QUATERNARY STUDIES IN THE PEACE RIVER DISTRICT, 1990: STRATIGRAPHY, MASS MOVEMENTS AND GLACIATION LIMITS (94P)

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KEYWORDS: Surficial geology, Quaternary, Pleistocene, Peace River, sedimentology, stratigraphy, C^{14}, mass movements, landslide dam, debris flows, Halfway River slide, Laurentide erratics, surficial maps.

INTRODUCTION

Quaternary geologic research was undertaken in 1991 in the Peace River region of northeastern British Columbia following reconnaissance studies in 1990 (Figure 3-8-1). The objectives of this work were to:

- Assess the Quaternary economic potential of the area, including aggregate and peat resources, through the production of detailed surficial geological maps (1:50 000 scale) suitable for industry use.
- Provide a practical database (surficial maps) of use to municipal, regional and provincial governments, which will be helpful in future land-use planning.
- Examine the nature of mass movements common to the area, which negatively effect the economic and social well being of the region.
- Contribute to the provincial Quaternary database by detailing the stratigraphic and sedimentologic history of the region.

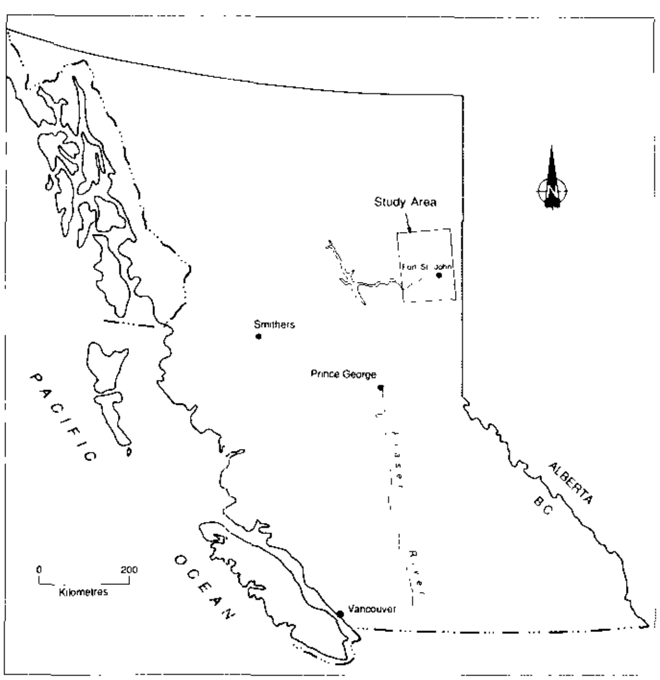

Figure 3-8-1. Surficial geology program, Peace River project study area.

Previous geologic work and surficial map coverage in the Peace River District has been reviewed elsewhere (Bobrowsky *et al.*, 1991 and references therein). With respect to the objectives of the present study Catto (1991, 1992) provides recent surficial coverage of eight map sheets in the area. The distribution and characteristics of surficial materials are discussed at length by the author, as are the economic and land-use implications for future development. A detailed compilation of field studies following completion of laboratory studies will appear in a separate publication. Given the above, the purpose of this paper is to provide preliminary results addressing the latter two project objectives. To meet this goal, brief comment is provided regarding three items:

- Subsurface mapping (stratigraphy and sedimentology).
- The areal distribution of Canadian Shield erratics.
- The morphologic characteristics of two recent mass movements.

STUDY AREA

The general study area encompasses a broad region of northeastern British Columbia which extends from the Rocky Mountain Foothills, at about longitude 122°15'W eastward to the provincial border with Alberta at longitude 120°W, and further delimited to the north at latitude 57°N and the south at latitude 55°N. Specifically stratigraphic studies were restricted to subsurface exposures occurring along the Peace River and its adjoining tributaries including the Beatton, Halfway and Kiskatinaw rivers. Mapping of erratic distribution included subsurface occurrences from stratigraphic studies, but also involved mapping of occurrences on the present land surface easily accessed by road or on foot. Mass movement research was also restricted to river and creek localities. The bedrock geology and physiography of the area has been reviewed previously (Bobrowsky *et al.*, 1991).

METHODOLOGY

Reconnaissance fieldwork during 1990 and extensive work during 1991 resulted in the identification of 77 localities suitable for detailed study. Fieldwork during 1991 consisted of three parts:

- Detailed examination of the stratigraphic and sedimentologic characteristics of subsurface exposures bordering the Peace River and its tributaries.
- Regional mapping documenting the surficial location of Canadian Shield erratics in the district.
- Cursory study of recent and prehistoric mass movements.

Subsurface studies involved examination of exposed sediments including the documentation of deposit characteristics such as elevation, thickness, nature of contacts, vertical and lateral extent, structures, texture, sorting, lithology and pebble fabrics. Sampling consisted of collecting bulk sediment samples (>4 kg) for textural and geochemical analysis and pebble samples for provenance studies, each sample consisting of 100 clasts. Radiocarbon samples ranged from 1.8 to 177 grams, limited in size only by the amount of material available. Both wood and bone were collected. Several samples are still being processed but a number of dates are available (Table 3-8-2). Pebble-fabric measurements consisted of trend and plunge measurements along the a-axis of clasts with a:b:c dimensions approaching 1.5:1:1. The number of clasts measured for fabric study ranged from 25 to 50 per sample.

Mapping of erratic distribution involved documenting the presence of distinct pink granite and granitic gneiss stones which originated on the Canadian Shield. Presence or absence of the diagnostic lithologies in the pebble counts of subsurface studies assisted in this mapping, but the bulk of information was obtained through systematic coverage along roads. Given the large area of examination, this type of survey proved most cost effective.

Mass movement studies were concerned with establishing the timing of the failure event(s). Organic materials were collected for C^{14} dating at exposed failure planes or shear zones for several slides along the river valleys. Detailed measurements for two recent mass-movement deposits were also established.

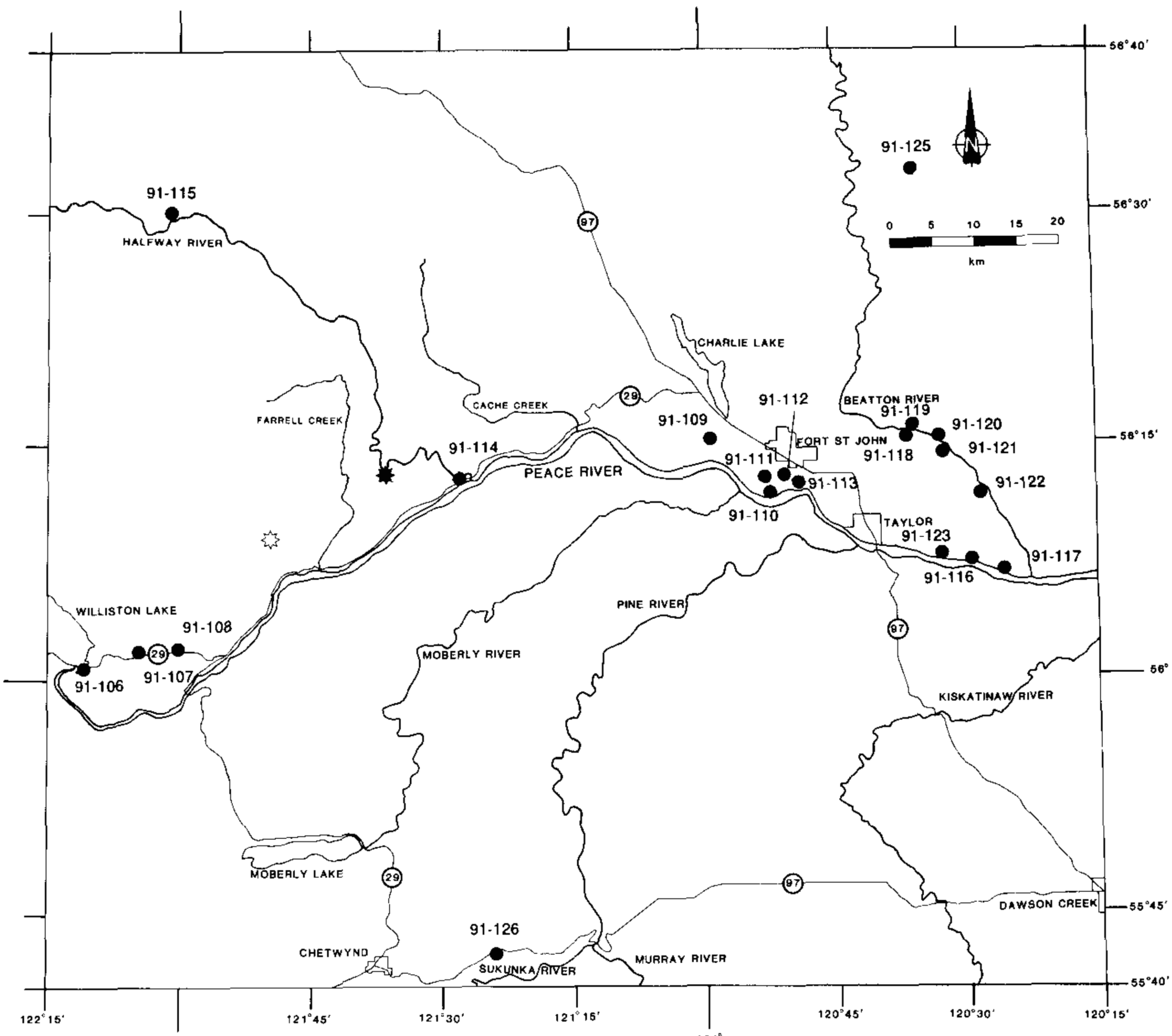

Figure 3-8-2. Location map of 1991 Quaternary localities in the Peace River study area. Coordinates for the sites given in Table 3-8-1. Closed star indicates location of Halfway River slide (PTB90-43) and open star indicates location of mud flow (PTB90-09).

TABLE 3-8-1
LOCATION OF 1991 STUDY SITES IN PEACE RIVER AREA

Locality	Latitude	Longitude	UTM	Elevation	NTS No.
91-106	56°01.0′	122°11.0′	ET 509078	700	94 B/1
91-107	56°01.6′	122°04.2′	ET 580093	738	94 B/1
91-108	56°01.9′	122°01.0′	ET 614099	708	94 B/1
91-109	56°14.9′	120°59.4′	FT 246353	716	94 A/2
91-110	55°11.8′	120°51.5′	FT 328298	487	94 A/2
91-111	55°12.5′	120°51.1′	FT 333311	625	94 A/2
91-112	55°12.8′	120°48.7′	FT 357317	625	94 A/2
91-113	55°12.3′	120°47.7′	FT 368309	625	94 A/2
91-114	55°12.8′	120°28.2′	ET 949307	487	94 A/3
91-115	56°30.4′	122°03.2′	ET 594621	655	94 B/9
91-116	56°07.7′	120°35.2′	FT 502229	403	94 A/2
91-117	56°07.2′	120°28.7′	FT 567221	533	94 A/1
91-118	56°15.7′	120°36.8′	FT 477376	426	94 A/7
91-119	56°15.7′	120°36.4′	FT 482377	419	94 A/7
91-120	56°15.2′	120°33.4′	FT 513366	426	94 A/7
91-121	56°14.4′	120°31.7′	FT 532352	411	94 A/2
91-122	56°12.1′	120°27.8′	FT 574311	403	94 A/1
91-123	56°08.0′	120°35.4′	FT 498234	533	94 A/2
91-124	56°07.6′	120°04.8′	FT 814238	548	94 A/1
91-125	56°33.0′	120°35.5′	FT 478698	693	94 A/10
91-126	55°42.6′	121°22.0′	FS 025749	722	94 P/11

TABLE 3-8-2
S.G.U. RADIOCARBON DATES IN PEACE RIVER AREA

Locality	Age	Lab. No.	Comments
90-02	10240 ± 160	AECV-1206C	Bone; postglacial gravels
90-04	110 ± 90	AECV-1213C	Wood; along shear zone of slide
90-06	420 ± 140	AECV-1437C	Wood; under diamicton (laboratory considers the sample unreliable and contaminated)
90-12	3400 ± 90	AECV-1204C	Wood/charcoal; paleosol underlies resedimented diamicton
90-47	2660 ± 90	AECV-1214C	Wood; along shear zone of slide
91-116	910 ± 80	AECV-1438C	Wood; 20 cm above shear zone of slide
91-122	830 ± 70	AECV-1439C	Wood; along shear zone of slide

TABLE 3-8-3
SUMMARY STATISTICS FOR THREE-DIMENSIONAL PEBBLE-FABRIC ANALYSIS

Fabric	Trend	Plunge	S1	S2	S3	N
PTB90-06	116.4°	13.1°	0.6986	0.1857	0.1157	50
PTB90-09A	286.0°	00.1°	0.7895	0.1804	0.0301	30
PTB90-09B	245.5°	02.9°	0.8579	0.0967	0.0454	25
PTB90-10	098.2°	05.7°	0.5001	0.3610	0.1389	50
PTB90-15	325.8°	18.9°	0.6489	0.2775	0.0736	50
PTB90-18	273.6°	04.3°	0.8552	0.1018	0.0429	25
PTB90-26	339.7°	03.7°	0.9024	0.0615	0.0361	50
PTB90-28A	355.7°	00.18	0.8015	0.1127	0.0858	50
PTB90-28B	027.8°	09.6°	0.6587	0.2709	0.0704	50
PTB90-37A	082.7°	01.4°	0.8907	0.0696	0.0397	50
PTB90-37B	222.5°	08.4°	0.8845	0.0876	0.0279	20
PTB90-37C	029.6°	02.1°	0.8141	0.1276	0.0583	25
PTB91-111	315.8°	29.4°	0.8675	0.0814	0.0511	50
PTB91-115	083.3°	12.6°	0.7372	0.1752	0.0876	25

STRATIGRAPHIC STUDIES

Twenty-one new localities were examined in addition to the 56 sites noted last year; with site elevations ranging from 403 to 738 metres above mean sea level (Figure 3-8-2). Table 3-8-1 lists the coordinates and elevations of the new sites. A total of 26 diamicton and sand bulk samples obtained from 14 sections are currently being processed for textural characteristics. Additionally, 21 pebble samples (100 clasts each) collected from 16 sections are also undergoing lithologic identification. A total of 14 pebble fabrics were determined on diamictons from 10 sections (Table 3-8-3). Descriptive observation of the various sediments supports the interpretations offered previously regarding the nature of diamicton, gravel, sand and fine (silt and mud) deposits (Bobrowsky *et al.*, 1991). Several examples of structureless, stratified and massive diamictons with interbeds were observed this year. Genesis is interpreted to be variable and case specific ranging from basal till to debris-flow accumulations. Similar variability is evident for the sand and gravel deposits, with diverse examples of massive, stratified, normal and reverse-graded accumulations recorded during 1991. A detailed discussion of the Quaternary stratigraphy and sedimentology of the Peace River District will appear in a separate publication, when analytical results from C^{14}, grain size and lithologic samples are available. Nonetheless, based on existing data, it now appears that for the Quaternary history of the region, the Model II scenario of Bobrowsky *et al.* (1991) is more likely to be the case than Model I (*i.e.*, Mathews 1978, 1980).

ERRATIC DISTRIBUTION

Part of the regional mapping objectives included observations on the areal distribution of diagnostic Laurentide erratics. Mathews (1980) interpreted the distribution of Canadian Shield granites in terms of the maximum extent of Late Wisconsinan Laurentide ice advance. Within our study area, Mathews' estimated western limit parallels the Alaska Highway in the north, extends about 17 kilometres west of Fort St. John in the central region and trends south some 30 kilometres west of Dawson Creek (Figure 3-8-3). Since this early work, access to remote areas has improved, allowing better coverage for distributional studies of erratics. As a result of this improved access, the western limit of Canadian Shield granites and gneisses now occurs at 56°30′N and 122°14′W in the north and 55°42′N and 121°12′W in the southern parts of the study area. The interpolated maximum limit therefore extends from the Wagner Ranch at the confluence of the Halfway and Graham rivers, continues southward to Hudson Hope and then bends slightly southeastward to approximately 30 kilometres east of Chetwynd. The newly proposed limit extends the previous estimate westward by about 60 kilometres.

MASS MOVEMENTS

Quaternary sediments in British Columbia are very prone to mass movement phenomena. Since 1856, processes including debris torrents, natural damming from landslides, piping-related subsidence, soil creep, slumping and many others are considered to have been directly and indirectly responsible for about 365 deaths and costs exceeding $500 million in Canada alone (Evans, 1989). One of the most historically active mass movement areas in this province, which is dominated by Quaternary sediments, is the Peace River District. Indeed, one study documented 212 sizable prehistoric slides occurring within unconsolidated sediments of the Peace River valley between Hudson Hope and the Alberta border (Thurber Consultants Ltd., 1976). The two end-members of the mass movement continuum are discussed in this paper in relation to the Peace River; namely, a large but rare landslide damming event and a small mud flow event.

Landslides which result in temporary or permanent damming of rivers have been documented in several areas in British Columbia. The earliest Canadian Cordillera event recorded, occurred on October 14, 1880 at about 2100 hours, when a landslide (volume = 15×10^6 m^3) south of Ashcroft blocked the Thompson River for about 44 hours (Evans, 1984). The cause of the slide appears to have been irrigation practices. On May 26, 1973, a landslide occurred on the south bank of the Peace River, directly west of the village of Attachie, some 60 kilometres west of Fort St. John. Between 11 and 17 million cubic metres of material failed along a 750-metre length of slope and temporarily dammed the Peace River for about 12 hours (Coulter, 1973; Thurber Consultants Ltd., 1981). This rapid debris flow, which lasted about 10 minutes, generated a water wave which ran up the opposite bank approximately 15 metres above river level (Coulter, 1973).

Several failures which have temporarily dammed rivers have occurred in northeastern British Columbia in the last few years. On May 5, 1990, at approximately 2300 hours, a failure occurred at Quintette coal mine (54°59′N; 121°03.5′W) and dammed the Murray River for about 12 hours. Waste rock, till and glaciolacustrine silts totalling

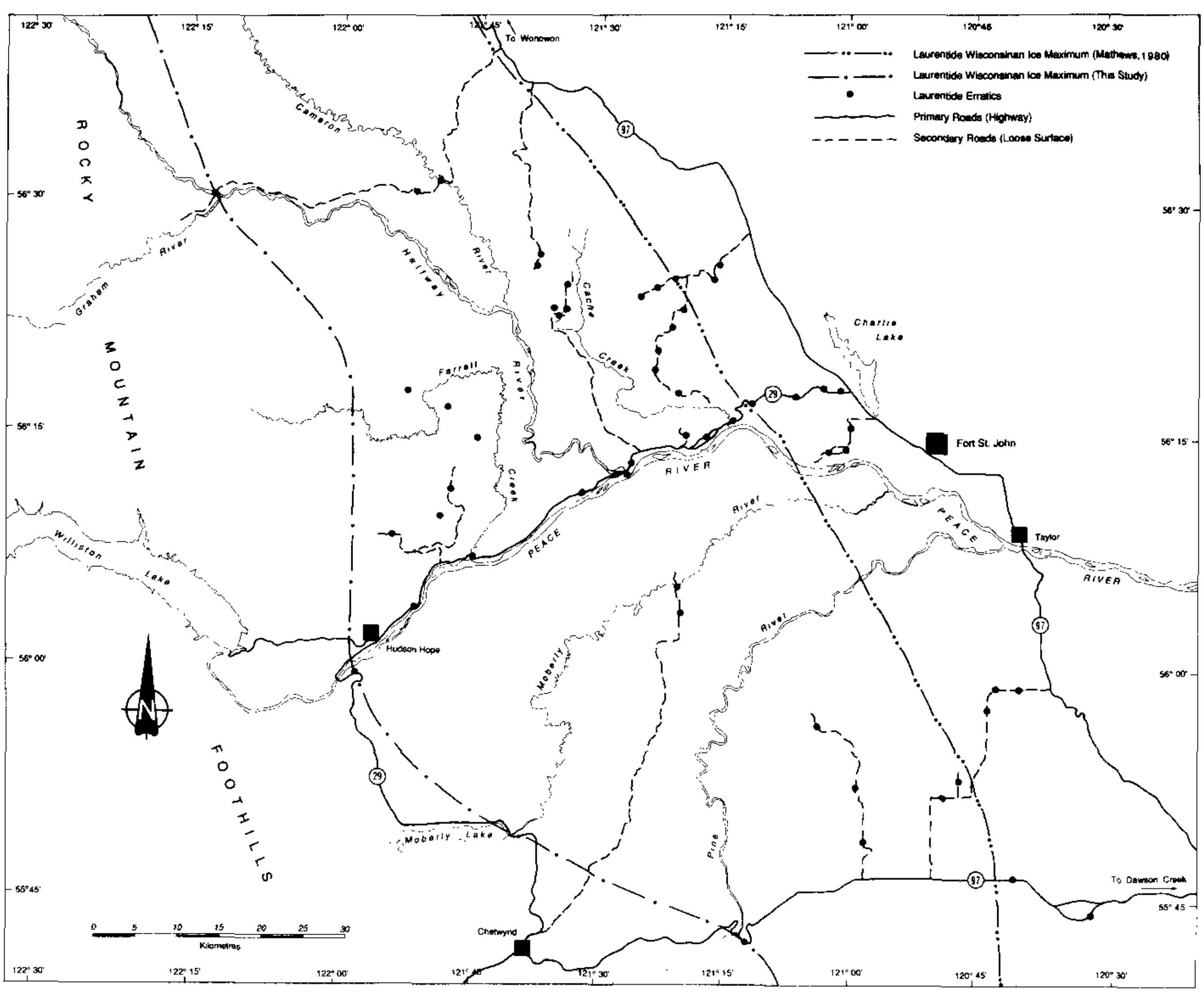

Figure 3-8-3. Map of Laurentide erratic distribution in northeastern British Columbia documented in this study. Note position of previous Laurentide boundary on the east side of the figure, relative to the new position to the west.

2.53 million cubic metres inexplicably failed at the mine dump. About 15 kilometres south of Fort Nelson (58°26'W; 122°52'N), on November 19, 1990 at 0230 hours, an unknown volume of Pleistocene sediments (till and glaciolacustrine silt) failed and dammed the Prophet River for 44.5 hours; apparently as a result of heavy rain. Finally, on August 20, 1989, at about 1500 hours, a landslide occurred on the Halfway River (56°13.4'N; 121°36.1'W) approximately 9.5 kilometres northeast of the Attachie slide. About 1.88 million cubic metres of unconsolidated material temporarily dammed the river for 6 hours (Plate 3-8-1). Details of this latter event are described below.

Heavy rainstorms, intense cloudbursts and concomitant runoff events often generate localized mass movements in steep and channelized terrain. The most significant type of movement consists of water-charged slurries of debris called debris torrents (~debris flows, mud flows, debris avalanches), but less significant variations including sediment-laden water floods and slumps can also occur. In North America, the average number of deaths due to mass movements is about 25 per year (Skermer, 1984). In western Canada, the impact of these common, small-scale events varies from negligible to devastating. For example, in British Columbia, rainstorms in early July, 1983, triggered 14 debris torrents between Hope and Chilliwack that severed transportation for 3 days (Evans and Lister, 1984). One estimate of debris torrent damage for western Canada places the death toll at 17 and the damage costs in excess of $100 million for the period 1962 to 1984 (VanDine, 1985).

Halfway River Slide

At approximately 1500 hours, on August 20, 1989, some 5.5 kilometres north of Highway 29, Pleistocene terrace sediments on the south side of the Halfway River catastrophically failed (Figure 3-8-2, Plate 3-8-1). The resultant debris flow of about 1.88 million cubic metres temporarily dammed the river for up to 6 hours, at which point overtopping of the dam was followed by breaching. The area of the river dammed by sediment measures approximately 100 by 440 metres. During the period of damming, the course of the Halfway was diverted northward across the vegetated floodplain and point bar on the opposite side of the river. The event can be considered a Type I landslide dam of Costa and Schuster (1988). The affected area of the flow is described in relation to three zones: an upper failure zone; a middle transitional zone; and a lower accumulation zone (Figure 3-8-4).

The slide motion originated on the first and second Pleistocene terrace surfaces some 275 metres south of the former shoreline. The back scarp of the upper failure zone is 330 metres from the lower terrace edge (line A of Figure 3-8-5), 690 metres from the present river shoreline and at an elevation of 65 metres above river level (Plate 3-8-2). The depth of the upper displaced mass averages 12 metres, whereas the width is about 270 metres (line B, Figure 3-8-5). The basal shear zone of the displacement coincides with Wisconsinan glacial diamicton which overlies Cretaceous silty shales of the Shaftesbury and/or Gates forma-

Plate 3-8-1. Aerial view to south of Halfway River landslide. Photograph taken August 21, 1989 one day after the failure. Note the volume and lateral extent of debris still blocking normal river flow. (Photo courtesy of D. Lister. MoTH).

tions. A considerable portion of the remobilized sediment remains in the upper failure zone, providing local relief up to 6 metres in height. A second debris mass originated at the south end of the transitional zone (275 metres from the water; Plate 3-8-3). The back scarp of the second failure (transitional zone) follows the edge of the lower Pleistocene terrace along a surface which is 320 metres long and 20 metres high (Figure 3-8-5). Sediment in the transitional zone consists of glaciolacustrine silt and clay and silt-rich diamicton derived from the upper terraces. A series of deep gullies and secondary failure scarps characterize the topographic surface in this zone. Relief reaches 8 metres over the disturbed topography. Several trees survived destruction during the sediment gravity-flow process, resulting in a vegetated medial ridge running parallel to the flow axis (Plate 3-8-3). The broad fan-shaped accumulation zone originally covered an area measuring 190 by 385 metres before fluvial erosion reclaimed much of the river's original course (lines E and F, Figure 3-8-5). The toe of the debris flow now forms a steep and actively calving front some 7 metres above the water surface (Plate 3-8-4). A series of overlapping debris-flow noses along the margin of the accumulation zone provide a stacked terrace-like morphology to the failure.

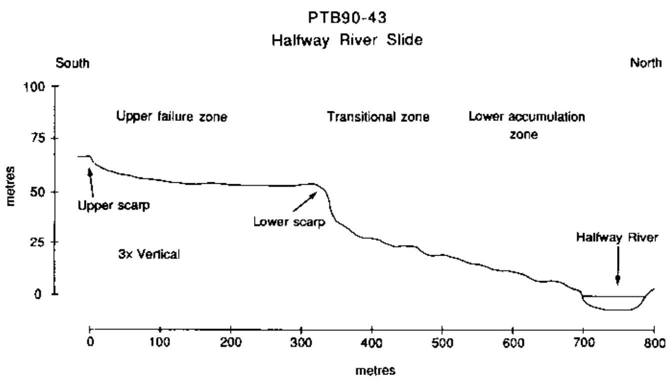

Figure 3-8-4. Longitudinal cross-section of locality PTB90-43 (Halfway River slide); failure occurred at 1500 hours on August 20, 1989. Mass movement is schematically divided into three parts: upper failure zone, transitional zone and lower accumulation zone.

We are unable to confirm the history of events preceding the failure, but the long-term triggering mechanism for slope failure proposed for the Attachie slide (*cf.* Thurber Consultants Ltd., 1981) warrants attention as a likely analogue to the Halfway River slide. A long history of jointing and cracking in the unconsolidated sediments on the upper terrace preceded the failure. Large and partially vegetated tensional cracks paralleling the terrace edge are evident east of the upper failure zone (Plate 3-8-2). Both attributes (size and vegetation) of the cracks suggest a prolonged period of distress, as well as active accommodation of the sediment to tensile stress. Several syndepositional cracks are further evident within the central basin of the upper failure zone. Prolonged ponding in the pre-failure cracks, water infiltration and eventual saturation of the unconsolidated sediment covering the bedrock apparently reached a critical threshold suitable for the rapid motion to take place on August 20. The precipitation records for the area do not support a rain-induced triggering mechanism as a spontaneous event, however, the long-term increasing pore-water pressure in the area may have reduced the effective internal shear resistance enough to trigger the failure (Figure 3-8-6). At the point of initial movement, the distressed sediments most likely underwent quick disintegration and began to flow in a fluid-like manner. Although there was no precipitation on the day of the event (Figure 3-8-6), the amount of water draining from the upper terraces (evident in Plate 3-8-1), as well as eyewitness accounts of the event, support the contention that a considerable amount of internal pore water was released from the Quaternary sediments.

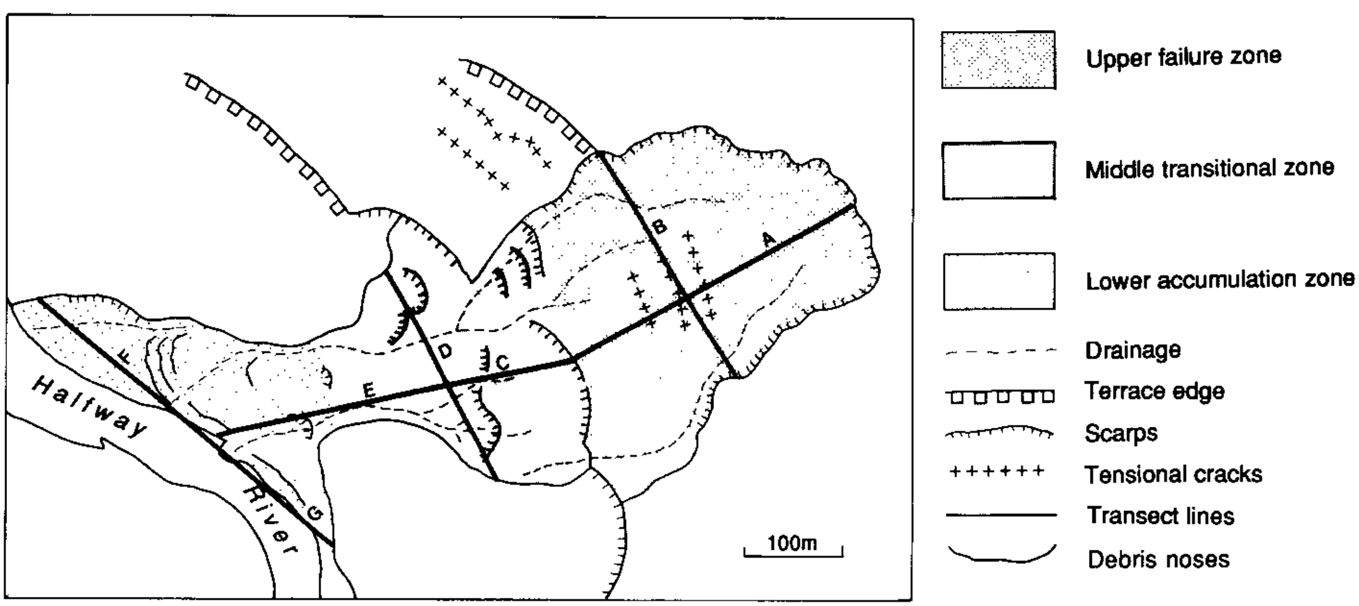

Figure 3-8-5. Plan view figure of Halfway River slide. Compare to series of photostereograms provided.

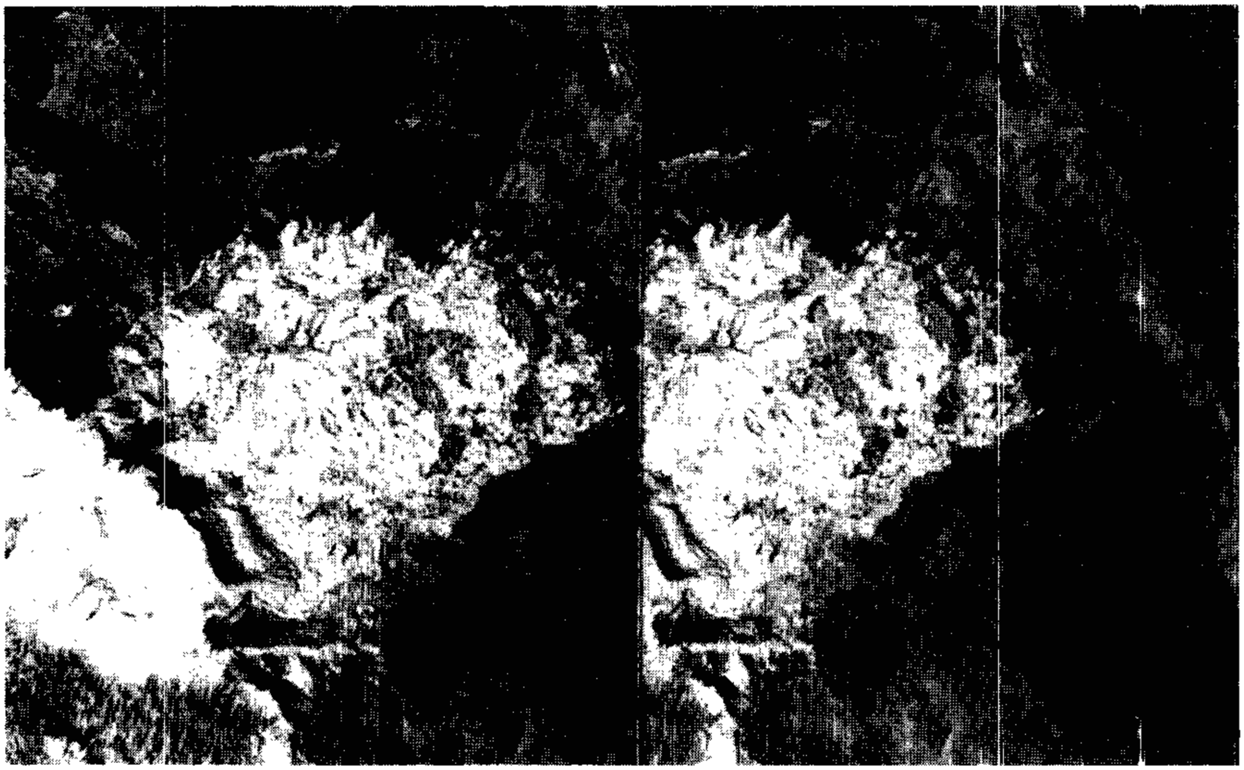

Plate 3-8-2. Photostereogram of the Halfway River slide, northeastern British Columbia. Upper failure zone. See Figure 3-8-5 for scale and details.

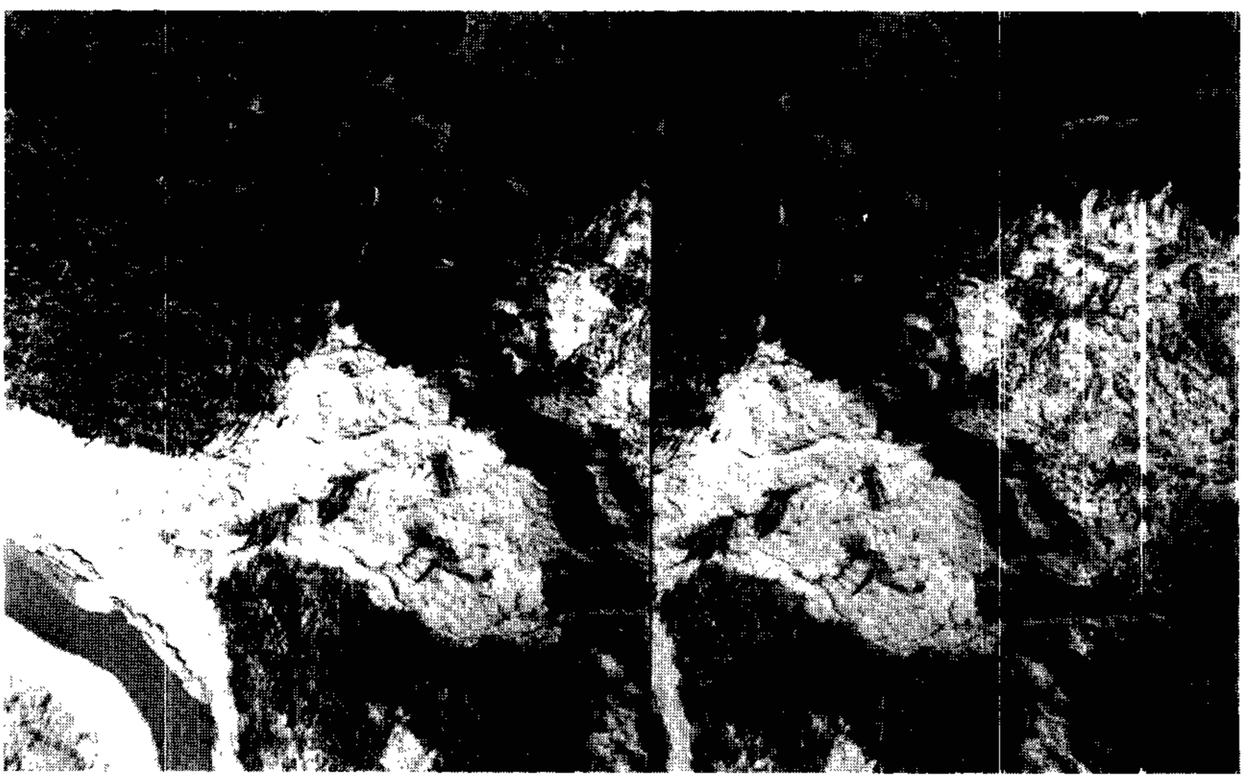

Plate 3-8-3. Photostereogram of the Halfway River slide, northeastern British Columbia. Transitional zone. See Figure 3-8-5 for scale and details.

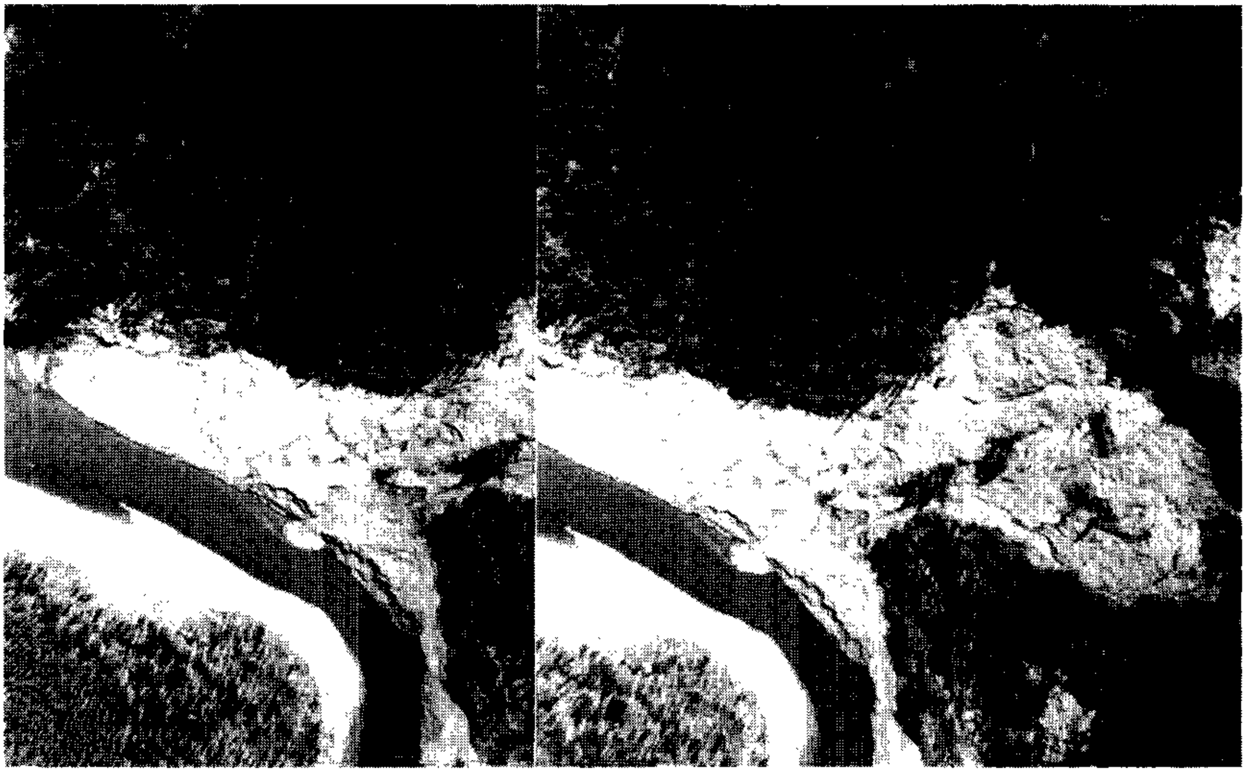

Plate 3-8-4. Photostereogram of the Halfway River slide, northeastern British Columbia. Lower accumulation zone. See Figure 3-8-5 for scale and details.

Plate 3-8-5. View down slope from end of elevated conduit gully toward nick point and amphitheatre feature.

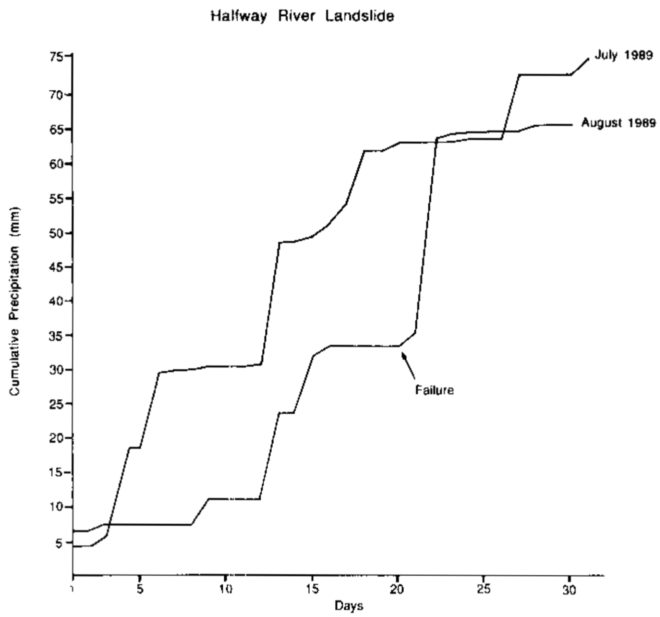

Figure 3-8-6. Precipitation record for the period preceding the Halfway River slide in northeastern B.C.

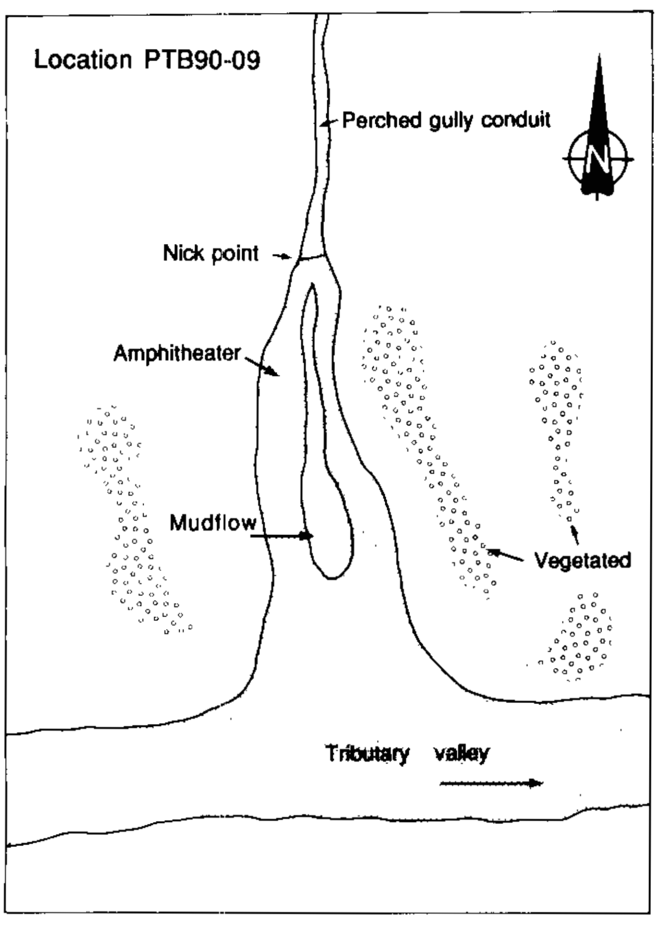

Figure 3-8-7. Conceptual plan view of locality PTB90-09 described in detail by Bobrowsky *et al.* (1991). Note location of (a) elevated conduit gully, (b) amphitheatre and (c) main tributary.

Mud Flow

On the evening of July 4, 1991, during a local rainstorm depositing 3.8 millimetres of precipitation, a small mud flow was deposited in a gully of a tributary valley containing a well-exposed stratigraphic section (Section PTB90-09 described in Bobrowsky *et al.*, 1991; Figure 3-8-7). The precipitation record for the area indicates that rainfall for that day, as well as for the preceding weeks, was essentially average for the time of year. Meteorological conditions often cited as generating debris flows can be discounted; instead, sediment disturbance by us during mapping is a more likely antecedent cause of this event which was finally triggered by the local rainstorm.

The geomorphology of the site consists of a gully 3 metres deep (A) which borders an open field on an upper terrace adjacent to a main tributary valley (C) Figure 3-8-7; Plate 3-8-5). The elevated gully (A) serves as a water conduit to a small amphitheatre-like erosional feature (B) which "represents the adjustment of the landscape to recurrent intervals of erosion by running water and slope failure" (Eisbacher and Clague, 1984:15). The elevated gully intersects the amphitheatre at a nick point 2 metres above the highest point of the sloped surface (Figure 3-8-8). The amphitheatre has a horizontal length of 55 metres and a height of 27.2 metres in relation to the main tributary valley (Figure 3-8-8).

A mud-flow scar and deposit occur within the amphitheatre feature. The plug-nose of the deposit is up to 1.5 metres thick and 4.5 metres wide (Plate 3-8-6). The outer edge of the plug is not well defined as the deposit actually continues down-slope to a lower sediment dump of lighter and finer grained material, but an approximate limit is 55 metres from the edge of the nick point. Debris in the plug consists of small to medium-sized angular blocks of hardened mud, a few fragments of which are over 1 metre in maximum dimension. These blocks represent sheared and fragmented pieces of the adjoining chute-channel walls. Their emergence at the surface of the flow is probably a result of intergranular dispersive forces, buoyancy of larger fragments and forward push of debris from behind (*cf.* Eisbacher and Clague, 1984). The up-slope end of the plug gradually grades into a tail feature which extends almost up to the amphitheatre edge at the base of the nick point (Plate 3-8-7). This proximal sediment accumulation consists mainly of large pebble to cobble-sized clast. Most of the clasts are remnants of the flow which lagged behind as the channel-flow forces diminished. Additional washing by rain further winnowed the fine sediments from this pebble-cobble lag. Lateral margins of the chute are defined by a levee, which represents the zone of laminar flow and sediment spill-over (Plate 3-8-8). The debris levees range in thickness from less than 5 centimetres to 70 centimetres. From crest to crest, the chute width averages 3.1 metres, whereas the depth ranges from 0.30 to 1.60 metres, averaging about 1.2 metres.

Much of the original sediment is derived from the bank walls of the conduit gully directly above the nick point (Plate 3-8-5). During the course of our work in the days preceding the mud flow event, our mapping of the section had severely lessened the sediment strength and integrity of

Plate 3-8-6. View up slope of mud-flow nose. Pick for scale is 65 centimetres long. Note angular nature and size of debris blocks. Note also marginal undercutting of slope on right side of photo (arrow).

Plate 3-8-7. View up slope of mud-flow channel scar. Arrow points to horizontal scale which is 3.1 metres in length. Note relation of marginal levee, slickensided surface and central washed-pebble lag deposit.

the gully walls. The precipitation on July 4 was sufficient to trigger sediment avalanching of the walls into the gully. The debris must have then cascaded over the nick point and was rafted down-slope for an additional 55 metres.

IMPLICATIONS

Stratigraphic and sedimentologic results which tend to support the Model II scenario of Bobrowsky *et al.* (1991) can be briefly viewed in relation to the extended erratic distribution data. The earliest glacial deposits in the region are clearly of Montane or Cordilleran origin, whereas the second glacial event has often been considered to be of both western and eastern ice provenance. However, the westward extension of the Laurentide ice maximum to the margin of the foothills discounts the possibility of ice coalescence near Fort St. John.

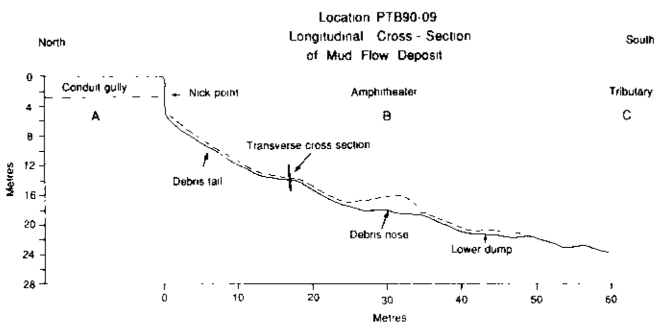

Figure 3-8-8. Longitudinal cross-section of PTB90-09 and mud flow deposited in the afternoon of July 4, 1991.

Throughout the Holocene, including today, the Peace River District has proven to be the centre of a variety of mass movement phenomena. Many of these events were and continue to be either threatening or costly. The large mass movement on the Halfway River which temporarily dammed the flow of water could have been disastrous under different circumstances. Rainfall historically proves to be a prime impetus for triggering slope failures (*cf.* Church and Miles, 1987; Evans and Clague, 1989). Long-term water accumulation appears to be a good explanation for the Halfway River slide. Precipitation for August, 1989 (Halfway River slide) was 64.9 millimetres which is over twice the 22.9 millimetre total for May, 1973 (Attachie slide). Neither month-end precipitation total reflects heavy rain.

Intensified study of the unstable slopes, failed slopes and slide deposits should be undertaken in the Peace region. For example, the slope movement adjacent to the Attachie slide currently ranges from 28 to 82 millimetres per year (D.R. Lister, personal communication, 1987). Although not exceptional (Big Slide near Quesnel has movement rates as high as 271 millimetres per year), this ongoing movement illustrates the continued threat that is posed by the immature landscape that typifies the Peace District. A number of measures can be adopted to assess and respond to mass movement threats (*cf.* Hungr *et al.*, 1987). Unfortunately, only a few of these measures are being actively pursued in the region. Continued geologic research is warranted.

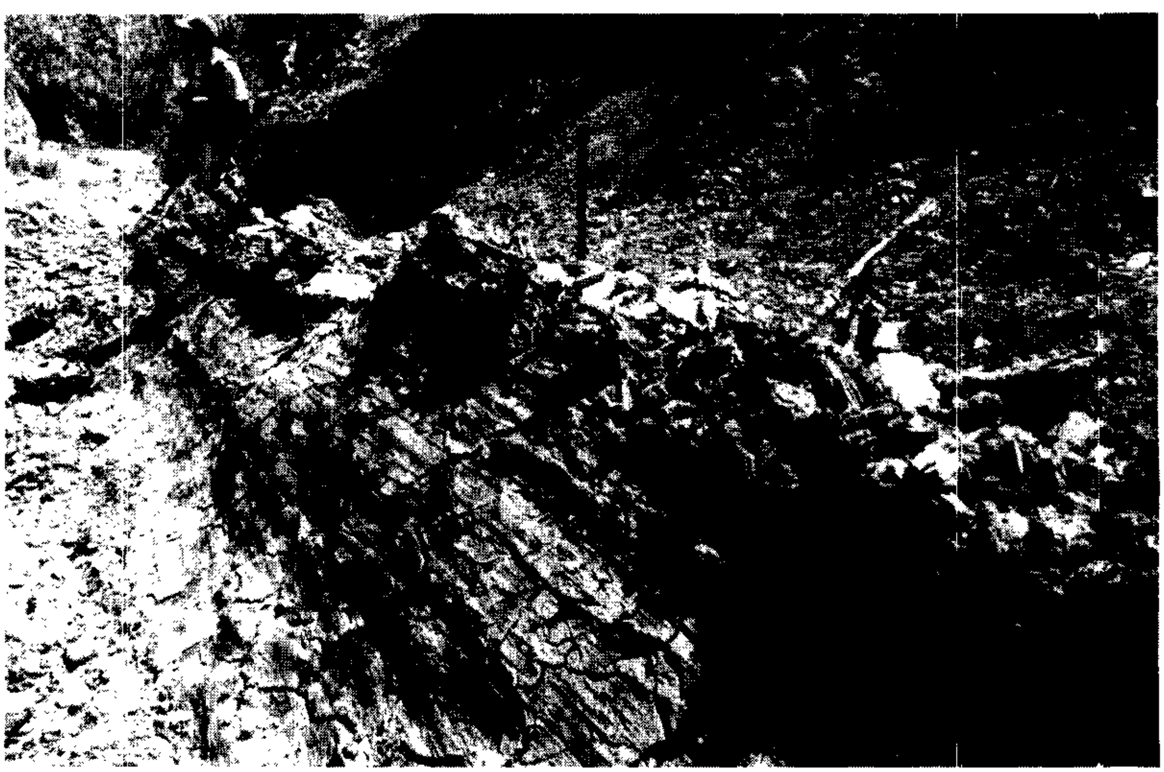

Plate 3-8-8. View down slope of mud-flow scar and deposit at locality PTB90-09. Note slickensided channel wall and prominent levee.

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