A PLIENSBACHIAN SUBMARINE SLOPE AND CONGLOMERATIC GULLY-FILL SUCCESSION: RICHTHOFEN TO CONGLOMERATE FORMATION TRANSITION (LABERGE GROUP), BRUTE MOUNTAIN, YUKON

John R. Dickie
Centre for Marine Geology,
Dalhousie University
Halifax, Nova Scotia
B3H 3J5

and

Frances J. Hein
Geology Department
University of Calgary
Calgary, Alberta
T2N 1N4

DICKIE, J.R., and HEIN, F.J., 1992. A Pliensbachian submarine slope and conglomeratic gully-fill succession: Richthofen to Conglomerate Formation transition (Laberge Group), Brute Mountain, Yukon. In: Yukon Geology, Vol. 3; Exploration and Geological Services Division, Indian and Northern Affairs Canada, p. 71-86

ABSTRACT

The diachronous Richthofen-Conglomerate Formation transition separates lithostratigraphic subunits of the Jurassic Laberge Group, Whitehorse Trough. The contact is superbly exposed on the west flank of Brute Mountain, south-central Yukon. This succession of Pliensbachian marine shales, sandstones and conglomerates records submarine gully and slope apron progradation. Distal prodelta shales and sandstones, conglomeratic chute/gully fill sequences, slope shales and slope conglomerates were deposited from the Middle Pliensbachian to the Early Toarcian.

Submarine chutes fed coarse clastic detritus past the shelf-break and across the slope. Ponding of coarse-grained mass flows built an onlap wedge against the slope, followed by deposition of mud turbidites and pelagic sediments. A rise in relative sea level continued during the deposition of the entire succession, suggesting the intercalated sequence formed as a result of variations in the rate of clastic input. The Brute Mountain succession is entirely of deep marine origin, typical of Laberge Group exposures elsewhere in the Whitehorse Trough.

Collision between the allochthonous Lewes River Arc and the cratonic margin of North America occurred during the Late Triassic. The final stages of convergence led to closure of the Whitehorse Trough seaway in the Middle Jurassic. Laberge Group strata record this closure. Brute Mountain exposures of late Early Jurassic age indicate that deep basin conditions existed at least into the Toarcian. Slope turbidite and pelagic sedimentary rocks place additional constraints on the timing of arc-continent collision. Significant shoaling of the Whitehorse Trough seaway apparently did not occur until after deposition of the Brute Mountain sequences.

RÉSUMÉ

La transition diachrone de la formation de Richtofen à la formation de Conglomerate sépare des sous-unités lithostratigraphiques du groupe jurassique de Laberge dans la dépression de Whitehorse. Le contact est magnifiquement mis à nu sur le flanc occidental du mont Brute dans la partie méridionale centrale du Yukon. Cette succession de shales, de grès et de conglomérats marins du Pliensbachien révèle la progradation sous-marine de ravins et d'une plaine alluviale. Des shales et des grès prodeltaïques distaux, des séquences de comblement conglomératique d'entailles et de ravins, des shales de talus et des conglomérats de talus ont été déposés du Pliensbachien moyen au Toarcien précoce.

Des entailles sous-marines acheminaient des débris clastiques au-delà de la rupture de pente et sur le talus. L'accumulation d'écoulements en masse de granulométrie grossière a construit un biseau d'aggradation contre le talus après quoi il y a eu dépôt de turbidites vaseuses et de sédiments pélagiques. Une élévation du niveau relatif des mers s'est poursuivie pendant le dépôt de toute la succession, ce qui suggère que la séquence intercalée doit sa formation à des variations des taux d'apport en matériaux détritiques.

Le succession du mont Brute, entièrement d'origine marine profonde, est caractéristique des affleurements du groupe de Laberge ailleurs dans la dépression de Whitehorse. Les unités intercalées consistent en séquences superposées de conglomérat et de shale.

La collision de l'allochtone de l'arche de Lewes River et de la marge cratonique de l'Amérique du Nord s'est produite au Trias tardif. Les derniers stades de convergence ont mené à la fermeture du passage marin de la dépression de Whitehorse au Jurassique moyen. Cette fermeture est documentée dans les couches du groupe de Laberge. Les affleurements datant de la fin du Jurassique précoce au mont Brute indiquent que des conditions de bassin profond se sont prolongées au moins jusqu'au Toarcien. Des turbidites de talus et des roches sédimentaires pélagiques limitent davantage dans le temps la collision arc-continent. Il n'y a apparemment eu diminution importante de la profondeur dans le passage marin de la répression de Whitehorse qu'après le dépôt des séquences du mont Brute.

INTRODUCTION

Brute Mountain is situated approximately 9 km south of Carcross and 4 km east of Bennett Lake in Carcross map area (105D-2), southern Yukon. The Brute Mountain locality lies north of the southern extremity of the Whitehorse Trough in Yukon (Fig. 1). It exhibits excellent outcrop exposure of the contact between two Lower Jurassic formations of the Hettangian to Bajocian Laberge Group within the Whitehorse Trough. This Pliensbachian to Toarcian succession consists of (1) a basal 80+ m thick argillaceous unit consisting of finely interbedded greywacke and grey-black silty mudstone; (2) 208 m of thick, massive, polymictic pebble to cobble conglomerate, grading laterally to volcanic litharenite and epiclastic (tuffaceous) greywacke that interdigitates with Unit (1) along-strike; (3) an upper, 80 m thick argillaceous succession of very finely laminated, very fine-grained sandstone and silty mudstone couplets associated with internally graded cherty mudstone; and (4) an overlying, laterally extensive sequence of massive pebble-cobble conglomerate 180 m thick (Figs. 2; 3).

An Early Jurassic age was determined from ammonite biochronozones. This, combined with its sedimentologic character, identified the Brute Mountain section as part of the Jurassic Laberge Group. In particular, the Richthofen and Conglomerate Formations of Tempelman-Kluit (1985) are represented. As part of a sedimentologic analysis of the Laberge conglomerates (e.g. Dickie and Hein, 1988; Dickie, 1989), the Brute Mountain study serves to (1) document diachroneity across the contact separating the Richthofen and Conglomerate Formations of the Laberge Group; (2) describe Jurassic deep-sea sediment mobilization and transport dynamics in terms of process and depositional environment; and (3) provide evidence for a deep Anvil Ocean (i.e. seaway between the Lewes River Arc and the Jurassic North American passive margin) prior to Middle Jurassic overriding of the cratonic margin by a volcanic arc terrane (Tempelman-Kluit, 1979).

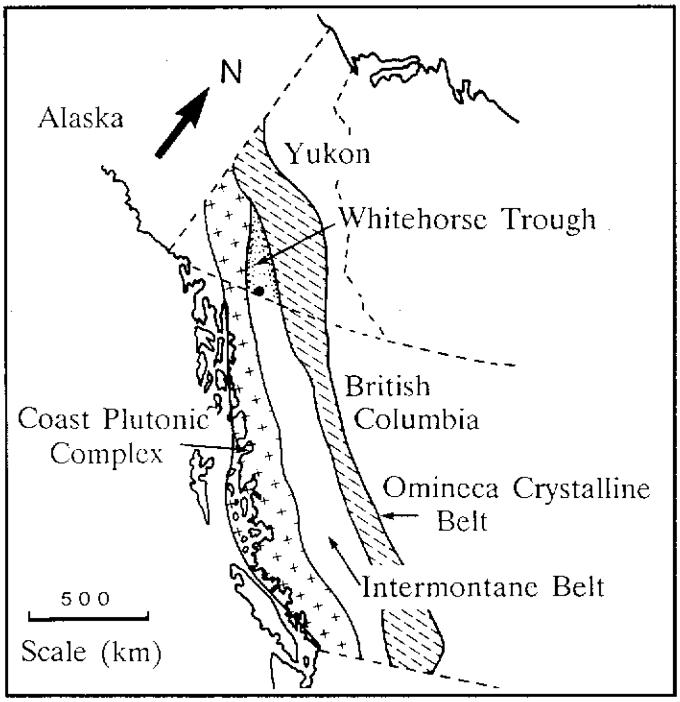

Figure 1. Location of Brute Mountain within the Whitehorse Trough. The Omineca Crystalline Belt, Intermontane Belt and Coast Plutonic Complex are depicted.

Brute Mountain stratigraphy and sedimentology was studied through detailed (bed-by-bed) and regional reconnaissance mapping. Facies stacking trends were tested by Harper's (1984) modified Markov Chain Analysis, involving statistical weighting of high probability facies transitions. The results were subsequently tested by the iterative proportional fitting method of Turk (1979). High probability facies sequences, thus determined, were interpreted in terms of flow mechanisms and environment. Maximum

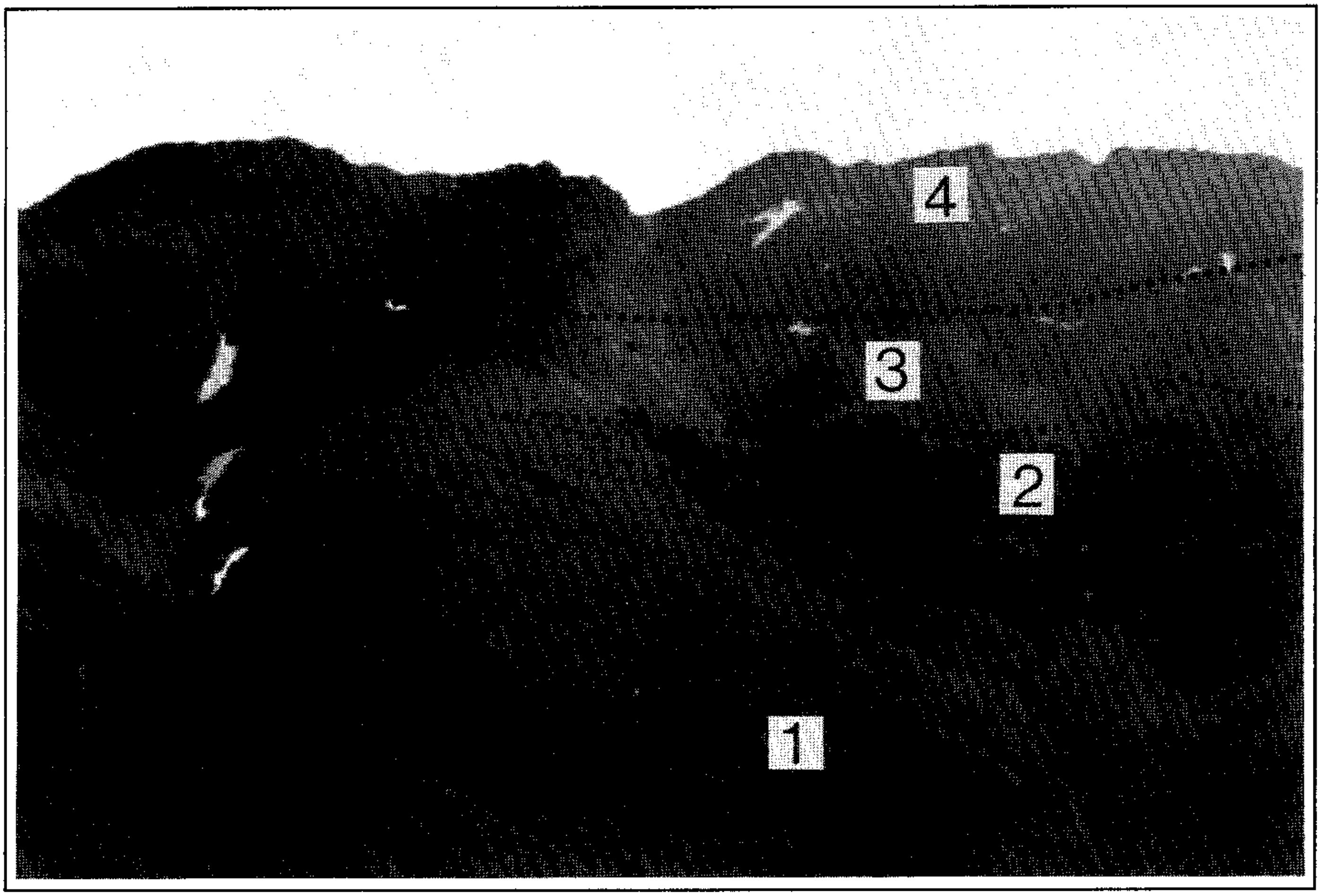

Figure 2. Brute Mountain exposure of the Laberge Group. Units 1-4 are depicted, as is the intercalated margin of Unit (2) where it fines laterally from conglomerate to sandstone. Units 1 and 3 are part of the Richthofen Formation, whereas Units 2 and 4 represent the Conglomerate Formation.

particle size (MPS) and bed thickness (Bth) trends, plotted against stratigraphic height, revealed how sequences fit within larger successions (megasequences) depicting temporal flow competence variations. Moving averages of MPS and Bth data assisted in separating large (i.e. sequence and megasequence) progradation/regression trends from bed-scale perturbations.

JURASSIC WHITEHORSE TROUGH EVOLUTION

The Mesozoic Whitehorse Trough is a northwest-trending, asymmetric, remnant forearc basin (Tempelman-Kluit, 1979; Morrison, 1981; Hansen, 1987; 1988). This basin extends from northern British Columbia into south-central Yukon. Situated between the Omineca Crystalline Belt to the east and Coast Plutonic Complex to the west, the Whitehorse Trough delimits the northern extent of the Intermontane Belt of the Canadian Cordillera. Whitehorse Trough strata and allochthonous terranes to the west are separated from autochthonous North American lithotectonic assemblages in the east by the Teslin Suture Zone (Fig. 4).

Coarse-grained conglomerates and associated facies of the Early Jurassic Laberge Group record forearc evolution during the final stages of arc-continent collision. The Lewes River volcanic arc (northern Stikine Terrane?) appears to have collided initially in the Latest Triassic (e.g. Monger et al., 1982). Basin fill characteristics of the Whitehorse Trough western belt (Wheeler, 1961) support a probable Rhaetian-Hettangian collision (Dickie, 1989). Convergence between the arc terrane and the miogeoclinal edge of North America was oblique (Hansen, 1987; 1988), typical of most plate collisions (Fitch, 1972). Tectonic transport of forearc slivers proceeded in the direction of the transverse component of oblique convergence (c.f. Fitch, 1972; Beck, 1983). The resulting arcward-stepping, dextral transpressive faults (Hansen, 1987; 1988) suggest that the accretionary complex abutted the continental margin, overriding the subduction trench in the process. Mechanical flexure of the basin between colliding blocks contributed to the development of the basin and long-term subsidence of the forearc.

Arc-continent collision led to tectonic incision and exhumation (uplift) of the arc plutons. Laberge conglomerate

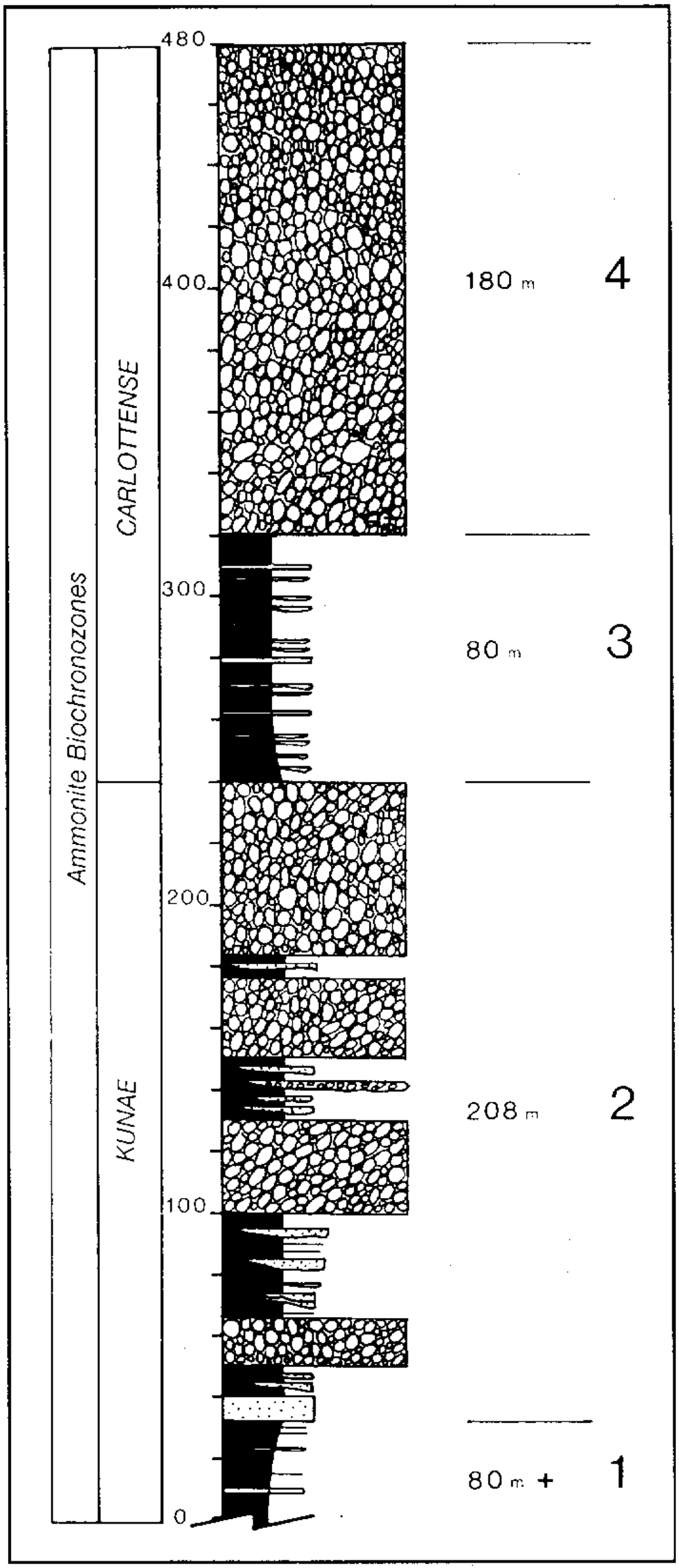

Figure 3. Generalized stratigraphy of the Brute Mountain section. Units 1-4 are shown (refer to Fig. 2). Ammonite biochronozones, defined from collections taken from organic shales, were used to define relative ages of strata.

petrographic evolution documents a progressive unroofing and dissection of the arc through a vertical decrease in volcanic clasts (e.g. basalt-andesite; saussurite; augite porphyry; agglomerate) and a concomitant increase in arc-derived plutonic clasts (e.g. megacrystic, lightly to non-foliated hornblende-biotite granodiorite; pink, megacrystic quartz monzonite; quartz diorite; leucogranite) (Dickie, 1989).

SEDIMENTOLOGY OF THE BRUTE MOUNTAIN SUCCESSION

Unit (1): Lower Argillite

Argillaceous strata, consisting of non-graded sandstone-mudstone couplets (Figs 5a-b; facies 4.1) and subordinate graded sequences (facies 4.2), reflect cyclic alterations of fine-grained bedload (distal, lower regime hyperpycnal flows) and suspension fallout of silt and clay. Graded beds display partial Bouma (1962) sequences (Fig. 5c). T^a and T^{ab} sequences are abundant, while truncated T^b and T^{bc} sequences are less common. Graded sandstone beds are capped by either T^c division mudstones or hemipelagite (rarely siliceous mudstone). Graded sandstones are the product of medium concentration, sandy turbidity currents. Synsedimentary compressional faults and folds are typical of steep-gradient systems. Downslope slip caused deformation of unconsolidated to semi-consolidated interbedded sand and mud.

Ammonites collected by the first author (identified by H. Tipper, Geological Survey of Canada) from Unit (1) shale (GSC Loc. No. C-117413) include Amaltheus c.f. stokesi, Fucinoceras sp., and Protogrammoceras (?). This collection places these strata in the Lower Kunae Zone of the late Middle Pliensbachian (Tipper, 1989, pers. comm.). Preserved organic debris occurs with authigenic pyrite horizons. Zoophycos trace fossils indicate poorly oxygenated, organic-rich bottom sediments. Unidentified, subvertical tubular burrows were formed as suspension feeders burrowed through unconsolidated turbidite sand.

Non-graded, variably stratified very fine-grained sandstones occur interbedded with organic-rich mudstones. Facies, sequences and Zoophycos trace fossils categorize this shale unit as being of distal prodelta/shelfbreak to upper slope origin (Frey and Pemberton, 1984). Submarine mass-flow beds and slide deformation suggest a fairly steep gradient system. These features are commonly associated with steeper gradients typical of continental slopes. Unit (1) shales were likely deposited in a distal prodelta-upper slope environment.

Unit (2): Lower Conglomerate

Unit (2), dominated by polymictic pebble-cobble (to boulder) conglomerate (Fig. 5d), overlies and laterally interfingers with Unit (1) shales. Graded-stratified (Fig. 6), clast-supported (ungraded), matrix-supported (coarse-tail) normally graded, and matrix-supported (coarse-tail) inversely

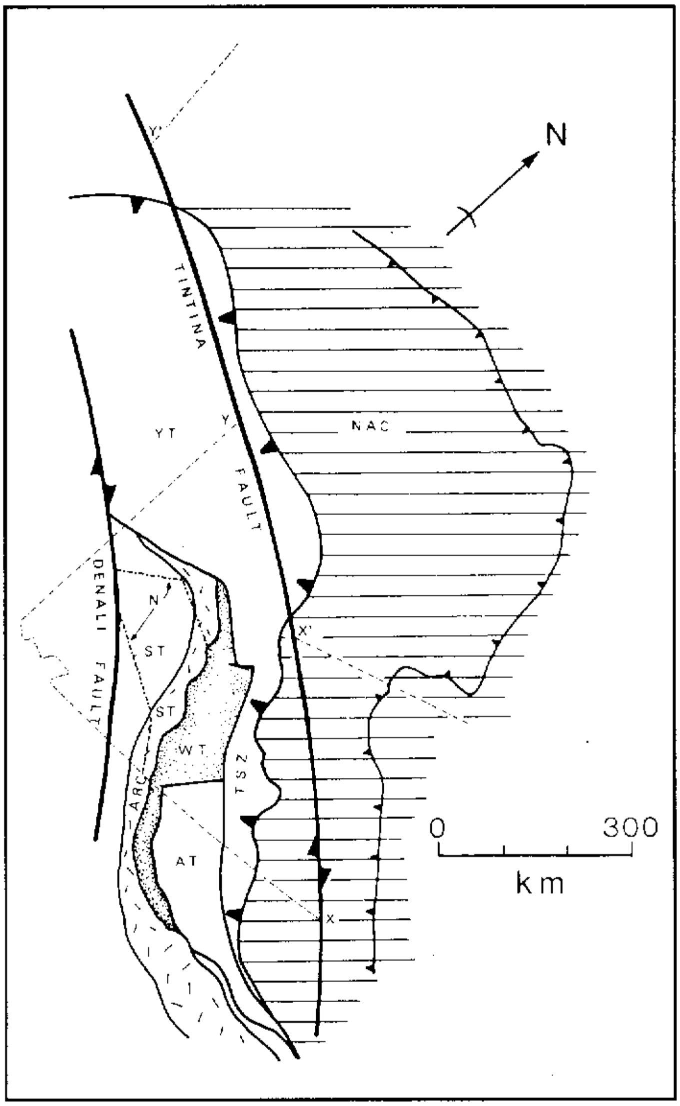

Figure 4. Northern Cordilleran terranes prior to 450 km of dextral strike-slip along the Tintina Fault (after Tempelman-Kluit, 1979). Reconstruction to present conditions may be reached by matching X-X' and Y-Y'. Terranes are depicted as: YT-Yukon Tanana Terrane; ST-Stikine Terrane (subdivided into Lewes River Arc (arc) and possible northern Stikinia; N-known exposures of Nisling Terrane; NAC-North American Craton; TSZ-Teslin Suture Zone. Hachures represent (small) present eastern extent of Cordilleran deformation and (large) Mesozoic deformation belt.

graded conglomerate form the dominant facies (facies 9.1, 10.2, 11.1 and 11.2, respectively). Unit (2) also contains lesser pebbly sandstone (facies 8.1), massive sandstone (facies 6.1), upper regime plane bed sandstone (facies 5.1), and combined-flow origin wavy stratified sandstone (facies 5.3).

Unit (2) coarse-grained facies are almost invariably of mass-flow origin, primarily representing cohesive and cohesionless debris flow sediment transport mechanisms. Graded-stratified conglomerate (facies 9.1) formed during velocity fluctuations in high-concentration, turbulent flows. Flows expanded laterally from cohesionless gravel dispersions and experienced frictional effects from the bounding chute walls. Internal organization of conglomerate beds extends from a disorganized core to graded-stratified (organized) margins.

Markov Chain Analysis (Harper, 1984) revealed two high-probability facies sequences. These consist of (1) turbidite sandstone-cohesionless debris flow conglomerate-hyperconcentrated flow pebbly sandstone (Figs. 7; 8), and (2) ungraded sandstone/mudstone-upper plane bed sandstone-wavy stratified sandstone-ungraded sandstone/mudstone (cyclic relationship). Sequence-scale trends (i.e. 10's m thick), observed in MPS and Bth plots, (Fig. 9) are representative of prograding mass flows.

Sequence 1 sandy turbidites preceded cohesionless debris plugs, perhaps being a product of flow dilution and gravitational bedload separation. Subsequent cohesive flows, possibly due to chute side-wall collapse, followed existing bathymetric contours (slide scars), yet true channelization is not evident. Mudstone rip-up clasts, which exhibit an a-b plane-parallel (relative to bedding) fabric, suggest erosion by turbulent flows. Orientation of clasts and their positions within beds indicates that slowing flows lost erosive energy, leaving clasts suspended above the bed by a combination of turbulence and dispersive pressure. Oriented clasts within cohesive flows may have experienced migration away from the high shear stresses generated along the base of the flow. Sequence 2 exhibits a predominance of bedload transport over mass transport. Storm waves modified suspended sediment during frictional freezing of thin, short periodicity turbidity flows. Storm surge entrainment of sand preceded cyclic resedimentation to a deeper water zone near storm wavebase. Wavy stratified sandstone is a product of combined flow (oscillatory storm currents and unidirectional mass-flow) and serves as an estimate of storm wavebase. Storm-generated structures in deep-water facies imply a fetch sufficiently large that larger storm waves (i.e. lowered wavebase) can be generated before impinging the coast.

Megasequence characteristics (Fig. 9) document the aggradation of mass-flow conglomerate sequences. These grade northwestward into sandstones and, eventually, into Unit (1) shales. To the southeast, conglomerate forms a monotonous stacked succession lacking shale interbeds. Channels are not evident; scouring of the substrate was minimal. The succession represents stacked mass-flow chute or gully fill sequences, combined to form a slope onlap wedge.

Unit (3): Upper Argillite

Unit (3) contains rare ungraded sandstone/mudstones (facies 4.1). Graded successions containing truncated turbidite

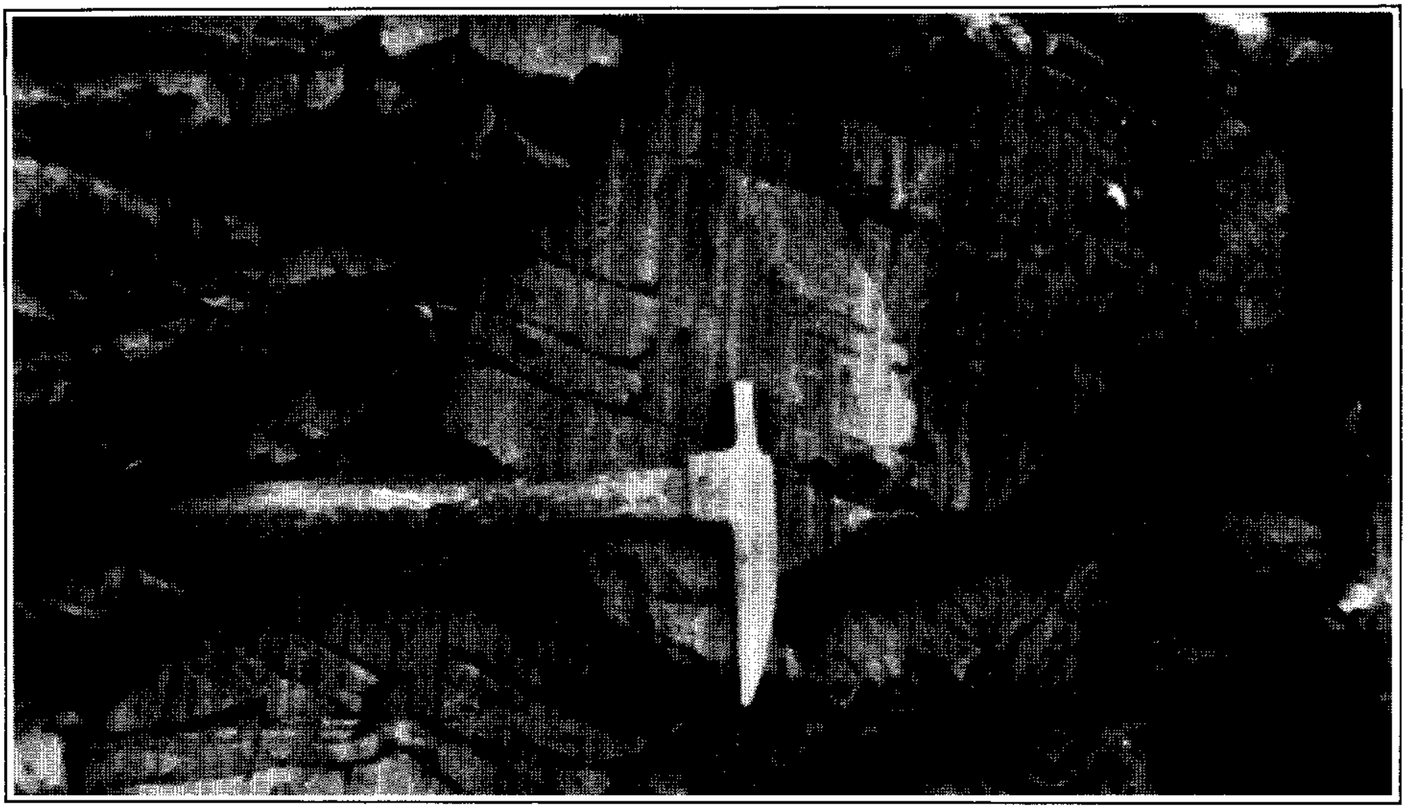

Figure 5a. Heterolithic facies 4.1, consisting of interbedded, ungraded sandstone and mudstone. Hammer for scale.

Figure 5b. Load-deformed ripple trains in ungraded sandstone-mudstone. Graded sandstone bands lie immediately above the lens cap.

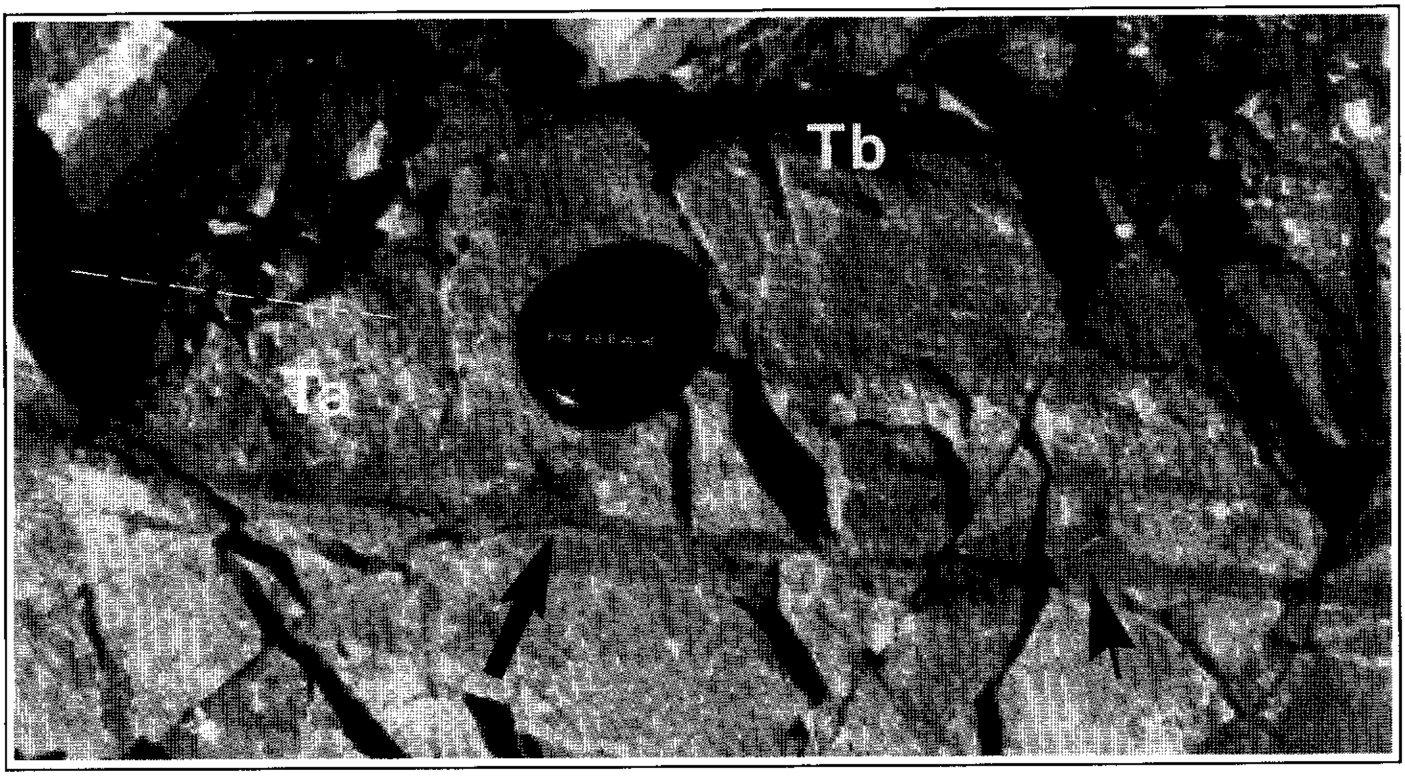

Figure 5c. Partial Bouma sequence in medium-grained sandstone. Ta and Tb divisions are marked. Rapid sediment loading caused load-injection of mudstone tongues (arrows) into the overlying sandstone during rapid fluid expulsion.

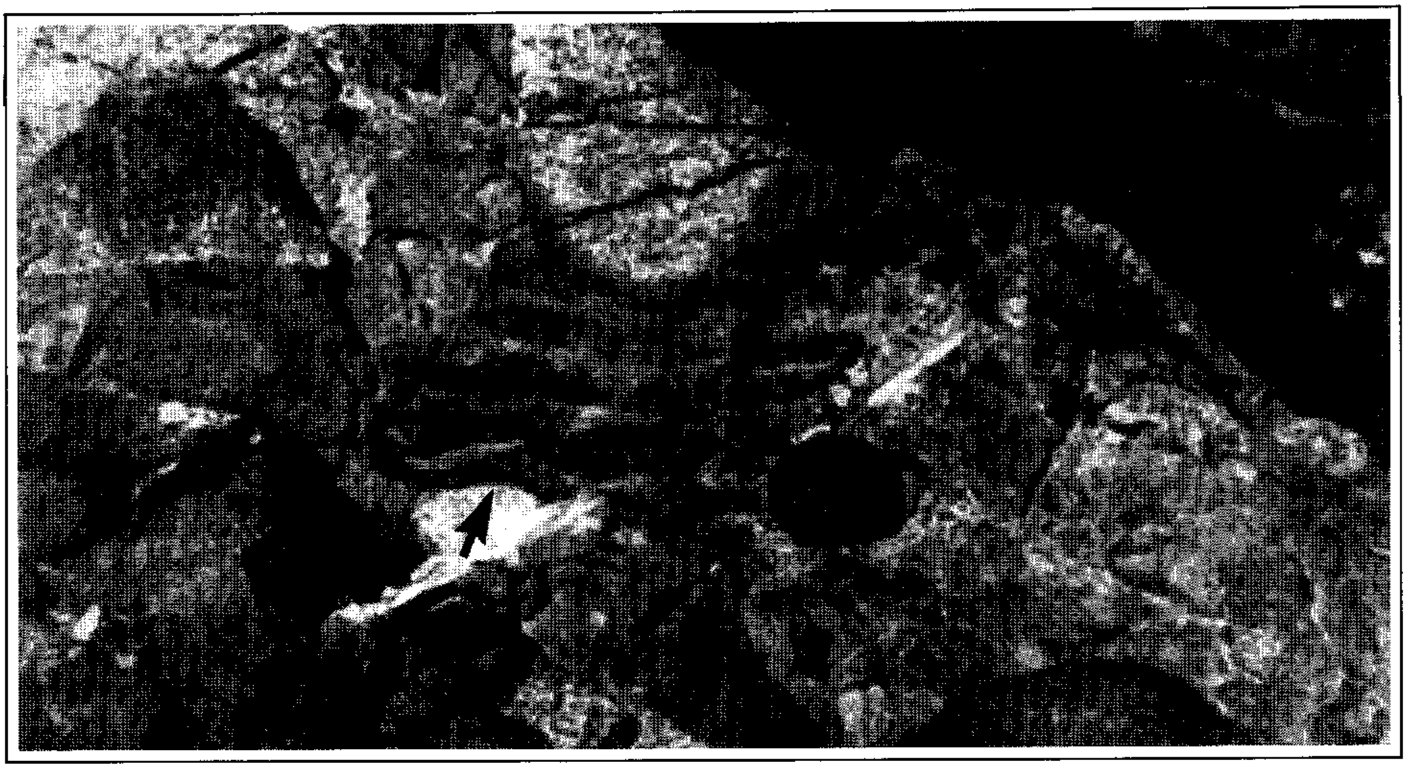

Figure 5d. Clast-supported cobble-boulder conglomerate (facies 10.2) with lens cap for scale. Note medium-grained to megacrystic biotite-hornblende granodiorite (pale clasts). A subangular clast of interbedded cross-stratified sandstone/black mudstone lies to the immediate upper left of the lens cap. This indicates certain cohesionless debris flows obviously possessed erosive turbulent energy, yet such clasts are exceedingly rare at this locality and tend to be restricted to the base of Unit (2).

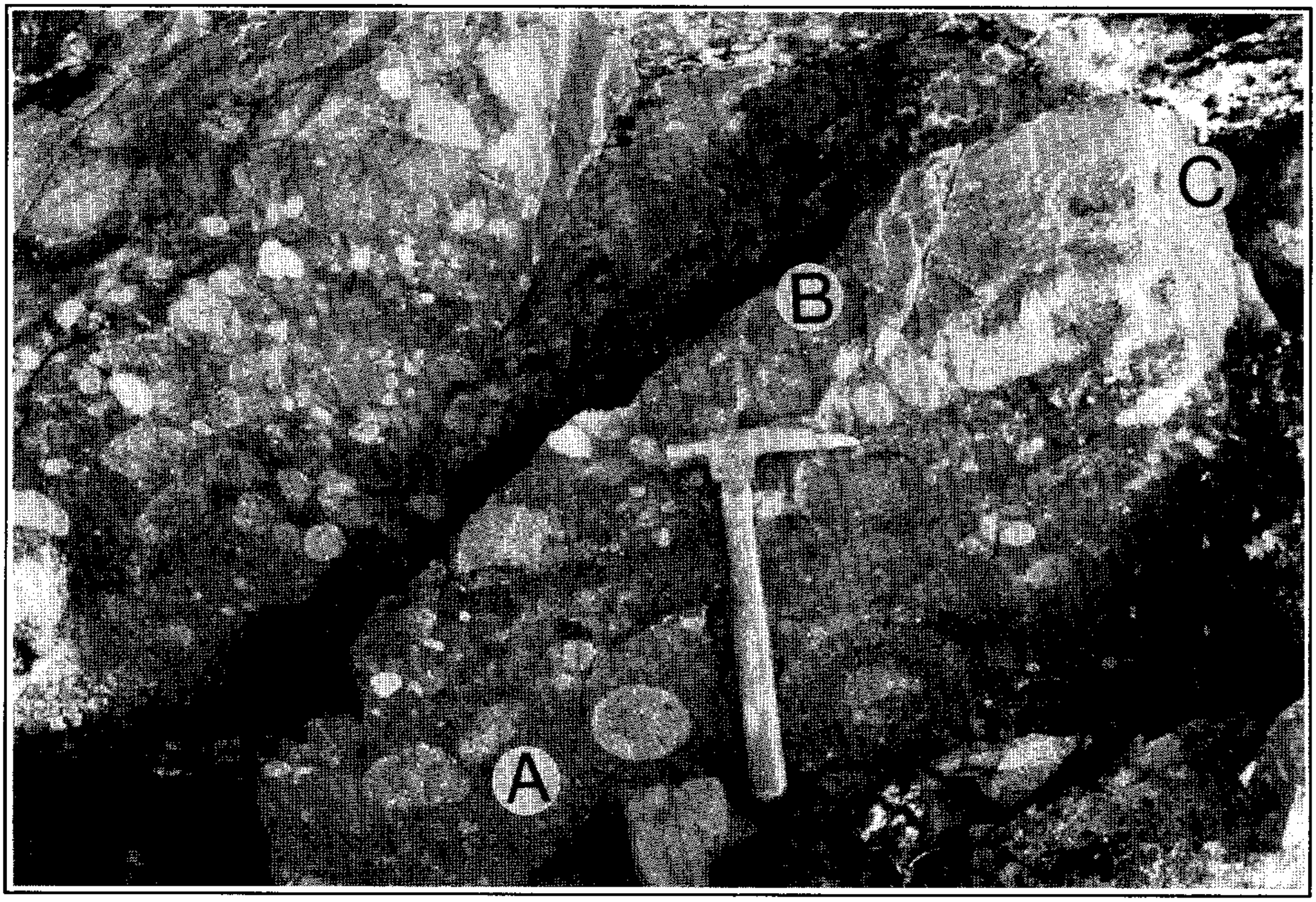

Figure 6. Graded-stratified conglomerate (facies 9.1). A: basal zone of massive, clast-supported conglomerate (cohesionless dispersion/ debris flow); B: medial zone of planar-stratified gravel; C: upper zone, containing upper plane-beds in medium-grained sandstone.

divisions are abundant, yet tend to be fine-grained and thin. Banded, cherty mudstone (to siltstone) is abundant higher in the section. While thinly bedded mudstones are locally massive, T^{2-6} mud turbidite divisions (Stow and Shanmugam, 1980) are abundant.

Banded mudstone was deposited by low-concentration turbidity currents and possible pelagic fallout. Authigenic pyrite is common, and tends to be associated with ammonite-bearing horizons. Planar pyritic and organic laminae formed along a highly reducing, oxygen poor and (seawater) sulphate-rich substrate.

Ammonites from Unit (3) (GSC Loc. No. 117414), including Protogrammoceras paltum, Protogrammoceras aff. pectinatum, Tiltonoceras aff. propinquum and Tiltonoceras facetum(?) belong to the Carlottense biochronozone of the uppermost Pliensbachian (H. Tipper, 1989, pers. comm.). Burrows are rare, but possible Zoophycos suggests a deep, poorly oxygenated environment. Locally, Nereites trace fossils occur. These are typical of bathyal settings which are frequently overrun by turbidity currents (Frey and Pemberton, 1984).

Deep marine trace fossils, pelagic fauna (ammonites), and extremely distal mass-flow processes (mud turbidites and associated facies) indicate a slope (to rise?) system.

Unit (4): Upper Conglomerate

Sequential stacking of clast-supported and matrix-supported conglomerate has created a conglomerate lithozone that is traceable along strike for over 5 km (Hart and Pelletier, 1989). A statistically significant facies stacking order is not present. Instead, vertical facies arrangements tend to be chaotic. MPS and Bth trends show fining and bed-thickening upward trends, indicative of ponding of mass flow gravels across the slope (Fig. 10). The lateral persistence of both individual beds and the entire conglomerate lithozone (Unit 4) combined with chaotic vertical ordering of mass-flow facies suggests a slope-apron interpretation.

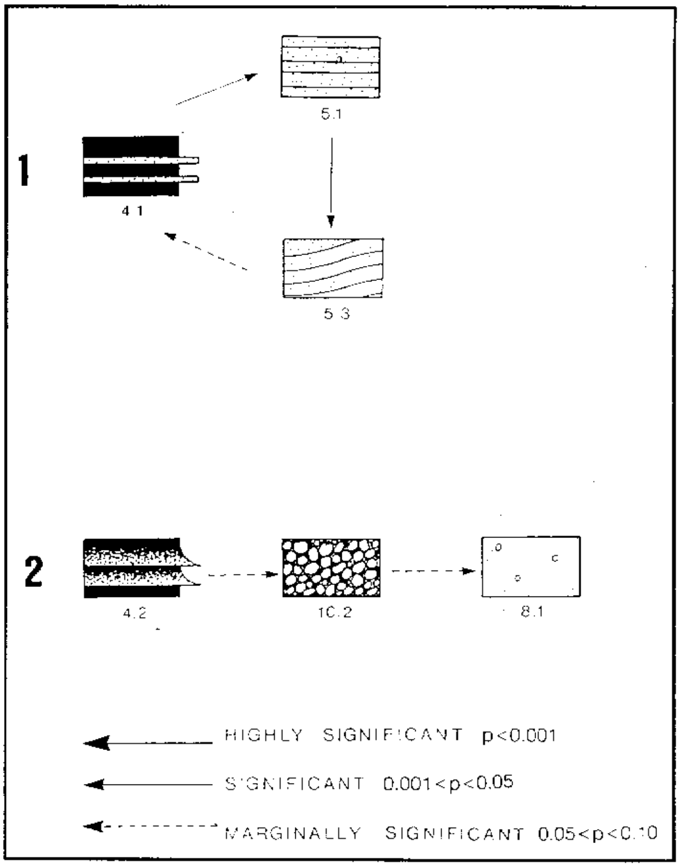

Figure 7. Statistically weighted facies transitions defining high-probability sequences. Sequence 1 shows a cyclic relationship between ambient prodelta shale sedimentation, later overrun by upper regime, plane-bedded sandstone and wavy-stratified (storm wavebase) sandstone. Sequence 2 defines a marginally significant succession between truncated turbidites, cohesionless debris flow-origin conglomerate, and pebbly sandstone (submarine hyperconcentrated flows).

DISCUSSION AND CONCLUSIONS

Sinemurian to Toarcian beds of the Conglomerate Formation overlie Hettangian to Pliensbachian (and Bajocian) Richthofen Formation shales throughout the Whitehorse Trough. Tempelman-Kluit (1985) described these units as formations of the Laberge Group, yet the units are strongly intercalated. They occur as laterally-equivalent lithozones, reflecting contemporaneous deposition of (coarse-grained) axial and (fine-grained) marginal portions of steep-gradient, mass-transport dominated submarine fans (Dickie, 1989). Lateral shifts in the locus of deposition, combined with variable sediment supply rates, created lithologic variability without a significant change in the environment of deposition. The intercalated and diachronous nature of the contact between these conglomerates and shales is well exposed at Brute Mountain. This stratigraphic relationship is inherent to the Laberge Group depositional systems as a whole. Thus, lithostratigraphic units may only have environmental significance in a very local sense.

Sedimentary facies, sequences and megasequences suggest that the Brute Mountain succession formed through an advancing prodelta lobe (Unit 1), entrenchment of a conglomeratic chute network (Unit 2), coarse-grained sediment "starvation" during chute/gully abandonment, continued deposition of deeper-water shales during a marine highstand (Unit 3), and ponding of mass flow gravel against the slope (Unit 4) (Fig. 11).

Based on the thickness of Unit (2) and the age range of Kunae and Carlottense ammonite zones (3.2 Ma) it is estimated that gravel accumulated at a rate of approximately 6.5 cm per thousand years. Considering that Unit (2) mass-flow conglomerates are typically 1-3 m thick, this low sedimentation rate suggests net bypass of the upper slope rather than accumulation in chutes. These conduits (chutes or shallow gullies) funnelled sediment deeper into the basin, preventing local buildup of gravel. Unit (3) shales document the cessation of coarse-grained sediment transport. These facies reflect even deeper marine conditions than those represented by Unit (2). Continued sea level rise coincided with a diminished gravel supply.

The Brute Mountain succession responded to continued marine transgression throughout the Middle to Late Pliensbachian. Stacking of Units 1-4 suggests variability in sediment supply rates, as opposed to transgressive and regressive control. No evidence exists for vertical shallowing; instead, facies indicate balanced sedimentation-subsidence rates. Gravel deprivation (Units 1 and 3) was compensated by continued deep-water, fine-grained processes.

Eustatic sea level charts for the Early to Middle Jurassic (Haq et al., 1987) show similarities to the trends expressed in the Brute Mountain section. However, long-term eustatic trends do not agree with these observed in the Whitehorse Trough, and coeval sections studied elsewhere in the basin exhibit a pronounced deviation from those of Brute Mountain (Dickie, 1989). While slope facies successions cannot be readily compared to shelf systems tracts, it must be possible to identify similar relationships (i.e. transgressive/ regressive) in slope basins where shelves are minimal or lacking. Bounding disconformities should be equivalent to conformable offlap successions in a slope setting (c.f. Haq et al., 1987).

A relative sea level rise due to tectonic subsidence is invoked to explain the depositional characteristics of the Brute Mountain succession. Sediment supply rates varied as a result of tectonic changes in the arc source area and possibly as a result of the activation of new feeder systems. The upper slope was an area of net sediment bypass until the Earliest Toarcian (Unit 4). At that time, gravel mass flows constructed a clastic apron parallel to the arc.

The presence of deep marine (i.e. slope) facies at Brute Mountain shows that a deep basin existed throughout the Pliensbachian and into the Toarcian. Thus, closure of the intervening seaway (Anvil Ocean - Whitehorse Trough)

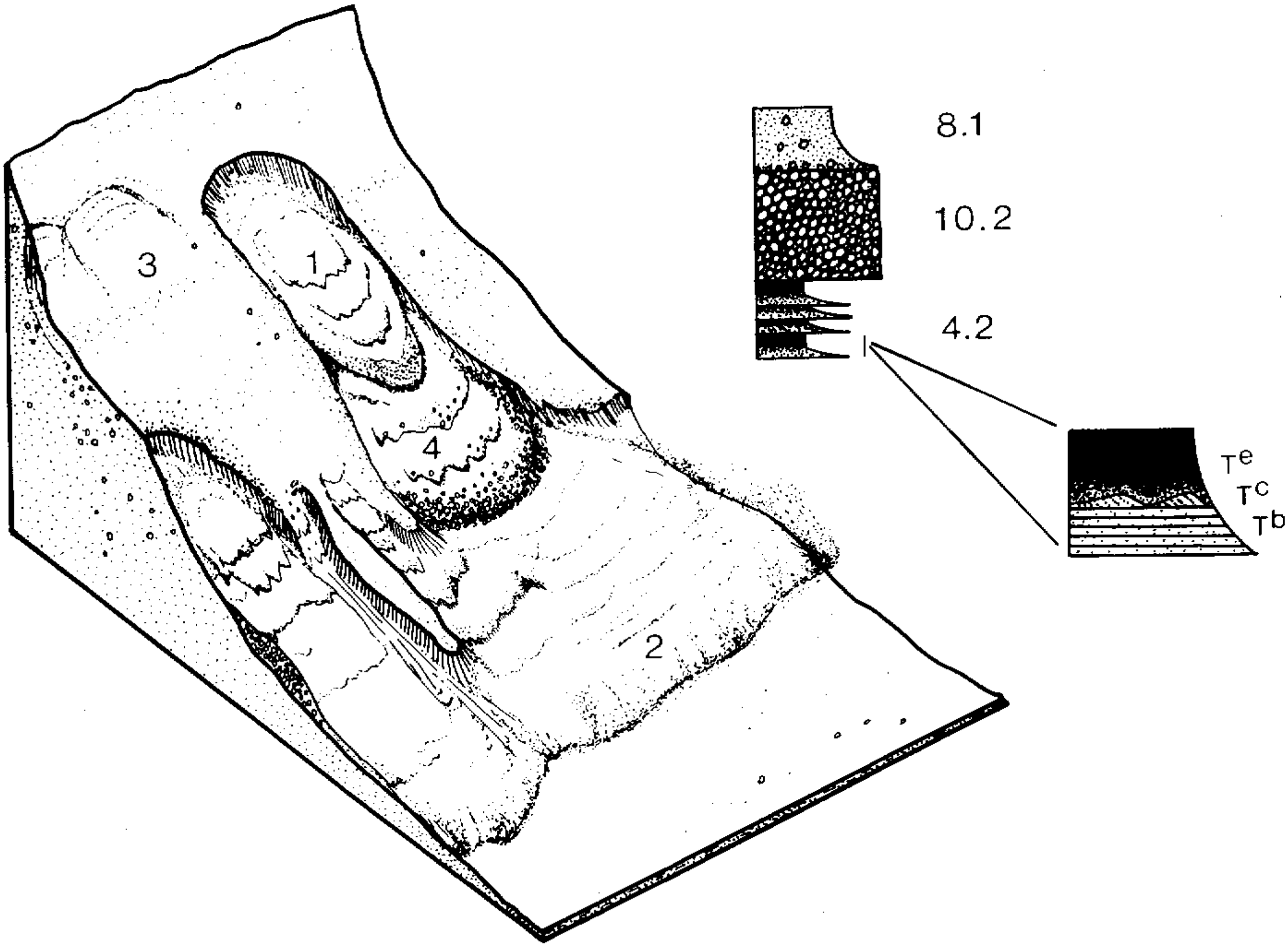

Figure 8. Schematic diagram showing the genetic interpretation of Sequence 2. 1: Facies 8.1 pebbly sandflow (hyperconcentrated) proceeds along a slide gully cut by the preceding mass flow. 2: The slide generates turbulence, homogenizing the flow and resulting in gravity-winnowing of fines (runout turbidite). 3: Incipient slide scar. 4: Cohesionless debris flow later overruns the turbidite apron.

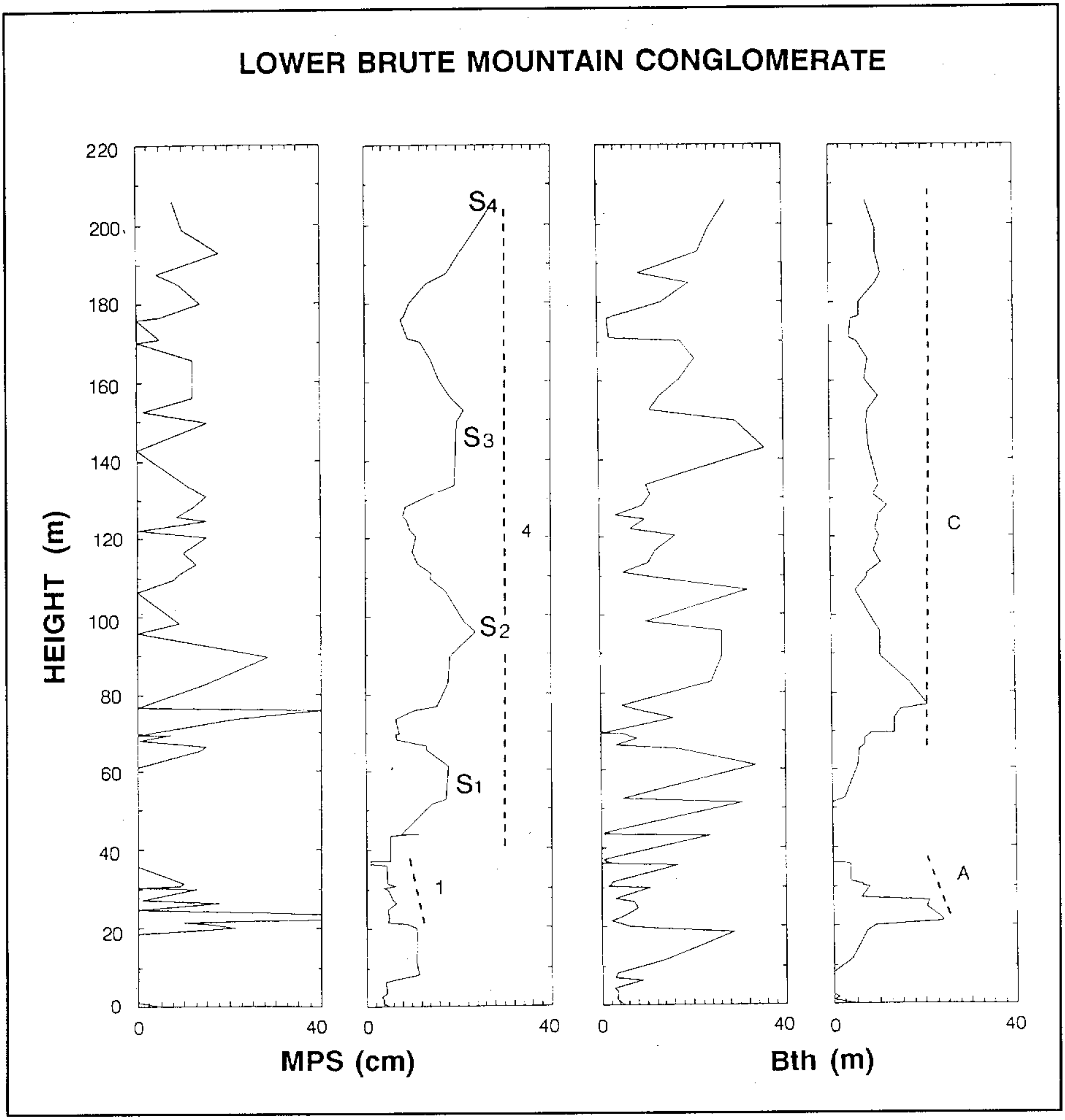

Figure 9. MPS and Bth trends for Lower Brute Mountain conglomerate (Unit 2). Mass-flow progradational sequences (S1-S4) are shown. The thick-bedded conglomerates of sequences 1-4 form an upward-fining and bed-thinning megasequence (1A) and an aggradational megasequence (4C). Plots, left to right, show raw and smoothed (3-point moving average) data for MPS (left two plots) and Bth (right two plots).

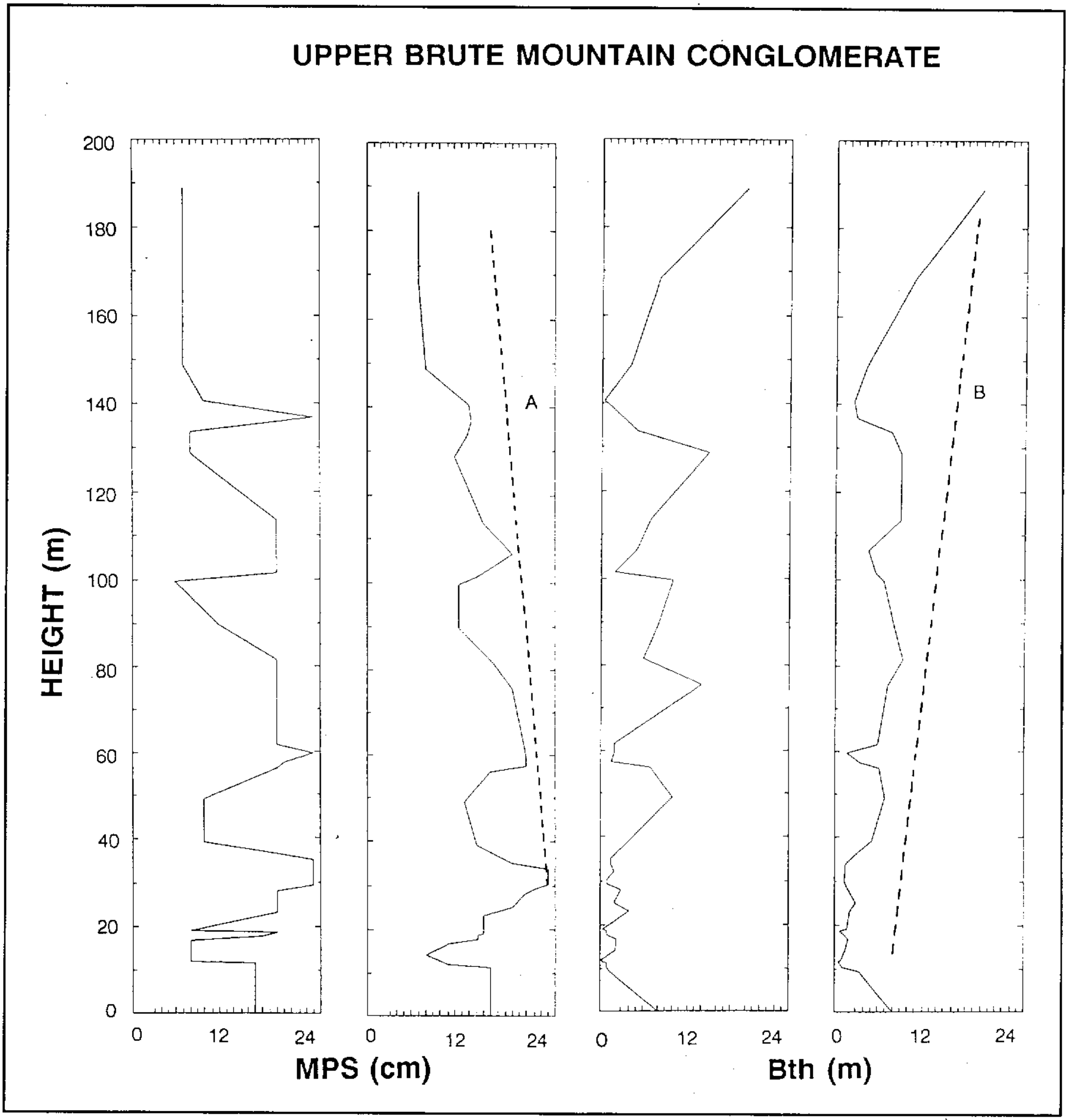

Figure 10. MPS and Bth trends for Upper Brute Mountain conglomerate (Unit 4). Coarsening-fining sequences correspond to thickening-thinning trends, suggestive of mass-flow ponding. Megasequence AB indicates long-term ponding and decreasing flow competence and possible source retreat. Raw (left) and smoothed (right; 3-point moving average) data are shown.

between the Lewes River Island Arc and the North American continent did not produce the shallowing-upward successions expected of an infilling basin during this time. Significant closure of the Anvil Ocean basin and the start of arc obduction (c.f. Tempelman-Kluit, 1979) did not produce distinctive features in the stratigraphic record of the Whitehorse Trough until the Middle Jurassic.

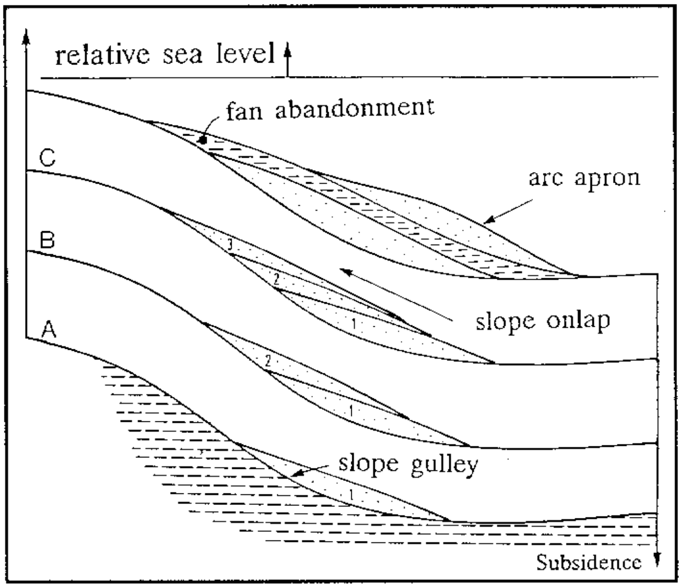

Figure 11. Schematic diagram depicting the general onlap relationship of the Brute Mountain succession. 1-3 represent successive sequences stacked against the upper slope, below the shelf break. Time series A-C (A is oldest) shows the general response to uplift and erosion in the sourceland coupled with tectonic subsidence across the slope and rise. Marine transgression continued during the cessation of coarse-grained input (Unit 3). (See text for additional discussion.)

ACKNOWLEDGEMENTS

The first author would like to thank Tom Pinkerton for able assistance in the field. Dr. Howard Tipper (Geological Survey of Canada) kindly identified ammonites collected by the first author. Craig Hart (Aurum Geological Consultants) released preprint copies of maps and was very informative during fascinating discussions on the geology of the Montana Mountain region. Funding and logistical support for the Brute Mountain study was through Exploration and Geological Services, Northern Affairs, Yukon, Canada, and a Northern Studies grant to J. Dickie.

REFERENCES

BECK Jr., M.E., 1983. On the mechanism of tectonic transport in zones of oblique subduction. Tectonophysics, Vol. 93, p. 1-11

BOUMA, A.H., 1962. Sedimentology of some Flysch Deposits: A Graphic Approach to Facies Interpretation. Elsevier: Amsterdam, 168 p.

COLEMAN, J.M., 1976. Deltas: Processes of deposition and models for exploration. Continuing Education Publication Company, Inc., Illinois, 102 p.

DICKIE, J.R., 1989. Sedimentary response to arc-continent transpressive tectonics: Laberge conglomerates (Jurassic), Whitehorse Trough, Yukon Territory. Unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 365 p.

DICKIE, J.R. and HEIN, F.J., 1988. Facies and depositional setting of Laberge conglomerates (Jurassic), Whitehorse Trough, Yukon. In: Yukon Geology, Vol. 2; Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 26-32.

FITCH, T.J., 1972. Plate convergence, transcurrent faults, and internal deformation adjacent to Southeast Asia and the western Pacific. Journal of Geophysical Research, Vol. 77, p. 4432-4461.

FREY, R.W. and PEMBERTON, S.G., 1984. Trace fossil facies models. In: Facies Models, R.G. Walker, (ed.); Geoscience Canada Reprint Series 1, p. 189-207.

HANSEN, V.L., 1987. Structural, metamorphic, and geochronologic evolution of the Teslin Suture Zone, Yukon: Evidence for Mesozoic oblique convergence outboard of the North American Cordillera. Unpublished Ph.D. thesis, University of Southern California, Los Angeles, California, 261 p.

HANSEN, V.L., 1988. A model for terrane accretion: Yukon-Tanana and Slide Mountain Terranes, northwest North America. Tectonics, Vol. 7, p. 1167-1177.

HAQ, B.Q., HARDENBOL, J., and Vail, P.R., 1987. Chronology of fluctuating sea levels since the Triassic. Science, Vol. 235, p. 1156-1166.

HARPER, C.W. (Jr.), 1984. Improved methods of facies sequence analysis. In: Facies Models, R.G. Walker, (ed.); Geoscience Canada Reprint Series 1, p. 11-13.

HART, C.J.R. and PELLETIER, K.S., 1989. Geology of Carcross (105D/2) and part of Robinson (105D/7) map areas. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, Open File 1989-1, 84 p.

MONGER, J.W.H., PRICE, R.A. and TEMPELMAN-KLUIT, D.J., 1982. Tectonic accretion and the origin of the two major metamorphic and plutonic welts in the Canadian Cordillera. Geology, Vol. 10, p. 70-75.

MORRISON, G.W., 1981. Setting and origin of skarn deposits in the Whitehorse Copper Belt, Yukon. Unpublished Ph.D. dissertation, University of Western Ontario, 306 p.

STOW, D.A.V. and SHANMUGAM, G., 1980. Sequence of structures in fine-grained turbidites; comparison of recent deep-sea and ancient flysch sediments. Sedimentary Geology, Vol. 25, p. 23-42.

TEMPELMAN-KLUIT, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: Evidence of arc-continent collision. Geological Survey of Canada, Paper 79-14, 27 p.

TEMPELMAN-KLUIT, D.J., 1985. Maps of Laberge (105E) and Carmacks (115I) map-areas. Geological Survey of Canada, Open File 1101.

TURK, G., 1979. Transition analysis of structural sequences. Discussion and reply. Geological Society of America Bulletin, Vol. 90, p. 989-991.

WHEELER, J.O., 1961. Whitehorse map-area, Yukon Territory 105D. Geological Survey of Canada, Memoir 312, 156 p.

Table 1. Summary facies table for Laberge conglomerates and associated lithofacies.

Class 1:	Micritic Limestone
Facies 1.1:	Micrite to Floatstone
Process:	Chemical precipitation of carbonate
Class 2:	Clastic limestone
Facies 2.1:	Calcarenite to rudite
Process:	Bedload transport; winnowing
Class 3:	Mudstone
Facies 3.1:	Red, desiccated silty mudstone
Process:	Suspension deposition of mud; minor tractional transport of silt to fine sand (cyclic); waning turbulent mass-flow; dehydration of mud; caliche development
Facies 3.2:	Red, bioturbated silty mudstone
Process:	Suspension deposition of mud (submarine); minor tractional transport of silt to fine sand under oscillatory flow; waning turbulent mass-flow; bioturbation by marine organisms
Class 4:	Heterolithic Facies
Facies 4.1:	Non-graded, interbedded sandstone-mudstone
Process:	Cyclic alteration of bedload sand transport with hemipelagic fallout. Minor current drift across ripple tops. Bioturbation indicates moderately anaerobic conditions
*Subfacies 4.1.1:	Non-graded sandstone; mudstone veneer
Process:	Cyclic alteration of bedload transport with carbonaceous mud fallout. Ripple drift indicates bedform aggradation
*Subfacies 4.1.2:	Convolute sandstone-mudstone
Process:	Fluidization of interbedded facies; slide folding of facies 4.1; ductile deformation followed by brittle failure
Facies 4.2:	Graded, interbedded sandstone-mudstone
Process:	Waning moderate to low-concentration turbidity currents
*Subfacies 4.2.1:	Graded siltstone-mudstone
Process:	Low-concentration turbidity currents; sorting of silt grains clay flocs in the subviscous flow layer (grading)
Facies 4.3:	Interbedded sandstone-carbonaceous mudstone
Process:	Alternating upper plane bed or turbulent mass-flow of sand or, rarely, bedform migration (trough cross-sets) and fallout of organic mud
Class 5:	Stratified sandstone
Facies 5.1:	Planar stratified sandstone
Process:	Upper regime plane bed flow; rarely lower plane bed deposition
*Subfacies 5.1.1:	Graded, planar-stratified sandstone
Process:	Frictional freezing of thin, sandy turbidity currents
Facies 5.2:	Low-angle stratified sandstone
Process:	Bidirectional upper regime flow across an inclined surface
Facies 5.3:	Wavy stratified sandstone
Process:	Rapid deposition through frictional freezing of thin, sandy turbidity currents under oscillatory flow influence (combined flow origin)
Class 6:	Massive sandstone
Facies 6.1:	Non-graded to normally graded sandstone
Process:	High concentration turbidity currents; grain flow

Class 7:	Cross-stratified sandstone
Facies 7.1:	Trough cross-stratified sandstone
Process:	Lower regime bedload transport
*Subfacies 7.1.1:	Vortex ripple-stratified sandstone
Process:	Reversing-flow bedload transport
Facies 7.2:	Planar-tabular cross-stratified sandstone
Process:	Bedload transport, migration of linear crested ripples
*Subfacies 7.2.1:	Cross-bedded sandstone-mudstone
Process:	Cyclic waning bedload, alternating bedform migration and abandonment
Facies 7.3:	Hummocky cross-stratified sandstone
Process:	Combined flow (storm suspension and bedload traction)
Class 8:	Pebbly sandstone
Facies 8.1:	Massive pebbly sandstone
Process:	Waning, semi-cohesive turbulent flow
Facies 8.2:	Trough cross-bedded pebbly sandstone
Process:	Cyclically waning bedload transport of sand and gravel; migration of large-amplitude sinuous crested bedforms
Facies 8.3:	Low-angle stratified pebbly sandstone
Process:	Scour filling by basal lag gravel; migration of sinuous crested bedforms under very shallow flow conditions
Class 9:	Graded-stratified conglomerate
Facies 9.1:	Graded-stratified conglomerate
Process:	Alternating suspension/traction deposition in high concentration turbidity flows experiencing velocity fluctuation
Facies 9.2:	Planar-tabular cross-bedded conglomerate
Process:	Upper regime bedload gravel transport; waning flow avalanche foreset grading
Class 10:	Clast-supported conglomerate
Facies 10.1:	Openwork conglomerate
Process:	Bedload transport of gravel; gradual waning flow-winnowing of matrix
Facies 10.2:	Massive to normally graded conglomerate
Process:	Cohesionless debris flow, low- or high-concentration turbidity flow (see text)
Facies 10.3:	Boulder conglomerate
Process:	Cohesionless, turbulent flow; rolling, saltation
Class 11:	Matrix-supported conglomerate
Facies 11.1:	Normally graded conglomerate
Process:	Hyperconcentrated flow
Facies 11.2:	Inversely graded conglomerate
Process:	Cohesive debris flow
Class 12:	Non-welded tuff
Facies 12.1:	Crystal tuff/tuffaceous sandstone
Process:	Subaqueous and subaerial pyroclastic flows; epiclastic equivalents
*Subfacies 12.1.1:	Calcareous tuff/tuffaceous sandstone
Process:	Turbulent ash flow across carbonate lagoon facies