FACIES AND DEPOSITIONAL SETTING OF LABERGE CONGLOMERATES (JURASSIC), WHITEHORSE TROUGH

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ABSTRACT

The Whitehorse Trough, south-central Yukon, originated as a Mesozoic fore-arc basin separating the allochthonous Stikine Terrane to the west from the North American craton. Late Triassic erosion of a volcanic arc supplied detritus to the basin. Subsequent cessation of volcanism, unroofing and deep erosion of the arc into the Middle Jurassic resulted in a progressive increase in granodioritic sediment.

Late Triassic-Jurassic Laberge conglomerate within the Whitehorse Trough are coarse, polymictic and typically massive. Inverse or normal grading, planar stratification and cross-bedding are less common. Conglomerates are debris flow, sheet-flood and bar deposits of braided alluvial fan-deltas. These conglomerates usually overlie and grade basinward into feldspathic graywacke or arkosic sandstone. Crystal tuffs grade laterally into sandstone and occur as interbeds as well. Sandstones commonly display trough cross-bedding or planar stratification. Hummocky cross-stratification rarely occurs in sandstones interbedded with bioturbated silty mudstone. Other facies include graded sandstone-mudstone with Bouma BC(E) sequences; float-stone/micritic limestone; and rare calcarenite/rudite. Sandstone-conglomerate facies transitions indicate a vertical progression from shallow marine and shoreface sedimentary strata of Late Triassic age to coarse alluvial fan conglomerates of Jurassic age, reflecting progradation of fan-delta systems with progressive infilling of the basin. The Stikine Terrane accreted to North America in the Late Jurassic with basin shallowing and closure reflected by changes in the sedimentary sequences.

RÉSUMÉ

Dans la partie sud-centrale du Yukon, la fosse de Whitehorse était initialement, au Mésozoïque, un bassin d'avant-arc qui à l'ouest séparait le terrane allochtone de Stikine du craton nord-américain. Durant le Trias supérieur, l'érosion d'un arc volcanique a fourni des débris au bassin. Ensuite, l'interruption du volcanisme, la découverture et l'érosion profonde de l'arc durant le Jurassique moyen ont eu pour effet une augmentation progressive de l'épaisseur des sédiments granodioritiques.

Le conglomérat de Laberge, d'âge triasique supérieur à jurassique, situé à l'intérieur de la fosse de Whitehorse, est grossier, polymictique et typiquement massif. Le granoclassement inverse ou normal, la stratification horizontale et la stratification oblique sont moins courants. Les conglomérats se composent de coulées boueuses, de dépôts d'inondation en nappe et de dépôts de bancs fluviatiles dans des cônes de déjection anastomosés. Généralement, ces conglomérats recouvrent des grauwackes ou des grès arkosiques, et passent progressivement à ce type de sédiments vers l'intérieur du bassin. Des tufs cristallins passent latéralement à des grès et se présentent également sous forme d'interstratifications. Généralement, les grès montrent une stratification croisée en auge ou une stratification plane. On rencontre rarement une stratification en bosses et creux dans les grès interstratifiés avec des pélites limoneuses bioturbées. Un autre faciès comprend des grès ou pelites granoclassés avec les séquences de Bouma BC(E); une roche de type float-stone/calcaire micritique; et très rarement des calcarénites/rudites. Des transitions de faciès du grès au conglomérat indiquent une progression verticale de strates marines peu profondes et de strates sédimentaires de zone infratidale, d'âge triasique supérieur, à des conglomérats grossiers de cônes alluviaux d'âge jurassique, ce qui indique une progradation des systèmes de cônes de déjection à mesure que s'est effectué le comblement du bassin. Le terrane de Stikine s'est joint par accrétion à l'Amérique du Nord pendant le Jurassique supérieur, et la diminution de profondeur et la fermeture du bassin se sont traduits par des modifications des séquences sédimentaires.

INTRODUCTION

The Whitehorse Trough, a northwest-trending synclinorium in the Cordilleran Intermontaine Belt (Fig. 1), contains a thick succession (6700 m +) of Late Triassic to Early Cretaceous calc-alkaline volcanic and volcaniclastic rock, reef limestone, greywacke, argillite, and conglomerate (Wheeler, 1961).

The Whitehorse Trough originated as a Triassic fore-arc basin (Templeman- Kluit, 1979). A volcanoplutonic arc, situated on the leading edge of the allochthonous Stikine Terrane, supplied volcanic flows and detritus to the basin. Tethyan-type framework and patch reefs, with bedded inter-reef deposits, flanked the arc in Carnian to Norian time (Reid et al., 1987). Arc-derived sediments were transported from the west to the basin by braided fan-deltas.

Jurassic sedimentary strata overlying upper Triassic limestone are the Laberge Group; whereas the limestone, interbedded clastics, and volcanics of Triassic age constitute the Lewes River Group. These units are separated by a discontinuous erosional unconformity along the basin margin, being conformable at the basin axis (Wheeler, 1961), Laberge/Lewes River beds were deposited by a single, continuously-operating depositional system, and have been (informally) considered as a single stratigraphic unit (Tempelman-Kluit, 1978; Hills et al., 1981). Jurassic basin-fill is predominantly coarse, polymictic conglomerate. In this study, Triassic-Jurassic conglomerates of the Whitehorse Trough are referred to as "Laberge conglomerates".

Nine stratigraphic sections of Laberge conglomerates were measured in detail on a bed-by-bed basis in the Whitehorse area.

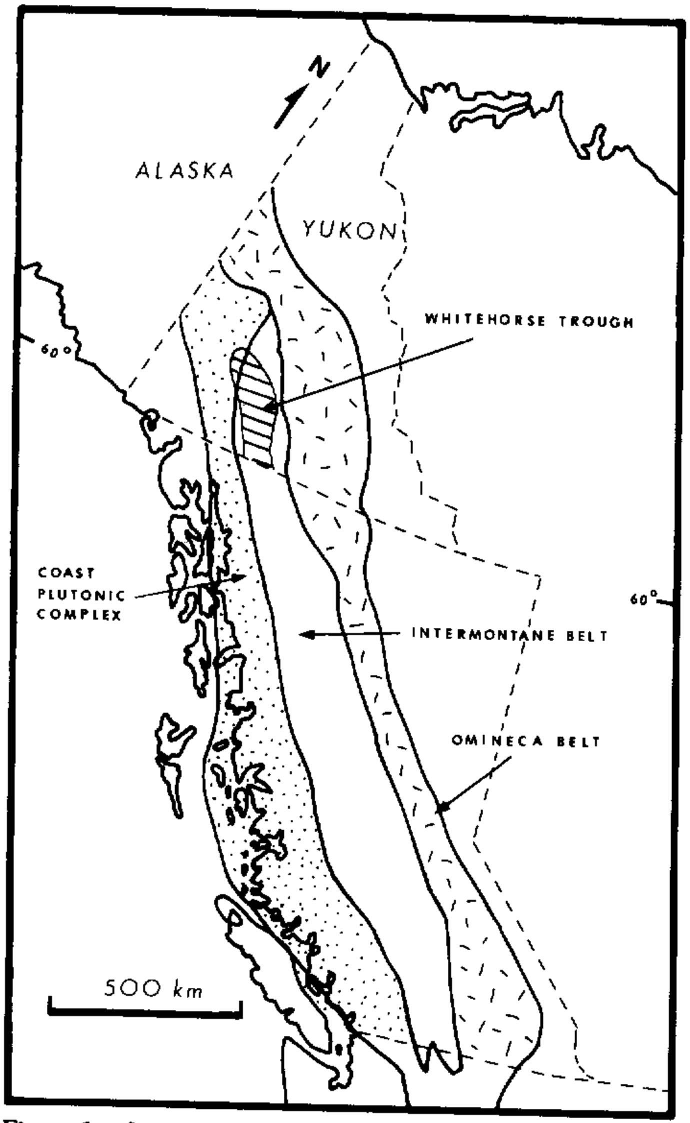

Figure 1. Location of Whitehorse Trough, northern cordillera.

Only three sections (Braeburn, Takhini Hotsprings and Fish Lake) provided continuous exposure and reliable fossil dates. Braeburn and Takhini Hotsprings (Fig. 2) conformably overlie the uppermost limestone of the Lewes River Group, which has a correlatable Carnian-Norian chronohorizon (Spondylospira lewesensis fauna; Tozer, 1958). The Fish Lake section (Fig. 2), ranges in age from Toarcian to (late) early Bajocian (Harpoceras to Stephanoceras ammonite zones; Wheeler, 1961). Braeburn and Takhini Hotsprings sections show marine to alluvial transition, whereas Fish Lake strata are entirely marine.

METHODS OF STUDY

Facies were delineated on the basis of lithology, sedimentary structures, and biogenic features. Facies sequences were used to interpret depositional environments. Fining- or coarsening-up sequences and bed-thinning or thickening trends were determined by plotting maximum particle size (MPS) (ave. of 10 largest clasts) and bed thickness against stratigraphic position. Moving average plots, using point-sets of 3, were used to smooth the data, thus eliminating bed-scale perturbations.

Clast lithology was plotted against stratigraphic position. Granodiorite (arc pluton) and volcanic clasts (tuff, basalt, dacite, andesite) are arc-derived, relating directly to erosion of the source terrane. Limestone clasts, eroded from Norian arc-flanking reefs and back-reef areas, were dated on the basis of conodont fauna. Trend recognition, coupled with facies interpretation, was used to separate autocyclic and allocyclic processes in these sections, thus putting constraints on depositional processes and controlling mechanisms.

FACIES

Facies for Laberge conglomerates were defined as follows:

1) Floatstone/Micritic Limestone Facies

Thick-bedded, grey, micritic limestone contains dispersed pelecypod, gastropod, calcareous sponge, and coral fragments. Rare sedimentary structures occur as parallel-laminated siliciclastic sand. This facies represents deposition in a carbonate lagoon/back-reef setting.

2) Calcarenite/Rudite Facies

Calcarenite/rudite is interbedded with facies (1) or grades from arkosic to greywacke sandstone beds. Fossil fragments (as in facies 1; ave. 4 cm) occur in clast-support with a sandy micrite matrix. Calcarenite/ rudite resulted from sandy turbulent flows eroding exposed (or shallow water) reef crests.

3) Red Mudstone

Red mudstone occurs as thick-bedded, typically massive beds (rare desiccation cracks with sand in-filling) (subfacies 3a), or as thin bedded, heavily bioturbated mudstone interbedded with grey arkosic sandstone (subfacies 3b). The former represents suspension deposition in abandoned alluvial fan stream channels, whereas the latter is indicative of a shallow marine (near shore) setting.

4) Interbedded Sandstone/Mudstone

Very fine sandstone/mudstone couplets display fining-up partial (BCE) Bouma sequences. Presence of ammonites indicates marine deposition, probably as delta-front turbidites. Similar beds, displaying coarsening-up sequences expressed as a vertically-increasing sand/shale ratio, represent prodelta deposits.

5) Stratified Sandstone

Fine to medium-grained sandstone occurs as planar-stratified beds (subfacies 5a), deposited by bar-top sheet-floods in a distal fan setting; or as low-angle stratified sandstone (subfacies 5b), which is defined by heavy mineral accumulations and represents shoreface bars created through fluvial/marine interaction.

6) Massive/Normally-graded Sandstone (Fig. 3)

Massive (also normally-graded) sandstone occurs in several environments, primarily representing deposition through subaqueous turbulent flows in a distal fan-delta setting (fluvial and shallow marine).

7) Cross-Stratified Sandstone

Trough cross-stratified sandstone (subfacies 7a) occurs in close association with hummocky cross-stratified sandstone (subfacies 7b), both of which occur in a shallow marine setting. The former occurs where reef influence prevented storm waves from breaking on the shoreline; whereas the latter represents storm-reworking along a non-barred coast.

8) Pebbly Sandstone

Pebbly sandstone occurs as normally-graded granule/pebble size (broken) euhedral plagioclase grains and lithic fragments set in a medium sand matrix (subfacies 8a). Trough cross-bedded pebbly sandstones (sets to 2.4 m) display pebble-

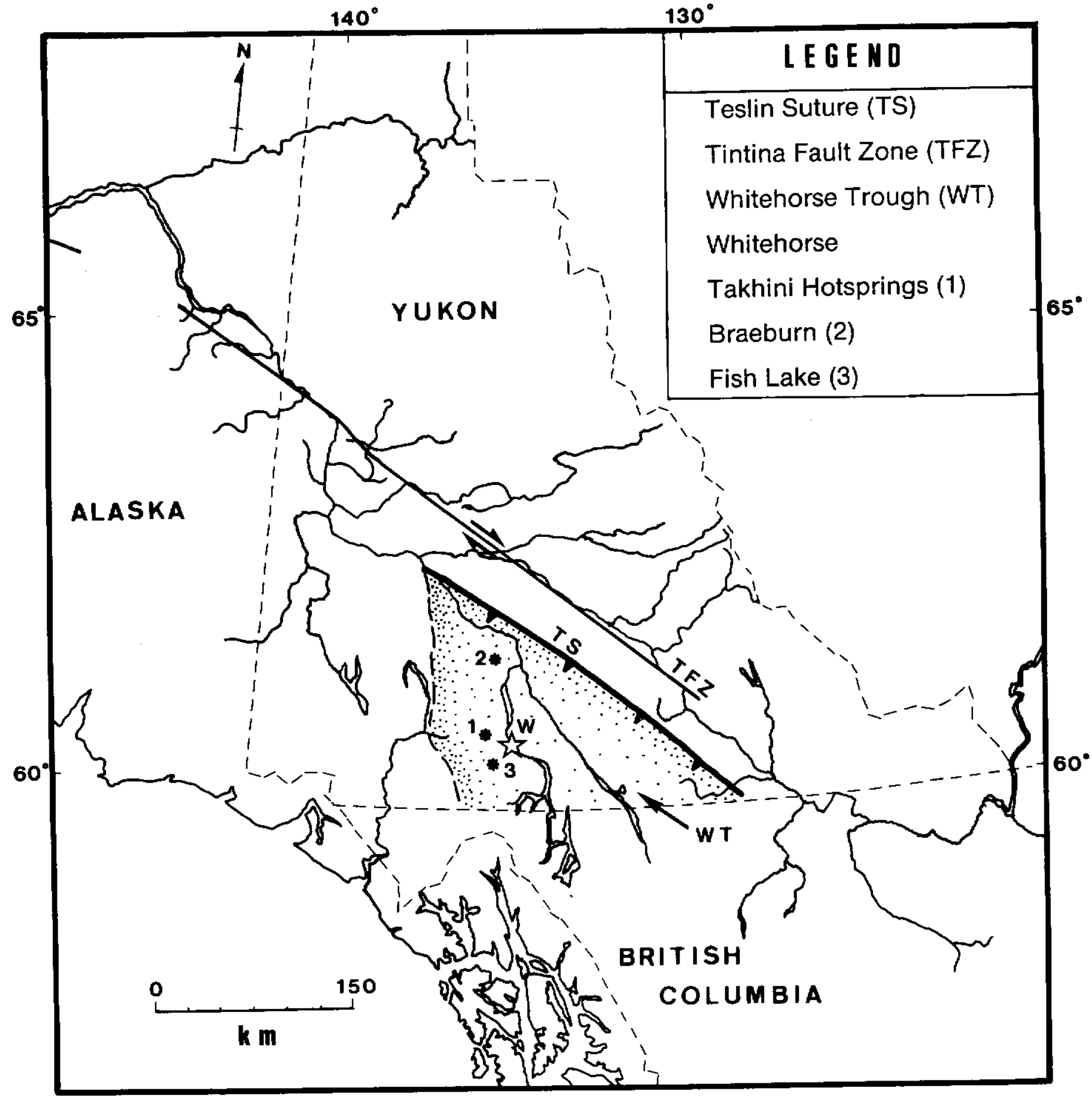

Figure 2. Location Map for studied sections and major tectonic features.

defined cross-beds (subfacies 8b). Low-angle cross-bedded pebbly sandstones line shallow scours, and grade into sheets (subfacies 8c). These represent subaqueous grain-flows, fluvial channel megaripples, and fan sheet-flood deposits, respectively.

9) Planar-Tabular Cross-Bedded Conglomerate

Matrix-supported polymictic conglomerate, displaying low-angle planar-tabular cross-beds (sets 50-80 cm), formed as foresets on transverse bars in the braided reach of a fan-delta.

10) Clast-Supported Conglomerate

Polymictic, chaotic, massive framework conglomerate (subfacies 10a) (Fig. 3) rarely displays a fabric with a-b planes of discoidal clasts parallel to bedding. Openwork (rarely) matrix-filled conglomerate (subfacies 10b) is typically massive, but rarely displays crude low-angle planar-tabular cross-beds. These reflect deposition by mass-flow gravel dispersions and braid-bar foresets, respectively.

11) Matrix-Supported Conglomerate

Normally-graded polymictic conglomerate (subfacies 11a) suggests deposition by hyperconcentrated flows, whereas reverse-graded conglomerate, typically displaying a sheared sandy mudstone base (subfacies 11b) is indicative of debris flow deposition.

12) Boulder Conglomerate (Fig. 4)

Boulder conglomerate is massive, containing clasts up to 2.5 m in diameter. Incised channel features, defining the base of many of these beds, suggest these conglomerates are proximal fan trench-fill deposits.

Figure 3. Laberge conglomerates, Annie Lake. Note that pebble conglomerate (Facies 10a) overlies scour-based coarse massive sandstone (Facies 6).

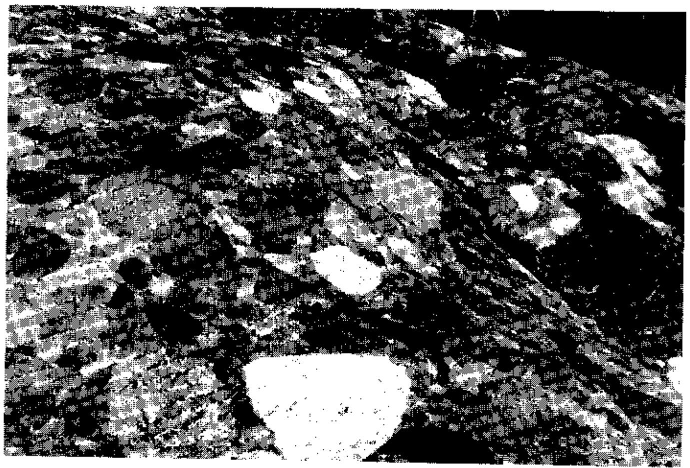

Figure 4. Laberge conglomerate, Alaska Highway Boulder conglomerate (Facies 12) displays chaotic fabric and clast-support. Hammer for scale.

FACIES TRENDS

Conglomerate beds at Takhini Hotsprings were observed to display an apparent cyclic nature, recognized as fining-up sequences (to mudstone) 5-15 m thick. In order to test for cyclicity, an embedded Markov Chain Analysis was performed (Miall, 1973). An identical test was performed on the correlative section at Braeburn. Braeburn trends were much less ordered, with the only strong trend exhibited as coarsening-up sequences.

The preferred facies trend at Takhini Hotsprings is shown in Figure 5. This sequence represents deposition within the braided reaches of possible fan-delta complexes. The lower coarsening-up sequence, from cross-bedded pebbly sandstone to sheet-like gravel lined scours and parallel laminated sandstone, is interpreted as a transition from a normal channel sedimentation to flood-flow deposition. The overlying chaotic conglomerates (debris flows) were perhaps triggered by similar flood events which deposited the underlying facies. Braided-reach conglomerate and debris flow facies tend to be overlain by fining-up siltstone-silty mudstone. Desiccation cracks suggest that these beds were deposited in spill-over channels which became exposed and inactive during low-flood conditions.

Fish Lake and Braeburn sections show few facies trends. Facies are very coarse and typically randomly stacked. At Braeburn there is some coarse-tail normal grading of angular volcanic clasts in pebbly sandstone beds. Fish Lake beds are mainly massive pebble/cobble conglomerates. Turbidite occurs at the base of the section; whereas minor bioturbated silty mudstone occurs toward the top. Fish Lake strata are interpreted as distal submarine fan-delta deposits with shallow marine facies at the top (upper 150 m).

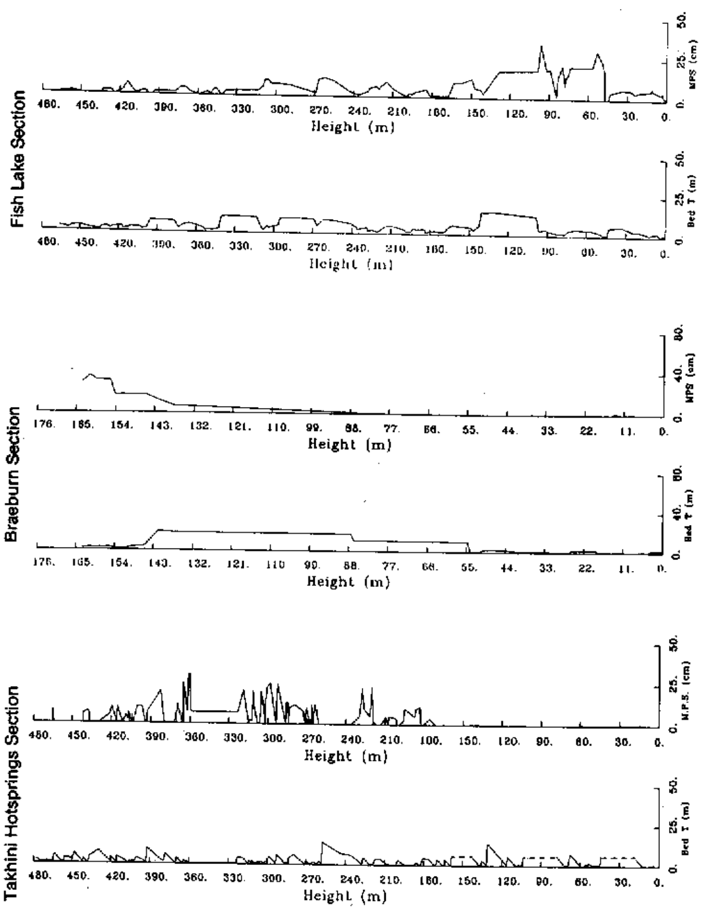

Figure 5. Maximum particle size (MPS) and bed thickness (Bed +) plots for measured sections. Takhini Hotspring data is non-smoothed, whereas the Braeburn and Fish Lake plots have been subjected to moving average techniques.

Broad-scale trends show that the three sections display coarsening-up sequences (120 m thick), with fining-up sequences at the top. Fish Lake strata are indicative of channel switching (or abandonment), followed by reactivation and progressive coarsening until shallow marine facies appear (top 150 m). Influx of arc-derived clasts follows grain-size trends (Fig. 6), suggesting tectonic activity controlled structural unroofing of arc plutons and fault talus generated in the source terrane. Bed-thickening trends are vague, but reflect channel abandonment cycles where conglomerates are capped by thick mudstone facies (Takhini Hotsprings section). This points to erosion-dominated, moderate-gradient fan surfaces, where short-lived depositional events were followed by long periods of non-deposition or erosion (Fig. 7) (abundant intraclasts; thick mudstone plugs). Bed-thinning trends at Braeburn are indicative of a steep-gradient erosion-dominated fan. Fining-up sequences probably represent re-equilibration of fan sediments to faulting, or back-stepping of source terrane faults which is unlikely to be extensive in a collisional (compressive) tectonic setting.

CONCLUSIONS

The Whitehorse Trough developed through oblique collision of the Stikine arc terrane with the North American craton. Arc deformation, resulting from vectoral separation of oblique subduction into normal and transcurrent stress fields (Beck, 1986), supplied detritus to the basin through exhumation and erosion of plutonic and volcanic arc material. Minor facies cycles represent ephemeral channel switching/abandonment on a distal fan (Takhini Hotsprings); whereas progressive overlap of proximal over medial fan debris flow facies (Braeburn) indicates fan progradation. Large-scale trends represent fan progradation and retreat, indicative of tectonic events in the source terrane. The overall effect is one of increasing "alluvial influence" on

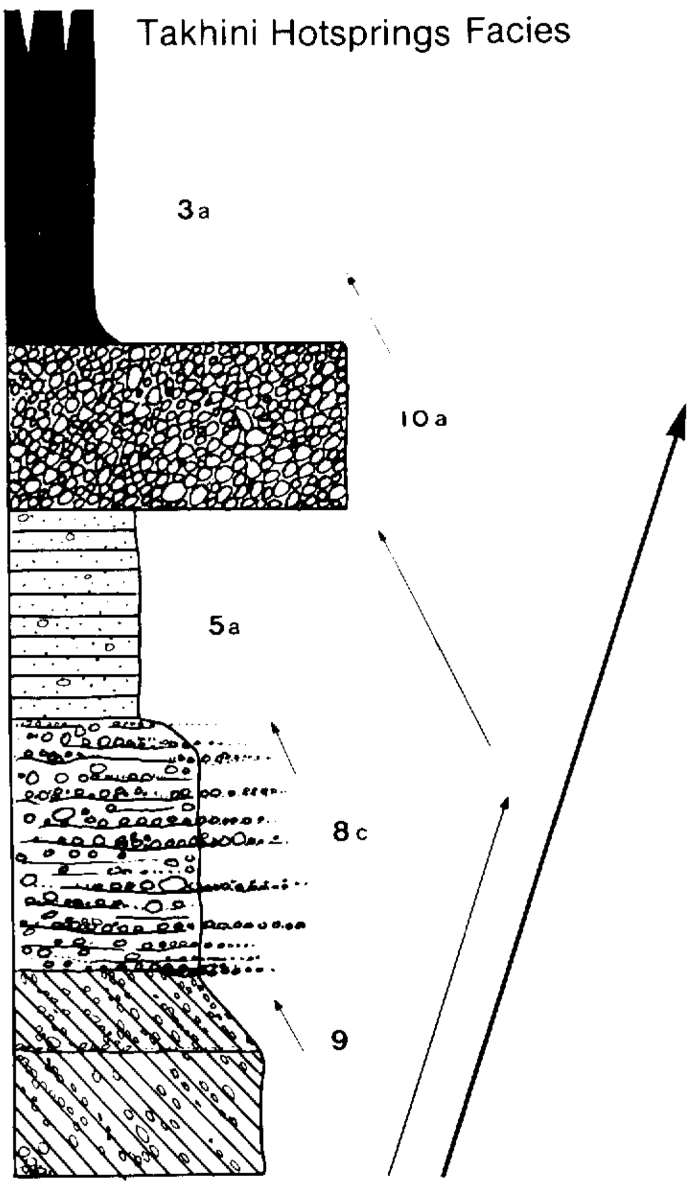

Figure 6. Preferred facies sequence; Takhini Hotsprings. Arrows depict bed-scale fining/coarsening trends and sequence-scale coarsening up trends.

sedimentation. Shallowing-up trends at Fish Lake occurred when the Stikine terrane accreted to the craton. Obduction of the arc terrane over the miogeocline (tectonic ramp) (C. Beaumont, 1988, pers. comm.) in Early Jurassic time (Tempelman- Kluit, 1979) created lithospheric depression of the ancient rifted margin, and induced tectonic subsidence, reflected by prograding (coarsening-up, erosion-dominated fans. By the Middle Jurassic, obduction caused the tectonic-subsidence regime to change to an orogenic regime. The transition is expressed in the sedimentary record as shoaling-up facies sequence.

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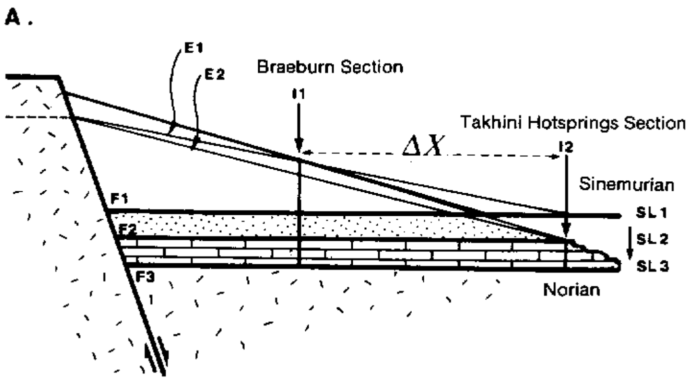

Figure 7a. Tectonic subsidence creates progradation and basinward migration of intersection point (I1 to I2) and erosion surface (E1 to E2). Braeburn section (proximal fan) and Takhini Hotsprings sections shown.

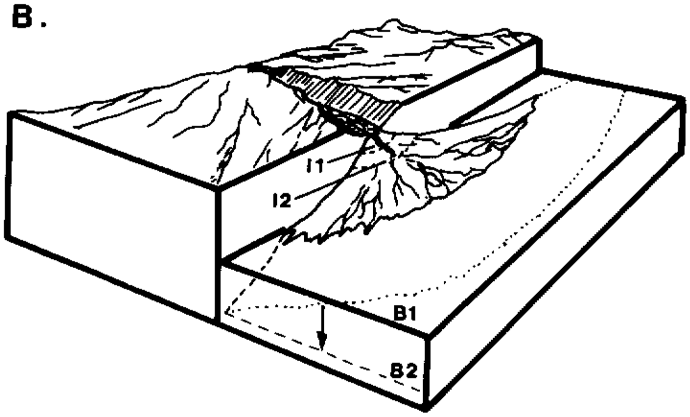

Figure 7b Block diagram of fan progradations. Drop in base level (B1 to B2) creates progradation of intersection point (I1 - I2).

Summary Facies Table

Facies	Lithology	Grading	Structures	Average Thickness
1	Floatstone/ Micrite	None	Planar Lamination (rare)	1.00 m
2	Calcarenite/ Rudite	None	None	1.40 m
3a	Red Mudstone	Normal	Desiccation cracks	3.30 m
3b	Red Mudstone	None	Bioturbation	0.40 m
4	Sandstone/Mudstone Couplets	Normal	BC (E) sequences	—
5a	Planar Stratified Sandstone	None	Planar stratification	0.50 m
5b	Low-angle Stratified Sandstone	None	Low-Angle stratification	0.15 m
6	Massive Sandstone	Normal	None	0.70 m
7a	Cross-Stratified Sandstone	None	Trough Cross-stratification	0.83 m
7b	Hummocky Cross-Stratified Sandstone	None (Normal)	HCS	0.40 m
8a	Granule/Pebble Sandstone	Normal; Reverse-to-Normal	None	1.00 m
8b	Trough Cross-Bedded Pebbly Sandstone	Normal	Trough Cross beds	1.00 m
8c	Low-Angle Stratified Pebbly Sandstone	None	Inclined stratification	0.40 m
9	Planar-Tabular Cross-Bedded Pebbly Sandstone	None	Planar-tabular Cross-beds	0.65 m
10a	Conglomerate (Clast-Support)	None (normal)	Massive; Imbrication	2.00 m
10b	Conglomerate (Openwork/Matrix-Filled)	None (Normal)	Massive (Inclined stratification)	0.90 m
11a	Conglomerate (Matrix-Support)	Normal (Coarse-Tail)	Massive	2.00 m
11b	Conglomerate (Matrix-Support)	Reverse; Reverse-to-Normal	Massive (Imbrication)	2.00 m
12	Conglomerate (Boulder/Clast-Support)	None (Reverse) (Normal)	Massive (a-b Axis Alignment)	2.50 m

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