A preliminary account of sedimentation in the lower Bowser Lake Group, northern British Columbia[1]

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Abstract

Preliminary investigation of the lower part of the Bowser Lake Group in Spatsizi and eastern Telegraph Creek map areas indicates a continuum of lithofacies ranging from relatively deep submarine fans, prodelta-slope with many incised submarine gullies and canyons, fan deltas, and interfan shelves. The succession ranges in age from late Bathonian or Callovian to possible Oxfordian. The transition from the fan delta-shelf facies assemblages to the prodelta-slope assemblage appears to pass through a depositional hinge. The submarine gullies and canyons, some more than 200 m thick, permitted coarse sediment to bypass the slope region and fed coarse grained submarine fans. Abrupt vertical and lateral facies changes indicate a dynamic depositional realm wherein sediment supply rates and routes changed frequently, probably in response to active tectonism in the sediment source terrain and rapid basin subsidence.

Résumé

L'étude préliminaire de la partie inférieure du groupe de Bowser Lake dans les régions des cartes de Spatsizi et de Telegraph Creek est indiquent un continuum de lithofaciès allant de cônes sous-marins relativement profonds, en passant par des talus avec de nombreux ravinements des cônes de déjection et canyons sous-marins, à des plates-formes intercônes. L'âge de la série varie du Bathonien supérieur ou Callovien à probablement l'Oxfordien. La transition des ensembles de faciès de cônes de déjection - plate-forme à l'ensemble de prodelta-talus semble passer par une charnière de sédimentation. Les ravinements et les canyons sous-marins, dont quelques-uns dépassent 200 mètres d'épaisseur, ont permis aux sédiments grossiers de contourner la région du talus pour alimenter des cônes sous-marins à grain grossier. D'abrupts changements de faciès verticaux et latéraux indiquent un lieu de sédimentation dynamique où les vitesses d'apport des sédiments et les routes changeaient fréquemment, probablement à la suite d'une tectonique active dans les terrains d'origine des sédiments et de la subsidence rapide des bassins.

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[1] Contribution to Frontier Geoscience Program

INTRODUCTION

The Middle to Upper Jurassic Bowser Lake Group, which underlies an enormous tract of northern Intermontane British Columbia, affords an excellent opportunity to examine gravel-dominated depositional regimes that range from nonmarine to relatively deep marine basins. Huge volumes of chert-dominated conglomerate, shed generally southwards, supposedly were derived from a northern component of the accretionary Cache Creek Terrane (e.g. Eisbacher, 1981). Preliminary investigations in the northern part of Bowser Basin (Spatsizi and Telegraph Creek map areas, Fig. 1) indicate that coarse sediment accumulated in fan deltas, with some dispersal over narrow, interfan shelves. However, large volumes of gravel and sand also bypassed the shelves, being funnelled down submarine canyons and gullies that were eroded into muddy prodelta-slope strata. The logical, basinward extensions of these sediment conduits, namely depositional systems indicative of proximal (conglomerate-dominated) and medial or distal (sand-mud dominated) submarine fans have also been found.

Each of these depositional realms contains a variety of lithofacies, herein grouped into broad facies assemblages: fan delta, shelf, prodelta-slope, and submarine fan. Possible alluvial equivalents of the fan deltas have been examined only briefly in strata of probable Oxfordian age.

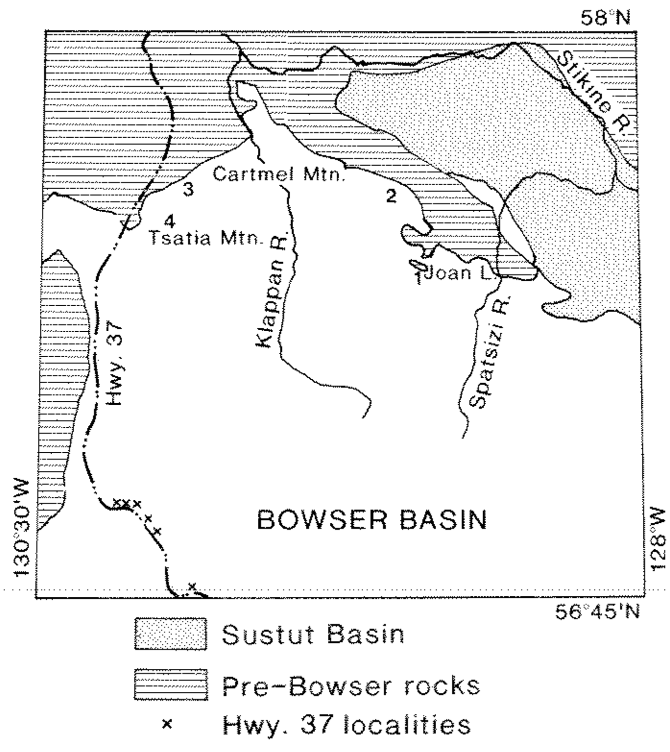

Figure 1. Location of principal measured sections illustrated in Figure 2. 1 = Joan Lake area, RAK 2,3,6 -89; 2 = Iceberg Canyon, RAK 7,9 -89; 4 = Todagin Mountain, RAK 11-89; 4 = Tsatia Mountain, RAK 14-89. Outcrops of turbiditic facies along Highway 37 are marked by crosses. The area covered includes Spatsizi map area, and parts of Telegraph Creek, Iskut and Bowser map areas.

The facies outlined in this report occur in the upper Bathonian to Oxfordian Ashman Formation of the Bowser Lake Group (Duffell and Souther, 1964; Tipper and Richards, 1976; Thompson et al., 1986). The Ashman Formation has traditionally been defined as a succession of dark grey siltstone and shale with thin, buff-weathering fine sandstone and conglomerate interbeds. Ashman strata in the Spatsizi and Telegraph Creek map areas contain significant quantities of conglomerate and coarser sandstone in sediment bodies of highly variable lateral and vertical extent. Although the Ashman succession overall has a recognizably coarsening upwards aspect, there is a great deal of lateral and vertical lithological variability which, in concert with complex structural deformation over most of the basin (Evenchick, 1988), creates major problems for correlation of stratigraphic sections. The degree to which this problem can be overcome will depend to a large extent on establishing a sound biostratigraphic framework. Current macropaleontological studies by T.P. Poulton (GSC) and R. Hall (University of Calgary) will augment existing palynological zonal schemes (e.g., Moffat et al., 1988; Cookenboo and Bustin, 1989). Thus, correlation of the measured sections shown in Figure 2 is necessarily preliminary.

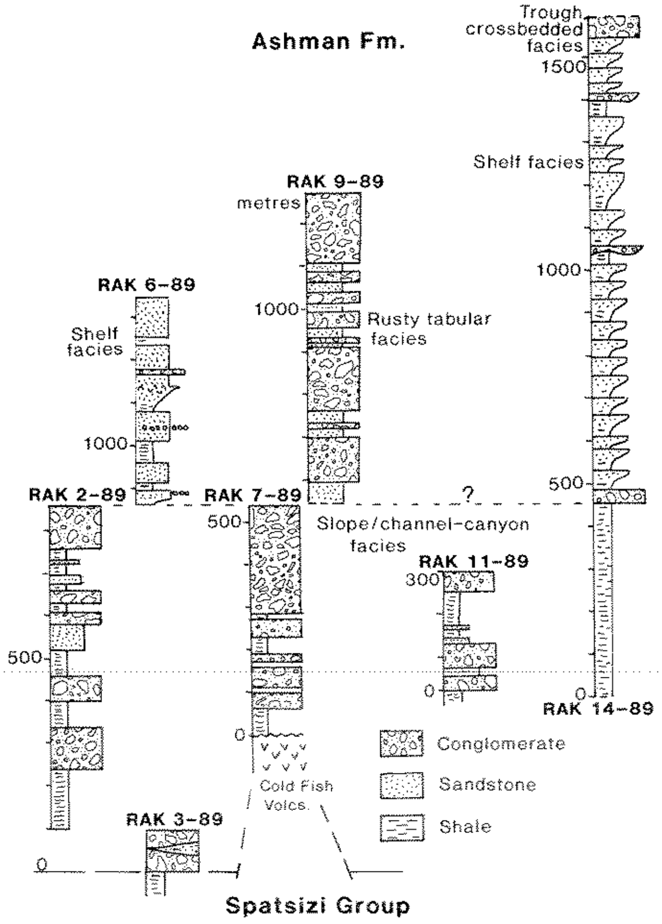

Figure 2. Measured sections, and broad facies designations through the lower Bowser Lake Group are shown schematically (and highly simplified). Section locations are indicated in Figure 1.

SUBMARINE FAN ASSEMBLAGE

Sandy turbidite facies

Tabular bedded, graded sandstones up to 3 m thick, and in places arranged in bed-thickening upwards successions, were observed in roadcuts between Barrage River and Bell II station (Fig. 1). Although the base of the Ashman Formation has not been found in this transect, it seems likely that the sandy turbidite facies is close to this contact, based on regional structural considerations. If so, then the facies is the lateral equivalent of the tabular conglomerate facies described below.

Thin bedded turbidites contain mostly Tb to Td (or the pelitic Te) Bouma divisions. More massive sandstone beds higher in the upwards-thickening successions are commonly composite, composed of two or three stacked and graded beds having Bouma Ta-Tb divisions and separated by a layer of shale rip-up clasts. Flame structures, flute and groove casts are common, and generally indicate south to southwest flow directions. At two localities, thickening upwards packages are capped by pebbly mudstone units up to 2 m thick; each thickening upwards package is about 50 m thick. A few ammonite, *Buchia* and *Astarte* fragments have been found. Trace fossils also are scarce; those recognized include *Planolites*, and possible *Gyrochorte* or *Didymaulichnus*.

Tabular conglomerate facies

A unit of conglomerate, in places more than 100 m thick, represents the lowest Bowser Lake Group at localities where contact with the underlying Spatsizi Group is exposed (e.g. Joan Lake area, Fig. 1). The unit can be traced laterally over several kilometres and has a tabular, sheet-like geometry, with local pinching and swelling. The geometric disposition of this facies is distinct from the lenticular (channelized) conglomerate facies found higher in the succession (Fig. 3). Internally the conglomerate unit is highly complex, consisting of stacked, conglomerate wedges, up to 50 m thick and tens to hundreds of metres wide. The conglomerate wedges in turn interfinger with wedges of interbedded sandstone and shale. Contacts between wedges are abrupt; coarsening or fining upwards stratigraphic patterns are rare.

The conglomerate wedges themselves are made up of smaller scale wedge sets, sometimes arranged into large, gently dipping (10-12°) foresets up to 15 m thick. Individual conglomerate foresets are capped by sandstone beds that pinch out up foreset dip. No smaller scale crossbedding has been observed.

Conglomerate frameworks range from clast-supported with pronounced pebble alignment (some imbrication), through a spectrum of fabrics that, at the opposite extreme, includes pebbly mudstone. Some beds contain inverse grading in their lower few centimetres; normal grading is less common. Associated sandstone wedges (up to a metre thick) also are nongraded, commonly parallel laminated; as with the conglomerates, no small scale crossbedding has been observed.

Interbedded turbiditic sandstone and shale compose relatively recessive wedge-shaped sediment bodies that interfinger with the conglomerates. Sandstone beds less than 40 cm thick are generally fine grained, having Tb to Td Bouma divisions. The rippled Tc divisions rarely contain convoluted laminae. These turbidites are arranged into both bed thickening- and bed thinning-upwards packages 2-4 m thick. Graded turbidites only a few centimetres thick typically contain numerous starved ripples that impart a pinch and swell character to the beds. Less common are beds of pebbly mudstone in which the mud matrix comprises 20-30 %.

PRODELTA-SLOPE ASSEMBLAGE

Shale facies

Thin, interbedded siltstone and shale compose much of the Ashman Formation. Both normally graded and nongraded beds a few millimetres to 20 cm thick occur. Delicate laminae are well preserved, bioturbation being uncommon and attesting to low levels of faunal activity. Ripples, including starved varieties also occur. More common, especially in graded beds (commonly Tb/Td or Tc/Td divisions), are indications of soft sediment deformation. These include pull-apart (boudinage) structures, detached load structures, convoluted laminae, and microfaults that extend through only a few centimetres of sediment. The soft sediment faults impart a wispy texture to the mudrocks — a characteristic feature of Ashman shales.

On a larger scale, low angle discordances are common and demarked by rapid thinning of sandstone beds, or sandstone filling of shallow channel structures generally less than a metre or two thick. The discordances are in some places associated with large scale slump packages (see below).

Slump facies

Soft sediment slumping is common in the Ashman mudrocks and may involve upwards of 50 m of stratigraphy. At Joan Lake a major slump package can be traced laterally for several kilometres (Fig. 1 and 3). Slump structures range in size from small folds of one or two metres amplitude, to large blocks of displaced, overturned and internally disrupted conglomerate 40 m thick. As expected, shales beneath the displaced blocks also exhibit considerable disruption; overlying deposits contain depositional discordances. Sandstone dykes are common in the slump packages. Notably, channel structures in the shale facies commonly are spatially associated with slump-generated discordances.

Lenticular conglomerate (channel) facies

An outstanding component of the shale lithofacies assemblage is lenticular conglomerate bodies ranging in thickness from a metre to more than 200 m thick, and from a few metres to perhaps 10 km wide (Fig. 3). In all cases examined, the channel-like conglomerates are encased in mudrocks; have abrupt top, base and marginal contacts; and are not associated with coarsening or fining upwards stratal trends. Basal contacts clearly are erosional with up to 5 m relief; some upper contacts also exhibit erosional discordances even though they are overlain by shaly lithologies. Channel margins range in orientation from gradual pin-

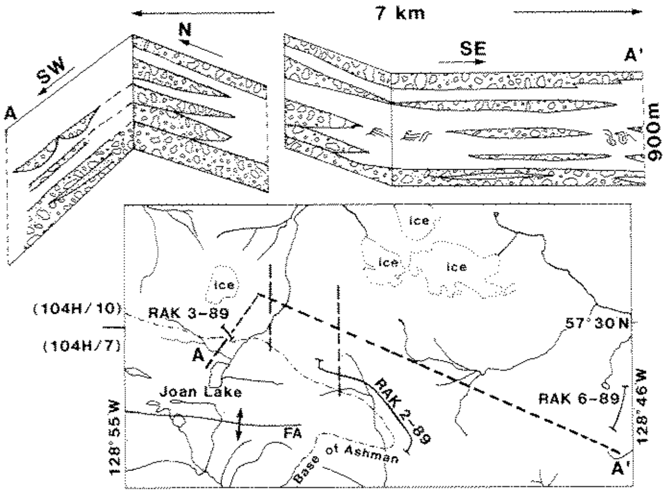

Figure 3. This fence diagram illustrates the three dimensional geometry of the tabular conglomerate facies (basal unit) and lenticular conglomerate facies in the Ashman Formation, Joan Lake area. Note the amalgamation of conglomerates into a thick (more than 200 m) unit in the northwest corner of the diagram, and the package of slumped beds that can be traced laterally for several kilometres within the intervening shale facies.

chouts to abrupt, subvertical walls 20-30 m high. Individual conglomerate bodies may also amalgamate into very thick units.

The internal organization of the lenticular conglomerate facies is complex (Fig. 4), but similar to the tabular conglomerate facies, with the exceptions that large conglomerate foreset are more common, and the thick, recessive (turbiditic) sandstone-shale wedges less common. Many of the large foresets have tangential toesets.

SHELF ASSEMBLAGE

Coarsening upwards sandstone facies

This facies is transitional, over a few metres, from strata of the prodelta-slope assemblage and ranges in thickness from 500 m (Joan Lake area) up to 1000 m (Mount Tsatia, Fig. 1 and 2). It also appears to be laterally equivalent, at least in part, to the tabular, rusty conglomerate facies (fan delta assemblage).

The facies is characterized by many stacked, coarsening and bed-thickening upwards units (cycles) up to 22 m thick. Each unit in turn contains several smaller scale coarsening upwards cycles. A few thin turbidites occur in the lower shaly components. Sandstone beds increase in thickness upwards, and in a few units pass into thin conglomerate beds or pebbly sandstone. Other stratigraphic trends within each cycle include an increase in the proportion of low-angle planar crossbeds and hummocky cross-stratification. Scour pockets filled with mud rip-up clasts interfinger with a few hummocky cross-stratified beds. Some trough crossbedding occurs in sandstones near the top of the facies successions, near the transition into the trough crossbedded conglomerate facies.

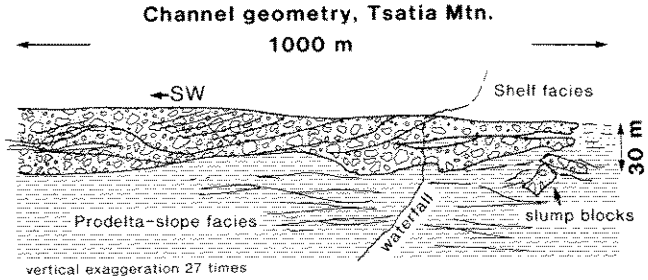

Figure 4. This field sketch illustrates the complex internal organization of the lenticular conglomerate facies at Mount Tsatia. Channel fill occurred in several stages, as indicated by the numerous lenses and veneers of mudrock, some containing thin, fine grained turbidites, and the complex association of large, shallow-dipping foresets with channel scour bases. Channel fill was characterized by lateral migration of thalwegs and vertical stacking of depositional units.

A greater diversity of trace fossils occurs in this facies than has been observed in any of the other facies; ichnogenera include *Planolites, Chondrites, Thalassinoides, Skolithos, Rosellia* (or *Asterosoma),* and possibly *Rhizocorallium* or *Zoophycus.*

Many of the cycles are capped by conglomerate beds that have a different character to conglomerate and pebbly sandstone associated more intimately with the coarsening upwards trends. These capping conglomerates are identified primarily by their poor sorting, abrupt bases, tops that grade into shale of the overlying unit, frameworks that become increasingly mud-matrix supported towards bed tops, generally abundant fossils, and the absence of bedforms. Fossils commonly include brachiopods, gastropods, ammonites, belemnites and bivalves, with the mud-dwelling *Pina* sometimes in growth position. Particularly fossiliferous examples of these conglomerates were found in the lower part of the shelf assemblage at Mount Tsatia (Fig. 2) which contains an abundance of the lower to middle Callovian ammonite *Cadoceras* (T. Poulton, R. Hall, personal communication, 1989).

FAN DELTA ASSEMBLAGE

Tabular, rusty conglomerate facies

Distinctly rusty weathering conglomerates in tabular, sheet-like units occur in successions at least 700 m thick in the Joan Lake-Mount Cartmel area (Fig. 2). They overlie strata of the prodelta-slope assemblage and are laterally equivalent to shelf assemblage facies. The facies also grades into the trough crossbedded conglomerate facies.

Individual conglomerate units range in thickness up to 20 m, and can be traced laterally for up to 8 km and more. At Icebox Canyon (Fig. 1) more than 30 such units occur within a 700 m thick succession. Most have abrupt tops, and bases that grade upwards from the intervening sandstone-shale intervals. Internally, the conglomerates consist of tabular and wedge shaped beds, and some foresets up to 10 m thick with angular discordances of 8-10°. Foreset layers are nongraded, either normal to bedding or up foreset dip. Sandstone wedges pinchout up-dip. Sandstones are parallel laminated and less commonly, trough crossbedded or rippled. Gravel ripples are relatively common, having amplitudes of 20 cm and wave lengths of about a metre.

Conglomerate frameworks include a broad spectrum of clast and matrix supported fabrics, similar to conglomerates in the prodelta-slope and submarine fan assemblages. In some cases, clast supported, laminate pebble conglomerates with pronounced clast alignment can be traced laterally within single depositional units into pebbly mudstone; one example has been observed in a thick foreset package (more than 100 m thick) near Mount Cartmel.

Stratigraphic trends throughout the rusty, tabular facies include:

— shallow channelling in the lowest conglomerate units becoming less common higher in the succession;

— thin, turbiditic sandstones in the recessive intervals generally are confined to lower stratigraphic intervals; higher in the succession the sandstones contain some trough crossbedding;

— the proportion of poorly sorted, clast and matrix supported fabrics decreases upwards, being replaced by better sorted clast supported frameworks, in concert with an increase in the abundance of crossbedding;

— the proportion of recessive lithologies decreases upwards;

— maximum clast size increase upwards, up to 16 cm across;

— the proportion and size of plant debris increase upwards.

Trough crossbedded conglomerate facies

Trough crossbedded, rusty-weathering pebble and cobble conglomerate is the youngest lithofacies at Mount Tsatia, where it gradationally overlies coarsening upwards sandstone-shale units of the shelf assemblage (Fig. 2). Ammonites within the associated shelf facies include the uppermost Callovian genus *Quenstedtoceras* (T. Poulton, personal communication, 1989). In the Mount Cartmel area the facies appears to be in gradational contact with subjacent tabular, rusty conglomerates. Festooned trough crossbeds up to 2 m thick contain abundant wood. Carbonaceous shale was seen at one locality east of Mount Tsatia but was not examined in detail. Sandstone lenses also contain trough crossbeds, some planar tabular crossbeds and parallel laminae. Conglomerate frameworks are all clast-supported and hence contrast the highly variable framework types found in the other conglomerate facies.

INTERPRETATION OF FACIES

The sandy turbidite facies constitutes the sandy component of a series of south to southwest prograding submarine fan lobes, and compares favourably with Facies B of Mutti and Ricci Lucchi (1978). It is the most basinward component of the submarine fan assemblage seen to date, although the low proportion of muddy lithologies and turbidite beds of distal character (e.g., compared to Facies D of Mutti and Ricci Lucchi, 1978), suggests a position well up on the fans, still within reach of cohesive, muddy debris flows. The tabular conglomerate facies, exposed farther north, is tentatively assigned to a more proximal position on the submarine fans, perhaps at the toe-of-slope where submarine channels or canyons fed coarse sediment to the principal channels of adjacent fans. The locus of gravel transport within the proximal fan channels was constantly shifting, as evidenced by the complex array of conglomerate wedges that interfinger with the thin, fine grained turbidite-shale wedges. The latter have the characteristics of channel overbank deposits (e.g. Facies E of Mutti and Ricci Lucchi, 1978). Large foreset conglomerate units may be analogous to point bar deposits in high sinuosity alluvial channels, reflecting migration of channel thalwegs, although actual modes of deposition were quite different. Most conglomerates have the characteristics of debris flows with the range of conglomerate fabrics indicating that sedimentation processes also were quite variable. Debris flow mechanisms ranged from noncohesive, highly sheared flows (rapid flow), to cohesive, slow moving mud plugs. Changing flow mechanisms can even be demonstrated within single depositional units, where pebbly mudstones form the distal, slower moving portions of flows.

Aspects of the shale facies are typical of slope settings wherein sedimentation rates were relatively low (compared to the adjacent submarine fans), and where most sediment of medium sand size and greater was bypassed through an extensive system of channels, gullies and in some cases, steep-walled submarine canyons. The abundance of both large- and small-scale soft-sediment deformation structures in the shales attests to an unstable seafloor, consistent with higher depositional slopes than the adjacent basin floor and shelf. Sediment was probably derived from pelagic and hemipelagic sources, in addition to overbanking of the incised channels. All gullies and canyons observed so far are eroded into shale facies. Deposition within these channels was often episodic; like the submarine fan channels, the locus of sediment transport and deposition seems also to have frequently migrated. Channels were usually abandoned suddenly as indicated by abrupt tops. The spatial association of slump discordances in the mudrocks and many channel structures further suggests a possible causal relationship, where sediment was directed through slump-enhanced topographic depressions on the sea floor. The abrupt, commonly eroded terminations of these sediment conduits may also have been the result of slope failure (an idea suggested by T. Poulton). Abrupt changes in sediment supply to the channels may also have played a role.

The transition from the slope facies to the tabular, rusty conglomerate and coarsening upwards sandstone facies is everywhere gradational, but abrupt. This may indicate some kind of depositional hinge between the shallower (shelf and fan delta) and deeper (submarine fan) parts of the basin. All criteria characterizing the coarsening upwards sandstone facies indicate an actively aggrading and prograding shelf environment that frequently was subjected to storms. Each cycle of shelf deposition was terminated by a transgressive event that left its mark as poorly sorted, fossiliferous conglomerate caps, or lags; these transgressive lags are distinct from conglomerate beds that form part of the coarsening upwards trends in some cycles (perhaps reflecting proximity to shoreface). The transition from the conglomerate lags to mudrocks of succeeding cycles approximates the position of maximum flooding during each transgression.

Rusty, tabular conglomerates that are laterally equivalent to the shelf facies are interpreted as the distal parts of fan deltas. Deposition on the deeper portions of the fans was primarily by sediment gravity flow; presumably these flows also fed sediment into the submarine gullies and canyons. Some sediment was dispersed by traction currents (sand and gravel ripples); the proportion of bed-load transportation seems to have increased in the shallower, shoreward parts of the fans with probable shoreface components also preserved (trough crossbedded facies).

A PRELIMINARY VIEW OF THE REGIONAL PICTURE

The overall setting on the lower Bowser Lake Group (principally Ashman Formation, in the Spatsizi and eastern Telegraph Creek map areas, can be viewed as a complex of fan deltas and interfan shelves, that fed coarse sediment through prodelta-slope gullies and canyons onto submarine fans (Fig. 5). Preliminary paleocurrent analysis indicates that sediment transport was towards the south and southwest (confirming suggestions by Tipper and Richards, 1976 and Eisbacher, 1981). The lateral extent of the fan deltas is not yet known. It is clear, however, that this was an extremely dynamic system. Thick, stacked fan delta deposits, and the abrupt appearance and termination of submarine channels in the adjacent slope attest to rapidly changing sediment supply and abrupt lateral shifts at points where sediment was introduced into the basin. Such changes ultimately are related to changing base levels in the sediment source area. Given the thickness of the succession overall, the huge volumes of very coarse sediment even in the deeper parts of the basin, and the brief period of sediment accumulation, the most reasonable control on basin architecture was probably tectonic — that is rapid basin subsidence coupled with rapid uplift and erosion of the (northern) source terrain.

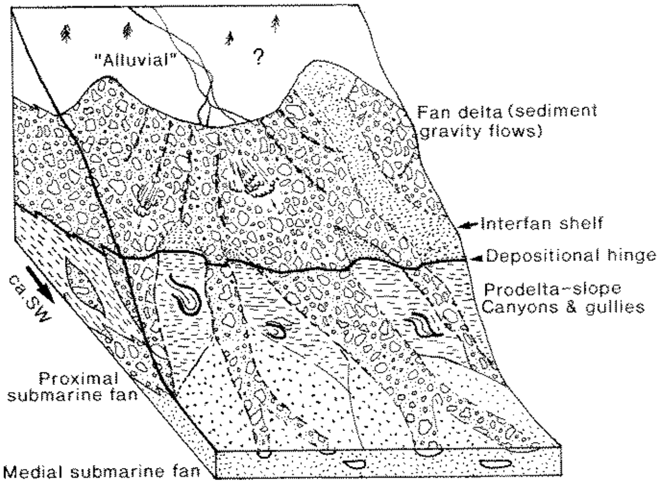

Figure 5. A hypothetical reconstruction of the paleoenvironmental setting for lower Bowser Lake Group strata in the Spatsizi and eastern Telegraph Creek map areas. The stratigraphic package represents a prograding complex of fan deltas and laterally associated shelves, slope, submarine channels and submarine fans. Depositional hinge refers to a marked geomorphic boundary at the shelf/fan delta-slope break, that is inferred from abrupt facies transitions. The "alluvial" component of the hypothesis has yet to be examined in detail.

ACKNOWLEDGMENTS

Carol Evenchick introduced me to Bowser Basin geology, with all its vagaries and foibles; Terry Poulton (ISPG), Russell Hall (University of Calgary), and John Callomon (University of London) led me through some of the intricacies of the biostratigraphy, and Shawna Vossler assisted in the field. All of these people are thanked.

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