiite-quartzite supracrustal successions that generally overlie older than 2.8 Ga crust, which extend from Baffin Island to north of Baker Lake. In the Rae domain northwest of Baker Lake the Woodburn Lake Group comprises a 2735-2710 Ma komatiite-quartzite succession overlain by ca. 2630 felsic volcanic and terrigenous sedimentary rocks (Zaleski and Davis, 2002) (Fig. 4.1).

Ryan et al. (2000) proposed that the Big Lake Shear Zone south of Chesterfield Inlet (not shown on map) represents the northern extent of the Rae-Hearne boundary (Ryan et al., 2000). This structure formed at ca. 2.5 Ga, and was re-activated at 1.9 Ga (Ryan et al., 2000). Extending eastward from the eastern shore of Baker Lake, the Kramanituar complex is a granulite-facies metamorphic complex of ca. 1.9 Ga gabbro, anorthosite, and granitoids (Sanborn-Barrie, 2001). Eastward along Chesterfield Inlet, the Uvauk complex is a similar ca. 1.9 Ga granulite-facies metamorphic complex, but contains ca. 2.6 anorthosite (Mills, 2001).

Southwest of Baker Lake – Chesterfield Inlet, at Angikuni Lake, the Rae-Hearne boundary is represented by the Tulemalu fault zone (Tella and Eade, 1986) (Fig. 4.1). The Angikuni Lake area was the site of ca. 2.62-2.61 Ga syn-tectonic granite emplacement (Aspler et al. 2002) and 2.56-2.5 Ga high-grade metamorphism (Berman et al., 2002a). Monazite inclusions in garnet indicate that 2.56-2.5 Ga and 1.9 Ga high-grade metamorphism and associated deformation extend from Chesterfield Inlet along the trend of the STZ to Angikuni Lake, part of a high-pressure corridor (Berman et al., 2002a).

The southwest segment of the STZ, which extends into Saskatchewan, is represented by crustal scale shear zones, which have multistage histories. The oldest deformation is by defined by ca. 2.63-2.6 Ga syn-tectonic granites (Hanmer et al., 1994), followed by 1.9 Ga mafic intrusions and granulite-facies metamorphism (Baldwin et al., 2003; Mahan et al., 2003). The STZ appears to have a similar history along its length, from the Kramanituar complex to the Striding Athabasca Mylonite Zone.

From findings of the Western Churchill NATMAP project, the Hearne domain has been subdivided into northwestern, central, and southern Hearne subdomains (Davis et al., 2000; Hanmer and Relf, 2000). Although rocks of the northwestern Hearne subdomain are isotopically juvenile, rocks from Angikuni Lake, MacQuoid Lake, and Rankin Inlet indicate interaction with older crust (Sandeman, et al., 2000). This includes Nd isotopic evidence for older sources (> 2.85 Ga; Sandeman, 2001), and old detrital zircons from the MacQuoid Lake area (up to 3.4 Ga; Davis et al., 2000). The northwestern Hearne and southeastern Rae margins are characterized by high- pressure metamorphism at ca. 2.5 Ga and 1.9 Ga (Berman et al., 2000; 2002a). Tectonic assembly of the Rae and Hearne Provinces is considered to have resulted in 2.5 Ga metamorphism and deformation (Davis et al., 2000), and subsequent reworking after ca. 1.9 Ga has further modified this boundary (Davis et al., 2000; MacLachlan et al., , 2005, in press; Ryan et al., 2000; Sanborn-Barrie et al., 2001).

The boundary between the northwestern and central Hearne is the Tyrrell Shear Zone (MacLachlan et al., 2005, in press) (Fig. 4.1). Earliest deformation of the Tyrrell Shear Zone is recorded by syn-tectonic emplacement of ca. 2.66-2.62 Ga granites, and youngest reactivation took place at ca. 1.83-1.81 Ga (MacLachlan et al., 2005, in press).

The central Hearne subdomain comprises the Tavani and Kaminak greenstone belts, and is typified by isotopically juvenile 2.71-2.68 Ga supracrustal rocks and 2.7-2.65 Ga calc-alkaline granitoid rocks (Davis et al., 2000; 2004; Hanmer et al., 2004; and Sandeman et al., 2004).

Little is known of the southern Hearne, which has yielded older U/Pb ages than the central Hearne, particularly where it is basement as old as ~3.0 Ga (Bickford et al., 1994) to the Wollaston Group, a rift to foreland basin succession related to the THO (e.g. Tran et al., 2003).

The 1.84-1.72 Ga Baker Lake Basin overlies the northeastern extent of the STZ, unconformably overlying the Kramanituar Complex and the Chesterfield Fault Zone (Fig. 4.1). The greater Baker Lake Basin is informally sub-divided into the Kamilukuak, Dubawnt, Wharton, Angikuni, and Baker Lake sub-basins (Fig. 4.2; Rainbird et al., 2003). It is host to siliciclastic and volcanic strata of the Dubawnt Supergroup, which are block faulted and locally tilted but unmetamorphosed.

4.2.2 Stratigraphy of the Baker Lake Basin

The Dubawnt Supergroup (Donaldson, 1965; 1966; 1967; Gall et al., 1992) is sub-divided into 3 unconformity-bounded groups (Fig. 4.3). The Baker Lake Group is characterized by arkosic sandstone, polymictic conglomerate, and alkaline flows and volcaniclastic rocks. The Wharton Group is characterized by sub-arkose and volcaniclastic sandstone, volcaniclastic conglomerate, and rhyolite flows. The Barrensland Group is represented in the Baker Lake Basin by quartz arenite of the Thelon Formation. Rainbird et al. (2003) provided a sequence stratigraphic framework for the Dubawnt Supergroup based on provisos of Krapez (1996; 1997), in which the three groups are equivalent to the Baker, Whart, and Barrens second-order sequences. These correspond to the tectonic stages of rift, modified rift, and thermal relaxation (intracontinental basin) respectively. Second-order sequences were further sub-divided into third-order sequences; third-order sequences of the Thelon Formation were described by Hiatt et al. (2003).

Previous detailed studies of the Baker Sequence have focused on volcanology and igneous petrology. Alkaline volcanic and volcaniclastic rocks of the Baker Sequence comprise the Christopher Island Formation (Donaldson, 1965; 1967). Flows of the Christopher Island Formation were characterized by LeCheminant et al. (1989) as porphyritic clinopyroxene-phlogopite trachyandesites and K-feldspar-phyric trachytes, and by Peterson and Rainbird (1990) as minette and felsic minette flows respectively. Minettes are potassic, calc-alkaline, phlogopite+clinopyroxene-phyric lamprophyres (Rock, 1987; Rock 1991). Christopher Island Formation minette flows are ultrapotassic, strongly enriched in light rare earth elements, and contain high abundances of incompatible elements (LeCheminant et al., 1989). Petrogenesis is considered to have been from volatile-rich mafic alkaline melts of metasomatized, sub-continental lithospheric mantle (LeCheminant et al., 1987; Peterson and LeCheminant, 1993;

Cousens et al., 2001; Peterson et al., 2002). Examination of glimmerite xenoliths led Peterson and LeCheminant (1993) to conclude that the source region was similar to that which produces lamproite melts - a strongly metasomatized mantle that was previously depleted by extraction of basaltic melts, thereby explaining the strong depletion in Ca, Na, and Al, and enrichment in light rare earth elements and large ion lithophile elements. Because some of the minettes contain K-feldspar phenocrysts they are not proper minettes, but are commonly associated with minettes elsewhere and in the literature have been informally designated "felsic minettes" (Rock, 1987; Rock, 1991; Peterson and Rainbird, 1990; Davis et al., 1996; Feldstein and Lange, 1999). Peterson et al. (2002) consider felsic minettes of the Christopher Island Formation to be crustally contaminated minette-equivalents.

A generalized volcanic succession for the Christopher Island Formation is basal felsic minette-, minette-, and upper felsite flows and volcaniclastic equivalents (Peterson and Rainbird, 1990; Hadlari and Rainbird, 2001). Felsite flows locally display flow banding, autoclastic breccia, and sub-centimetre k-feldspar phenocrysts. This tripartite volcanic subdivision provides the basis for correlation of the Kamilukuak to Baker Lake sub-basins, across the greater Baker Lake Basin, and is supported by geochronology (Rainbird et al., in press). Analyses of phlogopite phenocrysts from a minette flow at the base of the Baker Sequence, and a syenite intrusion that intrudes the lower Baker Sequence yield $^{40}Ar/^{39}Ar$ ages of 1845± 12 Ma and 1810 ± 11 Ma respectively (Rainbird et al., 2002; see discussion Rainbird et al., in press). A more precise U-Pb zircon age of 1833 ± 3 Ma has been obtained from a felsic minette flow from the Kamilukuak sub-basin, providing the best constraint on basin formation (Rainbird et al., in press). This age is within error of an $^{40}Ar/^{39}Ar$ age of 1837 ± 8 Ma obtained from a minette flow at Aniguq River (Rainbird et al., in press) and is consistent with an age of 1832 ± 28 Ma obtained from a lamprophyre dyke southeast of Baker Lake Basin that is considered to be co-magmatic with Baker sequence volcanic rocks (Pb-Pb apatite; MacRae et al., 1996). A lower age limit for the Baker second-order sequence is delimited by 1785±3 Ma, derived from laminated carbonate cements interpreted as travertine, from alluvial deposits from Kamilukuak sub-basin (Pb-Pb isochron from calcite; Rainbird et al., 2002).

4.3.0 Stratigraphy of the Baker Sequence

4.3.1 Baker Lake sub-basin

In the Baker Lake sub-basin (Fig. 4.4), the Baker second-order sequence comprises 5 third-order sequences and a correlative tripartite volcanic succession (Fig. 4.5; Chapter 3). Three types of 3^{rd} -order sequence occur in the Baker Lake sub-basin. A high accommodation alluvial sequence consists of an upward-coarsening to upward-fining succession of 4^{th}-order sequences. A low accommodation alluvial sequence consists of a generally upward-fining succession of 4^{th}-order sequences, where the sequence boundary is an erosional surface below coarse alluvial deposits. A mixed alluvial-lacustrine sequence comprises an upward-fining to upward-coarsening succession of 4^{th}-order sequences. Third-order sequences are interpreted as pulses of accommodation and subsequent infill by the sedimentary system in response to basin-margin normal faulting. Fourth-order mixed alluvial-lacustrine sequences record smaller-scale base level fluctuations. Fourth-order alluvial sequences were probably influenced by lateral channel switching processes.

From northwest to southeast, across the axis of Baker Lake sub-basin (from Thirty Mile Lake to Aniguq River), thickness of the Baker Sequence increases from ~500 m to over 2,500 m (Fig. 4.5). Accordingly, thicknesses of 3rd-order sequences increase from ~100-150 m to up to 500 m. Because 3rd -order sequences are scaled relative to the total thickness of the Baker Sequence, these thicknesses reflect differential accommodation and basin asymmetry (Chapter 3). This is consistent with the distribution of facies -- thick alluvial fan deposits near the southeast margin, braided fluvial deposits toward the centre, and fluvial, floodplain, eolian, and lacustrine deposits near a depocentre at Christopher Island (Fig. 4.6). Paleocurrent data indicate drainage was directed toward an inferred depocentre, indicating that the basin was a hydrologically closed system (Fig. 4.4). Combined, these features are indicative of a northeast-southwest trending half-graben with a hinged margin to the northwest and a master fault to the southeast.

In the Thirty Mile Lake area an almost complete composite section of the Baker Sequence yields a thickness of approximately 2.5-3.0 km (Fig. 4.5). The lower succession of 3rd-order sequences is retrogradational, indicating that at the basin scale, $A<SF$. The progradational top indicates that $SF>A$. The entire succession represents early high subsidence followed by low subsidence and infilling of the basin (Chapter 3).

Relationships between the sequence stratigraphy and the tripartite volcanic stratigraphy are made on the basis of clast lithologies and interfingering of sedimentary and volcanic units (Fig. 4.5). Sequences B-1 and B-2 are correlative with felsic minette flows. Minette volcanism initiated at localized volcanic centres near the B-2/B-3 sequence boundary, indicated by the occurrence of a few minette clasts in conglomerates at the base of sequence B-3. By sequence B-4, minette volcanism had increased in volume to blanket most of Baker Lake Basin. Sequence B-5 is correlated to the youngest volcanic sub-division of felsite flows.

At Thirty Mile Lake, the B-2/B-3 sequence boundary marks a change in facies from alluvial fan to gravel-bed braided stream (Fig. 4.5). This is consistent with back-stepping of the master fault system, resulting in widening of the basin and a retreat of alluvial fan facies, a common attribute of normal fault systems (e.g. Morley, 2002).

This sedimentological change occurred at the same time as the transition from felsic minette to minette volcanism, and at the beginning of deposition at Aniguq River (Fig. 4.5). Felsic minettes, by the stability of their phenocryst assemblage (Esperança and Holloway, 1987) are indicative of minette-composition melts that had equilibrated at lower crustal levels. Notably, Peterson et al. (2002) consider the felsic minettes to be crustally contaminated minettes. Proper minettes have a phenocryst assemblage indicating phenocryst-melt stability at mantle pressures (Esperança and Holloway, 1987), and therefore indicate rapid transport of melt from the lithospheric mantle. Thus, the felsic minette flows indicate extrusion of alkaline melts that had resided within the crust, and which had previously been derived from a lithospheric mantle source. That this new phase of near primary mantle melt extrusion is correlated with an abrupt increase in the size of the basin is attributed to a genetic linkage: decompression melting within the lithospheric mantle triggered by extension expressed within the overlying basin (Sandeman et al., 2000; Cousens et al., 2001).

Models for rift basin evolution sub-divide upward-fining to -coarsening successions into rift initiation, rift climax, and post-rift stages (Prosser, 1993). During rift initiation the Baker Lake sub-basin formed as a half-graben hosting alluvial fan, braided fluvial, eolian, and lacustrine sedimentary environments, with extrusion of felsic minette lavas in localized centres. Increased accommodation via normal faults resulted in an upward-fining succession of 3rd-order sequences. The B-2/B-3 sequence boundary marks inferred back-stepping of the normal fault system, concurrent with the transition from felsic minette to minette volcanism. At the rift climax stage, sequence B-4, minette flows virtually covered the entire basin. The post-rift stage is marked by coarser deposits of sequence B-5 and felsite volcanism.

4.3.2 Greater Baker Lake Basin

Sequences B-1 to B-4 are continuous from the Angikuni- to Baker Lake sub-basin (Fig. 4.7), consistent with the suggestion by Aspler et al. (2004) that Baker Sequence rocks from these basins are tectonostratigraphic equivalents. The tripartite volcanic succession extends across the entire Baker Lake Basin from the Kamilukuak- to Baker sub-basin, and geochronology, though not extensive, suggests this is a temporal correlation (Rainbird et al., in press).

Strike-slip basins grow laterally, leading to diachronous sedimentation along the basin axis and anomalously thick stratigraphic sections (e.g. Aspler and Donaldson, 1985). So, the correlation of sedimentary sequences between the Baker Lake and

Angikuni sub-basins, together with contemporaneity of volcanic facies across the greater Baker Lake Basin, reinforces the interpretation that Baker Lake Basin was an extensional (possibly trans-tensional) basin rather than a strike-slip basin.

4.4.0 Faulting of Baker Lake Basin

4.4.1 Intra-Baker Sequence faults

Based on stratigraphic relationships, sedimentary facies, and paleocurrents, Baker Lake sub-basin is interpreted as a half-graben with a bounding fault along its southern margin. Although this fault is not exposed within the basin, Ryan et al. (2000) identified a northeast-southwest trending, post-1.9 Ga brittle fault southeast of Baker Lake sub-basin that is cross-cut by the post-Baker Sequence South Channel Fault (Blake, 1980), and postulated that it could be the main normal fault that bounded the Baker Lake sub-basin.

Quartz vein breccia zones trending northwest (~340°) transect Christopher Island Formation volcanic rocks (Fig. 4.8a). Minette lithons within the stockwork provide a maximum age for these dilational faults. A minimum age is constrained by the presence of quartz stockwork clasts containing minette lithons within Baker Sequence (B-5) conglomerate at Kunwak River, directly below the Baker-Whart sequence boundary-unconformity (Fig. 4.8b). These faults are therefore considered to be syn-depositional, basin-transverse dilational faults (Hadlari and Rainbird, 2001).

Within the Baker Lake sub-basin, syn-Baker Sequence faults are not well enough defined to determine whether the basin formed in a strike-slip or extensional setting, so indirect evidence is applied. Adjacent to the Angikuni sub-basin, Aspler et al., (1999) noted that minette dykes, likely feeders to flows exposed within the Angikuni sub-basin, trend northeast, parallel to the Baker Lake Basin. This indicates existence of a component of northwest-southeast extension transverse to the basin axis during Christopher Island Formation volcanism, inconsistent with a strike-slip basin model (Aspler et al., 2004).

The northeast-trending, northwest-dipping Tyrrell shear zone juxtaposes low-metamorphic grade rocks of the Yathkyed greenstone belt that preserve Archean K-Ar ages (K-Ar hornblende, 2430-2485 Ma; Eade, 1986) in the hanging wall, against footwall gneisses and granitoids (MacLachlan et al., 2005). Although early dip-slip motion was likely Archean, footwall rocks that were at amphibolite metamorphic grade at ca. 1835 Ma were juxtaposed against greenschist-facies hanging wall rocks by ca. 1816-1810 Ma. However, there is no evidence for deformation between ca. 1835 Ma and ca. 1816 Ma, possibly due to transposition by dextral-normal ductile shearing between ca. 1816 Ma and ca. 1810 Ma (MacLachlan et al., in press). This age range overlaps with the ca. 1.84-1.81 Ga age of volcanic and intrusive rocks from Baker Lake Basin. In addition to contemporaneous normal sense of displacement, the northwest dip of the fault relative to Angikuni sub-basin is consistent with the Tyrrell shear zone being a mid- to upper-crustal part of the fault network that bounded Baker Lake Basin.

The Wharton sub-basin is bounded to the east by faults trending northwest (Fig. 4.2). Facies relations and bedding attitudes indicative of back rotation suggest that these were basin-margin growth faults (LeCheminant et al., 1981). Paleocurrent data indicate that alluvial fans prograded west and southwest, feeding an axial braided fluvial system trending north to northwest (LeCheminant et al., 1981). These relations define a northwest-trending half-graben, oriented at high angle to the east-northeast trend of the greater Baker Lake Basin, prompting LeCheminant et al. (1981) to suggest that this was an allochthogen, or triple point junction within the rift system. Since adjacent strike-slip basins would be expected to have parallel trends, northeast *and* northwest trending half-graben further reinforce the interpretation of an overall extensional rather than strike-slip setting. Furthermore, extensional faulting on the margins of both basin trends (trending NE and WNW) requires oblique-slip on both fault systems resolving into N-S or E-W overall extension. Considering the dextral-normal kinematics of the northeast-trending Tyrrell shear zone (MacLachlan et al., in press), overall extension was probably directed N-S.

Conversely, the Dubawnt sub-basin trends east-west (Fig. 4.2) and is bounded by faults containing a composite siliciclastic succession much thicker than elsewhere in the greater Baker Lake Basin (Rainbird et al., 2003). It is considered to have formed as a small strike-slip basin during Baker Sequence time (Rainbird and Peterson, 1990; Rainbird et al., 2003).

In summary, Baker Lake Basin formed in response to regional N-S directed extension. Just as the Tyrrell shear zone is a re-activated older structure, so then are the structures that bounded the Baker Lake Basin, resulting in a series of northeast-trending half-graben. This is consistent with models involving decompression melting of the lithospheric mantle to produce the Christopher Island Formation volcanic rocks. In this predominantly extensional environment, footwall rocks to the Tyrrell shear zone were exhumed from amphibolite to greenschist metamorphic grade between ca. 1835 Ma and ca. 1816 Ma. Since lineation associated with ca. 1816-1810 Ma, the dextral-normal shear sense of the Tyrrell shear zone is quite shallow (MacLachlan, in press), it is likely that faulting changed from normal to predominantly strike-slip; the Dubawnt sub-basin formed during the latter strike-slip phase.

4.4.2 Post-Whart-, pre-Barrens Sequence deformation

Whereas the present position of the Baker Lake Basin is due to intra-Baker Sequence faulting (described above), the present structure of the Baker Lake Basin was largely determined by post-Whart-, pre-Barrens Sequence displacement on brittle faults. Three fault sets cut across both the Baker and Whart sequences, and occur throughout the greater Baker Lake Basin: (1) an east-west trending set of normal faults that bound rotated fault blocks; and (2) a conjugate array of strike-slip faults.

4.4.2.1 Normal Faults

At Thirty Mile Lake (Fig. 4.9), east-trending (~100°) faults bound north-dipping blocks that increase in dip from 30° to over 70°, from north to south. Since there are no penetrative fabrics nor structures such as folds to indicate some other process, this rotation is inferred to be due to dip-slip motion on listric normal faults. The distribution of bedding attitudes therefore indicates increased normal fault displacement and rotation from north to south, on faults that dip to the south. An analogy for this style of faulting is provided by the Basin and Range province of western U.S.A. (e.g. Brady et al., 2000).

At Aniguq River and directly west of Pitz Lake, east-trending normal faults bound fault blocks within which the Baker and Whart sequences display identical bedding attitudes that face south, with dips increasing toward the north. The attendant normal faults therefore dip north, and increase in degree of rotation in this direction. Most of these normal faults are not exposed but are inferred to underlie valleys infilled with Quaternary sediments. However, an east-west trending fault that cuts Whart sequence rhyolite is exposed in outcrop west of Pitz Lake (Fig. 4.10a). It dips to the north, and slickensides indicate dip-slip with a normal sense of displacement.

If the observations from Thirty Mile Lake to Aniguq River are considered as a transverse cross-section across the basin, then the configuration is that of normal faults dipping away from, and increasing rotation of fault blocks away from, a horst at the basin centre. These faults displace the Baker and Whart sequences, and where these sequences are in the same fault block, both have the same bedding attitudes with dips of up to 70°. Since the Barrens Sequence generally has dips less than 5°, principal displacement on these normal faults must have occurred after deposition of the Whart Sequence but before deposition of the Barrens Sequence. At the basin centre south of Pitz Lake where bedding attitude is sub-horizontal (Fig. 4.4), the Barrens Sequence unconformably overlies the Baker Sequence (Fig. 4.5). Thus, the orientation of normal faults suggests that this location was a central horst with normal faults stepping out to the north and south. This is consistent with stratigraphic relations which indicate that the central region was subject to erosion during post-Baker- and pre-Barrens Sequence north-south extension.

At eastern Baker Lake, the east-west trending normal faults are represented by a fault that has juxtaposed Baker Sequence conglomerate against anorthosite of the

Kramanituar complex (Rainbird et al., 1999). This fault dips south with a normal sense of displacement (Fig. 4.10b). A single north-trending normal fault is also present in the eastern Baker Lake area (Rainbird et al., 1999).

4.4.2.2 Strike-slip faults

Within the Baker Lake sub-basin a conjugate set of strike-slip faults occur as northwest-trending (340°) faults with dextral offset and northeast-trending (040°) faults with sinistral offset. These faults cut the Baker and Whart sequences as well as the east-trending normal faults. Minor offset of the Barrens Sequence occurs.

At Thirty Mile Lake a northwest-trending set (~340°) of faults is parallel to the set of intra-Baker sequence dilational faults (Fig. 4.9). Displacement of map units greater than ~50 m occurs on the late strike-slip faults, but the identical trends suggests that post-Whart sequence displacements occurred by reactivation of pre-existing structures. Additionally, although principal displacement occurred post-Whart Sequence, north of Pitz Lake Rainbird et al. (2003) identified overthickened sandstone units adjacent to a 340°-trending fault indicating syn-Whart displacement.

The Christopher Island area in the eastern Baker Lake sub-basin (Fig. 4.11) is dominated by dextral ~340° striking strike-slip faults. Sinistral ~040° striking faults have lesser offset (generally less than 50 m). At Christopher Island the conjugate fault set is best exemplified by the South Channel Fault, a northwest-trending dextral fault that separates the basal unconformity of the Baker Sequence by ~10 km (Schau and Hulbert, 1977).

This strike-slip fault system accommodated north-south shortening and east-west extension. North-south shortening would be expected to re-activate the east-west trending normal faults, but this hasn't been observed. Presence of a north-striking normal fault at Bowell Island near the eastern shore of Baker Lake (Rainbird et al., 1999), and also north-trending normal faults in the Kamilukuak sub-basin (Peterson and Rainbird, 1990), indicate that this system was probably driven by a component of regional east-west extension.

4.4.2.3 Fractures

Fracture sets are well developed in massive, volcaniclastic mudstones of the Christopher Island Formation, adjacent to the South Channel Fault (Fig. 4.11). Fractures oriented at 340°, 040°, and 100° together with tension gashes and a monoclinal set of kink bands are parallel to the fault sets that occur throughout the Baker Lake sub-basin (Figs. 4.12a-d). Fractures trending 040° show progressive sinistral rotation that has locally produced tension gashes (Fig. 4.12a).

Subvertical fractures trending ~100° have been rotated to a trend of ~340° to form a monoclinal set of kink bands (Fig. 4.12b). This dextral rotation produced a kink band trend of ~040°. Fig. 4.12c shows two kink bands formed by dextral rotation of fractures trending ~100°; these are linked by a set of fractures parallel to the rotated segment of the kink band and parallel to other fractures trending ~340°. Fig. 4.12b-c are considered to represent progressive states showing the incipient formation of fractures that trend ~340°. Where well developed, the fracture sets have mutually cross-cutting relationships (Fig. 4.12d).

These observations indicate that the succession of events was: 1) formation of the 100° fractures; 2) kinking; 3) formation of 340° fractures initially linking internal kink band fabric, which was generally coincident with 4) formation of 040° fractures and sinistral tension gashes; and 5) small-scale displacement on all fractures, resulting in mutually cross-cutting relationships.

Kink bands form in rocks that have a strong planar anisotropy (Ramsay, 1967). Experiments indicate that they form when maximum stress is at a low angle to the anisotropy (Gay and Weiss, 1974). However, these results apply best constrained to conjugate kink bands, not to the monoclinal set observed here. Sense of shear relative to the initial planar fabric will result in a sympathetic sense of rotation for a monoclinal kink set (Cruikshank et al., 1991). Thus, relative to the 100° fractures, the rock was subject to dextral shear. This may have been related to development of the dextral 340° fractures, to transtension related to presumably extensional forces that formed the 100° fractures, or to both. Subsequent linkage of the internal fabric between kink bands by fractures as part of incipient formation of the 340° fracture set favours the former explanation.

In summary, tension gashes indicate that the 040° fractures were characterized by sinistral kinematics, and kink bands suggest that the 340° fractures were dextral. Thus the fractures sets trending 040° and 340° are antithetic, comprising a conjugate array. Generally, the conjugate fracture array cross-cuts or deforms the east-west trending set (~100°). Mutually cross-cutting relations suggest that the east-west set was reactivated after the conjugate fracture array formed, although the sets probably were broadly contemporaneous.

4.4.2.4 Relations between fractures and faults

The trends of the fractures are parallel to the regional Whart Sequence faults and their kinematics are identical to the offsets indicated by the regional faults. Fractures are best developed in proximity to major faults, such as the South Channel Fault, and are therefore interpreted as mesofault-type fractures formed as part of the regional macrofault sets (cf. Peacock, 2001).

The implication of the fracture data that the east-west trending normal faults and the conjugate set of strike-slip faults may be coeval is problematic because they indicate opposite orientations of extension. The east-west trending normal faults accommodated north-south extension, whereas the conjugate strike-slip faults accommodated north-south shortening and east-west extension. As discussed previously, the strike-slip faults are parallel to pre-existing structures. So, if the primary component of extension was accommodated by the normal faults, then the conjugate strike-slip set may have accommodated a secondary component of extension in the east-west direction by reactivating a pre-existing fault system. It is also possible that the orientation of extension changed over time, and that this deviation was accommodated by the conjugate strike-slip system. Thus, a finite strain ellipse accommodating both fault systems would be oriented with the long axis inclined to the normal of the 100° fault set. It is unlikely that the conjugate fault set was driven by north-south contraction, because that would have re-activated the east-west trending normal faults as reverse faults, leading to basin inversion, a situation for which there is no evidence.

In summary, this episode of faulting and related fracturing represents extension that was oriented primarily north-south. A component of east-west extension is inferred to have been mostly accommodated by conjugate strike-slip displacement on a pre-existing fault system, but also by certain north-south trending normal faults. This occurred as multiple discrete events, during transtension, or both, probably over a protracted phase of overall extension. Although there is evidence for syn-Whart activity, principal displacement on the normal and conjugate strike-slip fault systems post-dated deposition of the Whart Sequence (ca. 1.76-1.75 Ga) and predated the Barrens Sequence (1720 +/- 6 Ma; Miller et al., 1989).

4.4.3 Post-Barrens Sequence reactivation

The Thelon Formation of the Barrens Sequence is cross-cut by the three fault sets that post-date the Whart sequence, but resulted in only minor offset, and minimal tilting as indicated by sub-horizontal bedding attitudes. This is considered to represent minor reactivation to which some of the uranium mineralization in the Thelon Basin is related (Fuchs and Hilger, 1989; Kyser et al., 2000).

4.5.0 Evolution of Baker Lake Basin: Summary

The greater Baker Lake Basin formed during overall north-south extension. Half-graben bounded by oblique-slip faults trended primarily northeast-southwest, parallel to the STZ, but the Wharton sub-basin trends northwest-southeast. Within the Baker Lake sub-basin, alluvial fans at the basin margins fed transverse and axial braided streams leading to lacustrine and eolian depocentres. Lithospheric extension led to decompression melting of the lithospheric mantle, likely beginning at ca. 1.85 Ga. This was followed by eruption of felsic minettes at localized volcanic centres within half-graben beginning at ca. 1.84 Ga. These represent mantle melts that probably had resided within, and were possibly contaminated by, continental crust (Peterson, 1994; Peterson et al., 1994, 2002). This phase is recorded by stratigraphic sequences B-1 and B-2, the rift initiation phase of the Baker Lake Basin (Fig. 4.13a). By the time sequence B-3 was deposited, the basin had widened and accommodation increased due to back-stepping of the normal fault system. Increased extension resulted in a renewed pulse of mantle melts recorded by a transition from felsic minette to minette volcanism near the B-2/B-3 sequence boundary. By the late stages of sequence B-4, minette volcanics had virtually blanketed the entire basin, marking the rift climax (Fig. 4.13b). This extension-dominated oblique-slip phase is considered to overlap with exhumation recorded in the footwall of the Tyrrell shear zone after metamorphism at ca. 1835 Ma (MacLachlan et al., in press). Sequence B-5 represents clastic infilling of remaining accommodation space after minette volcanism in a low accommodation setting, during a post-rift stage (Fig. 4.13c). During this post-rift stage, oblique-slip along faults bounding the Baker Lake Basin likely became dominated by strike-slip as lithospheric thinning decreased or ceased. Magmatism was represented by felsite domes, ca. 1810 Ma syenite plugs, and the youngest of the Hudson suite granitoid rocks. This time interval probably overlapped with dextral-normal shear on the Tyrrell shear zone between ca. 1816 Ma and ca. 1810 Ma (MacLachlan et al., in press). The youngest deposits of the Baker Sequence are older than ca. 1785 Ma.

The absence of basalt indicates that the asthenosphere was not involved in melting and so the alkaline melts were probably not a product of advective heat applied by magmas derived from the mantle (LeCheminant et al., 1987). In this respect, Baker Sequence rifting of Baker Lake Basin is considered to have been passive (c.f. Sengör and Burke, 1978; Ruppel, 1995; Sengör, 1995).

After deposition of the ca. 1.76-1.75 Ga Whart Sequence the Baker Lake Basin was subject to another phase of north-south extension. Strata were rotated north and south by east-west trending listric normal faults. Extension oblique to the main set of normal faults was accommodated by a pre-existing conjugate strike-slip system, involving faults that were active during the Baker and Whart sequences, and local north-south trending normal faults. Following extensional faulting, uplift, and extensive erosional planation and regolith development, the ca. 1720 Ma base of the Barrens Sequence was deposited over the region and since then has almost everywhere retained sub-horizontal bedding attitudes.

4.6.0 Discussion and regional implications

The integration of sedimentological and stratigraphic analysis, with new geochronological constraints provided by Rainbird et al., (2002; 2003; and in press), regional mapping (LeCheminant et al., 1979a; 1979b; 1980; 1981; 1983; Peterson and Rainbird, 1990; Rainbird and Peterson, 1990), and petrologic studies (LeCheminant et al., 1987; Peterson and LeCheminant, 1993; Cousens et al., 2001; Peterson et al., 2002) has led to a convincing reconstruction of the Baker Lake Basin and a better understanding of the stages of its evolution. This understanding allows for a comparison with time-equivalent events at the scale of the Western Churchill Province that have been documented as a result of the Western Churchill NATMAP Project. For example, the Hudson granite suite is now known to have been emplaced at lower crustal levels coeval with the Baker Sequence (Peterson et al., 2002; Rainbird et al., in press). Faults with significant normal offset during Baker Sequence time have been identified regionally (e.g. the TSZ MacLachlan et al., 2005, in press). Magnetotelluric data have illuminated the conductive structure of the Rae-Hearne crust, providing estimates on the depth of the MOHO in the vicinity of Baker Lake Basin (Jones et al., 2002). The depth of the MOHO raises an interesting point related to the Baker Lake Basin: The Kramanituar complex records pressures 12-15 kbar (~36-45 km depth) at ca. 1.9 Ga, yet the crust at ~1720 Ma was only 36-40 km thick (assuming tectonic inactivity since deposition of the Thelon Formation beginning at ca. 1720 Ga). This allows for zero net crustal thickening over this time period, yet Barrovian metamorphism has been documented in the "high pressure corridor" of the northwestern Hearne subdomain and the southern Rae domain between ca. 1.89 and 1.85 Ga (Berman et al., 2002b; 2004), which implies that significant crustal thinning occurred between ~1.85 Ga and ~1.72 Ga. Was extension related to the Baker Lake Basin part of this crustal thinning process? Finally, how does extension along the trend of the STZ that led to formation of the Baker Lake Basin fit into the overall tectonic framework of the Western Churchill Province?

4.6.1 Pre-Baker Lake Basin history of the Western Churchill Province

There are two end-member tectonic assembly models for the Western Churchill Province. In an Archean model (Davis et al., 2000; Hanmer and Relf, 2000) supracrustal rocks of the Woodburn Group in the southern Rae domain were deposited in a continental setting at ca. 2735-2710 Ma (Zaleski and Davis, 2002). Juvenile, 2.7-2.65 Ga supracrustal belts of the northwestern Hearne sub-domain, though influenced by older crust of uncertain affinity, were amalgamated with the Rae domain prior to widespread intrusion of ca. 2.64-2.58 Ga granitoids. Supracrustal rocks of the central Hearne sub-domain were deposited at 2.71-2.67 Ga in an intra-oceanic arc setting (Hanmer et al., 2004; Sandeman et al., 2004). Ca. 2.55-2.5 Ga metamorphism in the northwestern Hearne, also recorded on the Tyrrell shear zone a possible boundary between the northwestern- and central Hearne sub-domains (MacLachlan et al., 2005), is postulated to post-date final assembly of a combined Rae-Hearne Archean craton.

Within the Archean assembly model, Baker Lake Basin formed on a major crustal break, the Snowbird Tectonic Zone, which formed by ca. 2.6 Ga and was reactivated in an intracratonic setting in the Paleoproterozoic. Deformation and metamorphism related to northwest-vergent shortening at ca. 1.89-1.85 Ga within the northwestern Hearne sub-domain is analogous to Laramide-style foreland deformation, which occurred hundreds of km from a convergent margin.

Alternatively, in a two phase Archean-Proterozoic assembly model for the Western Churchill Province, the Rae domain and northwestern Hearne sub-domain were amalgamated by ca. 2.6 Ga (Pehrsson et al., 2004). Beginning at 1.9 Ga the central Hearne sub-domain was accreted, and subsequent northwest-vergent 1.89-1.85 Ga deformation in the northwestern Hearne sub-domain and southern Rae domain records shortening related to a microcontinent-continent collision.

However, problems with Archean-Proterozoic assembly include the lack of evidence for a magmatic arc to consume crust that would have separated the two crustal blocks, the lack of an arc signature in the youngest Hurwitz and Amer group rocks, the absence of coeval south-vergent fold and thrust deformation of the central Hearne sub-domain, and the problematic Archean history of structures bounding the central and northwestern Hearne sub-domains (e.g. Tyrrell shear zone). Although new data will shed light on these outstanding problems, 2.6-2.5 Ga amalgamation of a Rae-Hearne craton is herein presumed to be most likely.

4.6.2 Baker Sequence: Initiation of Baker Lake Basin

Several observations suggest that Baker Lake Basin formed in an extensional tectonic environment. These include the apparent synchroneity of deposition along the longitudinal axis of the Baker Lake sub-basin, coeval juxtaposition of amphibolite- and greenschist-facies rocks against a potential basin-bounding fault (the Tyrrell Shear Zone), voluminous mantle-derived minette flows, and the orientation of lamprophyre dykes.

The Kramanituar Complex underwent ca. 1.9 Ga exhumation from the lower to middle crust, although final unroofing likely post-dated ca. 1.89-1.85 Ga deformation and metamorphism and preceded the Baker Sequence. Within the Nowyak Complex, located south of the Tyrrell shear zone, Ter Meer (2001) considered that post-tectonic garnet breakdown and ca. 1.82 Ga matrix monazite were related to ca. 1.82 Ga granite plutonism and uplift. This relation also is hinted at within the Uvauk Complex, where Mills (2001) postulated that garnet breakdown and retrograde metamorphism was related to Hudson granite intrusion. Thus, final unroofing of the Kramanituar Complex preceded Baker

Lake Basin formation but it appears that other metamorphic core complexes southeast of the basin underwent exhumation coeval with deposition of the Baker Sequence and exhumation of Tyrrell shear zone footwall rocks, possibly by a similar mechanism.

Lamprophyre flows and dykes equivalent to the Christopher Island Formation occur along the Snowbird Tectonic Zone from Baker Lake to within 20 km of the Martin Group in Saskatchewan (Donaldson, 1968; Ashton et al., 2004). The Martin Group, comprises coarse siliciclastic deposits that are possibly correlative to those in Baker Lake Basin, and was deposited in an areally restricted, high accommodation basin (Donaldson, 1968; Fraser et al., 1970; Macey, 1973; Ashton et al., 2004). Basaltic volcanic rocks with geochemical characters indicating derivation from an enriched mantle source are considered to have an age of ca. 1.82 Ga (Morelli et al., 2002; Ashton et al., 2004). Correlation along the STZ implies that greater Baker Lake Basin is the most northerly of a series of fault-bounded, volcanic basins that parallel the STZ and formed at ca. 1.84-1.82 Ga. Since the Committee Bay supracrustal belt (Fig. 4.1) was undergoing ca. 1.85-1.82 Ga tectonometamorphism related to deformation of the Baffin Island segment of the Trans-Hudson Orogen at this time (Carson et al., 2004), this zone of extension didn't extend much farther northeast than the Baker Lake sub-basin.

Models for passive rifting involve stresses on lithospheric plates exerted from plate margins, as opposed to upwelling of mantle below active rifts (e.g. Sengör and Burke, 1978; Ruppel, 1995; Sengör, 1995); thus, the cause of extension that produced the Baker Sequence was probably related to tectonic events at the continental margin. At ca. 1850 Ma, the western cratonic margin was on the west side of Slave Province, represented by the ca. 1.95-1.84 Ga Wopmay orogen (Hoffman, 1988). Closer to the Baker Lake Basin in the Saskatchewan-Manitoba segment of the Trans-Hudson Orogen, the 1865-1850 Ma Wathaman Batholith records continental arc magmatism after accretion of the La Ronge – Lynn Lake arc (Meyer et al., 1992; Corrigan et al., 2001) (Fig. 4.14a). Convergent margins can induce hinterland extension by hinge retreat due to slab rollback, which is accompanied by back-arc extension (Forsyth and Uyeda, 1975; Molnar and Atwater, 1978). Ansdell (1995) has proposed that cessation of Wathaman Batholith magmatism was due to ca. 1.85 Ga accretion of the Flin Flon - Glennie complex to the southern Hearne craton (Fig. 4.14b). Subduction continued on the southeastern side of the Flin Flon - Glennie complex, and as a result the "Kisseynew back-arc basin" formed between 1.85-1.84 Ga due to subduction rollback. Felsic and mafic retro-arc magmatism continued from 1840 to 1820 Ma (Hollings and Ansdell, 2002). Basin inversion occurred during the terminal collision phase of the Trans-Hudson Orogen beginning at ca. 1.83 Ga Ma, and all rocks underwent amphibolite-facies metamorphism at ca. 1815-1800 Ma, during collision of the Superior craton (Ansdell, 1995; Hollings and Ansdell, 2002). With respect to this model, extension in the Baker Lake Basin and thus, along the STZ, coincided with the initiation of the "Kisseynew back-arc basin", and would similarly be due to subduction roll-back (Fig. 4.14c). Late Tertiary extensional basins of eastern China that formed as part of the rifting event responsible for opening of the Japan Sea (Tian et al., 1992; Ren et al., 2002) provide appealing analogues. These basins contain alkaline basalts that are interpreted as melts of the upper mantle (Fan and Hooper, 1991), similar to the alkaline basalts of the Martin

Group. After rifting of a paleo-Honshu continental arc, back-arc basin spreading began at ca. 22 Ma, and most of the Japan Sea ocean floor had formed by ca. 15 Ma (Taira, 2001). This was accompanied by the migration of arc magmatism toward the trench, indicating slab rollback and subduction retreat. Closure of the Japan Sea is postulated to be presently underway (Tamaki and Honza, 1985), suggesting an opening-closing cycle of approximately 30 Ma duration.

The distance from the Baker Lake Basin to the Trans-Hudson Orogen seems large (~500 km); however, a retro-arc extension model has been applied to the Rio Grande rift on the east side of the Colorado Plateau (Lawton and McMillan, 1999), approximately 1000 km from the west coast of North America (considering 50-100% extension of the Basin and Range, this was probably 600-700 km). The Rio Grande rift formed during subduction along the west coast of Laurentia, but prior to subduction of the East Pacific Rise and large-scale Basin and Range extension (Wernicke and Snow, 1998; Lawton and McMillan, 1999). Based in part on the Rio Grande rift, Lawton and McMillan (1999) suggested a three phase model for formation of passive continental rifts behind arc systems. During phase 1, continental arc magmatism weakens the crust. Phase 2 involves slab rollback causing continental extension, lithospheric melting, and deposition in rift basins. During phase 3, slab foundering, mantle upwelling and local decompression melting of the asthenosphere leads to eruption of ocean-island-like basalts within the rift basins. Phase 2 fits the BLB well, but phases 1 and 3 do not.

First, there are no arc-related plutons in the crust beneath the BLB to support comparison to Phase 1, so thermal weakening of the crust does not account for the location of the BLB. However, a crustal-scale discontinuity such as the STZ would provide a mechanical explanation. Second, the absence of asthenospheric melts of phase 3 are absent from the Hudson granite suite and the Baker Sequence, can be accounted for if the lithosphere was sufficiently thick to prevent decompression melting of upwelling asthenosphere.

In considering the minette - calc-alkaline granite association (MCG) of the Christopher Island Formation lamprophyres, Peterson et al. (2002) have speculated on retro-arc processes including slab breakoff and asthenospheric upwelling. Crustal thickening was discounted as the sole cause of lithospheric melting because minettes have high liquidus temperatures. Additionally, the large areal extent of the Hudson granitoid suite may indicate that minette magmas weren't the only heat source for crustal melting. Lithospheric mantle melting was attributed to a combination of extension and heat flux from upwelling asthenosphere after slab breakoff beneath the THO hinterland. It was noted that the lack of evidence for a juvenile mantle source is an outstanding problem, in addition to time required for geotherms to rise through the lithosphere to melt the lower crust. Thus, emplacement of the Hudson granitoid suite was considered to sufficiently post-date a crustal thickening event to allow geotherms to rise. This crustal thickening event may be related to ca. 1.89-1.85 Ga deformation and metamorphism of the northwestern Hearne sub-domain and southern Rae domain (e.g. Berman et al., 2002; Pehrsson et al., 2001). Combining arguments offered by previous authors, a modified model would be "passive" retro-arc extension, decompression melting of the lithospheric mantle (Cousens et al., 2001), and advective heat flux by alkaline magmas to melt the lower crust (Sandeman et al., 2000). Additionally, thick lithosphere may have prevented melting of potentially upwelling asthenosphere. Whereas extension did post-date a regional shortening event, it's not clear if the Hudson granitoids formed due to anatexis, to advective heat flux, or to both at different times.

As an alternative to the retro-arc extension model, if collisional tectonics at the southern Hearne margin began when the Baker Lake Basin was initiated, then a lateral tectonic escape model can by applied (Peterson, 1994; Rainbird et al., 2003). But, as a result of emerging geochronologic data, basin formation is considered to have occurred at ca. 1.84 Ga (Rainbird et al., in press), preceding THO terminal collision and within the time interval of a postulated back arc basin (Ansdell et al., 1995; Hollings and Ansdell, 2002). Additionally, since strike-slip fault systems shorten and extend without a change in thickness, a lateral tectonic escape model fails to account for: upper mantle melts; exhumation of rocks in the northwestern Hearne subdomain; and inferred crustal thinning post-dating ca. 1.89-1.85 Ga regional shortening and metamorphism in the northwestern Hearne sub-domain and southern Rae domain. Retro-arc extension is therefore here considered a more favourable model.

Another alternative is that ca. 1.89-1.85 Ga fold-and-thrust deformation in the northwestern Hearne sub-domain and southern Rae domain was due to accretion of the central Hearne sub-domain beginning at ca. 1.9 Ga (Pehrsson et al., 2004). It is uncertain what the subduction polarity would have been, because evidence for a magmatic arc is absent. Baker Lake Basin would have formed during post-collisional extension during which prior crustal thickening was reversed and the MOHO restored to approximately the present depth of 36-40 km (Jones et al., 2002). With respect to magmatism, the Hudson granitoid suite would initially record lower crustal melting due to rising geotherms following crustal thickening. Subsequent crustal melting could have been due to advective heat supplied from minette magmas that formed by extensional decompression-melting of the lithospheric mantle, perhaps supplemented by slab break-off and asthenospheric upwelling. This fits a model proposed by Peterson et al. (2002): in which a zone of mixed crust and upper mantle formed during a shortening event which resulted in middle crustal melting to form the Hudson granitoid plutons; Subsequently the minettes may have formed during extension related to slab breakoff, gravitational collapse, and/or strike-slip faulting. But as stated previously, Archean amalgamation of a combined Rae-Hearne domain is herein considered most likely.

4.6.3 Baker Sequence: Evolution of Baker Lake Basin

Continent-continent collision of the Superior and Rae-Hearne cratons led to tectonic shortening in Saskatchewan-Manitoba (ca. 1.83-1.80 Ga) as well as in Baffin Island segments of the Trans-Hudson orogen, including the Committee Bay supracrustal belt located west of Baffin Island (ca. 1.85-1.82 Ga; Carson et al., 2004)(Fig. 4.1). The Kisseynew back-arc basin underwent inversion and metamorphism by ca. 1.82 Ga (Ansdell et al., 1995; Hollings and Ansdell, 2002), shortly before folding and thrusting of the Martin Group (Ashton et al., 2004). However, the Baker Lake Basin was situated between the deformational foci of the Superior- Western Churchill Province collision, and thus was not subject to shortening-related deformation.

Orogenic shortening associated with THO terminal collision may have driven "lateral escape tectonics" in the Baker Lake Basin area, characterized by strike-slip faults and basins, as described from southeast Asia adjacent to the Himalayan Orogen. (Tapponier and Molnar, 1979). Notably, the latest motion on the normal fault systems that bounded the Baker Lake Basin would have been primarily strike-slip, contemporaneous with dextral-normal shear sense, associated with a lineation plunging shallowly northeast, on the Tyrrell Shear Zone between 1816 Ma and 1810 Ma (MacLachlan et al., in press). Because strike-slip fault systems shorten/extend without a change in thickness, decompression melting of lithospheric mantle would have ceased, consistent with eruption of fractionated felsite flows. In Baker Lake sub-basin there are only a few thin deposits younger than the minette flows suggesting that subsidence was minor. In the late stages of basin evolution, sediment and volcanic flux outpaced accommodation, which resulted in the post-rift signature of sequence B-5 (Fig. 4.14d). This suggests a two phase history of the Baker Lake Basin: initially within a high accommodation, extension-dominated setting (Fig. 4.14c), followed by a low accommodation, strike-slip-dominated system (Fig. 4.14d).

4.6.4 Whart Sequence

Rhyolite flows, dated at 1758 +/- 3 Ma and 1754 +/- 2 Ma (Rainbird et al., 2003), and sedimentary deposits of the Whart Sequence unconformably overlie the Baker Sequence. Rainbird et al. (2003) considered this to be a modified rift phase, subsequent to the initial rifting that formed the Baker Lake Basin. Detrital zircons populations include ca. 1.83 Ga ages likely derived from the Hudson granitoids (Rainbird et al., in press). Exhumation and erosion of the middle crustal levels into which the Hudson granitoids were intruded (Peterson et al., 2002), is also reflected in ca. 1.8-1.7 Ga Ar-Ar ages in northwestern Hearne between Yathkyed and Kaminak lakes (Sandeman, 2001) and ~1.75 Ga K-Ar ages in the Rae Province (Loveridge et al., 1988).

Deposition of the Whart Sequence was followed by extensional faulting, in part reactivating syn-Whart Sequence faults. These sets of faults occur throughout the greater Baker Lake Basin, and therefore represent regional post-Whart, pre-Barrens sequence extension. This may have been a continuation of syn-Whart Sequence faulting, where final attenuation was accompanied by uplift and erosional planation prior to deposition of the Barrens Sequence. Such a stage would have been analogous to extension in the uplifted Basin and Range (Wernicke and Snow, 1998; Stewart and Diamond, 1990), though on a smaller scale.

The link between basalt and rhyolite/granite magmatism, extension, and the post-collisional state of the THO prompted Peterson et al. (2002) to propose a mantle delamination model. This model has the advantage of accounting for the absence of minettes subsequent to Christopher Island Formation magmatism: "the source was removed by delamination and foundering of the lithospheric upper mantle, permitting generation of basalt by mantle upwelling." However, complete delamination didn't occur since M-T data (Jones et al., 2002) suggest that a thick lithospheric mantle presently exists below the Western Churchill Province.

4.6.5 Barrens Sequence

Following normal faulting, broad uplift, and chemical weathering, the Thelon Formation of the Barrens Sequence was deposited over a well-developed regolith across Baker Lake and Thelon basins (Ross and Chiarenzelli, 1985; Gall, 1994; Rainbird et al., 2004). Thelon Basin is interpreted as an intracontinental basin with slow, long-lived subsidence that probably was contemporaneous with formation of the Athabasca Basin in northern Saskatchewan (Gall et al., 1990; Rainbird et al., 2003; in press). Since it post-dates rifting of the Baker and Whart sequences by less than ~30 Ma, it fits models involving post-rift thermal subsidence (e.g. DeFrito et al., 1983). Stratigraphic thickness of the Thelon basin, paleocurrent data, and sedimentary facies indicate that subsidence was greater to the west, marking a northwestward shift in the locus of sedimentation relative to the BLB (Rainbird et al., 2003). If thermal subsidence was related to post-rift cooling of the lithosphere, then it traces maximum heat flux, and the northward shift is consistent with the inferred polarity of the faults that initially bounded Baker Lake Basin.

4.7.0 Conclusion

Rift initiation within the Baker Lake sub-basin resulted in deposition of coarse siliciclastic alluvium and localized extrusion of crustally contaminated, mantle-derived magmas (Peterson et al., 2002) within a northeast trending-half graben. During rifting, increased areal extent of the basin due to back-stepping of the normal fault system, as inferred from retrogradation of the sedimentary facies, was accompanied by voluminous and widespread extrusion of near primary upper mantle melts (Peterson and LeCheminant, 1993; Cousens et al., 2001; Peterson et al., 2002). Basin-bounding faults are considered to have been oblique-slip, with overall extension oriented north-south. This was contemporaneous with normal offset along a potential basin-bounding fault, the Tyrrell shear zone, between ca. 1835 Ma and ca. 1816 Ma (MacLachlan et al., in press).

The greater Baker Lake Basin is considered to have been part of a series of extensional, volcanically influenced basins spanning the length of the STZ, including the Martin group in northern Saskatchewan. Intracontinental extension is proposed to have been a far-field response to extension associated with ca. 1.85-1.84 Ga formation of the Kisseynew back-arc basin on the southeastern margin of the Rae-Hearne craton (Fig. 4.14c). Suggested analogs for this tectonic setting include the Rio Grande Rift (Lawton and McMillan, 1999), and Tertiary extensional basins of eastern China related to late Tertiary opening of the Japan Sea (Tian et al., 1992; Ren et al., 2002).

Upon ca. 1.82 Ga closure and inversion of the Kisseynew back-arc basin during terminal collision of the Superior and Rae-Hearne cratons, extension along the STZ transformed into post-ca. 1.82 Ga shortening in the Martin Basin and strike-slip lateral escape tectonics in the Baker Lake Basin (Fig. 4.14d). Minimal subsidence in the BLB and extrusion of fractionated products of minette magmas (Peterson, 1994; Peterson et al., 2002) accompanied this phase. This may indicate that lithospheric thinning had ceased, consistent with stratigraphic indications of a post-rift phase. This is postulated to be contemporaneous with dextral-normal kinematics on the Tyrrell shear zone between ca. 1816-1810 Ma, marking the lower ca. 1.81 Ga age range of the Hudson granites and Martell syenites.

Following a subsequent modified-rifting event at ca. 1.76-1.75 Ga, recorded by rhyolites of the Whart Sequence, variably north-south extension was accommodated by east-west trending normal faults, north-trending normal faults, and a conjugate strike-slip fault set. The ca. 1720 Ma base of the Barrens Sequence marked the formation of a broad intracontinental basin due to post-rift thermal subsidence.

AMZ - Amer Mylonite Zone
BF - Bathurst Fault
CBB - Committee Bay Belt
CFZ - Chesterfield Fault Zone
EAMT - East Athabasca mylonite triangle
FF-GD - Flin Flon-Glennie Domain
GSLSZ - Great Slave Lake Shear Zone
GBA - Great Bear Magmatic Arc
KCX - Kramanituar Complex
KD - Kisseynew Domain
SAMZ - Striding Athabasca Mylonite Zone
STZ - Snowbird Tectonic Zone
THO - Trans-Hudson Orogen
TM - Talston Magmatic Zone
TTZ - Thelon Tectonic Zone
TuFZ - Tulemalu Fault Zone
TySZ - Tyrrell shear zone
UCX - Uvauk Complex
WB - Wathaman Batholith
WBG - Woodburn Group
WBSZ - Wager Bay Shear Zone
WG - Wollaston Group

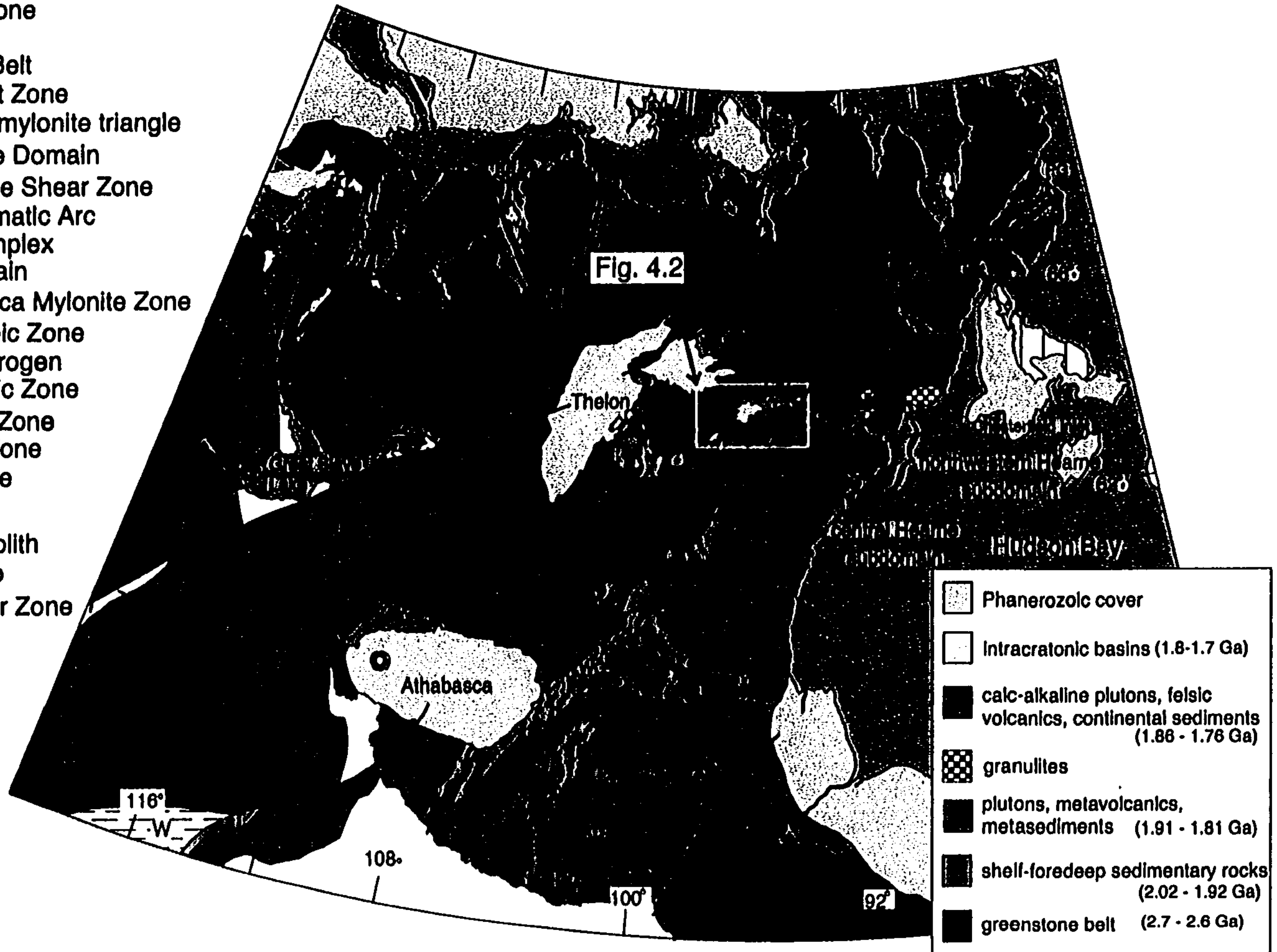


Figure 4.1: Regional geology map o f the western Canadian Shield, including the Archean Slave, Western Churchill (Rae-Hearne), and Superior provinces (after Wheeler et. al, 1997).

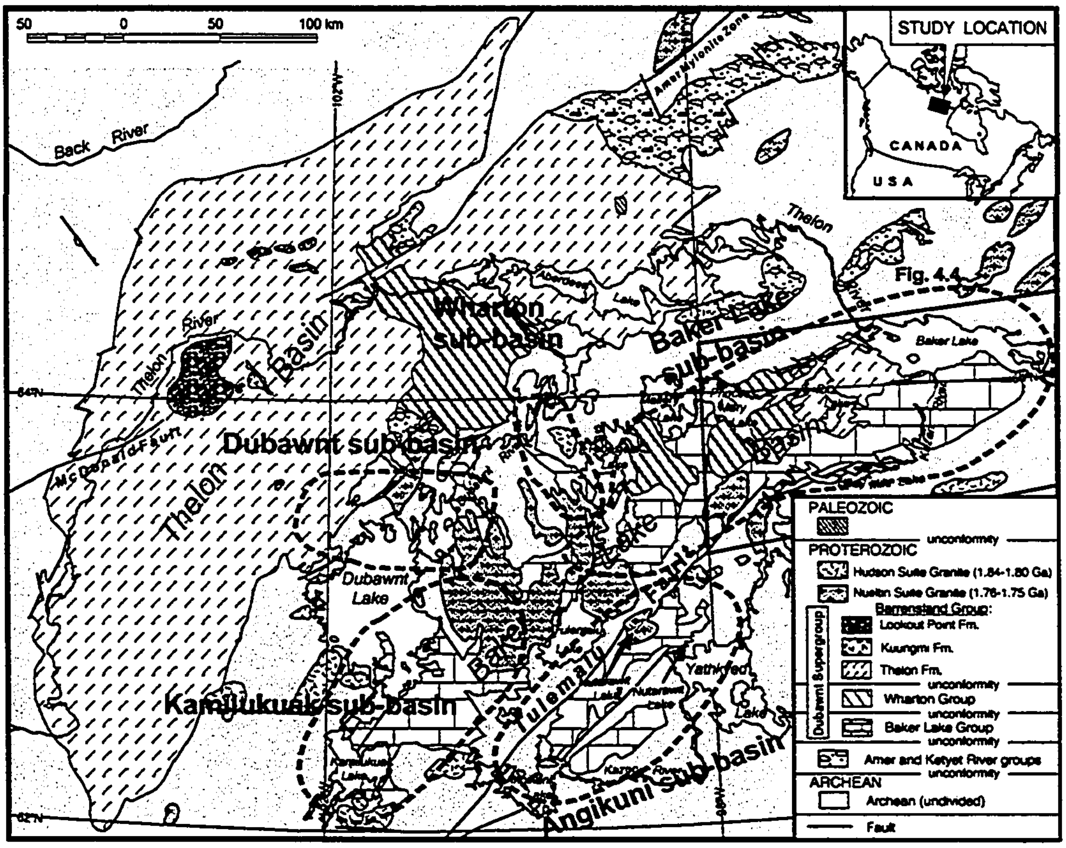


Figure 4.2: Geologic map of the greater Baker Lake Basin, highlighting the distribution of sub-basins (after Rainbird et al., 2003).

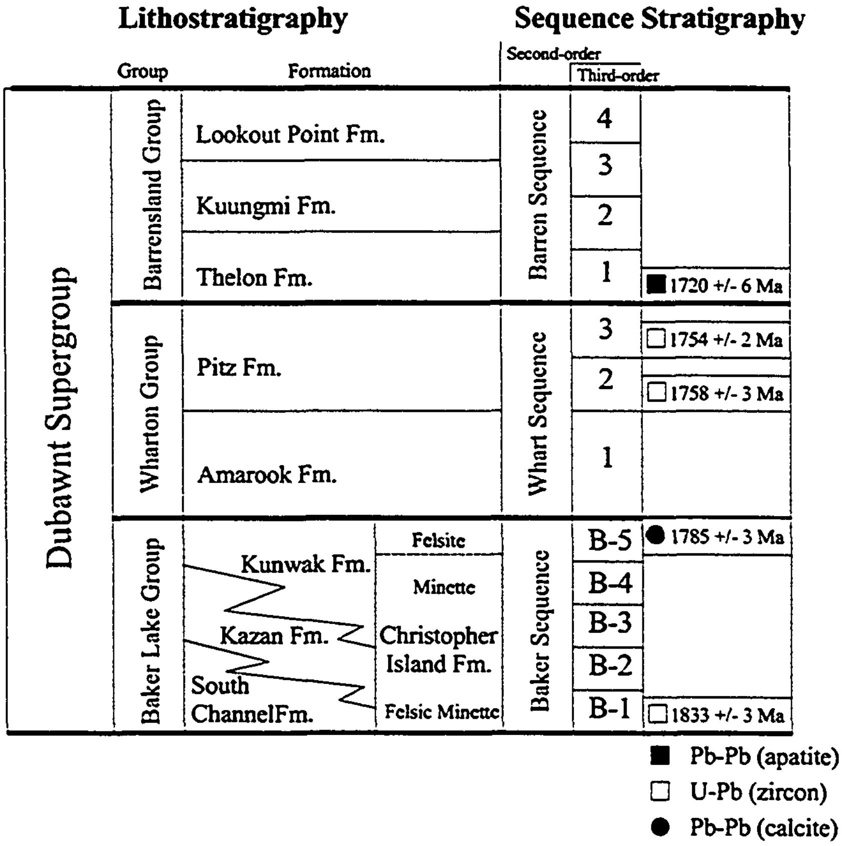


Figure 4.3: Litho- and sequence stratigraphy of the Baker Lake Basin. Geochronology sources: Thelon Fm., 1720 +/- 6 Ma (Miller et al., 1989); Pitz Fm., (Rainbird et al., 2001); Baker Lake Grp.,1785+/-3 Ma (Rainbird et al., 2002), 1833+/-3 Ma (Rainbird et al., in press).

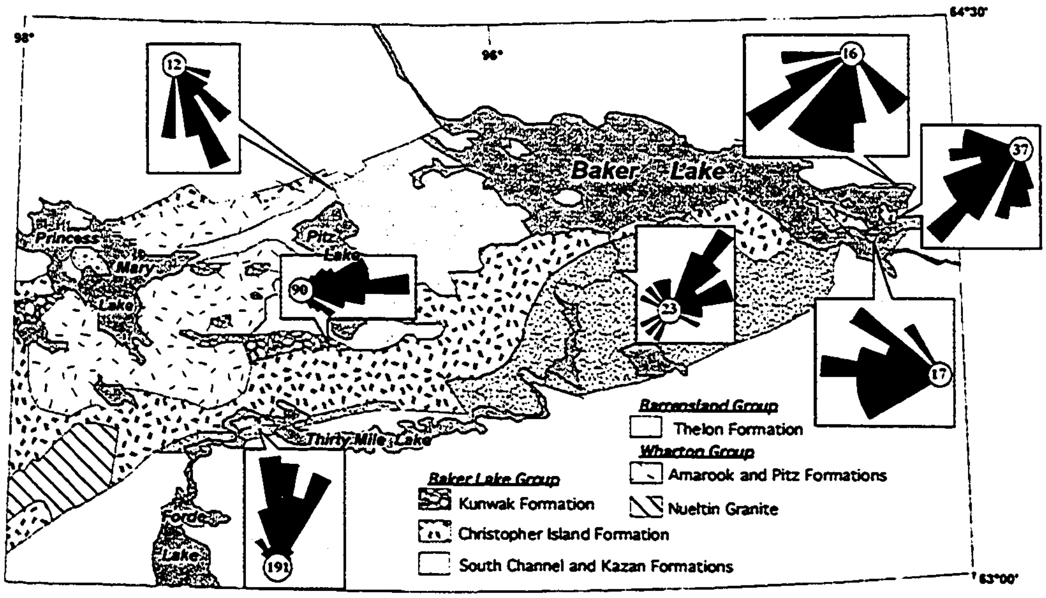


Figure 4.4: Geology of the Baker Lake sub-basin, including paleocurrent data derived from cross-set and primary current lineation measurements.

Figure 4.5: North-south cross-section of the Baker Lake Basin from Aniguq River to Thirty Mile Lake. The sedimentary and complementary volcanic-dominated sections are lateral equivalents. The Thirty Mile Lake volcanic section is composite. Note that the Kunwak River outcrop contains felsite clasts, equivalent to the youngest volcanic rocks at Thirty Mile Lake.

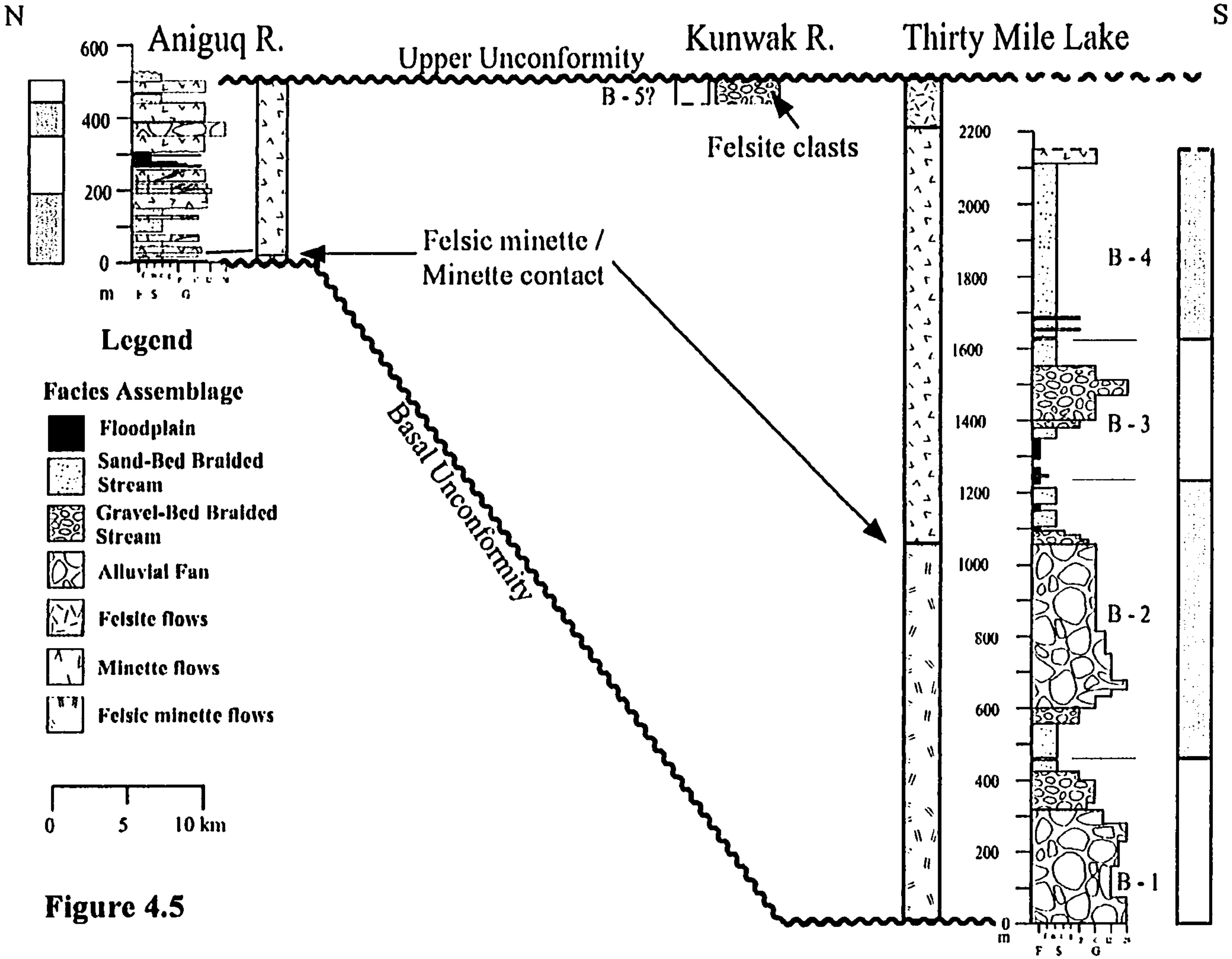

N
S
Aniguq R.
Upper Unconformity
Kunwak R.
Thirty Mile Lake
B - 5?
Felsite clasts
Felsic minette /
Minette contact
Basal Unconformity
B - 4
B - 3
B - 2
B - 1
Legend
Facies Assemblage
Floodplain
Sand-Bed Braided Stream
Gravel-Bed Braided Stream
Alluvial Fan
Felsite flows
Minette flows
Felsic minette flows
0
5
10 km

Figure 4.5

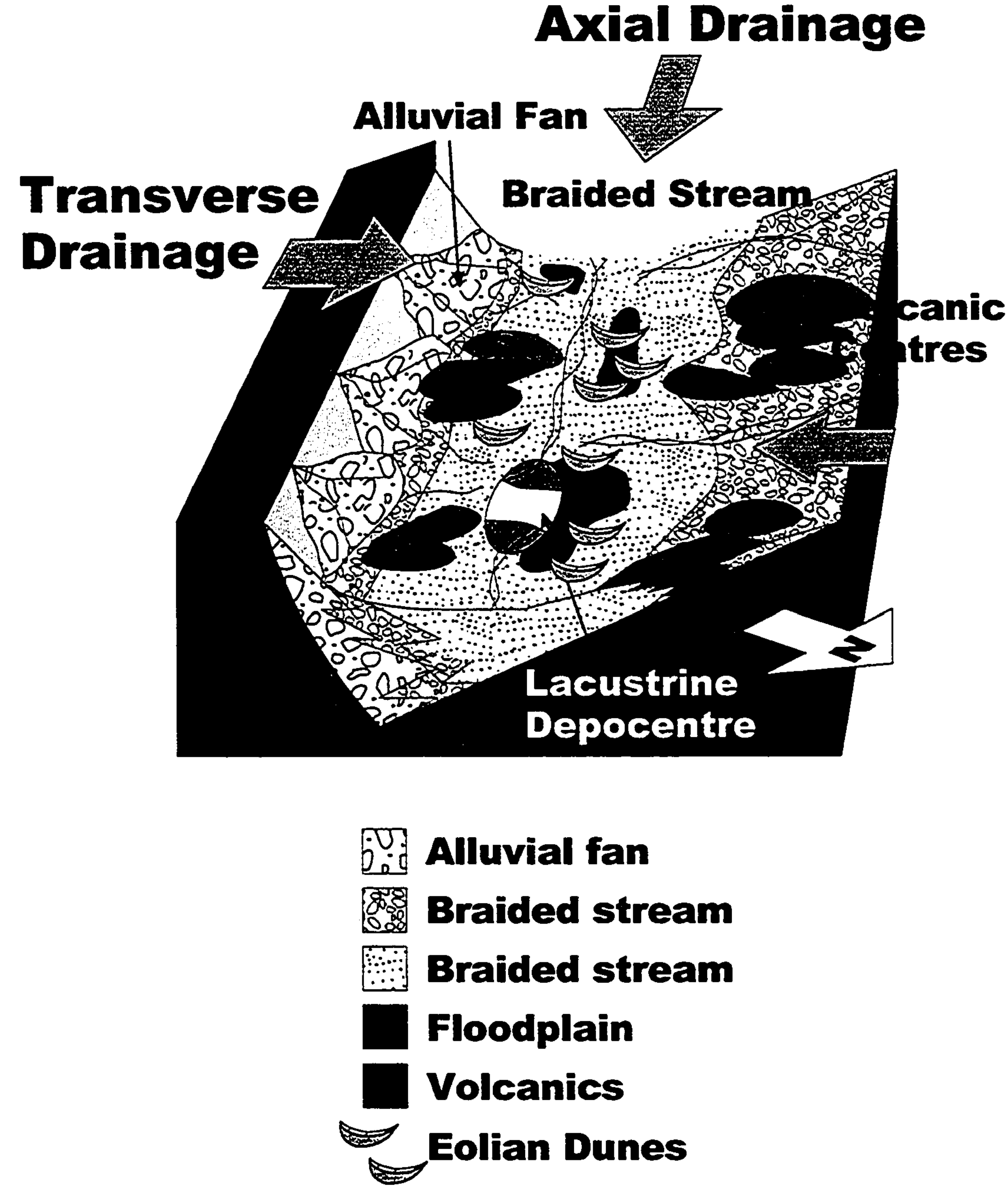


Figure 4.6: Block diagram of half-graben and facies tracts from the Baker Sequence of the Baker Lake sub-basin.

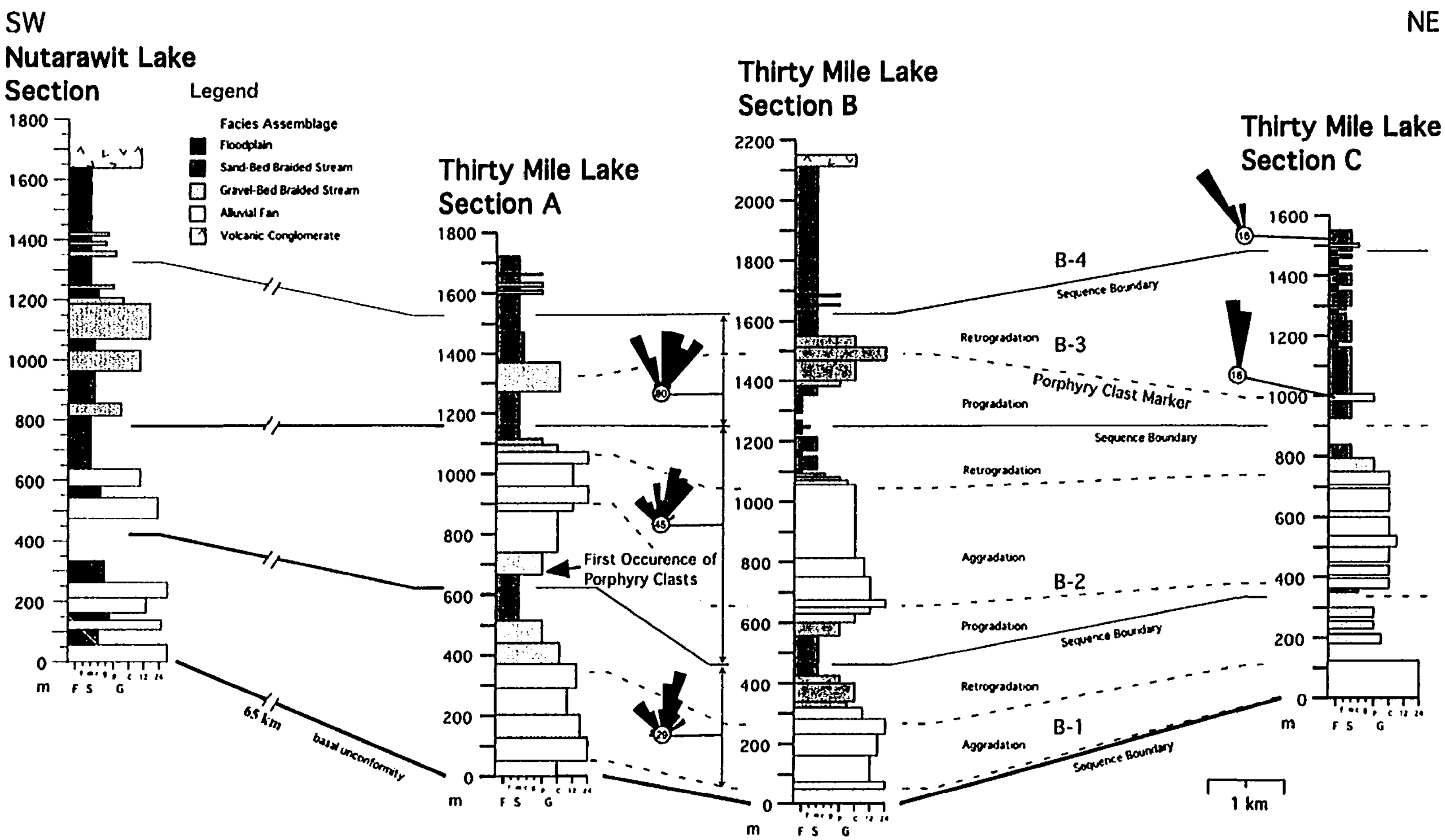


Figure 4.7: Sections of the sequences BL-1 to BL-4 from the Thirty Mile Lake area, correlated to a section from Nutarawit Lake linking the Baker Lake and Angikuni sub-basins. F = mud, S = sand, and G = gravel. See figure 4.2 for the location of Nutarawit Lake.

(a)

(b)

(c)

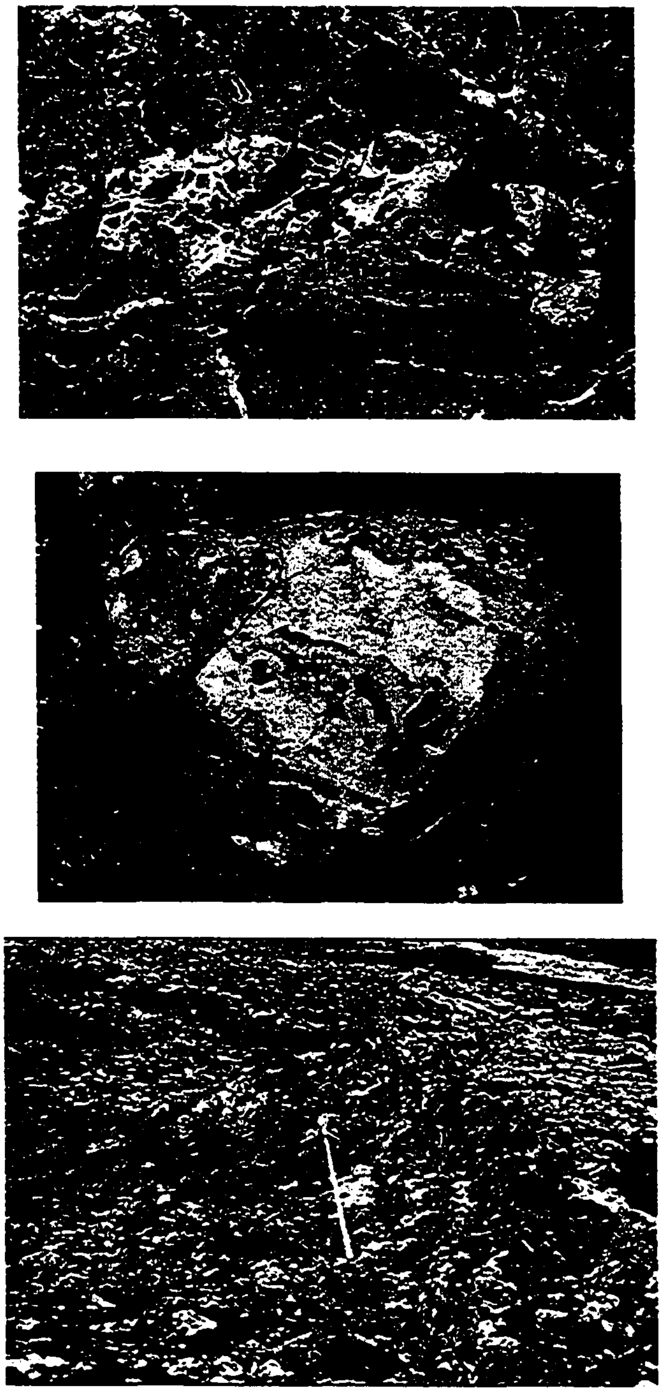


Figure 4.8: Strike-slip faults: (a) quartz stockwork in syn-Christopher Island Formation dilational fault; (b) quartz stockwork clast removed from conglomerate of sequence B-5; and (c) strike-slip fault of the 040° set, 80 cm pole on the fault line for scale.

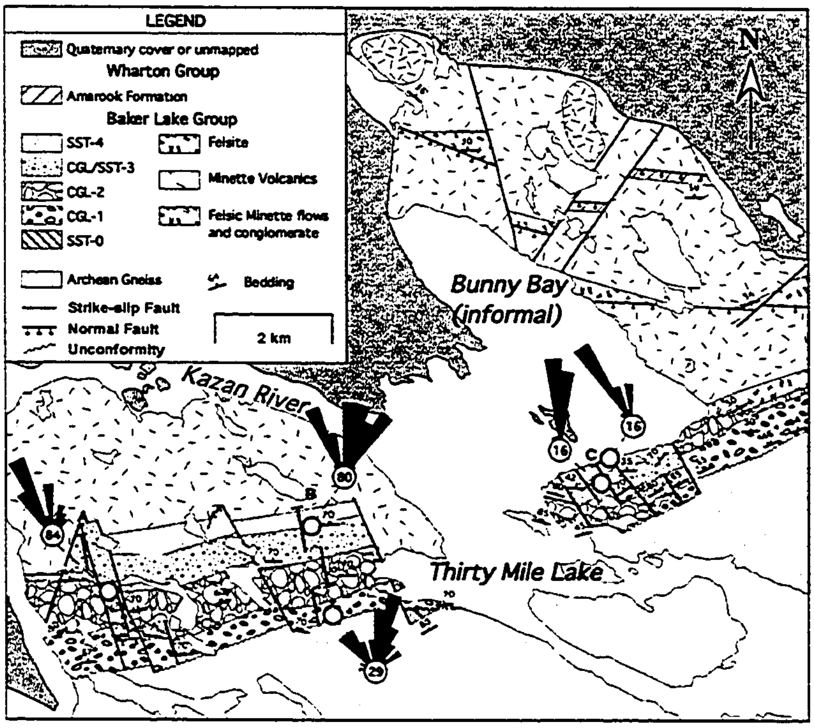


Figure 4.9: Geology of the Thirty Mile Lake study area.

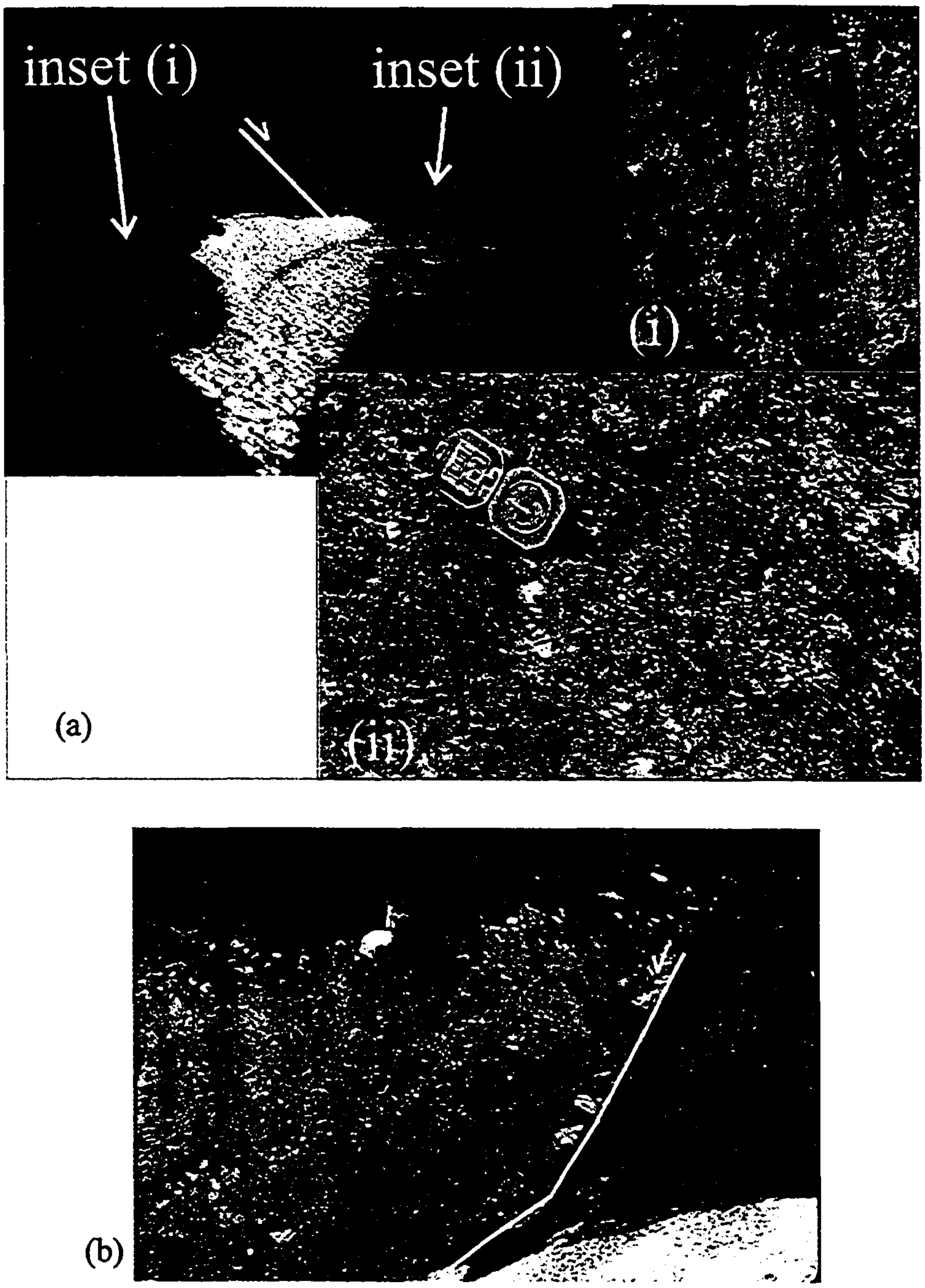


Figure 4.10: Normal faults: (a) north-dipping fault located west of Pitz Lake, inset (i) shows dip-slip slicken linears, and inset (ii) shows intense fractures parallel to the fault plane; (b) a normal fault that juxtaposes Baker Sequence conglomerate against anorthosite of the Kramanituar Complex.

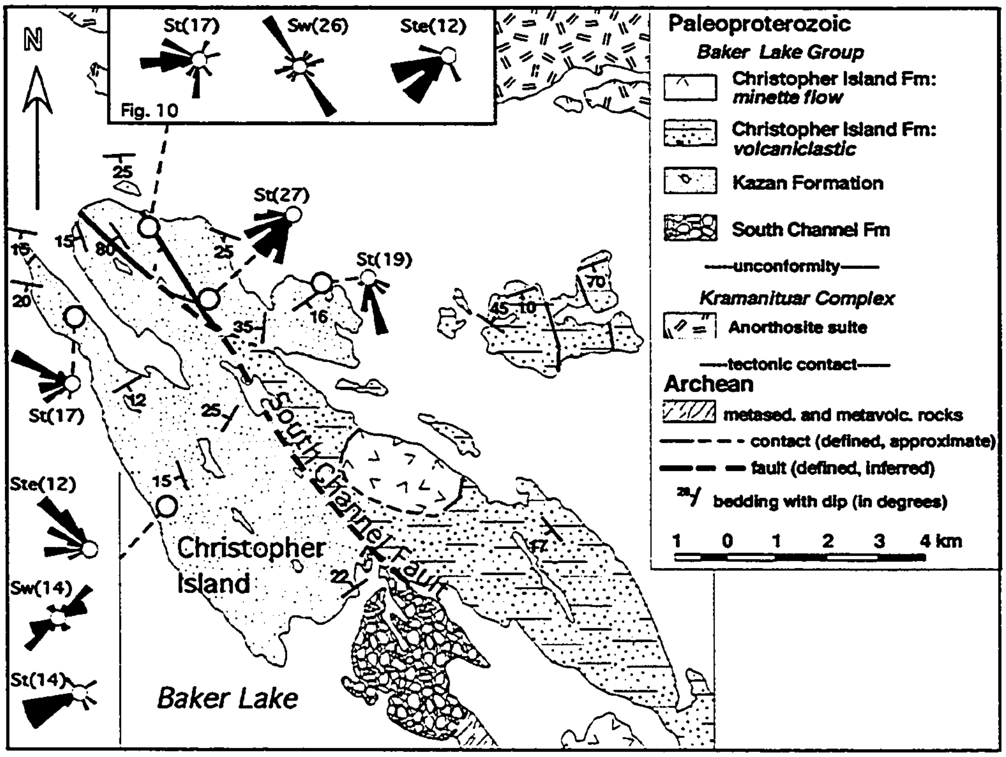


Figure 4.11: Geologic map of the Christopher Island study area including paleocurrent data (St = fluvial; Sw = wave ripple crests; Ste = eolian cross-sets).

Figure 4.12: Structures developed within relatively homogeneous volcaniclastic mudstone: (a) tension gashes indicating sinistral rotation of fractures trending ~040 ; (b) kink band; (c) fractures trending ~340 linking rotated, internal kink band fractures; (d) three fractures sets with mutually cross-cutting relations.

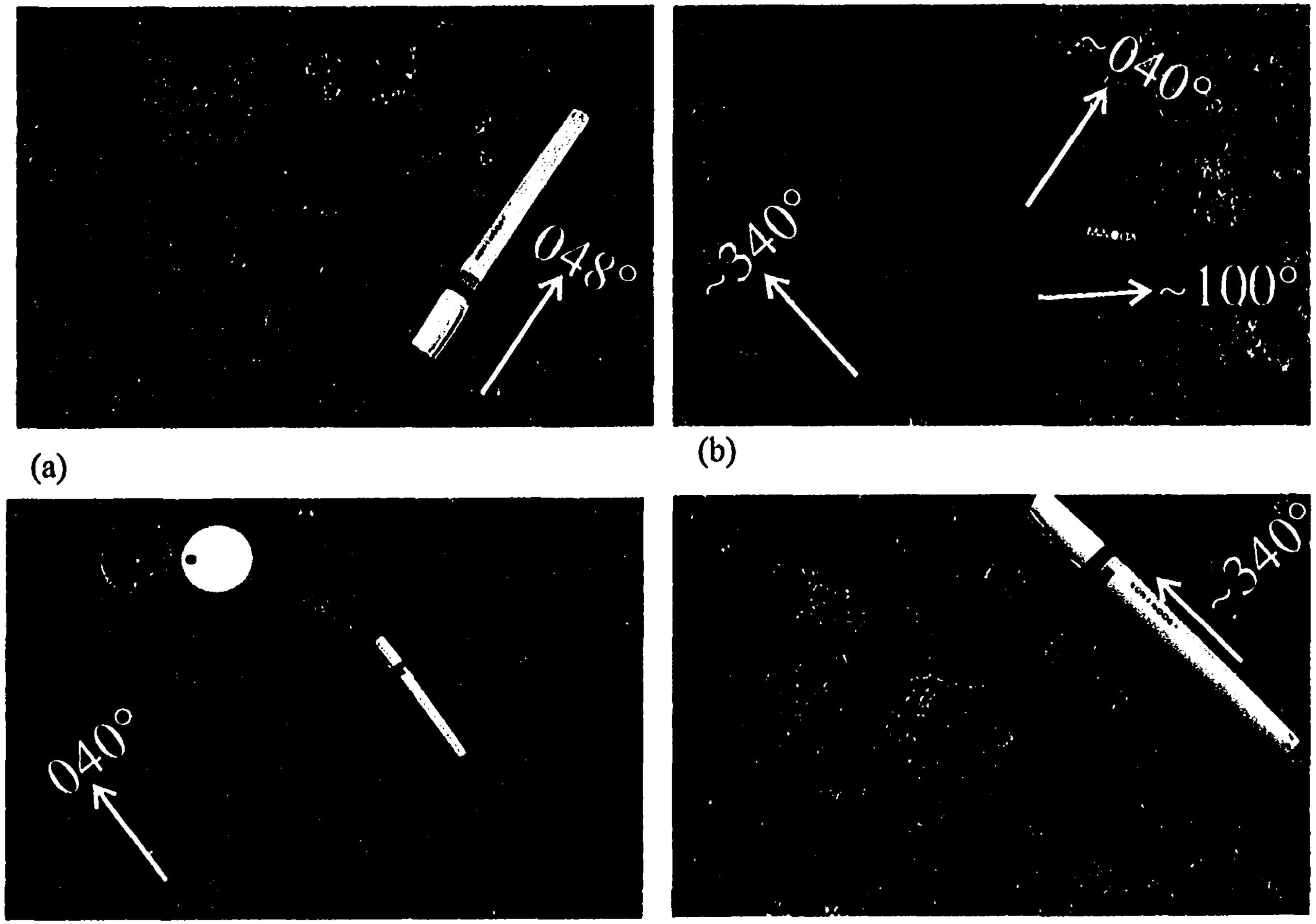


Figure 4.12

Paleogeographic Evolution of the Baker Lake Basin

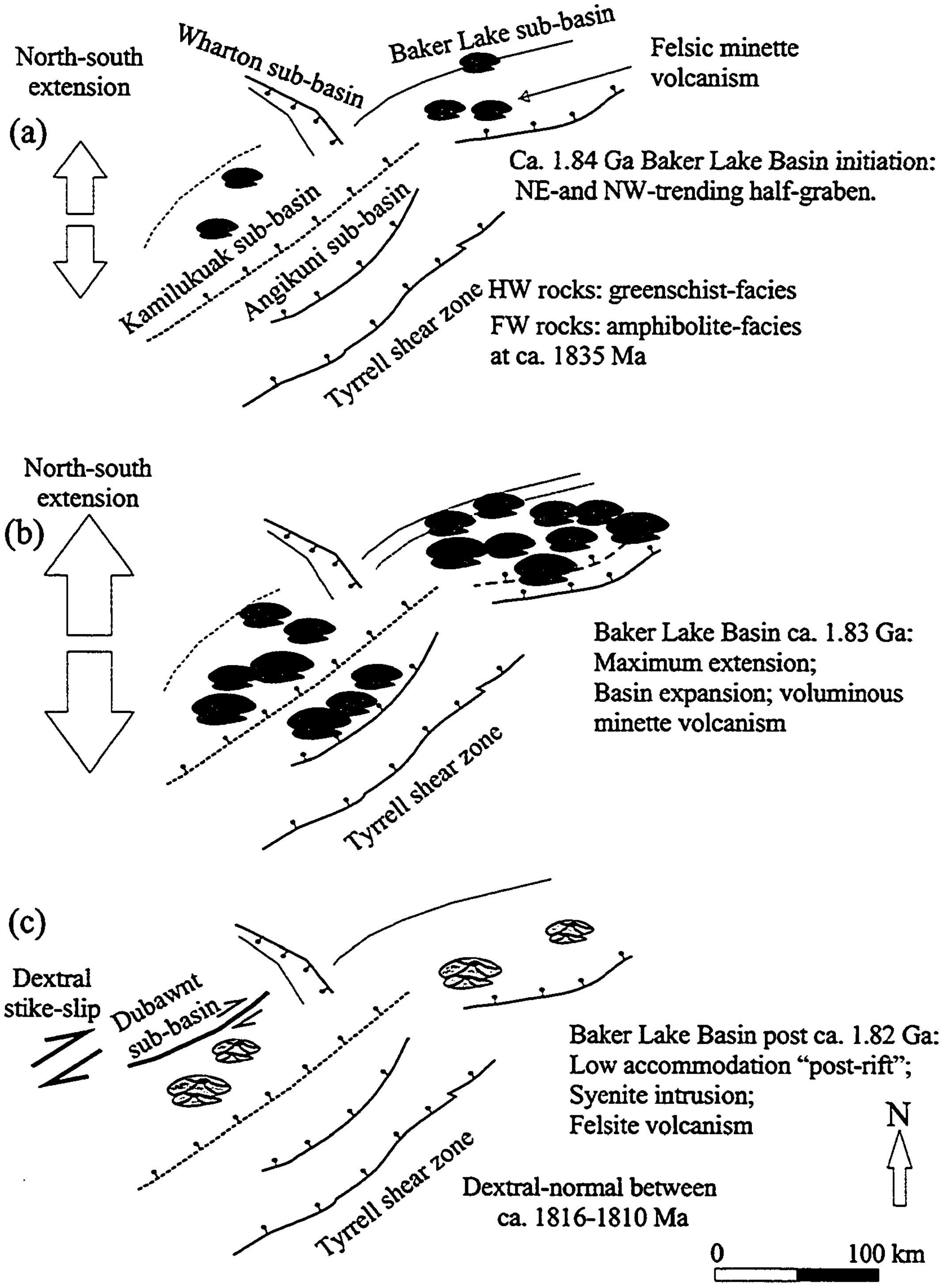
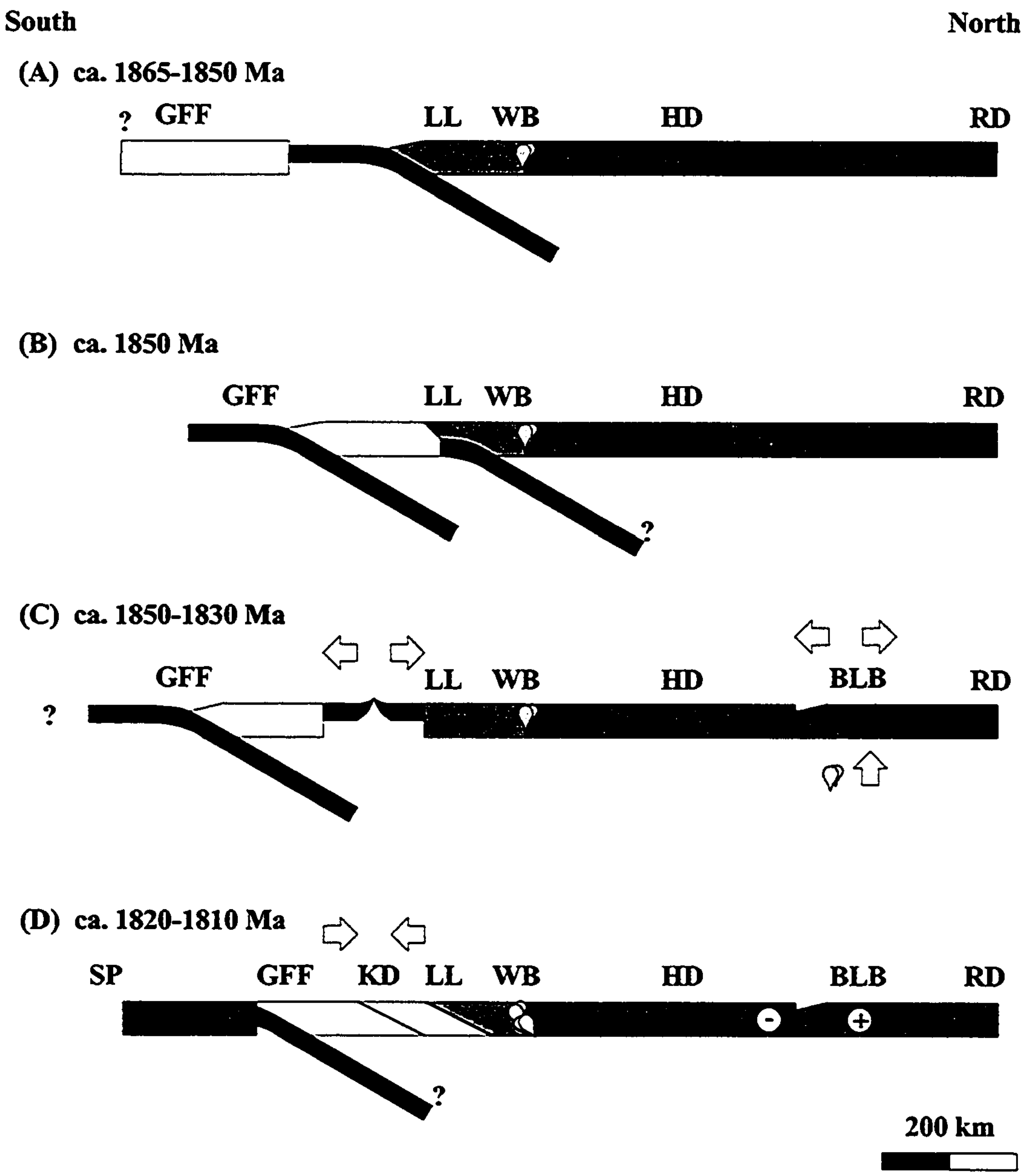


Figure 4.13: Plan view of the Baker Lake Basin during the three principal phases of the Baker Sequence.

Figure 4.14: Cartoon cross-section of the Western Churchill Province illustrating a proposed tectonic model for the Baker Lake Basin. (A) After accretion of the LaRonge – Lynn Lake arc to the southern Hearne margin, the Wathaman Batholith records Andean-style continental arc magmatism from ca. 1865-1850 Ma (Meyer et al., 1992). (B) By ca. 1850 Ma the Glennie – Flin Flon Domain collided with the allochthonous southern Hearne margin resulting in cessation of Wathaman Batholith magmatism (Ansdell, 1995). (C) Post-1850 Ma subduction retreat led to back arc extension and opening of the Kisseynew back-arc basin (Ansdell, 1995; Hollings and Ansdell, 2002). Retro-arc extension resulted in intracontinental rifting along the Snowbird Tectonic Zone, including the Baker Lake Basin. Minette flows derived from the lithospheric mantle were extruded throughout the basin. (D) Closure of the Kisseynew basin began at ca. 1830 Ma, peak metamorphic conditions were achieved at ca. 1820-1810 Ma (Hollings and Ansdell, 2002), and the Martin Group was deformed shortly after ca. 1820 Ma (Ashton et al., 2004). Baker Lake Basin faults transformed from normal to strike-slip and subsidence ceased. Since extension had ceased, melting of the upper mantle also ceased, and fractionated minette magmas were extruded as felsite domes within the basin.



GFF	Glennie - Flin Flon Domain
LL	LaRonge - Lynn L. Arc
KD	Kisseynew Domain
WB	Wathaman Batholith
SP	Superior Province
WCP	Western Churchill Province
BLB	Baker Lake Basin
HD	Hearne Domain
RD	Rae Domain

Figure 4.14

CHAPTER 5

SUMMARY OF CONCLUSIONS

The Baker Lake Basin records the intracontinental response to Paleoproterozoic orogenesis during the growth of Laurentia, and represents an integral stage in the tectonic evolution of the Western Churchill Province. The list below summarizes conclusions reached in each chapter:

Chapter 2:

1. Depositional environments for sedimentary rocks within the Baker Lake sub-basin include alluvial fan, gravel- and sand-bed braided stream, floodplain, eolian, playa, and lacustrine delta.
2. Sedimentological features such as ephemeral, flash flood-type alluvial deposits, playas, and eolian sandsheets and ergs, suggest that arid conditions prevailed during much of the period of deposition of the Baker Sequence. However, the presence of lacustrine and fluvial inter-dune deposits indicate a near-surface water table, and thus an overall semi-arid to semi-humid climate.
3. Paleocurrent data indicate that drainage consisted of two linked systems oriented transverse and axial-longitudinal relative to the basin margin. These converge on a depocentre near Christopher Island, suggesting a hydrologically closed basin.
4. Thick and coarse alluvial fan deposits are preserved at the present southeastern basin margin, suggesting that it approximates the paleobasin margin. Gravel-, sand-bed braided stream, and attendant floodplain deposits were deposited from the margins to the basin centre. Eolian deposits were deposited along the axis of the basin. Eolian,

playa, and thin deltaic deposits are confined to the eastern end of Baker Lake sub-basin at Christopher Island, and thus facies as well as paleocurrent data indicate that this area was the basin depocentre. These factors, along with a minimum five-fold increase in thickness from north to south across the basin (500 m to ~2.5 km), support an elongate, half-graben basin geometry with the main boundary fault to the southeast.

Chapter 3:

1. Through unification and some modification of existing models, a sequence stratigraphic model for alluvial systems is presented. The model considers sediment flux and water discharge as boundary conditions, subject to feedback effects, with primary tectonic control expressed as subsidence and marginal uplift, which are considered to have occurred together. Accommodation space is determined by relative level of the graded profile, a graded stream linking a sediment source to a subaqueous basin. Proximal to distal facies models are incorporated based on downstream fining and decrease in slope trends of rivers. Basinward migration of facies during deposition results in a progradational succession, and a sourceward migration of facies results in a retrogradational succession. Relative changes in facies are then interpreted based on the effects that subsidence and uplift are expected to have, primarily on slope. These include forced effects as a function of dynamic topography, but also establishment of grade through alluvial deposition. The latter is especially important because, *a priori*, it is the deposits that we seek to understand. With respect to the response to coeval basin subsidence and marginal uplift there is a

distinction between nearshore and proximal alluvial settings, which results in opposite successional trends. This resolves an issue in the literature: whether or not coeval alluvial and nearshore depositional sequences have opposite grain size-successional trends. An implication of the assumptions about systemic control is that this approach is inherently viable at generally large scales, for example 3rd order sequences of 1-10 Ma duration as defined by Mitchum et al. (1977) and Krapez (1996). It is an open question as to whether this model is applicable to lower order sequences.

2. This model, applied to the ca. 1.84-1.78 Ga Baker Sequence, is based primarily on a sequence stratigraphic methodology outlined by Krapez (1996; 1997) and followed by Rainbird et al. (2003). The Baker Sequence is considered to be second-order because it is recognized as a distinct tectonic stage with respect to basin formation, magmatism, temporal, and stratigraphic relations. It comprises five 3rd-order siliciclastic sequences, B-1 to B-5, generally 100-500 m thick, that can be correlated with tripartite volcanic-dominated stratigraphy within the Baker Lake sub-basin, and within the greater Baker Lake Basin (e.g. Kamilukuak sub-basin). Third-order sequences are composed of sets of ~10-15 m thick 4th-order sequences.
3. Three types of 3rd-order sequence are identified. *High accommodation alluvial sequences* are upward-coarsening to upward-fining. This reflects ability of the alluvial system to increase grade during marginal uplift – basin subsidence, and therefore implies high rates of sediment flux. Subsequent basin infilling and headland erosion resulted in minimum gradient facies and a high proportion of

sediment throughput. Low accommodation alluvial sequences have a coarse base and are upward-fining. *Mixed alluvial-lacustrine sequences* are located at the basin depocentre and are upward-fining to upward-coarsening. They consist of 4^{th}-order sequences that record lacustrine base level fluctuations, and have internal components that are analogous to transgressive- and highstand systems tracts. These depositional sequences are proposed to be laterally equivalent, and are related to accommodation produced by pulses of basin-margin normal faulting.

4. The succession of 3^{rd}-order sequences is upward-fining to upward-coarsening. Upward-fining is considered to reflect increasing accommodation at the 2^{nd} –order basin-scale, defining a rift initiation phase. Volcanism was active throughout the Baker Sequence, but reached a maximum in areal extent during sequences B-3 and B-4, coinciding with culmination of the retrogradational 3^{rd} -order sequence set at Thirty Mile Lake. Thus, according to the sequence stratigraphy this was the point of maximum accommodation, defining a rift climax phase. The coarser B-5 sequence post dates widespread minette volcanism and marks a decrease in accommodation equivalent to an immediate post-rift phase.

Chapter 4:

1. The 3-fold subdivision of the siliciclastic sequence stratigraphy into rift initiation (B-1 and B-2), -climax (B-3 and B-4), and post-rift (B-5) stages is correlative to the 3-fold subdivision of the volcanic sequence stratigraphy into felsic minette, minette, and felsite respectively. The transition from sequence B-2 to B-3 at the northern, hinged margin of the basin (e.g. Aniguq R.) marks initiation of accumulation and also

the onset of minette volcanism. Adjacent to the southern, faulted margin of the basin (Thirty Mile L.), this transition was marked by a retreat of facies and increase in minette volcanism. It is inferred that this resulted from backstepping of the basin-bounding normal fault system, which increased the areal extent of the basin. Sequence B-5 indicates a progradation of facies due to a decrease, or cessation, of subsidence during a post-rift phase.

2. Formed by syn-Baker Sequence normal faults, the orientation of most sub-basins including the Baker Lake sub-basin is northeast-southwest, parallel to the Western Churchill Province-scale trend of the Snowbird Tectonic Zone. Since the Wharton sub-basin trends northwest (LeCheminant, 1981), contemporaneous extension for both trends implies overall N-S or E-W extension. Dextral kinematics on structures such as the Tyrrell shear zone (MacLachlan et al., in press) is consistent with N-S extension. Syn-Baker Sequence dilational faults within the Baker Lake sub-basin trend northwest.
3. Post-Baker Sequence faults consist of an E-W trending normal fault set, and a conjugate strike-slip set. The Baker and Whart sequences generally have the same bedding attitude within fault blocks, but the Barrens Sequence is sub-horizontal. This phase of N-S extension therefore occurred between ca. 1.75 Ga and ca. 1.72 Ga.
4. Within the context of the Western Churchill Province, formation of the Baker Lake Basin at ca. 1.84 Ga followed fold and thrust fault deformation and metamorphism at 1.89-1.85 Ga (Berman et al., 2002). Initiation of Baker Lake Basin immediately followed exhumation of the Kramanituar Complex, indicated by an unconformable

relationship. The ca. 1.85-1.81 Ga Hudson granitoid suite overlapped temporally with the Baker Sequence, but was intruded within the middle crust without an extrusive equivalent (Peterson et al., 2002). Footwall rocks to the Tyrell shear zone were at amphibolite metamorphic grade at ca. 1835 Ma (MacLachlan et al., in press). Between ca. 1816-1810 Ma, the Tyrrell shear was characterized by dextral-normal kinematics and a shallowly dipping northeast lineation, with amphibolite-grade footwall rocks juxtaposed against greenschist-grade hanging wall rocks. Baker Sequence volcanic rocks were derived from lithospheric mantle melts (Peterson et al., 2002). An absence of associated basalts precludes involvement of the asthenosphere, and decompression melting is the favoured petrogenetic model for generation of this ultrapotassic volcanic province (Peterson et al., 2002). To resolve these factors, it is proposed that this area of the Western Churchill Province was subject to regional extension beginning at ca. 1.85 Ga, the maximum age of the Hudson granitoid suite. This presumes that the Hudson granitoids represent crustal melting triggered by advection of heat by mantle melts as proposed by Sandeman et al. (2000). First, the Kramanituar Complex was exhumed to the surface; then half-graben of the Baker Lake sub-basin formed. Initially volcanic products were crustally-contaminated felsic minettes. An increase in the areal extent of the Baker Lake sub-basin was accompanied by the onset of near primary minette volcanism, which increased in volume to blanket most of the basin. This is attributed to an increase in lithospheric-scale extension, and was probably coeval with exhumation of footwall rocks to the Tyrrell shear zone between ca. 1835 Ma and ca. 1810 Ma. Sequence B-5 and accompanying localized felsite flows of the post-rift stage indicate decreased subsidence. This latter stage may have been coeval with dextral shearing with a shallow lineation on the Tyrrell shear zone between ca. 1816Ma and 1810 Ma, and also the minimum age range of the Hudson granite suite (ca. 1.81 Ga).

5. The tectonic model presented considers that the Baker Lake Basin fits criteria for a passive rift, driven by lithospheric extension. Since a similar, fault-bound, contemporaneous basin occurs at the Saskatchewan segment of the STZ (Martin Group), and minette dykes extend southwest from the BLB to within 20 km of the Athabasca Basin, it is likely that the entire length of the STZ was characterized by extension. This may have been driven by far-field back-arc extension, during formation of the Kisseynew back-arc basin between ca. 1.85Ga and. 1.82 Ga. A tectonic analogue is the Rio Grande Rift prior to Basin and Range extension; basins of southeast China that formed during spreading of the Japan Sea offer additional analogues. Upon closure of the Kisseynew back-arc basin at ca. 1.82 Ga, during the terminal collision phase of the Trans-Hudson orogen, extension ceased. Due to the shape of the Superior craton, the Baker Lake Basin was sheltered from associated deformation. Conversely the Martin Basin was subject to folding and thrusting closely after ca. 1.82 Ga. The post-rift phase of the Baker Lake Basin may have been strike-slip dominated, as indicated by the (strike-slip) Dubawnt sub-basin and dextral-normal kinematics of the Tyrrell shear zone at ca. 1816-1810 Ma, in a lateral-escape tectonic setting.

REFERENCES

Allen, J.R.L. 1964. Primary current lineation in the Lower Old Red Sandstone (Devonian), Anglo-Welsh Basin. Sedimentology, 3, p. 89-108.

Annesley, I.R. and Madore, C., 2002. Timing and P-T conditions of Paleoproterozoic metamorphism, crustal melting, magmatism, deformation, and exhumation in the eastern sub-Athabasca basement, Hearne Province, Saskatchewan. GAC-MAC annual meeting, Program with Abstracts, p. 2.

Ansdell, K.M., Connors, K. and Stern, R.A., 1995. Kisseynew metasedimentary gneiss belt, Trans-Hudson orogen (Canada): Back-arc origin and collisional inversion. Geology, 23, p. 1039-1043.

Ashton, K.E. 1981. Preliminary report on geological studies of the "Woodburn Lake Group" northwest of Tehek Lake, District of Keewatin. In: Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 269-274.

Ashton, K.E. 1982. Further studies of the "Woodburn Lake Group" northwest of Tehek Lake, District of Keewatin. In: Current Research, Part A, Geological Survey of Canada, Paper 82-1A, p. 151-157.

Ashton, K.E. 1988. Precambrian geology of the southeastern Amer Lake area (66H/1), near Baker Lake, N.W.T.; unpublished Ph.D. Thesis, Queen's University, Kingston, 335 p.

Ashton, K.E., Hartlaub, R.P., Heaman, L.M., Morelli, R., Bethune, K.M., and Hunter, R.C., 2004. Paleoproterozoic sedimentary successions of the southern Rae

Province: Ages, origins, and correlations. GAC-MAC Annual Meeting, St. Catharines, Conference CD-ROM, Abstr. Vol. 29, p. 434.

Aspler, L.B., Chiarenzelli, J.R., and Cousens, B.L., 2004. Fluvial, lacustrine, and volcanic sedimentation in the Angikuni sub-basin, and initiation of ~1.84-1.79 Ga Baker Lake Basin, western Churchill Province, Nunavut, Canada. Precambrian Research, 129, p. 225-250.

Aspler, L.B., Chiarenzelli, J. R., Cousens, B.L., and Valentino, D., 1999. Precambrian geology, northern Angikuni Lake, and a transect across the Snowbird tectonic zone, western Angikuni Lake, Northwest Territories (Nunavut). Geol. Surv. Can., 1999-C: 107-118.

Aspler, L.B., Chiarenzelli, J.R., and McNicholl, V.J., 2002a. Paleoproterozoic basement-cover infolding and thick-skinned thrusting in the Hearne domain, Nunavut, Canada: intracratonic response to Trans-Hudson orogen. Precambrian Research, 116, p. 331-354.

Aspler, L.B., Cousens, B.L., and Chiarenzelli, J. R., 2002b. Neoarchean to Paleoproterozoic ensialic sedimentation and deformation across the Snowbird zone at Angikuni Lake, Western Churchill Province, Nunavut, Canada. Precambrian Res.

Aspler, L.B. and Donaldson, J.A., 1985. The Nonacho Basin (Early Proterozoic), Northwest Territories, Canada: Sedimentation and deformation in a strike-slip setting. In: (eds: Biddle, K.T. and Christie-Black, N.) Strike-slip deformation, basin formation, and sedimentation. SEPM Special Publication, 37, p. 193-209.

Aspler, L.B., Wisotzek, I.E., Chiarenzelli, J.R., Miklos, F.L., Cousens, B.L., McNicoll, and Davis, W.J., 2001. Paleoproterozoic intracratonic basin processes, from breakup of Kenorland to assembly of Laurentia: Hurwitz Basin, Nunavut, Canada. Sedimentary Geology, 142, p. 287-318.

Atchley, S.C., Nordt, L.C., and Dworkin, S.I., 2004. Eustatic control on alluvial sequence stratigraphy: a possible example from the cretaceous-tertiary transition of the Tornillo Basin, Big Bend National Park, West Texas, U.S.A. Journal of Sedimentary Research, 74, p. 391-404.

Ayers, J.C., Dunkle, S., Gao, S., and Miller, C.F., 2002. Constraints on timing of peak and retrograde metamorphism in the Dabie Shan Ultrahigh-Pressure Metamorphic Belt, east-central China, using U-Th-Pb dating of zircon and monazite. Chemical Geology, 186, p. 315-331.

Baas, J.H., 1994. A flume study on the development and equilibrium morphology of current ripples in very fine sand. Sedimentology, 41, p. 185-209.

Baldwin, J.A., Bowring, S.A., and Williams, M.L., 2003. Petrological and geochronological constraints on high pressure, high temperature metamorphism in the Snowbird tectonic zone, Canada. Journal of Metamorphic Geology, 21, p. 81-98.

Benvenuti, M., 2003. Facies analysis and tectonic significance of lacustrine fan-deltaic successions in the Pliocene-Pleistocene Mugello Basin, Central Italy. Sedimentary Geology, 157, p. 197-234.

Berman, R.B., Davis, W.J., Aspler, L.B., and Chiarenzelli, J.R., 2002a. SHRIMP U-Pb ages of multiple metamorphic events in the Angikuni Lake area, western Churchill Province, Nunavut. Radiogenic Age and Isotopic Studies: Report 15. Geological Survey of Canada, Current Research 2002-F3, 9 p.

Berman, R.G., Davis, W.J., Ryan, J.J., Tella, S., and Brown, N., 2002b. In situ SHRIMP U-Pb geochronology of Barrovian facies-series metasedimentary rocks in the Happy Lake and Josephine River supracrustal belts: implications for the Paleoproterozoic architecture of the northern Hearne domain, Nunavut. Radiogenic Age and Isotopic Studies: Report 15. Geological Survey of Canada, Current Research 2002-F4, 14 p.

Bickford, M.E., Collerson, K.D., and Lewry, J.F., Van Schmus, W.R., and Chiarelli, J.R., 1990. Proterozoic collisional tectonism in the Trans-Hudson orogen, Saskatchewan. Geology, 18, p. 14-18.

Bickford, M.E., Collerson, K.D., and Lewry, J.F., 1994. Crustal history of the Rae and Hearne provinces, southwestern Canadian Shield, Saskatchewan: constraints from geochronologic and isotopic data. Precambrian Research, 68, p. 1-21.

Blacknell, C., 1981. Sandy gravel accumulation in a fluvial environment. Geological Journal, 16, p. 287-297.

Blair, T.C., 1988. Development of tectonic cyclothems in rift, pull-apart, and foreland basins: Sedimentary response to episodic tectonism. Geology, 16, p. 517-520.

Blair, T.C., 1999. Cause of dominance by sheetflood vs. debris-flow processes on two adjoining alluvial fans, Death Valley, California. Sedimentology, 46, p. 1015-1028.

Blair, T.C., 2000a. Sedimentary processes and facies of the waterlaid Anvil Spring Canyon alluvial fan, Death Valley, California. Sedimentology, 46, p. 913-940.

Blair, T.C., 2000b. Sedimentology and progressive tectonic unconformities of the sheetflood-dominated Hell's Gate alluvial fan, Death Valley, California. Sedimentary Geology, 132, p. 233-262.

Blair, T.C. and McPherson, J.G., 1994. Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes, and facies. Journal of Sedimentary Research, 64, p. 451-490.

Blake, D.H., 1980. Volcanic rocks of the Paleohelikian Dubawnt Group in the Baker Lake – Angikuni Lake Area, District of Keewatin, N.W.T. Geological Survey of Canada, Bulletin 309, 39 p.

Boguchwal, L.A. and Southard, J.B., 1990. Bed configurations in steady unidirectional water flows. Part 1: Scale model study using fine sand. Journal of Sedimentary Petrology, 60, p. 649-657.

Bouma, A.H., 1962. Sedimentology of Some Flysch Deposits. Elsevier, Amsterdam.

Bray, H.E. and Stokes, S., 2004. Temporal patterns of arid-humid transitions in the south-eastern Arabian Peninsula based on optical dating. Geomorphology, 59, p. 271-280.

Brady, R., Wernicke, B., and Fryxell, J., 2000. Kinematic evolution of a large-offset continental normal fault system, South Virgin Mountains, Nevada. GSA Bulletin, 112, p. 1375-1397.

Brewer, J.A., Allmendinger, R.W., Brown, L.D., Oliver, J.E., and Kaufman, S., 1982. COCORP profiling across the Rocky Mountain Front in southern Wyoming, Part 1: Laramide structure. GSA Bulletin, v. 93, p. 1242-1252.

Bristow, C.S., Skelly, R.L. and Ethridge, F.G., 1999. Crevasse splays from the rapidly aggrading, sand-bed, braided Niobrara River, Nebraska: effect of base-level rise. Sedimentology, 46, p. 1029-1047.

Carr-Crabaugh, M. and Kocurek, G., 1998. Continental sequence stratigraphy of a wet eolian system: a key to relative sea level change. Relative Role of Eustasy, Climate, and Tectonism in Continental Rocks, SEPM Special Publication, 59, p. 213-228.

Carson, C.J., Berman, R.G., Stern, R.A., Sanborn-Barrie, M., Skulski, T, and Sandeman, H.A.I., 2004. Age constraints on the Paleoproterozoic tectonometamorphic history of the Committee Bay region, western Churchill Province, Canada: evidence from zircon and in situ monazite SHRIMP geochronology. Canadian Journal of Earth Sciences, 41, p. 1049-1076.

Cas, R.A.F. and Wright, J.V., 1987. Volcanic successions: modern and ancient. Boston, Allen & Unwin, 528 p.

Changsong, L., Eriksson, K., Sitian, W.Y., Jianye, R., and Yanmei, Z., 2001. Sequence architecture, depositional systems, and controls on development of lacustrine basin fills in part of the Erlian basin, northeast China. AAPG Bulletin, 85, p. 2017-2043.

Chiarenzelli, J.R. 1983. Mid-Proterozoic chemical weathering, regolith, and silcrete in the Thelon Basin, Northwest Territories. Unpublished Msc. Thesis. Carleton University, Ottawa, Ont., p. 205.

Clemente, P. and Pérez-Arlucea, M. 1993. Depositional architecture of the Cuerda Del Pozo Formation, Lower Cretaceous of the extensional Cameros Basin, North-Central Spain. Journal of Sedimentary Petrology, 63, p. 437-452.

Clemmensen, L.B., Øxnevad, I.E.I., and De Boer P.L., 1994. Climatic controls on ancient desert sedimentation: some late Paleozoic and Mesozoic examples from NW Europe and the Western Interior of the USA. Special Publication of the International Association of Sedimentologists, 19, p. 439-457.

Corrigan, D., Lucas, S.B., Maxeiner, R.O., Hajnal, Z., Zwanzig, H.V., and Syme, E.C., 2001. Tectonic assembly of the Saskatchewan-Manitoba segment of the Trans-Hudson orogen. Geological Association of Canada – Mineralogical Association of Canada, Annual Meeting, Program with Abstracts, 12, p. 35.

Cousens, B.L., Aspler, L.B., Chiarenzelli, J.R., Donaldson, J.A., Sandeman, H., Peterson, T.D., and LeCheminant, A.N., 2001. Enriched Archean lithospheric mantle beneath western Churchill Province tapped during Paleoproterozoic orogenesis, Geology, 29, p. 827-830.

Dade, W.B. and Friend, P.F., 1998. Grain-Size, Sediment-Transport Regime, and Channel Slope in Alluvial Rivers. Journal of Geology, 106, p. 661-675.

Davis, W.J., Hanmer, S., Aspler, L., Sandeman, H., Tella, S., Zaleski, E., Relf, C., Ryan, J., Berman, R., and MacLachlan, K., 2000. Regional differences in the Neoarchean crustal evolution of the western Churchill Province: can we make sense of it? In: GeoCanada 2000. GAC-MAC, Joint Annual Meeting, Calgary, CD-ROM, abstract 864.

Davis, W.J., Hanmer, S., and Sandeman, H.A., 2004. Temporal evolution of the Neoarchean Central Hearne supracrustal belt: rapid generation of juvenile crust in a suprasubduction zone setting. Precambrian Research, 134, p. 85-112.

Davis, L.L., Smith, D., McDowell, F.W., Walker, N.W., and Borg, L.E., 1996. Eocene potassic magmatism at Two Buttes, Colorado, with implications for Cenozoic tectonics and magma generation in the western United States. GSA Bulletin, 108, p. 1567-1579.

Davis, W.J. and Zaleski, E., 1998. Geochronological investigations of the Woodburn Lake Group, western Churchill Province, Northwest Territories: preliminary results. In: Radiogenic Age and Isotopic Studies: Report 11. Geological Survey of Canada, Current Research 1998-F, p. 89-97.

DeFrito, R.F., Cozzarelli, F.A., and Hodge, D.S., 1983. Mechanism of subsidence of ancient cratonic rift basins. Tectonophysics, 94, p. 141-168.

Donaldson, J.A., 1965. The Dubawnt Group, District of Keewatin and Mackenzie. Geological Survey of Canada, Paper 64-20, 11 p.

Donaldson, J.A., 1966. Geology, Schultz Lake, District of Keewatin. Geological Survey of Canada, Preliminary Map 7-1966, scale 1:250 000.

Donaldson, J.A., 1967. Study of the Dubawnt Group, Report of Activities, Pt. A. Geological Survey of Canada, Paper 67-1A, 25 p.

Donaldson, J.A., 1968. Proterozoic sedimentary rocks of northern Saskatchewan. Geological Survey of Canada, Report of Activities, Paper 68-1A.

Elliott, T., 1974. Interdistributary bay sequences and their genesis. Sedimentology, 21, p. 611-622.

Embry, A.F., 1989. A tectonic origin for Third-order depositional sequences in extensional basins – Implications for basin modeling. In: Cross, T.A. (ed.), Quantitative Dynamic Stratigraphy. Prentice Hall, p. 491-501.

Eriksson, K.A. and Simpson, E.L., 1998. Controls on spatial and temporal distribution of Precambrian eolianites. Sedimentary Geology, 120, p. 275-294.

Esperança, S. and Holloway, J.R., 1987. On the origin of some mica-lamprophyres: experimental evidence from a mafic minette. Contributions to Mineralogy and Petrology, 95, p. 207-216.

Feldstein, S.N. and Lange, R.A., 1999. Pliocene Potassic Magmas from the Kings River Region, Sierra Nevada, California: Evidence for Melting of a Subduction-Modified Mantle. Journal of Petrology, 40, p. 1301-1320.

Fielding, C.R., 1984. Upper delta plain lacustrine and fluviolacustrine facies from the Westphalian of the Durham coalfield, NE England. Sedimentology, 31, p. 547-567.

Fisher, R.V. and Schmincke, H.-U., 1984. Pyroclastic rocks. New York, Springer-Verlag, 528 p.

Flowers, R.M., Baldwin, J.A., Bowring, S.A. and Williams, M.L., 2002. Age and significance of the Proterozoic Chipman dyke swarm, Snowbird Tectonic Zone, northern Saskatchewan. GAC-MAC annual meeting, Program with Abstracts, p. 35-36.

Forsyth, D.W., and Uyeda, S., 1975. On the relative importance of the driving forces of plate motion. Royal Astronomical Society Geophysical Journal, 43, p. 163-200.

Foster, G., Gibson, H.D., Parrish, R., Horstwood, J.F., and Tindle, A., 2002. Textural, chemical and isotopic insights into the nature and behaviour of metamorphic monazite. Chemical Geology, 191, p. 183-207.

Fraser, J.A., Donaldson, J.A., Fahrig, W.F., and Tremblay, L.P., 1970. Helikian Basins and Geosynclines of the northwestern Canadian Shield. Baer, A.J. (Ed.), Symposium on Basins and Geosynclines of the Canadian Shield. GSC-paper 70-40, p. 213-230.

Fryberger, S.G., Schenk, C.J. and Hesp, P., 1988. Pin stripe lamination; a distinctive feature of modern and ancient eolian sediments. Eolian Sediments: Sedimentary Geology, 55, p. 1-15.

Fryberger, S.G., Schenk, C.J., and Krystinik, L.F., 1988. Stokes surfaces and the effects of near-surface groundwater-table on aeolian deposition. Sedimentology, 35 p. 21-41.

Fuchs, H.D., and Hilger, W. 1989. Kiggavik (Lone gull): an unconformity-related uranium deposit in the Thelon Basin, Northwest Territories, Canada. In:

MüllerKahle, E. (Ed.), Uranium Resources and Geology of North America. International Atomic Energy Agency, Vienna, pp. 429-454.

Gall, Q., 1994. The Proterozoic Thelon paleosol, Northwest Territories, Canada. Precambrian Research, 68, p. 115-137.

Gall, Q., Peterson, T.D., and Donaldson, J.A., 1992. A proposed revision of early Proterozoic stratigraphy of the Thelon and Baker Lake basins, Northwest Territories. Current Research Part C, Geological Survey of Canada, p. 129-137.

Gay, N.C. and Weiss, L.E., 1974. The relationship between principle stress directions and the geometry of kinks in foliated rocks. Tectonophysics, 21, p. 287-300.

Glover, B.W. and O'Beirne, A.M., 1994. Anatomy, hydrodynamics and depositional setting of a Westphalian C lacustrine delta complex, West Midlands, England.

Hadlari, T. and Rainbird, R.H., 2000. Sequence stratigraphy and sedimentology of the Paleoproterozoic Baker Lake Group in the Baker Lake Basin, Thirty Mile Lake, Nunavut Territory. Geological Survey of Canada, Current Research 2000-C9, p. 10.

Hadlari, T. and Rainbird, R.H., 2001. Volcano-sedimentary correlation and fault relationships in the Baker Lake sub-basin, Thirty Mile Lake area, Nunavut. Geological Survey of Canada, Current Research 2001-C10, p. 9.

Hanmer, S., Parrish, R., Williams, M.L., and Kopf C., 1994. Striding-Athabasca mylonite zone: complex Archean deep-crustal deformation in the East Athabasca mylonite triangle, N. Saskatchewan, Canadian Journal of Earth Sciences, 31, p. 1287-1300.

Hanmer, S. and Relf, C., 2000. Western Churchill NATMAP Project: new results and potential significance. In: GeoCanada 2000. GAC-MAC, Joint Annual Meeting, Calgary, CD-ROM, abstract 79.

Hanmer, S., Sandeman, H.A., Davis, W.J., Aspler, L.B., Rainbird, R.H., Peterson, T.D., Ryan, J.J., Roest, W.R., Relf, C., Irwin, D., 2004. Tectonic setting of the Neoarchean Henik-Kaminak-Tavani supracrustal belt, Western Churchill Province, Canada: a geological perspective. Precambrian Research, 134, p. 63-83.

Hanmer, S., Tella, S., Sandeman, H.A., Ryan, J.J., Hadlari, T, and Mills, A., 1999. Proterozoic reworking in Western Churchill Province, Gibson Lake – Cross Bay area (Kivalliq Region, Nunavut), Part 1: General Geology. Geological Survey of Canada, Current Research 1999-C , p. 55-65.

Hanmer, S., Williams, M., Kopf, C., 1995. Striding-Athabasca mylonite zone: implications for the Archean and Early Proterozoic tectonics of the western Canadian Shield. Canadian Journal of Earth Sciences, 32, 178-196.

Hartlaub, R.P., Ashton, K.E., Heaman, L.M., and Chacko, T., 2002. Was there an ~2000 dm long Neoarchean extensional event in the Rae Craton? Evidence from the Murmac Bay Group of northern Saskatchewan. GAC-MAC annual meeting, Program with Abstracts, p. 46-47.

Heaman, L.M. and LeCheminant, A.N., 1993. Paragenesis and U-Pb systematics of baddeleyite (ZrO_2). Chemical Geology, v. 110, p. 95-126.

Hemmingway, C.J. and Sandeman, H.A., 1999. Geochemical and Sm-Nd isotopic study of Paleoproterozoic basaltic and gabbroic rocks of the Hurwitz Group, Kaminak Lake area, Kivalliq region, Northwest Territories. Radiogenic and Isotope Studies: Report 12; Geological Survey of Canada, Current Research 1999-F, p. 53-62.

Hiatt, E.E., Kyser, K., and Dalrymple, R.W., 2003. Relationships among sedimentary, stratigraphy, and diagenesis in the Proterozoic Thelon Basin, Nunavut, Canada: implications for paleoaquifers and sedimentary-hosted mineral deposits. Journal of Geochemical Exploration, 80, p. 221-240.

Hjellbakk, A., 1997. Facies and fluvial architecture of a high-energy braided river: the Upper Proterozoic Seglodden Member, Varanger Peninsula, northern Norway. Sedimentary Geology, 114, p. 131-161.

Hoffman, P.F., 1988. United Plates of America. Annual Review of Earth and Planetary Sciences, 16, p. 543-603.

Hooke, R.L., 1967. Processes on arid-region alluvial fans. Journal of Geology, 75, p. 438-460.

Hunter, R.E., 1977. Terminology of cross-stratified sedimentary layers and climbing-ripple structures. Journal of Sedimentary Petrology, 47, p. 697-706.

Jervey, M.T., 1988. Quantitative geological modeling of siliciclastic rock sequences and their seismic expression. In: Wilgus et al., (ed.) Sea Level Changes- An Integrated Approach, SEPM Special Publication, 42, p. 47-69.

Jo, H.R., Rhee, C.W., and Chough, S.K., 1997. Distinctive characteristics of a streamflow-dominated alluvial fan deposit: Sanghori area, Kyongsang Basin (Early Cretaceous), southeastern Korea. Sedimentary Geology, 110, p. 51-79.

Jones, A.G., Snyder, D., Hanmer, S., Asudeh,.I., White, D., Eaton, D., and Clarke, G., 2002. Magnetotelluric and teleseismic study across the Snowbird Tectonic Zone, Canadian Shield: A Neoarchean mantle suture? Geophysical Research Letters, 29, 10.

Kocurek, 1981. Significance of interdune deposits and bounding surfaces in aeolian dune sands. Sedimentology, 28, p. 753-780.

Kocurek, G. and Havholm, K.G., 1993. Eolian sequence stratigraphy – a conceptual framework. In: Weimer, P. and Posamentier, H.W. (Eds.), Siliciclastic Sequence Stratigraphy, Recent Developments and Applications. Memoir of the American Association of Petroleum Geologists, 58, p. 393-409.

Krapez, B., 1996. Sequence stratigraphic concepts applied to the identification of basin-filling rhythms in Precambrian successions. Australian Journal of Earth Sciences, 43, p. 355-380.

Krapez, B., 1997. Sequence stratigrahic concepts applied to the identification of depositional basins and global tectonic cycles. Australian Journal of Earth Sciences, 44, p. 1-36.

Kyser, T.K., Hiatt, E.E., Renac, C., Durocher, K., Holk, G.J., Deckart, K., 2000. Diagenetic fluids in Paleo- and Meso-Proterozoic sedimentary basins and their implications for long protracted fluid histories. In: Kyser, K. (Ed.), Fluids and Basin Evolution. Mineralogical Association of Canada, Ottawa, p. 225-262.

Lane, E.W., 1955. The importance of fluvial morphology in hydraulic engineering. American Society of Civil Engineering Proceedings, 81, 17 p.

Lawton, T.F. and McMillan, N.J., 1999. Arc abandonment as a cause for passive continental rifting: Comparison of the Jurassic Mexican Borderland rift and the Cenozoic Rio Grande rift. Geology, 27, p. 779-782.

LeCheminant, A.N., Ashton, K.E., Chiarenzelli, J., Donaldson, J.A., Best, M.A., Tella, S., and Thompson, D.L., 1983. Geology of the Aberdeen Lake map area, District of Keewatin: Preliminary report. Current Research, Part A, Geological Survey of Canada, Paper 83-1A, p. 437-448.

LeCheminant, A.N., Ianelli, T.R., Zaitlin, B., and Miller A.R., 1981. Geology of the Tebesjuak Lake Map Area, District of Keewatin: A progress report. Current Research, Part B, Geological Survey of Canada, Paper 81-1B, p. 113-128.

LeCheminant, A.N., Lambert, M.B., Miller, A.R., Booth, G.W., 1979a. Geological studies: Tebesjuak Map Area, District of Keewatin. Current Research, Part A, Geological Survey of Canada, Paper 79-1A, p. 179-186.

LeCheminant, A.N. and Heaman, L.M., 1989. Mackenzie igneous events, Canada: middle Proterozoic hotspot magmatism associated with ocean opening. Earth and Planetary Science Letters, 96: 38-48.

LeCheminant, A.N., Leatherbarrow, R.W., Miller A.R., 1979b. Thirty Mile Lake Map Area, District of Keewatin. Current Research Part B, Geological Survey of Canada, Paper 79-1B, p. 319-327.

LeCheminant, A.N., Miller A.R., and LeCheminant, G.M., 1987. Early Proterozoic alkaline igneous rocks, District of Keewatin, Canada: petrogenesis and mineralization. From: Pharoah, T.C., Beckinsale, R.D., and Rickard, D. (eds.). Geochemistry and Mineralization of Proterozoic Volcanic Suites. Geological Society Special Publication, 33, p. 219-240.

LeCheminant, A.N. and Roddick, J.C., 1991. U-Pb zircon evidence for widespread 2.6 Ga felsic magmatism in the central District of Keewatin, N.W.T. In: Radiogenic Age and Isotopic Studies: Report 4, Geological Survey of Canada, Paper 90-2, p. 91-99.

Leeder, M.R., 1995. Continental rifts and proto-oceanic rift troughs. In: Busby and Ingersoll (Eds.), Tectonics of Sedimentary Basins. Blackwell Science, p. 119-148.

Legaretta, L. and Uliana, M.A. 1991. Jurassic-Cretaceous marine oscillations and geometry of back-arc basin fill, central Argentine Andes. In: MacDonald, D. I. M. (ed.) Sedimentation, tectonics and eustasy. International Association of Sedimentologists Special Publication, 12, p. 429-450.

Lewry, J.F., Hajnal, Z., Green, A., Lucas, S.B., White, D., Stauffer, M.R., Ashton, K.E., Weber, W., and Clowes, R., 1994. Structure of a Paleoproterozoic continent-

continent collision zone: a LITHOPROBE seismic reflection profile across the Trans-Hudson Orogen, Canada. Tectonophysics, 232, p. 143-160.

Livaracci, R.F., 1991. Role of crustal thickening and extensional collapse in the tectonic evolution of the Sevier-Laramide orogeny, western United States. Geology, v. 19, p. 1104-1107.

Loveridge, W.D., Eade, K.E., Sullivan, R.W., 1988. Geochronological studies of Precambrian rocks from the southern District of Keewatin. Geological Survey of Canada, Paper 88-18, p. 36.

Lucas, S.B., Syme, E.C., Ashton, K.E., 1999. Introduction to Special Issue 2 on the NATMAP Shield Margin Project: The Flin Flon Belt, Trans-Hudson orogen. Manitoba and Saskatchewan. Canadian Journal of Earth Sciences, 36, p. 1763-1765.

Macey, G., 1973. A sedimentological comparison of two Proterozoic red-bed successions (the South Channel and Kazan formations of Baker Lake N.W.T., and the Martin Formation at Uranium City, Saskatchewan). Unpublished MSc. thesis. Carleton University, p. 175.

Mack, G.H. and Leeder, M.R., 1999. Climatic and tectonic controls on alluvial-fan and axial-fluvial sedimentation in the Plio-Pleistocene Palomas half graben, Southern Rio Grande Rift. Journal of Sedimentary Research, 69, p. 635-652.

Mackin, J. H. 1948. The concept of the graded river. Bulletin of the Geological Society of America, 59, 463-512.

MacLachlan, K., Davis, W.J., and Relf, C., 2005. U/Pb geochronological constraints on Neoarchean tectonism: multiple compressional events in the northwestern Hearne Domain, Western Churchill Province, Canada. Canadian Journal of Earth Sciences, 42, p. 85-109.

MacLachlan, K., Davis, W.J., and Relf, C., in press. Paleoproterozoic reworking of an Archean thrust fault in the Hearne domain, Western Churchill Province: U-Pb geochronological constraints. Canadian Journal of Earth Sciences.

MacLachlan, K., Relf, C., and Davis, W.J., 2000. U-Pb geochronological constraints on structures controlling distribution of tectonothermal domains, Yathkyed Lake area, western Churchill Province. In: GeoCanada 2000. Geological Association of Canada – Mineralogical Association of Canada, Joint Annual Meeting, Calgary, CD-ROM, abstract 751.

MacRae, N.D., Armitage, A.E., Miller, A.R., Roddick, J.C., Jones, A.L., Mudry, M.P., 1996. The diamondiferous Akluilâk lamprophyre dyke, Gibson Lake area, N.W.T. In: A.N. LeCheminant, D.G. Richardson, R.N.W. DiLabio and K.A. Richardson (Editors), Searching for Diamonds in Canada; Geological Survey of Canada, Open File 3228, pp. 101-107

Mahan, K.H., William, M.L., and Baldwin, J.A., 2003. Contractional uplift of deep crustal rocks along the Legs Lake shear zone, western Churchill Province, Canadian Shield. Canadian Journal of Earth Sciences, 40, p. 1085-1110.

Marshall, J.D., 2000. Sedimentology of a Devonian fault-bounded braidplain and lacustrine fill in the lower part of the Skrinkle Sandstones, Dyfed, Wales. Sedimentology, 47, p. 325-342.

Martin, A.J., 2000. Flaser and wavy bedding in ephemeral streams: a modern and an ancient example. Sedimentary Geology, 136, p. 1-5.

Mazzotti, S. and Hyndman, R.D., 2002. Yakutat collision and strain transfer across the northern Canadian Cordillera. Geology, 30, p. 495-498.

Meyer, M.T., Bickford, M.E., and Lewry, J.F., 1992. The Wathaman batholith: An Early Proterozoic continental arc in the Trans-Hudson orogenic belt, Canada. GSA Bulletin, 104, p. 1073-1085.

Miall, A.D., 1977. A review of the braided river depositional environment. Earth Science Reviews, 13, p. 1-62.

Miall, A.D., 1991. Stratigraphic sequences and their chronostratigraphic correlation. Journal of Sedimentary Petrology, 61, p. 497-505.

Miall, A.D., 2001. Cryptic sequence boundaries in braided fluvial successions. Sedimentology, 48, p. 971-985.

Miller, A.R., 1980. Uranium geology of the eastern Baker Lake Basin, District of Keewatin, Northwest Territories, Canada. Canadian Journal of Earth Sciences, 26, p. 867-880.

Mills, A. 2001. Tectonic evolution of the Uvauk complex, Churchill Province, Nunavut Territory, Canada. M.Sc. thesis, Carleton University, Ottawa, Ontario, Canada.

Mitchum, R.M., Vail, P.R., and Thompson, S., III, 1977. Seismic stratigraphy and global changes of sea level, Part 2: The depositional sequence as a basic unit for stratigraphic analysis. In: Payton, C.E. (ed.), Seismic Stratigraphy – Applications to hydrocarbon exploration. American Association of Petroleum Geologists Memoir 26, p. 53-62.

Molnar, P. and Atwater, T., 1978. Inter-arc spreading and Cordilleran tectonics as alternates related to the age of subducted oceanic lithosphere. Earth and Planetary Science Letters, 41, p. 330-340.

Moores, E.M., Wakabayashi, J., and Unruh, J.R., 2002. Crustal-Scale Cross-Section of the U.S. Cordillera, California and Beyond, It's Tectonic Significance, and Speculations on the Andean Orogeny. International Geology Review, 44, p. 479-500.

Morelli, R.M., Ashton, K.E., Ansdell, K.M., and Maxeiner, R.O., 2002. Geochemical investigation of the Martin Group igneous rocks, Beaverlodge Domain, northwestern Saskatchewan. GAC-MAC annual meeting, Program with Abstracts, p. 77.

Morley, C.K. 2002. Evolution of large normal faults: Evidence from seismic reflection data. AAPG Bulletin, 86, p. 961-978.

Morley, C.K., VanHauwaert, De Batist, M., 2000. Evidence for high-frequency cyclic fault activity from high-resolution seismic reflection survey, Rukwa Rift, Tanzania. Journal of the Geological Society, London, 157, p. 983-994.

Mutti, E., Tinterri, R., Benevelli, G., di Biase, D., and Cavanna, G., 2003. Deltaic, mixed and turbidite sedimentation of ancient foreland basins. Marine and Petroleum Geology, 20, p. 733-755.

Mountney, N.P. and Russell, A.J., 2004. Sedimentology of cold-climate aeolian sandsheet deposits in the Askja region of northeast Iceland. Sedimentary Geology, 166, p. 223-244.

Nummedal, D., Riley, G.W., and Templet, P.L. 1993. High-resolution sequence architecture: a chronostratigraphic model based on equilibrium studies. In: Posamentier, H. W., Summerhayes, C. P., Haq, B. U., and Allen, G. P. (eds.) Sequence Stratigraphy and Facies Associations. International Association of Sedimentologists, Special Publication, 18, p. 55-68.

Oaie, G., 1998. Sedimentological significance of mudstone microclast intervals in Upper Proterozoic turbidites, central Dobrogea, Romania. Sedimentary Geology, 115, p. 289-300.

Olsen, T., Steel, R., Høgseth, K., Skar, T., and Røe, S.L., 1995. Sequential architecture in a fluvial succession: Sequence stratigraphy in the Upper Cretaceous Mesaverde Group, Price Canyon, Utah. Journal of Sedimentary Research, B65, p. 265-280.

Paola, C. and Mohrig, D., 1996. Paleohydraulics revisited: paleoslope estimation in coarse-grained braided rivers. Basin Research, 8, p. 243-254.

Paola, C. and Seal, R., 1995. Grain size patchiness as a cause of selective deposition and downstream fining. Water Resources Research, 31, p. 1395-1407.

Paterson, J.G. 1986. The Amer belt: remnant of an Aphebian foreland fold and thrust belt. Canadian Journal of Earth Sciences, 23, p. 2012-2023.

Paterson, S.R., Miller, R.B., Alsleben, Whitney, D.L., Valley, P.M., and Hurlow, H., 2004. Driving mechanisms for >40 km of exhumation during contraction and extension in a continental arc, Cascades core, Washington. Tectonics, 23, TC3005.

Peacock, D.C.P. 2001. The temporal relationship between joints and faults. Journal of Structural Geology, 23, p. 329-341.

Pehrsson, S.J., Jenner, G.A., and Kjarsgaard, B.A., 2002. The Ketyet River group: correlation with Paleoproterozoic supracrustal sequences of northeastern Rae and implications for Proterozoic orogenesis in the western Churchill Province. GAC-MAC annual meeting, Program with Abstracts, p. 90.

Peterson, T.D., 1994, Early Proterozoic ultrapotassic volcanism of the Keewatin Hinterland, Canada. In: Meyer, H.O.A., and Leonardos, O.H., eds., Proceedings, 5th International Kimberlite Conference, Volume 1: Kimberlites, related rocks and mantle xenoliths: Brasilia, Campanhia de Pesquisa de Recursos Minerais, p. 221–235.

Peterson, T.D., 2002. Geology, Dubawnt Lake area, Nunavut-Northwest Territories. Geological Survey of Canada, "A" Series Map , 2021A, 2002.

Peterson, T.D., Esperança, S. and LeCheminant, A.N., 1994. Geochemistry and origin of the ultrapotassic rocks of the Churchill Province, Canada. Mineralogy and Petrology, 51: 251-276.

Peterson, T.D. and LeCheminant, A.N., 1993. Glimmerite xenoliths in Early Proterozoic ultrapotassic rocks from the Churchill Province. The Canadian Mineralogist, 31, p. 801-819.

Peterson, T.D, LeCheminant, A.N., and Rainbird, R.H., 1989. Preliminary report on the geology of northwestern Dubawnt Lake area, District of Keewatin, N.W.T. Current Research, Part B, Geological Survey of Canada, Paper 89-1C, p. 173-183.

Peterson, T.D. and Rainbird, R.H., 1990. Tectonic and petrological significance of regional lamproite-minette volcanism in the Thelon and Trans-Hudson hinterlands, Northwest Territories (Nunavut). Current Research, Part C; Geological Survey of Canada, Paper 90-1C, p. 69-79.

Peterson, T.D. and Van Breeman, O., 1999. Review and progress report of Proterozoic granitoid rocks of the western Churchill Province, Northwest Territories (Nunavut). In: Current Research 1999-C, Geological Survey of Canada, p. 110-127.

Peterson, T.D. and Van Breeman, O., Sandeman, H., and Cousens, B., 2002. Proterozoic (1.85-1.75 Ga) igneous suites of the western Churchill province: granitoid and ultrapotassic magmatism in a reworked Archean hinterland. Precambrian Research, 119, p. 73-100.

Phillips, J., 2003. Alluvial storage and the long-term stability of sediment yields. Basin Research, 15, p. 153-163.

Plint, A.G. and Browne, G.H., 1994. Tectonic event stratigraphy in a fluvio-lacustrine, strike-slip setting: the Boss Point Formation (Westphalian A), Cumberland Basin, Maritime Canada. Journal of Sedimentary Research, B64, p. 341-364.

Plint, A.G., McCarthy, P.J., and Ubiratan, F.F. 2001. Non-marine sequence stratigraphy: Up-dip expression of sequence boundaries and systems tracts in a high-resolution framework, Cenomanian Dunvegan Formation, Alberta foreland basin, Canada. AAPG Bulletin, 85, p. 1967-2001.

Posamentier, H.W., Jervey, M.T., and Vail, P.R., 1988. Eustatic controls on clastic deposition I – conceptual framework. In: Wilgus, C. K. et al. (ed.) Sea Level Changes - An Integrated Approach, SEPM Special Publication, 42, p. 109-124.

Posamentier, H.W., Summerhays, C.P., Haq, B.U., and Allen, G.P., 1993. Sequence stratigraphy and facies associations. International Association of Sedimentologists Special Publication, 18, p.

Posamentier, H.W. and Vail, P.R., 1988. Eustatic controls on clastic deposition II – conceptual framework. In: Wilgus, C. K. et al. (ed.) Sea Level Changes - An Integrated Approach, SEPM Special Publication, 42, p. 125-154.

Prosser, S., 1993. Rift-related linked depositional systems and their seismic expression. In: Williams, G.D., and Dobb, A. (eds.), Tectonics and Seismic sequence stratigraphy, Geological Society Special Publication, 71, p. 35-66.

Quinlan, G.M., and Beaumont, C., 1984. Appalachian thrusting, lithospheric flexure and the Paleozoic stratigraphy of the Eastern Interior of North America. Canadian Journal of Earth Sciences, v. 21, p. 973-996.

Quirk, D.G., 1996. 'Base profile': a unifying concept in alluvial sequence stratigraphy. In: Howell, J. A. and Aitken, J. F. (eds.), High Resolution Sequence Stratigraphy: Innovations and Applications, Geological Society Special Publication, 104, p. 37-49.

Rainbird, R.H., Davis, W.J., Smith, S., Stern, R.A., Peterson, T.D., Parrish, R.R., and Hadlari, T., in press. Ar-Ar and U-Pb dating of primary and diagenetic minerals from the late Paleoproterozoic Baker Lake Basin, western Churchill Province, Nunavut, Canada. Journal of Geology.

Rainbird, R.H., Davis, W.J., Stern, R.A., Hadlari, T., and Donaldson, J.A., 2002. Integrated geochronology of the late Paleproterozoic Baker Lake Group (Dubawnt Supergroup), Baker Lake Basin. Geological Association of Canada-Mineralogical Association of Canada Annual Meeting, Abstracts v. 26, p. 123.

Rainbird, R.H., Hadlari, T., and Donaldson J.A., 1999. Stratigraphy and paleogeography of the Paleoproterozoic Baker Lake Group in the eastern Baker Lake Basin, Northwest Territories (Nunavut). Current Research, Geological Survey of Canada, p. 43-53.

Rainbird, R.H. and Hadlari, T., 2000. Revised stratigraphy and sedimentology of the Paleoproterozoic Dubawnt Supergroup at the northern margin of Baker Lake basin, Nunavut Territory. Geological Survey of Canada, Current Research 2000-C8, p. 9.

Rainbird, R.H., Hadlari, T., Aspler, L.B., Donaldson, J.A., LeCheminant, A.N., and Peterson, T.D., 2003. Sequence stratigraphy and evolution of the

Paleoproterozoic intracontinental Baker Lake and Thelon basins, western Churchill Province, Nunavut, Canada. Precambrian Research, 125, p. 21-53.

Rainbird, R.H., Hadlari, T. and Davis, W., 2001. Sequence stratigraphy and tectonic setting of the 1.78-1.74 Ga Wharton Group, Baker Lake and Thelon Basins, Western Churchill Province, Nunavut, Geological Association of Canada-Mineralogical Association of Canada Annual Meeting, Abstracts with Programs, v. 26, pp. 123.

Rainbird, R.H., and Peterson, T.D., 1990. Physical volcanology and sedimentology of lower Dubawnt Group strata, Dubawnt Lake, District of Keewatin, N.W.T. In: Current Research, Part C, Geological Survey of Canada, Paper 90-1C, p. 207-217.

Ramsay, J.G. 1967. Folding and Fracturing of Rocks. McGraw-Hill, New York.

Reid, I. and Frostick, L.E., 1987. Towards a better understanding of bedload transport. In: F.G. Ethridge, R.M. Flores and M.D. Harvey (Editors), Recent Developments in Fluvial Sedimentology. Society of Economic Paleontologists and Mineralogists Special Publication, 39, p. 13-20.

Reinfelds, I. And Nanson, G., 1993. Formation of braided river floodplains, Waimakariri River, New Zealand. Sedimentology, 40, p. 1113-1127.

Ren, J., Tamaki, K., Li, S., and Junxia, Z., 2002. Late Mesozoic and Cenozoic rifting and its dynamic setting in Eastern China and adjacent areas. Tectonophysics, 344, p. 175-205.

Rhee, C.W., Jo, H.R., and Chough, S.K., 1998. An allostratigraphic approach to a non-marine basin: the north-western part of a Cretaceous Kyonsang Basin, SE Korea. Sedimentology, 45, 449-472.

Rhee, C.W., Yang, W.H., and Chough, S.K., 1993. Contrasting development patterns of crevasse channel deposits in Cretaceous alluvial successions, Korea. Sedimentary Geology, 85, p. 401-410.

Rock, N.M.S., 1984. The nature and origin of calc-alkaline lamprophyres: minettes, vogesites, kersantites and spessartites. Transactions of the Royal Society Edinborough, 74, p. 193-227.

Rock, N.M.S., 1987. The nature and origin of lamprophyres: an overview. In: Alkaline Igneous Rocks, Fitton, J.G. and Upton, B.G.J., (eds.). Blackwell Scientific Publications, p. 191-226.

Rock, N.M.S., 1991. Lamprophyres. Blackie, London, 285 p.

Roddick, J.C., Henderson, J.R., and Chapman, H.J., 1992. U-Pb ages from the Archean Whitehills-Tehek lakes supracrustal belt, Churchill Province, District of Keewatin, Northwest Territories; In: Radiogenic Age and Isotopic Studies: Report 6; Geological Survey of Canada, Paper 92-2, p. 31-40.

Ross, G.M. and Chiarenzelli, J.R., 1985. Paleoclimatic significance of widespread Proterozoic silcretes in the Bear and Churchill provinces of the northwestern Canadian Shield. Journal of Sedimentary Petrology, 55, p. 196-204.

Ross, G.M. and Eaton, D.W., 2002. Proterozoic tectonic accretion and growth of western Laurentia; results from Lithoprobe studies in northern Alberta. Canadian Journal of Earth Sciences, 39, p. 313-329.

Ruppel, C. 1995. Extensional processes in continental lithosphere. Journal of Geophysical Research, 100, p. 187-215.

Ryan, J.J., Hanmer, S., Sandeman, H.A., and Tella, S. 2000. Archean and Paleoproterozoic fault history of the Big Lake shear zone, MacQuoid-Gibson lakes area, Nunavut. Geological Survey of Canada, Current Research 2000-C8, 9 p.

Ryan, J.J., Davis, W., Berman, R., Sandeman, H., Hanmer, S., and Tella, S., 2000. 2.5 Ga granulite-facies activity and post-1.9 Ga low-grade reactivation along the Big Lake shear zone, MacQuoid-Gibson lakes area (Nunavut): a fundamental boundary in the Western Churchill Province. In: GeoCanada 2000. Geological Association of Canada – Mineralogical Association of Canada, Joint Annual Meeting, Calgary, CD-ROM, abstract 924.

Sambrook Smith, G.H. and Ferguson, R.I., 1995. The gravel-sand transition along river channels. Journal of Sedimentary Research, A65, p. 423-430.

Sanborn-Barrie, M., 1994. Structural investigation of high-grade rocks of the Kramanituar complex, Baker Lake area, Northwest Territories. Geological Survey of Canada, Current Research 1994-C, p. 311-316.

Sanborn-Barrie, M., Carr, S.D. and Thériault, R., 2001. Geochronological constraints on metamorphism, magmatism and exhumation of deep-crustal rocks of the

Kramanituar Complex, with implications for the Paleoproterozoic evolution of the Archean western Churchill Province, Canada. Contributions to Mineralogy and Petrology, 141: 592-612.

Sandeman, H.A., 2001. 40Ar-39Ar geochronological investigations in the central Hearne domain, western Churchill Province, Nunavut: a progress report. Radiogenic Age and Isotopic Studies: Report 14. Geological Survey of Canada, Current Research 2001-F4, 23 p.

Sandeman, H.A., Cousens, B.L., and Hemmingway, C.J., 2003. Continental tholeiitic mafic rocks of the Paleoproterozoic Hurwitz Group, Central Hearne sub-domain, Nunavut: insight into the evolution of the Hearne sub-continental lithosphere. Canadian Journal of Earth Sciences, 40, p. 1219-1237.

Sandeman, H.A., Hanmer, S., Davis, W.J., Ryan, J.J., and Peterson, T.D., 2004. Neoarchean volcanic rocks, Central Hearne supracrustal belt, Western Churchill Province, Canada: geochemical and isotopic evidence supporting intra-oceanic supra-subduction zone extension. Precambrian Research, 134, p. 113-141.

Sandeman, H.A., LePage, L.D., Ryan, J.J., and Tella, S., 2000. Field evidence for commingling between ca. 1830 Ma lamprophyric, monzonitic, and monzogranitic magmas, MacQuoid-Gibson Lake area, Nunavut. Geological Survey of Canada, Current Research 2000-C5, 10 p.

Seal, R. and Paola, C., 1995. Observations of downstream fining on the North Fork Toutle River near Mount St. Helen's, Washington. Water Resources Research, 31, p. 1409-1419.

Sengör, A.M.C., 1995. Sedimentation and tectonic of fossil rifts. In: Busby, C.J. and Ingersoll, R.V. (Eds.), Tectonics of Sedimentary Basins. Blackwell Science, p. 53-118.

Sengör, A.M.C. and Burke, K., 1978. Relative timing of rifting and volcanism on Earth and its tectonic implications. Geophysical Research Letters, 5, p. 419-421.

Shanley, K.W. and McCabe, P.J. 1994. Perspectives on the Sequence Stratigraphy of Continental Strata. AAPG Bulletin, 78, p. 544-568.

Schumm, S.A. 1976. Episodic erosion: a modification of the geomorphic cycle. In: Melhorn, W.N. and Flemal, R.C. (eds.), Theories of landform development. Publications in Geomorphology, State University of New York, Binghamton, 69-85 p. Reprinted in 1982 by Allen and Unwin, London.

Schumm, S.A. 1977. The Fluvial System. New York, John Wiley and Sons, 338 p.

Schumm, S.A. 1985. Patterns of alluvial rivers. Annual Review of Earth and Planetary Sciences, 13, p. 5-27.

Schumm, S.A. and Khan, H.R., 1972. Experimental study of channel patterns. GSA Bulletin, 83, p. 1755-1770.

Simpson, E.L, Alkmim, F.F, Bose, P.K., Bumby, A.J., Eriksson, K.A., Eriksson, P.G., Martins-Neto, M.A., Middleton, L.T., and Rainbird, R.H., 2004. Sedimentary Dynamics of Precambrian Aeolianites. In: Eriksson, P.G., Alterman, W., Nelson, D.R., Mueller, W.U., and Catuneanu, O. (Eds.), Tempos and Events in Precambrian Time, Chapter 7.6: Sequence Stratigraphy and the Precambrian. Elsevier, Amsterdam, p. 642-656.

Sohn, Y.K., Rhee, C.W., Kim, B.C., 1999. Debris Flow and Hyperconcentrated Flood-Flow Deposits in an Alluvial Fan, Northwestern Part of the Cretaceous Yongdong Basin, Central Korea. The Journal of Geology, 107, p. 111-132.

Sønderholm, M. and Tirsgaard, H. 1998. Proterozoic fluvial styles: response to changes in accommodation space (Rivieradal sandstones, eastern North Greenland). Sedimentary Geology, 120, p. 257-274.

Southard, J.B. and Boguchwal, L.A., 1973. Flume experiments on the transition from ripples to lower flat bed with increasing sand size. Journal of Sedimentary Petrology, 43, p. 1114-1121.

Southard, J.B. and Boguchwal, L.A., 1990. Bed configurations in steady unidirectional water flows. Part 2: Synthesis of flume data. Journal of Sedimentary Petrology, 60, p. 658-679.

Stewart, J.H. and Diamond, D.S., 1990. Changing patters of extensional tectonics: Overprinting of the basin of the middle and upper Miocene Esmeralda Formation in western Nevada by younger structural basins. In: Wernicke, B.P. (ed.), Basin and Range extensional tectonics near the latitude of Las Vegas, Nevada. GSA Memoir, 176, p. 447-475.

Stokes, W., 1968. Multiple parallel truncation bedding planes – a feature of wind-deposited sandstone formations. Journal of Sedimentary Petrology, 38, p. 510-515.

Stow, D.A.V. and Shanmugan, G., 1980. Sequence of structures in fine-grained turbidites: comparison of recent deep-sea and ancient flysch sediments. Sedimentary Geology, 25, p. 23-46.

Sweet, M.L., 1999. Interaction between aeolian, fluvial and playa environments in the Permian Upper Rotliegend Group, UK southern North Sea. Sedimentology, 46, p. 171-187.

Taira, A., 2001. Tectonic evolution of the Japanese Island Arc System. Annual Review of Earth and Planetary Science Letters, 29, p. 109-134.

Tapponier, P. and Molnar, P., 1979. Active faulting and Cenozoic tectonics of the Tien Shan, Mongolia, and Baykal regions. Journal of Geophysical Research, 84, p. 3425-3458.

Tapponier, P., Zhiqin, X., Roger, F., Meyer, B., Arnaud, N., Wittlinger, G., Jingsui, Y., 2001. Oblique stepwise rise and growth of the Tibet Plateau. Science, 294, p. 1671-1677.

Tella S. and Eade, K.E., 1986. Occurrence and possible tectonic significance of high-pressure granulite fragments in the Tulemalu fault zone, District of Keewatin, N.W.T., Canada. Canadian Journal of Earth Sciences, 23, p. 1950-1962.

Tella, S., LeCheminant, A.N., Sanborn-Barrie, M., and Venance, K.E., 1997. Geology and structure of parts of the MacQuoid Lake map area, District of the Keewatin, Northwest Territories. Geological Survey of Canada, Current Research 1997-C, p. 123-132.

Ter Meer, M., 2001. Tectonometamorphic history of the Nowyak Complex, Nunavut, Canada. Unpublished M.Sc. thesis. Carleton University, Ottawa, Canada, 285 p.

Tian, Z.Y., Han, P., and Xu, K.D., 1992. The Mesozoic-Cenozoic East China rift system. Tectonophysics, 208, p. 341-363.

Tippett, C.R. and Heywood, W.W., 1978. Stratigraphy and structure of the Northern Amer Group (Aphebian), Churchill Structural Province, District of Keewatin. In: Current Research, Part B, Geological Survey of Canada, Paper 78-1B, p. 7-11.

Todd, S.P., 1989. Stream-driven, high-density gravelly traction carpets: possible deposits in the Trabeg Conglomerate Formation, SW Ireland and theoretical considerations of their origin. Sedimentology, 36, p. 513-530.

Tran, H.T., Ansdell, K., Bethune, K., Watters, B., and Ashton, K., 2003. Nd isotope and geochemical constraints on the depositional setting of Paleoproterozoic metasedimentary rocks along the margin of the Archean Hearne craton, Saskatchewan, Canada. Precambrian Research, 123, p. 1-28.

Vail, P.R., Mitchum, R.M., Todd, R.G., Widmier, J.M., Thompson, S. III, et al., 1977. Seismic stratigraphy and global changes of sea level. In: Payton, C. E, (ed.) Seismic Stratigraphy Applications to Hydrocarbon Exploration. American Association of Petroleum Geologists, Memoir, 26, p. 49-212.

Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Vail, P.R., Sarg, J.F., Loutit, T.S., and Hardenbol, J., 1988. An overview of the fundamentals of sequence stratigraphy and key definitions. Society of Economic Paleontologists and Mineralogists Special Publication, 42, p. 39-46.

Wernicke, B. and Snow, J.K., 1998. Cenozoic tectonism in the central Basin and Range; motion of the Sierran-Great Valley block: International Geology Review, 40, p. 403-410.

Wescott, W.A., 1993. Geomorphic thresholds and complex response of fluvial systems – some implications for sequence stratigraphy. American Association of Petroleum Geologists Bulletin, 77, p. 1208-1218.

Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V., and Roest, W.R. (comp.) 1997. Geological Map of Canada, Geological Survey of Canada, Map D1860A.

Wright, G.M., 1955. Geological notes on the central district of Keewatin, Northwest Territories. Geological Survey of Canada, Paper 55-17.

Wright, G.M., 1957. Geological notes on the eastern district of Mackenzie, Northwest Territories. Geological Survey of Canada, Paper 56-10.

Wright, G.M., 1967. Geology of the southeastern barren grounds, parts of the Districts of Mackenzie and Keewatin. Geological Survey of Canada, Memoir 350, p. 91.

Wright, V.P. and Marriott, S.B. 1993. The sequence stratigraphy of fluvial depositional systems: the role of floodplain storage. Sedimentary Geology, 86, 203-210.

Zaleski, E., Corrigan, D., Kjarsgaard, B.A., Jenner, G.A., Kerswill, J.A., and Henderson, J.R., 1997. Preliminary results of mapping and structural interpretation from the Woodburn project, western Churchill Province, Northwest Territories. In: Current Research 1997-C, Geological Survey of Canada, p. 91-100.

Zaleski, E. and Davis, W.J., 2002. Mantle-derived magmatism and continental rift deposits of the Neoarchean Woodburn Lake group, Western Churchill Province. GAC-MAC annual meeting, Program with Abstracts, p. 130.

Zaleski, E., Duke, N., L'Heureux, R.L., Davis, W.J., and Wilkinson, L., 1999a. Clastic and chemical sedimentary sequences, Woodburn Lake group, Amarulik Lake to Tehek Lake, western Churchill Province, Northwest Territories (Nunavut). In: Current Research 1999-C; Geological Survey of Canada, p. 19-28.

Zaleski, E., L'Heureux, R.L., Duke, N., Wilkinson, L., and Davis, W.J., 1999b. Komatiitic and felsic volcanic rocks overlain by quartzite, Woodburn Lake group, Meadowbank River area, western Churchill Province, Northwest Territories (Nunavut). In: Current Research 1999-C; Geological Survey of Canada, p. 9-18.

Zaleski, E., Pehrsson, S.J., Duke, N., Davis, W.J., L'Heureux, R., Greiner, E., and Kerswill, J.A., 2000. Quartzite sequences and their relationships, Woodburn Lake group, western Churchill Province, Nunavut. In: Current Research 2000; Geological Survey of Canada, 10 p.

Zhao, G. and Johnson, A.M., 1991. Sequential and incremental formation of conjugate sets of faults. Journal of Structural Geology, 13, p. 887-895.