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Geomorphology and Late Wisconsinan sedimentation in the Stikine River Valley, northern British Columbia

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Abstract

The Stikine River Valley (SRV) contains a thick and well-exposed sequence of Late Wisconsinan glaciolacustrine and glacial sediments. The glaciolacustrine sequences record the development of Glacial Lake Stikine (GLS), an advance-phase glacial lake produced when the advance of Coast Mountain glaciers impeded the westward drainage of the Stikine River. These deposits fine upwards and fill the deeply incised pre-glacial drainage system. The thickness of GLS sediment indicates that a significant time-lag occurred between the advance of alpine ice in the Coast Mountains and regional ice cover at the study region. A deformation till and a melt-out till overlie the glacial lake sediments. The lack of any ice-directional features in the till, and the lack of lodgement till in regions covered by glaciolacustrine sediment may be an indication that thin ice with low basal shear stresses existed within the SRV. Deglaciation in the SRV resulted in the formation of a complex suite of depositional and erosional landforms. Ice persisted as a stagnating, down-wasting valley glacier and both subglacial and ice marginal drainage networks were most likely present. A sedimentary record of the development of a retreat-phase glacial lake is not evident. Catastrophic drainage of a Late-glacial to Holocene basalt- or ice-dammed lake was responsible for extensive erosion that created a scabland near the village of Tahltan.

1. Introduction

The Stikine River Valley (SRV) is a major physiographic feature in northwestern British Columbia; the Stikine River flows to the west and cuts through the Coast Plutonic Complex. The advance of the Late Quaternary Cordilleran Ice Sheet resulted in ponding in many of the valleys in British Columbia and the deposition of a variety of sediments indicative of changing environmental conditions (Watson and Mathews, 1944; Fulton, 1967; Clague, 1989; Eyles and Clague, 1991; Ryder and Maynard, 1991; Huntley and Broster, 1994). The SRV contains a thick and well-exposed sequence of Late Wisconsinan glaciolacustrine and glacial sediments. These sediments record the development of Glacial Lake Stikine (GLS, Fig. 1), an advance-phase glacial lake produced when the advance of Coast Mountain glaciers impeded the westward drainage of the Stikine River (Ryder and Maynard, 1991).

The SRV has also been subject to volcanic processes. Periodic eruptive activity associated with Mt. Edziza (Souther, 1992) has resulted in the extrusion of at least seven separate basalt flows during the Middle Pleistocene that flowed down the Klastline River (Fig. 1) into the SRV. These flows exist today as isolated basalt remnants and can be found from 5 km upstream to 37 km downstream of the Klastline–Stikine confluence (Read and Psutka, 1985). Holocene basalt flow remnants are located at the Stikine–Klastline and Stikine–Tahltan confluences (Fig. 1); whether they originated from Mt. Edziza or were the product of extrusion from regional fissures is unclear (Read and Psutka, 1985). The juxtaposition of fluvial, glacial and lacustrine sediment with these basalts has resulted in this region being particularly valuable for investigating Quaternary environmental history. The basalts have provided a means of both preserving and dating sedimentary records of environmental change (Spooner et al., 1996a).

In this paper we interpret the stratigraphy and sedimentology of Late Pleistocene and Holocene deposits within the SRV, with the intent of elucidating the general environmental conditions that were active from the Late Pleistocene through the Holocene. Of particular

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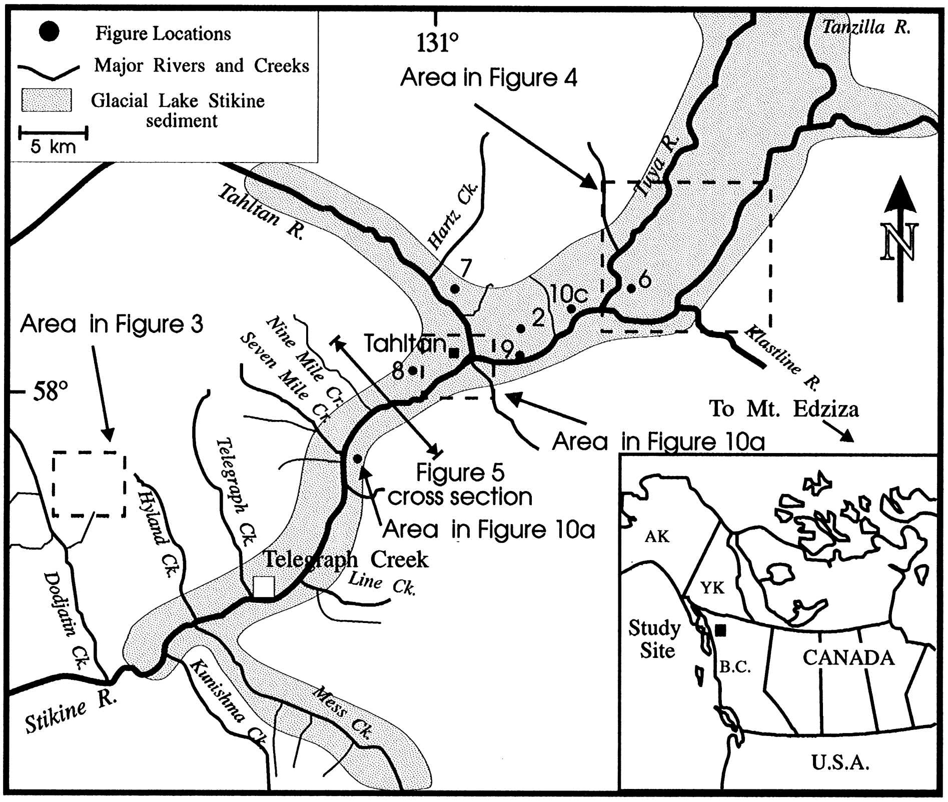

Fig. 1. Location of study site and scenes. The distribution of Glacial Lake Stikine sediments is also depicted.

interest are: (1) the formation and duration of Glacial Lake Stikine, (2) the nature of Late Pleistocene and Holocene depositional and erosional processes and (3) the duration and mode of regional deglaciation within the SRV.

2. Site location

The segment of the SRV considered in this paper starts at the confluence of the Stikine River and the Tanzilla River and continues west to the mouth of Hyland Creek (Fig. 1). The tributary valleys of the Tuya River and Tahltan River were also investigated. This region was chosen partly for practical reasons as the Dease Lake–Telegraph Creek Road parallels much of this route and facilitates access. As well, though considered part of the Grand Canyon of the Stikine River, this section of the river valley is less deeply incised (typically about 200 m compared to 400–600 m upstream of the mouth of the Tanzilla River), has a wider cross-sectional profile and contains more sediment exposures relative to the much narrower river valley upstream.

3. Previous research

In the latter part of the last century, Dawson (1898) completed a regional reconnaissance of the central SRV while travelling to the gold fields in the Yukon. He initiated the concept of the amalgamation of expanding alpine ice and the formation of a *confluent ice mass* over the plateau regions of northern British Columbia. Regional mapping by Cockfield (1926), Johnson (1926), Watson and Mathews (1944), and Kerr (1948) resulted in the collection of ice-movement and overburden-thickness data, work that has been supplemented more recently by that of Gabrielse and Souther (1962) and Gabrielse (1998).

Watson and Mathews (1944), Kerr (1948), and Lambert (1974) all noted that there was no regional evidence of multiple glaciation in northwestern British Columbia. Gabrielse and Souther (1962) however, noted that till often covered morphological features that might be ascribed to previous glaciations. Evidence for a pre-late Wisconsin interglacial interval in northern British Columbia came from the Babine Lake area (near Smithers) where a mammoth bone found in organic-rich silts was dated at 34,000–43,000 ^{14}C yr BP. Also, data gathered in the southern Yukon by Klassen (1977) and a number of subsequent workers indicated that pre-late Wisconsin glaciation occurred there.

Episodic Quaternary volcanism on Mt. Edziza and extrusion of basalt flows into the ancestral SRV followed by river incision has resulted in the exposure of intercalated basalt remnants and sediments along sections of the Stikine River. An initial interest in the placer potential of the gravels preserved between basalts in the Stikine River canyon (Johnson, 1926) and a more recent interest in the structural integrity of the canyon strata (Read and Psutka, 1985) have produced an expanding data base on the chronology of basalt deposition in the Stikine River canyon (Spooner et al., 1996a).

Work by Ryder (1987), Ryder and Clague (1989), and Ryder and Maynard (1991) has resulted in a comprehensive overview of northern British Columbia glacial stratigraphy and chronology. Regional terrain inventory mapping projects (Ryder, 1981, 1983) provided much of the stratigraphic data referred to in later papers. Ryder and Maynard (1991) suggested that glacial stages defined for southern British Columbia are applicable to the Stikine Plateau as well. Following their example the term *Fraser* glaciation will be applied to the Late Wisconsin time interval.

Ryder and Maynard (1991) indicated that an initial phase of Fraser glaciation in the Coast Mountains was responsible for the obstruction of westerly drainage and the formation of GLS. Coincident with the formation of GLS, alpine glaciers developed on the higher peaks on the intermontane Stikine Plateau. Ice divides may have shifted eastward as ice built up in the Coast Mountains to levels higher than in the accumulation centres of the plateau (Clague, 1989). At the climax of Fraser Glaciation ice was thought to have flowed radially outwards from accumulation centres in the Skeena and Coast Mountains. Clague (1989) suggested that deglaciation in the interior regions was dominated by downwasting and stagnation. Glacial ice remained active in the deep valleys even as it began to stagnate on the plateau (Clague, 1989). According to Ryder and Maynard (1991) the SRV may have been occupied by an active outlet glacier and the post-glacial Grand Canyon of the Stikine may have been initiated as a subglacial tunnel valley.

Read and Psutka (1985) mapped terraces and abandoned channels along the SRV from upstream of the mouth of the Tanzilla River to Dodjatin Creek (Fig. 1) and surmised that they were a result of post-Wisconsinan glacial erosion and abandonment as the Stikine River incised down to its present level. At the mouth of the Tahltan River burnt twigs under Holocene Big Raven basalt remnants were dated at 8300 ^{14}C yr BP (Read and Psutka, 1985). The Big Raven basalt occurs about 100 m above the present level of the Stikine River and overlies a thin veneer of sorted fluvial gravel that in turn overlies clay-rich diamicton Fig. 2.

4. Regional surficial geology, SRV

Evidence for pre-Fraser glaciation in the SRV is confined to sections of intercalated basalt and sediment

Fig. 2. View of the Stikine River Valley infill sediments near the village of Tahltan (Fig. 1). Arrow points to spring (note trees) that occurs at the contact (indicated by dashed line) between glaciolacustrine sediments and overlying sandy diamictons.

Fig. 3. A small poorly developed cirque on the eastern edge of the Boundary Ranges west of Telegraph Creek (Fig. 1). No erratics are found on these flat-topped mountains indicating that they may not have been covered by a regional ice cap.

along the Stikine and Tahltan Rivers. Glaciolacustrine and glacial sediment preserved beneath Middle Pleistocene basalts have been interpreted as being deposited at about 330 ka on the basis of geomorphology, paleomagnetism, and radiometric dating (Spooner et al., 1996a).

West of Telegraph Creek (Fig. 1), an upland plateau that borders the Coast Mountains contains small, poorly developed cirques (Fig. 3). The lack of till or erratics on the plateau surface is an indication that Fraser glaciation in this area was concentrated in alpine and trunk valleys and that these elevated surfaces may have remained free of regional ice sheet cover (Spooner, 1994).

Fraser glaciation resulted in extensive sedimentation within the SRV and on the adjacent uplands (e.g. Fig. 2). Much of this sediment was thought to have been deposited in advance-phase GLS (Ryder and Maynard, 1991).

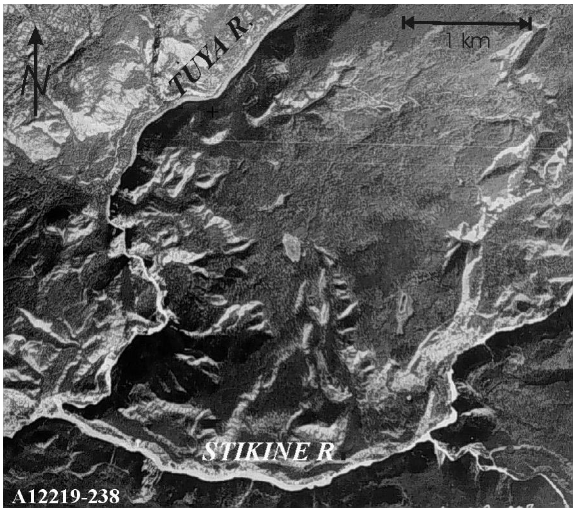

Fig. 4. Image taken at the Junction of the Tuya River and the Stikine River (Fig. 1). The region is covered by Glacial Lake Stikine sediment, which in turn is overlain by Fraser Till and is devoid of any surficial indicators of ice movement.

The lake extended from west of Kunishma Creek (Fig. 1) northeast up the Stikine River and tributary rivers to at least the mouth of the Klappan River (Ryder and Maynard, 1991). The sediment package blankets topography and forms a local plateau surface (Fig. 2). The extent of the lake has been inferred from exposures of lacustrine sediments along the Stikine River and its major tributaries. GLS probably increased in size and depth as ice thickened to the west (Ryder and Maynard, 1991). The lacustrine sediments are locally as much as 150 m thick (Fig. 2), which suggests that GLS may have existed for a considerable length of time.

Regional glaciation resulted in erosion of bedrock and development of ice-directional features. Drumlins are well developed to the east of the study area and in the Mess Creek valley (Fig. 1) but are conspicuously absent from the area now blanketed by GLS sediments (Fig. 4). Bedrock exposed above the elevation of GLS sediments is striated where it has not been degraded by weathering. In general, striated bedrock within the SRV indicates southwesterly ice movement.

Deglaciation in the SRV was characterized primarily by erosion. Terraces and perched paleochannels are located along major river valleys west of the Tanzilla River/Stikine River confluence but are most common along the SRV, west of Tahltan, where canyon morphology becomes more subdued. They are not continuous along the Stikine River and only dissected remnants remain.

5. Stratigraphy, sedimentology, and geomorphology of the SRV: observations and interpretations

5.1. General stratigraphy

The SRV contains a complex suite of glacial, glaciolacustrine, and fluvial sediments that are exposed in the headscarps of landslides and along the walls of the Stikine River Canyon (Fig. 5). GLS sediments form a generally fining-upwards sequence of sorted sediment and diamicton. This glaciolacustrine sequence is best preserved at the Tuya River–Stikine River confluence

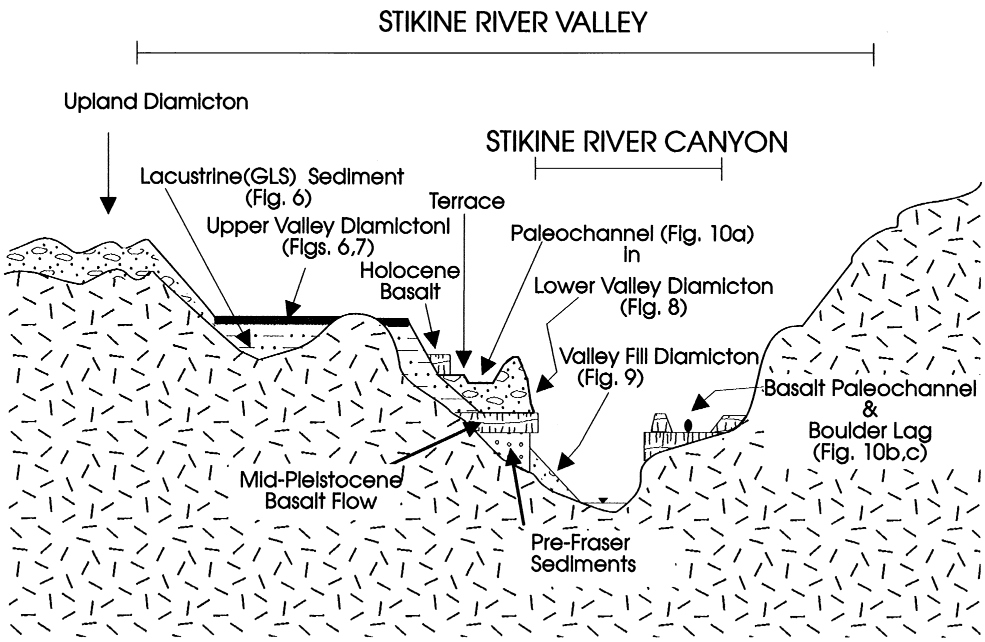

Fig. 5. Schematic cross-section of the Stikine River Valley (not to scale) showing the relative locations of the various units described.

(Fig. 1) where GLS sediments are overlain by diamictons that can exceed 20 m in thickness and have been interpreted as Fraser till (Ryder and Maynard, 1991; Spooner et al., 1996b). The till and lacustrine sediments infill the irregular, moderate-relief, bedrock surface in the vicinity of the Tahltan River mouth. Downstream in the SRV, a sequence of massive, laminated, and deformed diamictons (Lower Valley Diamicton; Fig. 5) has been deposited. This sediment package is rarely greater than 10 m in thickness. In the valley bottom, plastered against the walls of the Stikine River canyon, a highly deformed coarse gravel diamicton (Valley Fill Diamicton; Fig. 5) that reaches thicknesses of 30 m has been deposited.

5.2. Glaciolacustrine sediments

GLS sediment forms a 150 m thick stratified sediment sequence and is well exposed near the mouth of the Tuya River (Fig. 6). The sediments were deposited to an elevation of 800 m a.s.l. The glaciolacustrine sediments are deposited unconformably on moderately indurated yellow-stained gravels of indeterminate age (unit 1, Pre-Fraser Gravels; Fig. 6). These gravels are similar to those described elsewhere in northwestern British Columbia by Huntley and Broster (1994) and Eyles and Clague (1991) as being Pre-Wisconsinan or older. The glaciolacustrine sediment (unit 2, Fig. 6) can be separated into a coarse-grained member (unit 2a, Fig. 6) and an overlying finer-grained unit (unit 2b, Fig. 6). Unit 2a consists of thin but laterally extensive, normally graded silt, sand, and gravel beds that are separated by diamictons of varying thicknesses. Fine to medium sand beds are massive, cross-bedded and cross-laminated; the latter often contain silt–clay laminae with occasional stones. Paleocurrent directions are similar to the present flow directions in these valleys. Some of the beds that underlie the

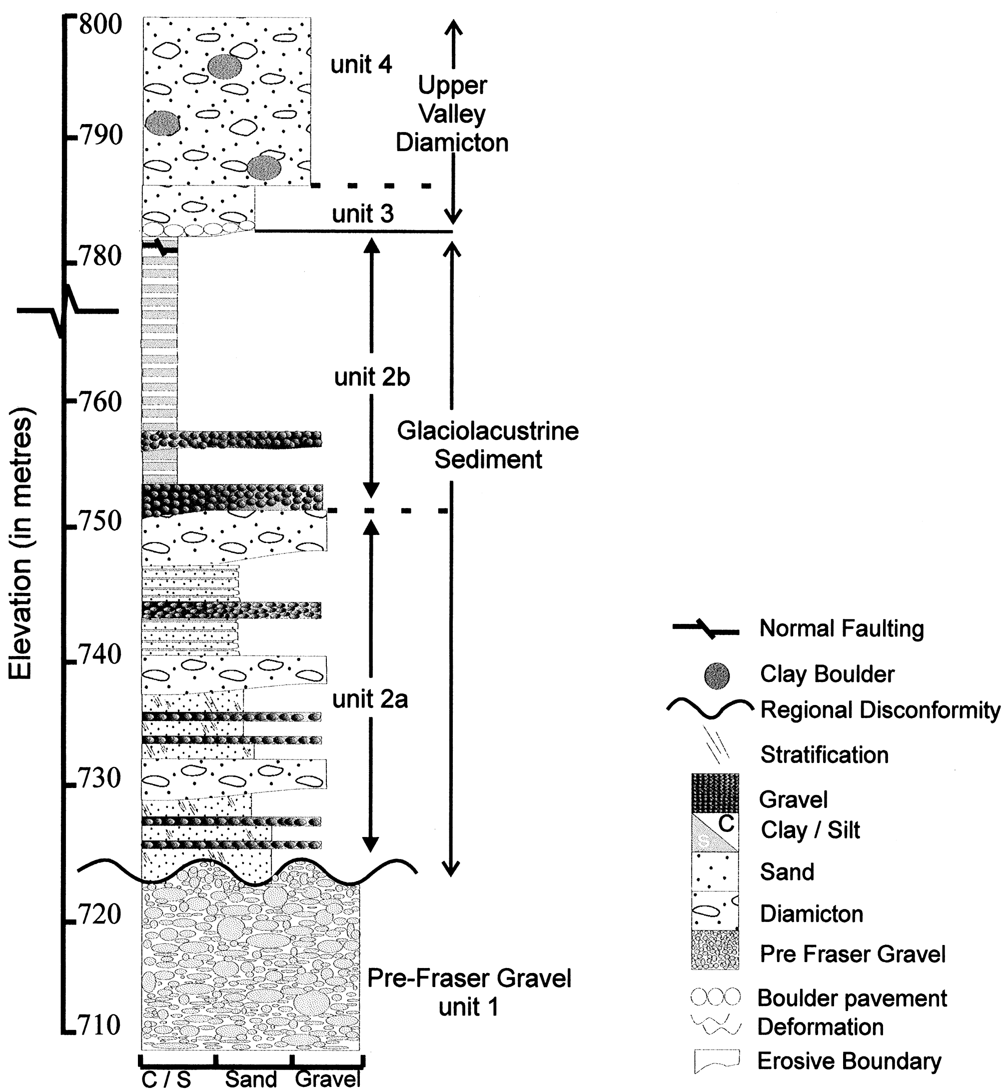

Fig. 6. Stratigraphic section of GLS glaciolacustrine sediment and overlying diamictons at the Tuya River–Stikine River confluence (Fig. 1).

diamictons are deformed and contain small-scale diapiric structures. Stratified medium to coarse sand and gravel beds may record erosion and winnowing of underlying strata associated with fluctuating water levels during initial infilling of the basin. The diamictons contain up to 30% clasts which are predominantly volcanic; they are massive to weakly stratified and occasionally contain rafted angular clasts of the underlying stratified silt. They are not laterally continuous and characteristically have erosional bases. Stratification within the diamictons may be the result of the superimposition of debris flows. The rafts of silt and clay record the incorporation of previously deposited lacustrine sediment during valley-slope slumping. Similar diamictons have been described by Eyles and Clague (1987), and Huntley and Broster (1994) as being the product of valley-slope slumps that transformed into lake-marginal subaqueous debris flows. Slumping may have been initiated when infilling of the basin by water destabilized the valley sides, producing turbulent, water-rich slurries.

Unit 2b is 10–30 m thick and consists of fine-grained rhythmites and occasional well-sorted gravel beds (Fig. 6). The rhythmites are composed of 1–3 cm thick clay to silt laminae that often have a thin, fine sand lag at the base. The coarse bases of these rhythmites are probably the distal sedimentary expression of turbidity current deposition; the finer sediment may represent deposition from suspension. Though the rhythmites may be annual deposits, their varying thicknesses may indicate that they are the distal products of turbidity current deposition. Gravel layers are well sorted and have erosional bases; they also have concave-up bases when observed perpendicular to paleoflow. These gravels are similar to channel deposits described by Eyles and Clague (1991) as being the product of either traction currents on the floor of the lake or increased flow during lake lowstands.

The general fining-upwards sequence observed in the glaciolacustrine sequence is a result of basin deepening and widening as the SRV became filled with meltwater. Coarse, cross-stratified lacustrine sediments at the Tuya River section record continued confinement of water flow and sediment to the submerged valleys as the lake deepened. Rhythmites at the top of the lacustrine section are indicative of a transgressive environment and indicate that flow expansion and the creation of a lower energy lacustrine environment occurred in response to basin widening as GLS overtopped the Stikine River and tributary river canyons. Near the top of the glaciolacustrine sequence, deformation structures and normal faulting become ubiquitous. The contact with the Upper Valley Diamicton (Fig. 5; Units 3 and 4, Figs. 6 and 7) is erosional and loading coupled with the water-saturated nature of the underlying sediment probably produced the deformation.

5.3. Glacial sediments

A thin (< 5 m) veneer of poorly stratified clay-rich diamicton with cobble- to boulder-sized clasts was deposited on bedrock and on the lee side of bedrock knobs on the plateau adjacent to the SRV (> 800 m a.s.l.; Upland Diamicton, Fig. 5); this diamicton is not in stratigraphic contact with GLS sediments. The diamicton contains well rounded to angular, striated clasts and is well indurated. When thicker than 2 m the sediment is often highly deformed and normal faulting and diapiric structures are common. We interpret the Upland Diamicton as a lodgement till.

A coarse-grained diamicton (Fraser Till; Ryder and Maynard, 1991) that ranges in thickness from 5 to 15 m blankets GLS sediment (Upper Valley Diamicton; Figs. 5–7). This diamicton contains striated and facetted cobble to boulder (> 2 m diameter) polymictic clasts, is poorly indurated, and truncates underlying glaciolacustrine sediment. The diamicton can be subdivided into two facies. The lower facies (unit 3, Fig. 6) is up to 2 m thick, is clay-rich, moderately indurated, often faulted and deformed, and has a discontinuous boulder pavement at its base. The upper facies (unit 4, Fig. 6) is 3–10 m thick, coarse grained (sand- and cobble-rich), poorly indurated and characteristically contains well-rounded clasts of the GLS sediment (Fig. 7a and b). Discontinuous beds of sorted sand and gravel are common in the upper facies. The contact between these two facies is sharp. The lower facies is found only at exposures located along the margins of the SRV and was formed by either lodgement processes or glacial deformation of GLS sediment. The latter is preferred as the deformation evident both within and at the base of this facies and the presence of a boulder pavement are features that are consistent with subglacial deformation and deformable beds (Clark, 1991; Hart, 1995). Water-saturated GLS sediment may provide the low-strength material required for this process and, as these conditions would persist wherever GLS sediments were deposited, may also explain the regional extent of the boulder pavement. The discontinuous sorting and poor induration noted in the upper facies are characteristics of a melt-out till. The rhythmically bedded silt and clay clasts may have been transported and rounded in low-viscosity ice, a process that would require the sediment to be frozen before incorporation (Gorrell and Shaw, 1991). It is unlikely that they represent boudins formed by subglacial glaciotectonic deformation (Hart and Roberts, 1994).

Along the upper canyon walls west of Tahltan clay-rich, well-indurated diamicton layers that are inclined at about 30° (unit D, Fig. 8) are overlain by a sand-rich unit that is horizontally bedded and contains lenses of poorly sorted sediment (unit C, Fig. 8). The contact between these units is sharp and erosional. Unit D contains well-rounded to angular rhythmically bedded silt–clay clasts

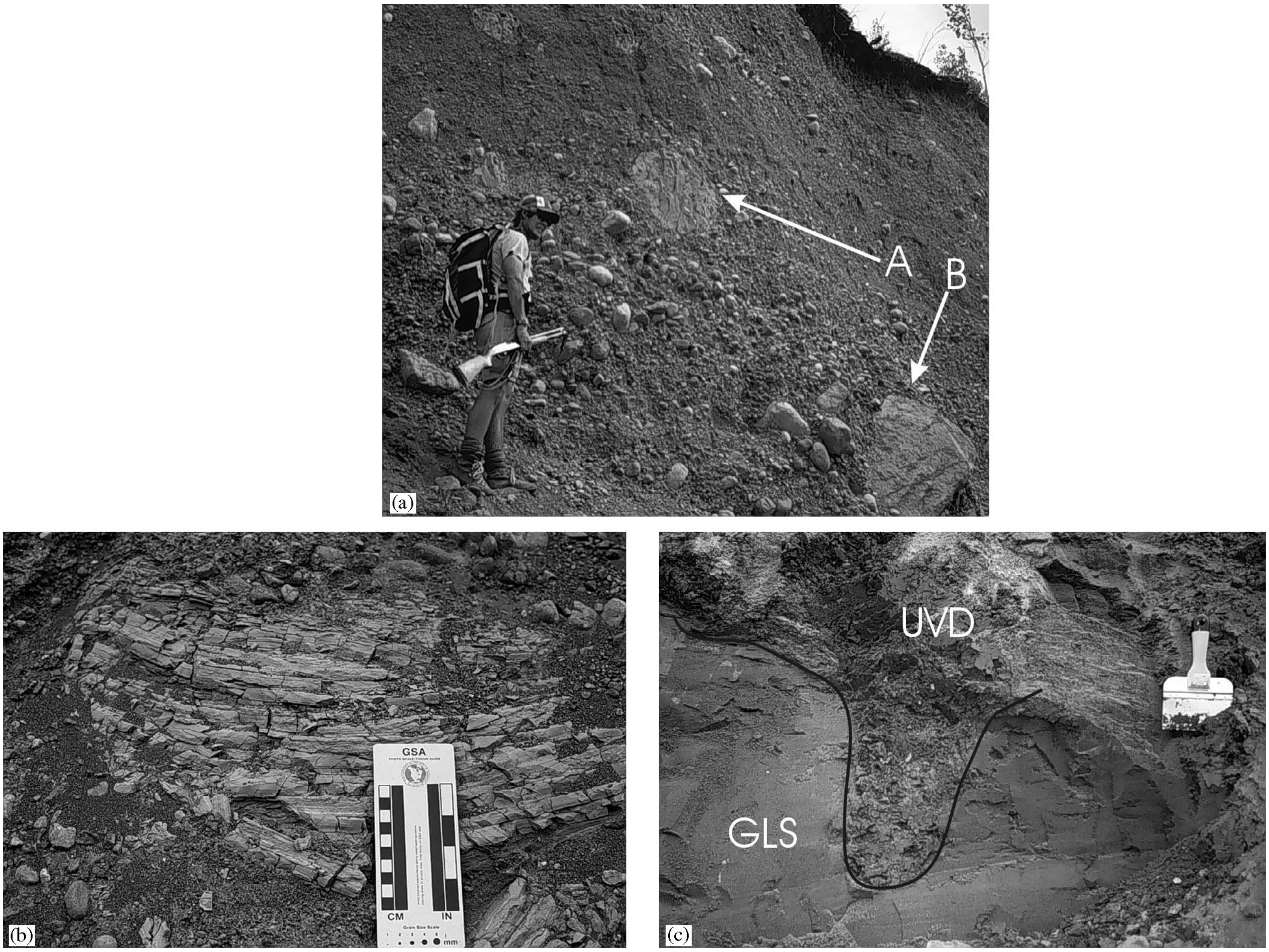

Fig. 7. Upper Valley Diamicton (Fraser Till). A: The Upper Valley Diamicton overlies Glacial Lake Stikine sediment. This diamicton is poorly indurated, contains large sediment (A) and boulder (B) clasts and some sorted sediments indicating that it was probably deposited by melt-out processes. B: Well-rounded rhythmically bedded clay clast. This clast probably originated from the underlying glaciolacustrine sediment that was frozen at the time of incorporation. C: Contact between the Upper Valley Diamicton (UVD: Fraser Till) and Glacial Lake Stikine (GLS) massive silt. Deformation at this contact is an indication that the sediment was probably water saturated at the time of till emplacement.

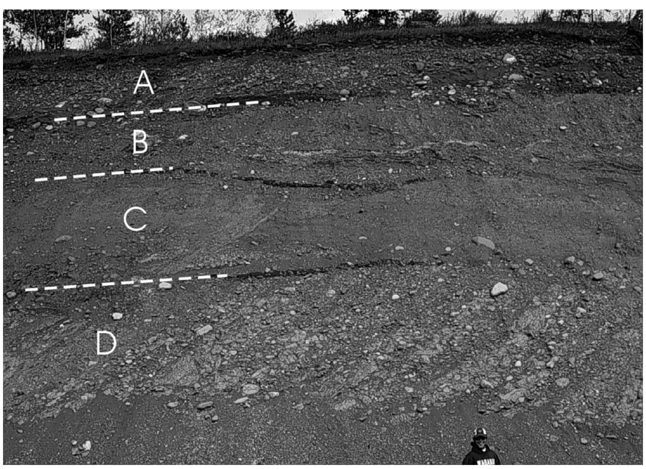

Fig. 8. Lower Valley Diamiction. Units D and C were deposited by englacial and proglacial processes, respectively. Unit B is a coarse diamicton that was deposited from stagnating ice. Unit A is colluvium. Note person at the bottom for scale.

similar to those observed in the Upper Valley Diamicton (Fig. 7a and b) that overlies the GLS sediment. The layering in unit D (Fig. 8) probably reflects stratification of englacial debris; the attitude of the stratification is probably a result of both post-depositional deformation and the original internal geometry of the debris within the ice. The lack of sorting and preservation of the unlithified clasts indicate that this sediment was not stream transported a significant distance. Englacial bedding attitudes are commonly preserved in melt-out tills (Shaw, 1985) and preservation of unlithified clasts is also common. Stratification within unit D extends laterally for about 20 m; deformation obscures stratification past this point. Unit C (Fig. 8) was probably deposited by proglacial processes dominated by meltwater flow and sorting. This sequence is thought to represent deposition by melt-out and proglacial processes during deglaciation (Lower Valley Diamicton, Fig. 5). A well-indurated

Fig. 9. Valley Fill Diamicton. A highly deformed, poorly indurated, coarse diamicton found in the lower Stikine River Canyon. This sediment was deposited by stagnating ice during regional deglaciation.

clay-rich diamicton with few large-sized clasts overlies these two units (unit B, Fig. 8). Unit B (Fig. 8) may represent a local re-advance or, more likely, adjustment of the ice in the valley. Vertical piping of sediment through the lower two units indicates that loading occurred while these sediments were saturated but prior to the deposition of unit B. Unit A (Fig. 8) is colluvium. There is no evidence of retreat-phase lacustrine deposition in the SRV.

Glacial sediments deposited at low elevations in the Stikine River Canyon are characteristically poorly sorted and coarse. At the base of the canyon a highly deformed, coarse diamicton that has a sandy matrix is plastered against the canyon walls (Valley Fill Diamicton; Figs. 5 and 9). Though the diamicton contains lenses of sorted gravel and sand, the sorted sediment is often highly deformed, and is found only as isolated pods within this unit. The deposits are poorly indurated and are not compacted; they contain occasional unlithified clasts. This sediment is interpreted as subglacial to proglacial valley fill sediment, perhaps deposited as ice stagnated in the SRV during deglaciation. The lack of sorting and presence of sediment rafts may be indicative of little transport; the former may partially be a result of post-depositional deformation. Much of this sediment may have been deposited as debris flows of unstable, water-saturated sediment deposited on valley sides as ice down-wasted in the valley.

5.4. Surficial features

Streamlined forms are conspicuously absent from the central portion of the study region (Fig. 4) where the GLS and Fraser Till sequence is thickest. Perched paleochannels (Fig. 10a), crescentric scouring, boulder lags, "scab-like" Pleistocene basalt remnants (Fig. 10b), streamlined water-erosional forms, and lee-side deposits are all common in the SRV from the mouth of the Tuya River valley to Telegraph Creek (Fig. 10; Spooner and Osborn, 1991; Read and Psutka, 1985). This landform assemblage and the "scabbed" geomorphology that they create closely resemble erosional forms that were created by the Glacial Lake Missoula Flood in the channel scablands of eastern Washington State (Spooner and Osborn, 1991; Baker and Bunker, 1985). Both bedrock and sediment paleochannels have steep-sided, flat-based cross-sectional profiles. Some sediment paleochannels are partially infilled with poorly sorted, coarse-grained sediment and can contain nested crescentric scours. Boulders are common on the floors of both paleochannels and average about 2 m in diameter (Fig. 10c); similar boulder lags were associated with the Late Pleistocene Bonneville Flood in the Snake River Plain, Idaho (Malde, 1968). The bedrock paleochannels are best developed where the SRV is relatively narrow; the sediment paleochannels are most common west of Seven Mile Creek where the SRV is less constrained and valley-side sediment is common.

5.5. Post-glacial sediments

During the Holocene the SRV has been dominated by incision and erosion. As such, few outcrops of post-glacial sediment are evident. A thin veneer (1–5 m) of well-sorted, open-work gravel can be found on some erosional terraces. This sediment has been preserved beneath the Big Raven Formation (Read and Psutka, 1985), a basalt of early Holocene age (8300 BP) and indeterminate origin. The Big Raven basalt is found as isolated erosional remnants at elevations of about 300 m a.s.l. between the village of Tahltan and the mouth of the Tuya River (Fig. 1). The gravel is in erosional contact with both the Valley Fill Diamicton and GLS sediment.

6. Geological history

Glacial Lake Stikine sediments, though generally fine grained, are cross-bedded in the lower portions of the lacustrine sequence and indicate flow directions similar to those presently active in the river valleys in which the lacustrine sediments are preserved. Early in the evolution of advance-phase lacustrine sedimentation, flow was probably constrained (and thus relatively strong) within the narrow, canyonized lower portions of the major river valleys. Under these conditions coarser sediment could be transported well into the lake before deposition. The rhythmites that become common towards the top of most sections and the general fining upwards nature of the glaciolacustrine sedimentation indicate that as glaciation proceeded the basin enlarged and intrabasin flow became less constrained, current velocities declined and only the finer-grained sediment could be suspended and ultimately deposited.

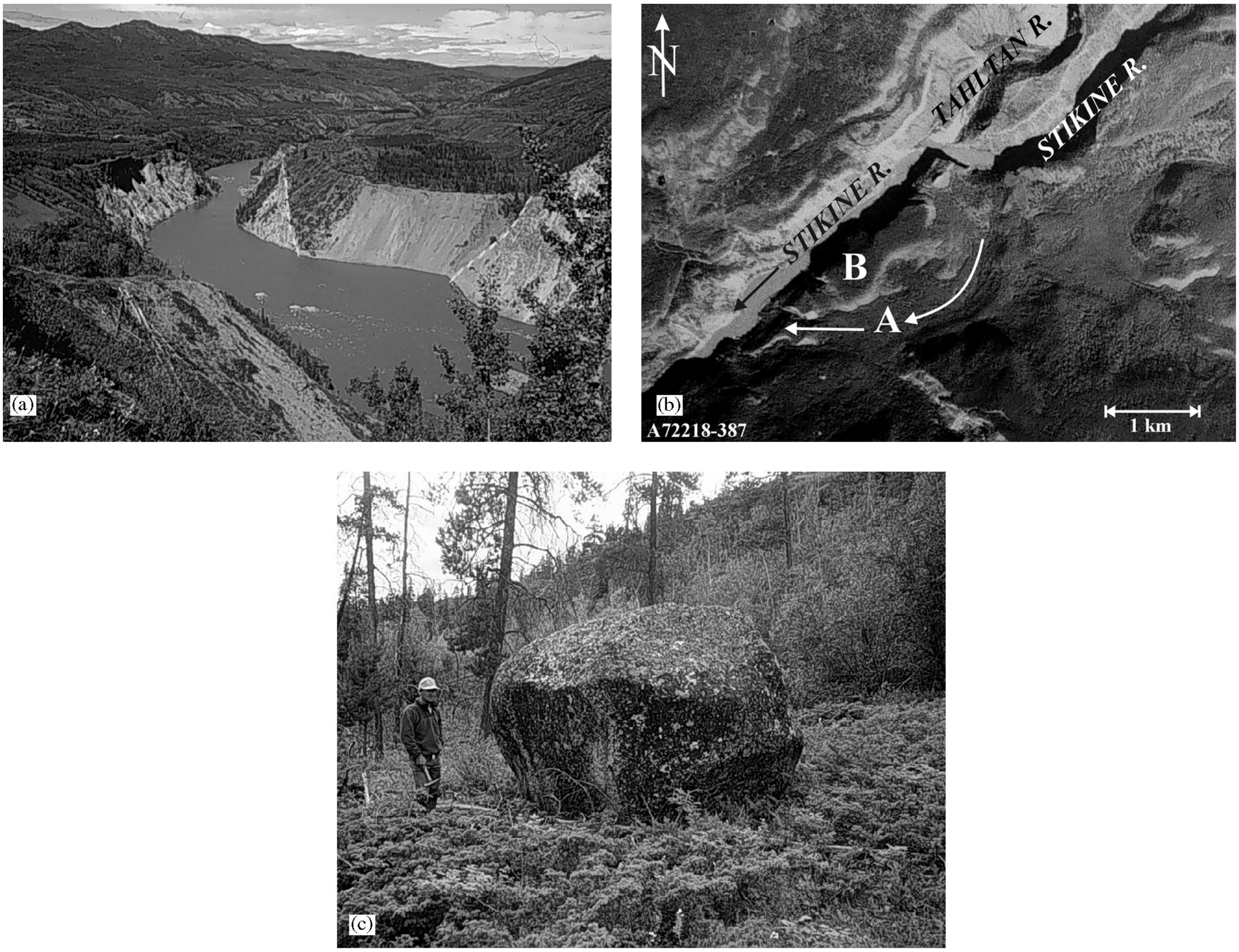

Fig. 10. A: Sediment-filled paleochannel. These paleochannels often contain back-stepping crescentric scours indicative of rapid downcutting. B: Perched, basalt-floored paleochannel (A) and an isolated basalt remnant (B) that has been eroded near the Tahltan River/Stikine River confluence. The basalt-floored paleochannels are steep-sided and the floors have been swept clean of all sediment save large rounded boulders, 2–4 m in diameter (C), an indicator of the intensity of post-glacial meltwater erosion. The arrows show present and past (inferred) flow directions.

The thick glaciolacustrine sequence is suggestive that the lag between alpine ice advance in the Coast Mountains and ice cover in the interior was considerable. The lack of any palynomorphs in the glaciolacustrine sequence suggests that conditions during this transition were relatively harsh and\or that intermontane ice advanced to the margins of GLS and remained there for some time, perhaps covering the lake body. The presence of angular gravel dropstones in the rhythmites indicates that ice was nearby.

As regional glaciation proceeded, ice inundated the region. The highlands surrounding the SRV were probably covered by an ice sheet while the major river valleys (Taku, Stikine and Iskut) served as conduits for the westward movement of ice. While GLS was ice covered, sedimentation may have continued at the lake margins. Strong traction currents on the floor of the lake and underflows resulting from large influxes of meltwater as ice advanced may have kept the central, canyonized portions of the SRV free of lacustrine sediment accumulation.

Similar sequences of Late Wisconsinan advance-phase glaciolacustrine sedimentation have been described by Eyles and Clague (1991) and Huntley and Broster (1994). The glaciolacustrine sequence reported in this paper also closely resembles a Middle Pleistocene (Isotope Stage 10) advance-phase glacial lake sequence preserved under basalts in the Stikine River canyon (Spooner et al., 1996b). However, the Late Wisconsinan sequence is much thicker and the finer-grained facies, particularly the rhythmites are largely absent from the Middle Pleistocene sequence.

Ryder and Maynard (1991) indicate that the SRV harboured a major outlet glacier. This glacier may have significantly altered the morphology of the SRV and eroded much of the lacustrine sediment deposited in GLS during initial ice advance in the Coast Mountains. Thin, deforming ice may have formed as a consequence of the high gradient that existed between the valley-bounding upland and the floor of the SRV. Till plastered to the sides of the canyon (Fig. 8) is the sedimentological evidence of ice occupation. The lack of both lodgement till and ice-directional features on the GLS/Fraser Till sequence may be an indication that, where in contact with GLS sediments, ice did not have an erosional base. Alternatively, ice may have been thin and basal shear stresses low, conditions that may not be conducive to drumlin formation (Patterson and Hooke, 1995). Deformation within the GLS sediments does indicate that loading and shearing took place. Ryder and Maynard (1991) also suggest that the post-glacial Grand Canyon of the Stikine was initiated as a tunnel valley during Fraser glaciation. However, though subglacial meltwater flow probably significantly altered the morphology of the SRV, the presence of middle Pleistocene-aged basalt at the floor of the canyon is testament to early, pre-Fraser formation of much of the canyon (Read and Psutka, 1985; Spooner et al., 1996a).

During and following glaciation the Stikine River aggraded, as indicated by the fluvial gravels under the Big Raven basalt. Read and Psutka (1985) contend that fluvial gravels alone underlie both the Big Raven basalt and the sediment paleochannels and were deposited as the Stikine River aggraded following deglaciation. Our observations indicate that during deglaciation, outlet-glacier ice probably persisted in the SRV. Fulton (1967), Clague (1989), and Eyles and Clague (1991) indicated that Cordilleran ice might have remained longest in deep valleys that at one time were occupied by trunk glaciers. Much of the valley fill sediment found at the base of the canyon and underneath Big Raven basalt at the mouth of the Tahltan River may have been deposited by melt-out processes from the stagnating ice mass. This early phase of aggradation was followed by gradual incision which created both sediment and bedrock paleochannels. Some of the sediment paleochannels may have formed subglacially as tunnel valleys (cf. Shaw, 1985). This would account for their box-like cross-sectional profile and the lack of sinuosity. The deposition of poorly sorted sediment in some sediment paleochannels does post-date paleochannel formation; sediment at the margins of a stagnating valley ice lobe may have in-filled local depressions (the paleochannels) as the ice wasted. If this were the case the paleochannels must have developed subglacially. Alternatively, the paleochannels might have developed at the margins of a stagnating ice sheet; the point of termination of the paleochannel may be the point where meltwater issuing from ice first eroded valley fill sediment. Channel-switching could have occurred as the ice mass wasted and the focus of the meltwater flow shifted. The abandoned channels might then have been in-filled with poorly sorted pro-glacial sediment.

The geometry of rock paleochannels, the boulder lags they contain and the variety of scour forms (crescentric scours, plunge-pools) found in some sediment paleochannels indicate that the flow that created or modified these features was both sustained and concentrated. Breaching of an up-stream ice dam is one possible scenario. Preliminary mapping to east of the study area has indicated that short-lived retreat-phase glacial lakes may have developed in the Dease Lake and Iskut regions. It is also possible that these features are a result of a flood that may have occurred after the Stikine River was temporarily dammed by the Big Raven basalt flow (8300 BP). The elevation of a rock paleochannel adjacent to the Big Raven basalt is significantly lower than the base of the basalt. As the basalt does not infill the paleochannel the paleochannel is likely younger. If so, then a flood created by the breaching of a lava dam is a possible scenario. However, the Big Raven basalt may be the product of a number of small isolated rift eruptions (Read and Psutka, 1985), perhaps not of sufficient volume to dam the Stikine River.

The lack of any evidence of post-glacial lacustrine deposition in the study area is unexpected. Similar valleys in central British Columbia (Fraser, Chilcotin; Eyles and Clague, 1991) contain a thin veneer of lacustrine sediment indicating that ice persisted longer in alpine areas to the west and impeded drainage during deglaciation (Eyles and Clague, 1991). The record of Middle Pleistocene glaciation from the Stikine Canyon also contains retreat-phase glaciolacustrine sediments (Spooner et al., 1996). It is unlikely that the lack of retreat-phase glaciolacustrine sediment in the Late Wisconsinan record of the SRV is a result of early ice retreat in the Coast Mountains as a number of alpine glaciers (Mud, Flood, and Great Glaciers) reach the base level of the Stikine River at present. It is more likely that subglacial and ice marginal drainage networks persisted through deglaciation perhaps, as Ryder and Maynard (1994) have suggested, as a consequence of rapid recession of the Stikine outlet glacier which could have been triggered by rising sea levels. If some sediment was deposited in a short-lived retreat-phase lake, it may have been eroded away during post-glacial incision.

7. Summary

General paleoenvironmental inferences can be made from the depositional and erosional features in the SRV. The thickness of the glaciolacustrine sequence indicates that a significant time-lag occurred between the advance of alpine ice in the Coast Mountains and regional ice cover at the study site. Though focused, turbulent meltwater flow was responsible for much of the initial erosion in the SRV during deglaciation, the existence of pre-Fraser basalt remnants in the bottom of the canyon indicates that the canyon had been excavated to its present depth at least 400,000 years ago. It appears most likely that regional ice persisted as a stagnating valley glacier, rather than a down-wasting regional ice cap, as Fulton (1967) has proposed for other regions of the Interior Plateau. The form of erosional features within the SRV indicates that a short period of sustained, highly erosive flow occurred, giving this region of the SRV a "scabbed" appearance. The Late Wisconsinan glaciolacustrine and glacial sediment assemblage within the SRV is inherently unstable. Hazard prediction and risk assessment are possible but the practicality of carrying out such a study is limited by areal extent of the susceptible deposits.

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