Late Wisconsinan paleosols and macrofossils in Chehalis Valley: paleoenvironmental reconstruction and regional significance

by

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Abstract

A subalpine coniferous forest occupied the Chehalis Valley before 19,980 ± 70 years BP (UCIAMS 126600), according to plant and insect macrofossils and paleosol evidence preserved in Late Pleistocene-aged sediments. The paleoclimate was similar to the modern Engelmann spruce-subalpine fir (ESSF) ecosystem that occurs at high elevation with cold and wet climates today. The Chehalis Valley evidence challenges the interpretation that the Coquitlam Stade and the Port Moody Interstade were regional and driven by climate change. Coquitlam till is absent from Chehalis and there was a coniferous forest present when other areas in southwest British Columbia were covered by Coquitlam Stade ice.

Keywords: paleosols; macrofossils; Chehalis valley; Coquitlam Stade; Port Moody Interstade

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Chapter 1. Introduction

The development of the Late Pleistocene stratigraphy of southwest British Columbia is mainly based on a few sites in the Fraser Valley (Figure 1-1). From this, a geologic history was developed that places the onset of glaciation by advance sediments of the Quadra Sands (Clague 1976), followed by the ice cover of the Coquitlam Stade (Hicock and Armstrong, 1981). Organic-rich sediment above Coquitlam Stade deposits at Hollyburn Creek, Sisters Creek, Seymour River, Port Moody, and Mary Hill was interpreted to represent warming and retreat of glaciers during the Port Moody Interstade (cf. Lian and Hickin, 1993, Hicock and Lian, 1995, and Lian et al., 2001). The area was then covered by ice again during the maximum Vashon Stade (Hicock and Armstrong, 1985). This two-phase glacial advance has not been identified outside of a limited geographic area in the western Fraser Valley, raising questions about the regional climate signal represented in this stratigraphy.

Ward and Thomson (2004) described the pattern of glacier advance and retreat in Chehalis Valley. They noted the absence of Coquitlam Stade sediments. Also, the first evidence of advancing glaciers in the area occurred approximately one thousand years later in Chehalis Valley compared to Coquitlam Stade sites in western Fraser Valley. The pattern was attributed to local geomorphology, ice-source area, and precipitation patterns rather than regional climate conditions.

Chehalis Valley is rich with Late Pleistocene sediments that have been exposed through natural mass wasting processes and mass wasting associated with forest, road, and rail development. Plant and insect macrofossils and paleosols within these sediments record the paleoenvironmental conditions during the time of deposition. At the same time that other areas of southwest British Columbia were covered by Coquitlam Stade glaciers, a spruce – fir forest existed in the Chehalis Valley. An environment similar to that recorded in the subsequent Port Moody Interstade sediments to the west occurred ~1000 years earlier in Chehalis Valley and persisted through mid-Coquitlam time but was no longer in the area by the time Port Moody Interstade sediments were deposited.

The regional interpretation of the Coquitlam Stade and Port Moody Interstade will be tested using a paleoenvironmental reconstruction of the Chehalis Valley and new radiocarbon ages.

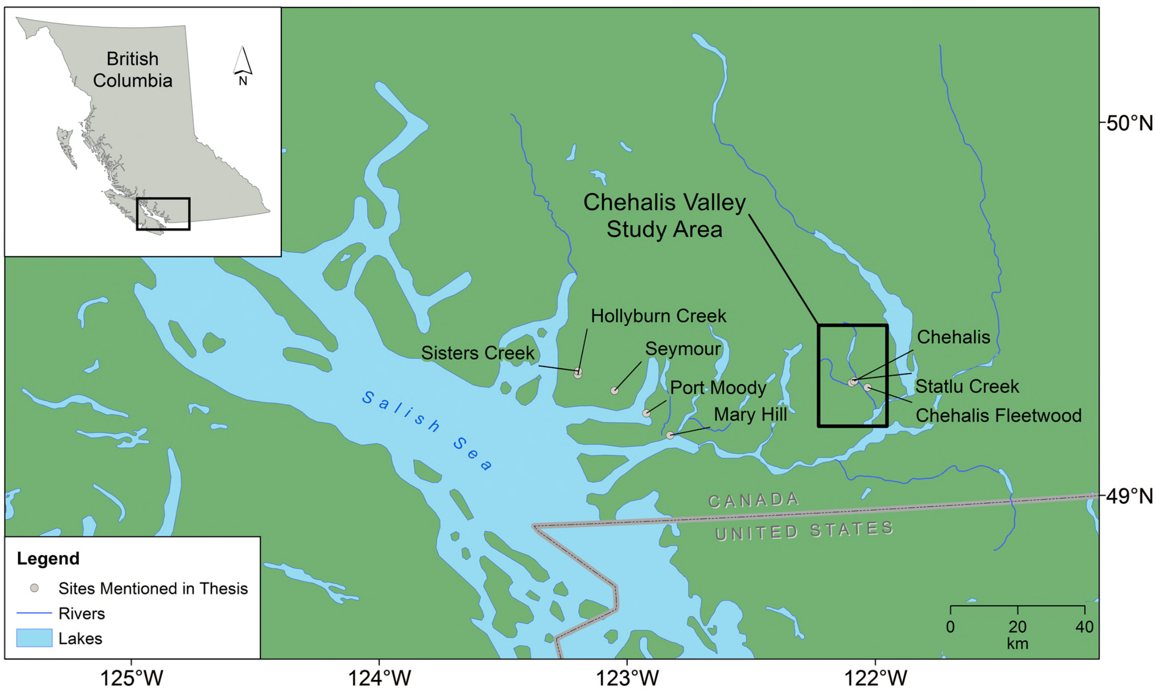

Figure 1-1. Southwest British Columbia with Port Moody Interstade sites and Chehalis Valley study area highlighted.

1.1 Chehalis Valley Study Area

The study area comprises the lower Chehalis River and Statlu Creek valleys within the Pacific Ranges of the Coast Mountains in southwest British Columbia (Figure 1-1). Chehalis River flows south from its headwaters for approximately 40 km to Harrison River. Statlu Creek flows west for approximately 12 km before joining Chehalis River, 10 km above the mouth near Harrison Mills. Chehalis and Elbow lakes are within the watershed, but Chehalis Lake is north of the study area and Elbow Lake is to the south. The Chehalis watershed is 245 km^2 in area and ranges in elevation from 20 m above mean sea level at the mouth to more than 2000 m above mean sea level in the northern headwaters. Statlu Creek drains a smaller watershed, 95 km^2, with elevations from 200 m to 1200 m above mean sea level.

Chehalis Valley has a history of timber harvesting, spanning over 100 years. Resource development has led to instability along roads and within forest cutblocks (McCombs and Chittenden, 1988). Some of these landslide scars reveal thick (>50 m) sediments, and other places have more than 100 m of Pleistocene sediments (Ward and Thomson, 2004). The study focuses on three sections within the study area that were exposed either through forest development and road building or by erosion.

1.1.1 Geology

There are two bedrock units in the study area. The first, located on the east side of Chehalis River and along Statlu Creek, is Lower Jurassic-aged intermediate and felsic volcanic rocks with associated volcaniclastic sediments of the Harrison Lake Formation (Monger and Journeay, 1994). The west side of Chehalis River and the area west of the Statlu Creek headwaters are underlain by Early to Late Jurassic-aged quartz diorite of the Mount Jasper pluton.

Harrison Lake Formation rocks are part of the Harrison Terrane, which is dominated by a thick succession of intermediate to acidic flows and pyroclastic rocks (Monger and Journeay, 1994). The volcanic successions represent relics of volcanic arcs of the Wrangellia Terrain dating to early Jurassic time. The Gambier Assemblage, an early to mid-Cretaceous-aged overlap assemblage, sits on the west side of Chehalis River.

Sediments in the study area are similar to those in other glaciated valleys in southwest British Columbia (cf. Clague, 1985). The valley is filled with thick sediments of mixed glacial and nonglacial origin. With increasing elevation up the valley sides, the sediments change from fluvial to glaciofluvial and glaciolacustrine to till with deglacial sediments capped by modern colluvial sediments (Ward and Thomson, 2004). The valley preserves pre-Fraser Glaciation sediments because it is narrow, has an irregular bedrock topography, and advance glaciolacustrine sediments that combined to inhibit glacial erosion.

The modern climate in Chehalis Valley is temperate, with a mean annual temperature of 8.6 °C and mean annual precipitation of 2160 mm (Wang et al., 2012). The ecosystem is classed as the coastal western hemlock very wet maritime (CWHvm1) biogeoclimatic zone (BC Ministry of Forests, 2008).

Chehalis Valley soils are Podzols, with Ferro-Humic and Humo-Ferric great groups present (*cf.* Soil Landscapes of Canada Working Group, 2010). They form under a temperate rainforest, with high precipitation and cool temperatures, on coarse-textured and acidic parent materials. In the lower elevation valley bottom adjacent to Chehalis River and Statlu Creek, there are some Duric Humo-Ferric Podzols that formed on glaciofluvial terraces.

1.1.2 Exposures

This study is based on three exposures (Table 1-1 and Figure 1-2). The first exposure, CH01, is located approximately 9 km up the Chehalis Forest Service Road (FSR). The exposure is a road cut that was refreshed during 2007 or 2008 when the bridge over Statlu Creek was replaced. Ballast material used for armouring the bank of Statlu Creek was blasted from bedrock at the base of the exposure. It is likely that gravels from the exposure were used for road construction.

Table 1-1. List of studied exposures.

Exposure Name	GPS Coordinates [A]	Elevation (m)	Location Description
CH01	10U 570995 5466703	150	On Chehalis FSR, approximately 1 km east of Statlu Creek bridge
CHFW01	10U 574893 5464646	160	West of Chehalis-Fleetwood FSR on older overgrown branch road
ST03	10U 570212 5466204	175	On south side of Statlu Creek, approximately 1.5 km upstream of Statlu Creek bridge. Accessed via deactivated road off Chehalis FSR

[A] Coordinate datum is NAD 83 UTM Zone 10.

The second exposure, CHFW01, is located on a branch of the Chehalis-Fleetwood FSR. A wood box culvert on the branch road became plugged with raveling gravels from a deltaic deposit and subsequently failed, exposing sediment under the former road surface. The modern landslide came to rest in a creek at the base of the slope, and the debris was subsequently washed away, leaving approximately 30 m of undisturbed late Pleistocene sediments exposed.

The third exposure is situated on the south bank of Statlu Creek. The exposure is best accessed from the top, via a deactivated branch road on the south side of Statlu Creek. Since the exposure is nearly vertical and approximately 30 m high, access is difficult and requires specialized safety equipment.

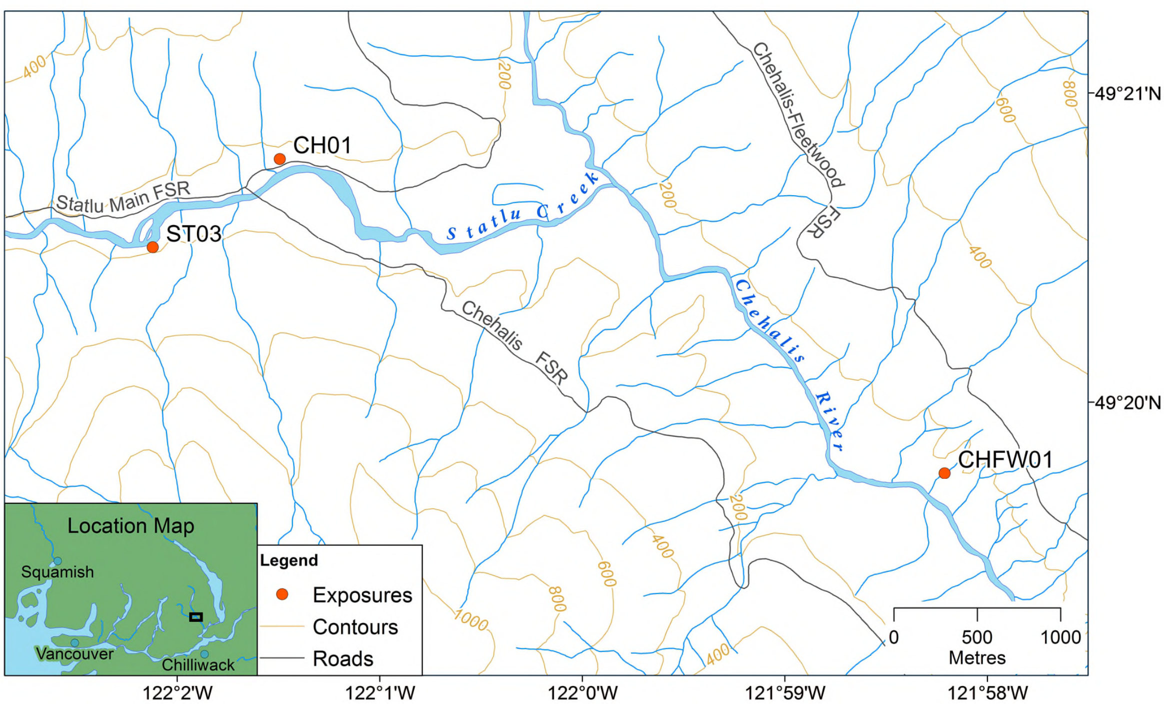

Figure 1-2. The location of three exposures examined during this study.

1.2 Project Evolution

Initially, this intent of this project was to study paleosols from Marine Isotope Stage (MIS) 3 in southwestern British Columbia. As it became apparent that exposures with known but unstudied paleosols would be nearly impossible to relocate, the study shifted focus to Chehalis Valley. Before the focus shifted, relocation of previously reported sites with paleosols was attempted and results are documented for future researchers. The sites were Rialto Creek near Castlegar, a road cut near Cherryville, Riggins Road near Lumby, and Sweetsbridge near Falkland. R. J. Fulton, the original investigator, revisited the last three sites. The Rialto Creek site was a borrow pit used during construction of a dam on the Columbia River (Westgate and Fulton, 1974). The sediments are no longer visible in the pit. Either the material that contained the paleosol was excavated when the pit was in use, or it was covered by slumping sediments and subsequently returned to forested vegetation. This site appears to have no potential for paleosols. The Cherryville exposure was located on a road cut adjacent to Highway 6 (Westgate and Fulton, 1974). The road was not relocated. It may be possible to find other exposures with similar stratigraphy near Cherryville but will likely require good fortune to visit the area during road construction. The Riggins Road exposure is located on Bessette Creek north of Lumby (Westgate and Fulton, 1974; Fulton and Smith, 1978). It is the type section for the MIS 3 Bessette Sediments. Although the exposure dates from MIS 3, it does not have a paleosol. The Sweetsbridge paleosol was reported (Westgate and Fulton, 1974) on the north side of the Salmon River and Highway 97 midway between Falkland and Vernon. The exposure was not relocated because the exposure was either overgrown since the site was described in the 1960s or it is located on private land with restricted access.

1.3 Previous Work/Literature Review

1.3.1 Stratigraphy of Southwest British Columbia

The late Pleistocene stratigraphic framework of southwest British Columbia (Figure 1-3) describes glacier advances and recessions during Fraser Glaciation. Evidence for the Coquitlam Stade between 21,700 ± 130 ^{14}C years BP (GSC 2416) and 18,700 ± 170 ^{14}C years BP (GSC-2344) (Hicock and Armstrong, 1981) was discovered at few sites in the western Fraser Lowland. Coquitlam Drift was first identified at a gravel pit in the Coquitlam watershed (Hicock and Armstrong, 1981). Additional locations with Coquitlam Drift, identified after it was first described, include Seymour River, Sisters Creek, and Hollyburn Creek (Lian and Hickin, 1993; Hicock and Lian 1995). It comprises till, glaciofluvial, ice-contact, and glaciomarine sediments (Hicock and Armstrong, 1981).

The Port Moody Interstade followed the Coquitlam Stade. The Sisters Creek Formation represents the Port Moody Interstade in the Fraser Lowland (Hicock and Lian, 1995). The holostratotype is located near Sisters Creek in the Capilano watershed in North Vancouver and parastratoptypes are within the Seymour Demonstration Forest and a now-closed landfill in Port Moody. The sediment at the Sisters Creek exposure is organic-rich silty sand that was dated to 17,700 ± 320 ^{14}C years BP (GSC-5723). Evidence, including root traces and colour changes, suggests the sediment experienced subaerial weathering. Port Moody sediments at the Port Moody Landfill site include a sequence of organic-rich silt and peat that was dated to 18,300 ± 170 ^{14}C years BP (GSC-2322). Lian and Hickin (1993) describe Sisters Creek sediments in the Seymour Valley. The sediments there are a single, organic-rich bed. These sediments appear to be reworked, but because they directly overlie Coquitlam Drift, they must have been deposited soon after. A 10-cm diameter log from just above the organic bed in Seymour Valley was dated to 18,490 ± 90 ^{14}C years BP, and a 50 cm log was dated to 17,600 ± 130 ^{14}C years BP, and a wood fragment from within the bed was dated at 17,910 ± 100 ^{14}C years BP. Port Moody sediments were deposited between 18,500 and at 17,500 ^{14}C years BP at these sites on the north shore of the Fraser River near Vancouver.

The ecosystem during the Port Moody Interstade, based on pollen recovered from peaty sediments, was a subalpine forest and parkland with fir and spruce growing under a temperate and moist climate, similar to the modern Engelmann Spruce Subalpine fir (ESSF) ecosystem (Lian et al., 2001). The fossil beetle assemblage indicates that there was an open forest, with some species that are now found at higher elevation in subalpine forests (Miller et al., 1985).

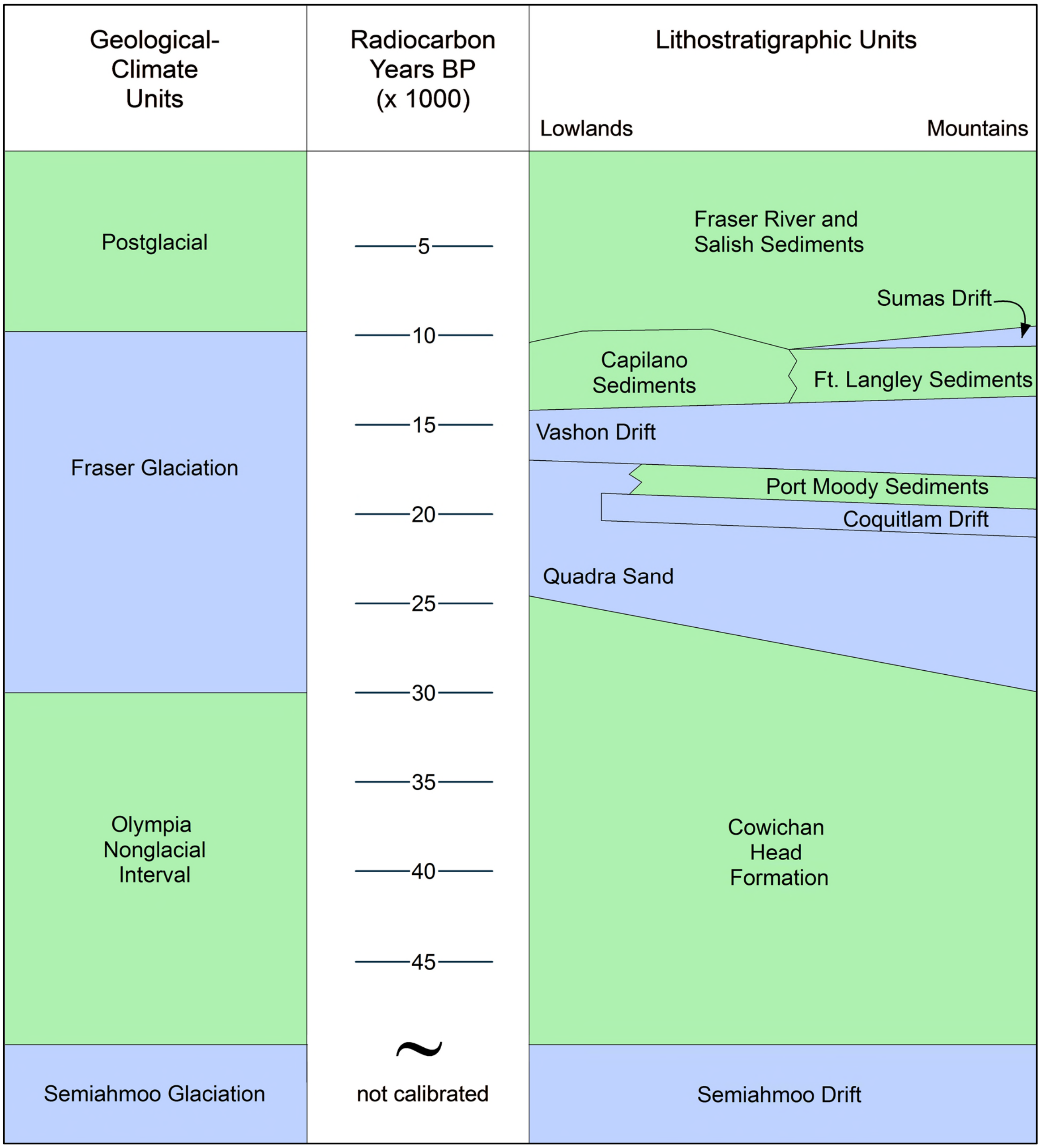

Figure 1-3. Generalized stratigraphic framework for southwest British Columbia (modified from Ward and Thomson, 2004).

Table 1-2. Radiocarbon dates from Port Moody Interstade sediments in southwest British Columbia.

Age (years BP)*	Lab Number	Material	Section	Locality	Reference
17,910 ± 100	Beta 40689	Wood	SVMS-13	Seymour Valley	Lian and Hickin, 1993
17,600 ± 130	Beta 38907	50 cm log	SVMS-11	Seymour Valley	Lian and Hickin, 1993
18,490 ± 90	Beta 38908	10 cm log	SVMS-9	Seymour Valley	Lian and Hickin, 1993
17,700 ± 320	GSC-5723	Wood	-	Sisters Creek	Hicock and Lian, 1995
18,000 ± 170	GSC-5691	*Abies* sp.	-	Sisters Creek	Hicock and Lian, 1995
18,600 ± 170	GSC-5656	*Abies* sp.	-	Hollyburn Creek	Hicock and Lian, 1995
18,300 ± 170	GSC-2322	*Abies* sp.	-	Port Moody Landfill	Hicock and Lian, 1995
18,600 ± 190	GSC-2194	*Picea* sp.	-	Mary Hill	Hicock and Lian, 1995
18,700 ± 170	GSC-2344	*Taxus brevifolia*	-	Mary Hill	Hicock and Lian, 1995

*All dates in this thesis are reported as uncalibrated radiocarbon years.

The ESSF is a subalpine ecosystem at high elevation near treeline. The dominant coniferous trees are Engelmann spruce (*Picea engelmanii)* and subalpine fir (*Abies lasiocarpa)*, with patches of heath, meadow, and grassland (Coupe et al., 1991). Typically, it has a cold, moist, and snowy continental climate with cool, short growing seasons and long, cold winters. Mean annual temperatures range from -2 ºC to +2 ºC, with a brief two month frost-free period. The ecosystem has variable precipitation because its high elevation and mountainous location adds a strong local control to precipitation.

Chehalis Valley

The Late Pleistocene history of Chehalis Valley is the focus of a 2004 study based on more than sixty sections (Ward and Thomson, 2004). The oldest sediments date to the Olympia nonglacial interval and are fluvial in origin. They record significant aggradation when base levels were higher than at present.

Overlying sediments were deposited in glacial environments. The valley was occupied by a lake that expanded when glaciers advanced across its mouth during the Fraser Glaciation. The valley sediments pass upward from glaciolacustrine to till, indicating ice cover. A second glaciolacustrine unit that marks the transition from ice cover to blockage of the mouth of the valley during deglaciation conformably caps the till. Three deltas in the study area record flow into the late glacial lake at successively lower levels as deglaciation progressed.

Ward and Thomson (2004) described generalized stratigraphic units in Chehalis Valley (Figure 1-4). Unit 1 is up to 11 m thick and lies about 20 to 25 above the present active channel of Statlu Creek. It comprises coarse-textured, clast-supported gravel with crude stratification and better sorting in its lower half. The clasts are rounded to subrounded, with few subangular clasts. Lithologies are granitic with few clasts of volcanic origin. At the S9 section, a 2.5 m thick organic-rich silt lens within Unit 1 was described (Ward and Thomson, 2004). It is well-stratified with silty very fine sand at the base coarsening upwards to medium sand. The organics are concentrated at the base of the lens and radiocarbon ages (Table 1-3) from a wood fragment and a twig are 19,850 ± 150 (WAT4254) and 20,060 ± 190 (AA50799). Radiocarbon ages from Unit 1 span the period from 29,820 ± 370 ^{14}C years BP (TO-9191) to 19,850 ± 150 ^{14}C years BP (WAT-4254). Ward and Thomson (2004) concluded that Unit 1 is fluvial deposition by aggrading ancestral Statlu Creek, in response to climatic deterioration associated with the onset of the Fraser Glaciation. They provided three rationale to explain the silt lens, a local glacial advance blocking Statlu Valley, a regional glacial advance blocking Chehalis Valley, or a local blockage by a landslide. Because the lens had a small extent, they favoured the third option. Subsequently, the gravel facies was reinterpreted to represent an oscillation of the blockage at the mouth of the Chehalis Valley.

Unit 2 is laminated silt and sand. The deposit is present in most exposures in the area and has a maximum thickness of 35 m. The lower beds of this unit contain abundant macrofossils and organic detritus. Material from four locations returned radiocarbon ages in the range between 19,500 ± 170 ^{14}C years BP (WAT-4285) and 17,380 ± 130 ^{14}C years BP (TO-9158). It is interpreted as dominantly low energy deposit in a glacial lake, formed from turbid underflow and suspension settling that became increasingly proximal upward as the glacier advanced up the valley (Ward and Thomson, 2004).

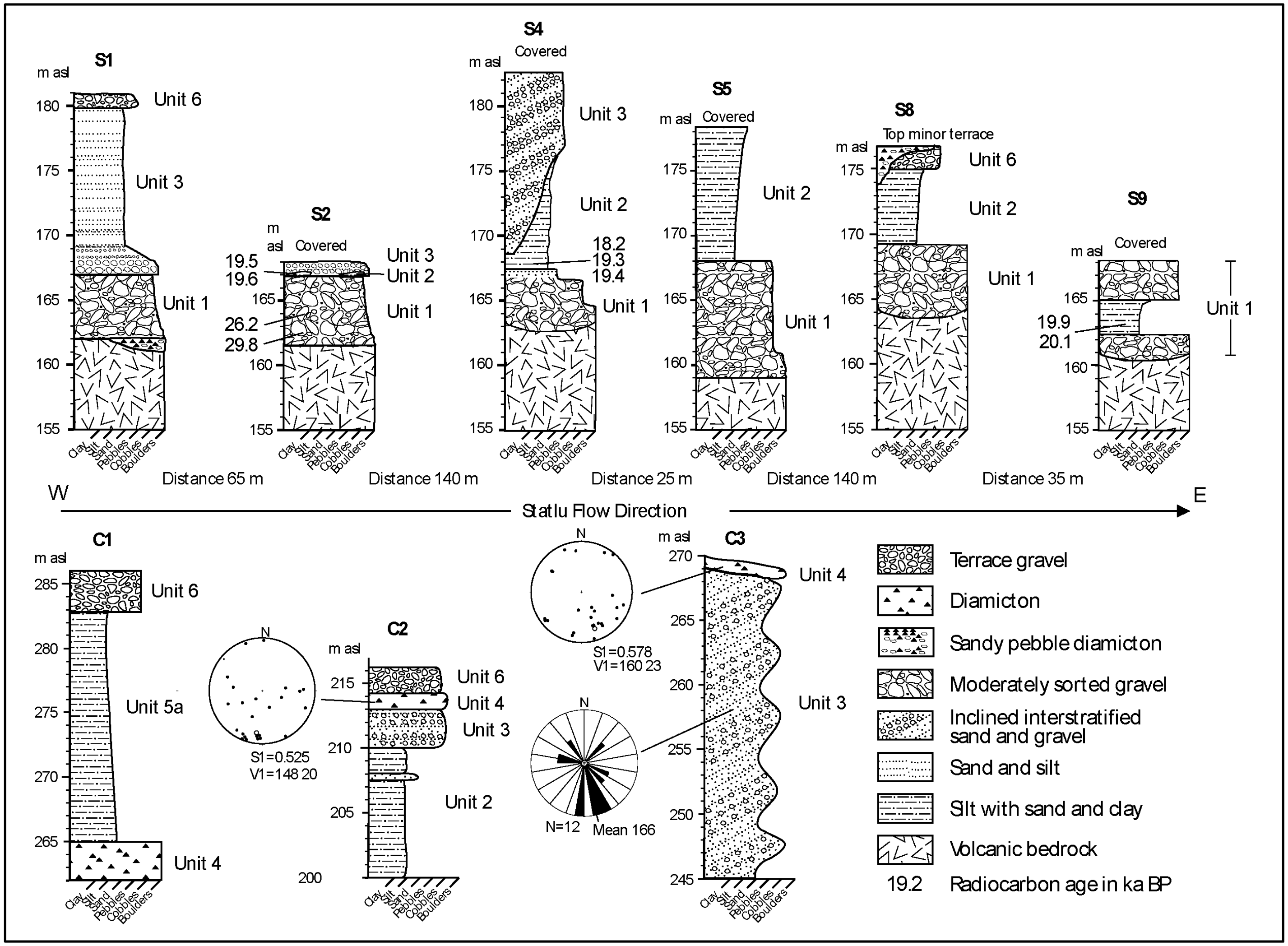

Figure 1-4. Stratigraphic logs showing units previously described in Chehalis Valley (Ward and Thomson, 2004, modified from their Figure 4).

Table 1-3. Radiocarbon Ages from Chehalis Valley (modified from Ward and Thomson, 2004).

Sample Number (BCW)	Age (years BP)	Lab. Number[a]	C^{13}	Material	Locality	Significance
010600-M1B	17,380±130	TO-9158	N/A	*Picea* sp. (spruce) twig terminal	CF2, Unit 2	Glaciolacustrine ponding event, macrofossils
010600-M1A	17,820±140	TO-9157	N/A	*Abies lasiocarpa* (sub alpine fir) needles	CF2, Unit 2	Glaciolacustrine ponding event, macrofossils
010600-M1C	18,380±100	AA48004	-24.9		CF2, Unit 2	Glaciolacustrine ponding event, macrofossils
071101-M1B	18,180±160	AA46118	-24.2	*Picea* sp. (spruce) twig terminal	Statlu	Glaciolacustrine ponding event, macrofossils
050601-M2	18,600±200	AA46122	-26.3	*Sambucus* sp. (elderberry) seeds (~6)	CF1, Unit 2	Glaciolacustrine ponding event, macrofossils
160698-W3	19,150±110	WAT-4169	-24.92	Wood – *Abies* spp. (Western fir)	CF2, Unit 2	Glaciolacustrine ponding event, macrofossils
110698-W3	19,300+150-140	WAT-4253	-23.53	Wood – *Picea sitchensis* Sitka Spruce	S4, Unit 2	Glaciolacustrine ponding event, macrofossils
110698-W1	19,400±120	WAT-4168	-26.09	Wood – *Abies spp.* (Western fir)	S4, Unit 2	Glaciolacustrine ponding event, macrofossils
100698-W1	19,600±170 19,500±170	WAT-4288 WAT-4285	-26.45	*Picea* spp.	S2, Unit 2	Glaciolacustrine ponding event (two analysis of same wood)
050601-M1	19,550±150	WAT-4255	-24.58	Bark (?) Peat (?)	CF1, Unit 2	Glaciolacustrine ponding event, macrofossils
280401-W1	19,850±150	WAT-4254	-28.2	Wood – *Abies* spp. (Western fir)	S9, Unit 1	Fine-grained lens (glaciolacustrine?) Unit 1
280401-M3	20,060±190	AA50799	-23.4	*Abies* sp. twig terminal	S9, Unit 1	Fine-grained lens (glaciolacustrine?) Unit 1
250500-M3	26,150±330	AA44046	-24.3	Charcoal	Statlu-upstream	Interstadial gravel of unit 1
250500-M4	29,820±370	TO-9161	N/A	Charcoal	Statlu-upstream	Interstadial gravel of unit 1

[a] Laboratories: TO IsoTrace, University of Toronto; AA Arizona; WAT Waterloo.

Unit 3 is composed of interstratified sand and gravel and has a maximum thickness of more than 25 m. The lower contact is erosional. Unit 3 sediments were interpreted as subaqueous outwash based on the interstratification, continuous bedding of fine sand and silt, presence of lonestones, and lateral fining typical of a glaciolacustrine environment (Ward and Thomson, 2004).

Unit 4 is a diamicton with a dense, overconsolidated silty sand matrix and 30% to 35% clasts. The clasts are mostly subround to subangular pebbles with striae and facets. This sediment is interpreted as till deposited by ice flowing down Chehalis Valley (Ward and Thomson, 2004).

Unit 5a is up to 19 m of silt and sand that ranges from laminated beds with normal grading to massive silt. It records deposition in a glacial lake that shifted in extent as ice retreated both up and down the valley. The normally graded laminated beds represent turbid underflows, and the massive beds likely represent either rapid deposition or resedimentation from subaqueous mass wasting events (Ward and Thomson, 2004).

Unit 5b is foreset bedded gravel capped by horizontally bedded gravel that is present in Chehalis Valley at Maisel Creek, on the east side of the valley near CHFW01, and near the present mouth of Chehalis River. The beds are composed of moderately to well-sorted gravel to pebbly coarse sand. This unit represents the foreset and topset beds of deltas deposited by streams flowing into the glacial lake in which the sediments in Unit 5a were deposited (Ward and Thomson, 2004).

Unit 6 is composed of a wide range of sediments including terrace gravel and colluvial diamicton. Ward and Thomson (2004) interpreted this unit as paraglacial, with source areas and deposition governed by the previous glaciation.

1.3.2 Paleopedology

Paleopedology is the science of paleosols, soils that formed on a past landscape under environmental conditions that no longer act on the soil either because of significant environmental and climate change or due to burial (Schaetzl and Anderson, 2005). Paleosols are studied to glean information about past soil-forming environments

(Retallack, 2001; Schaetzl and Anderson, 2005). They provide indirect evidence about past environments because they are rarely preserved as complete soils and they may undergo post-burial alteration (Schaetzl and Anderson, 2005).

Paleosols are difficult to identify so specific criteria are required to confirm their presence. They are identified by patterns of organic matter and clay content enrichment with depth (Schaetzl and Anderson, 2005). Clay content is depleted in surface horizons then increases with depth as translocated clay accumulates. Organic matter content is greatest near the top of the profile and decreases with depth. They can also be identified based on the presence of root traces, soil horizons, and other pedogenic features such as peds, columns, and clay skins (Retallack, 2001; Retallack in Schaetzl and Anderson, 2005).

Applying modern soil description methods to paleosols assumes that the ancient soil forming factors and processes are the same as modern soil forming factors and processes (Catt, 1990). This method does not account for post-burial alterations that change the morphological and chemical properties of the soil. Such post-burial changes can obscure features used to interpret soil formation and can lead to misclassification of the soil when using a classification developed to classify modern soils.

Post-burial paleosol modifications include soil welding, sediment mixing, cryoturbation, deposition, thermal alteration, and dust accumulation (Ruhe and Olson, 1980; Olson and Nettleton, 1998). Welded soils form due to shallow burial, continued sediment aggradation, or truncation, which allows soil formation to continue on the newly modified surface (Olson and Nettleton, 1998). Truncation of paleosols occurs when upper horizons are eroded or oxidized. Sediment mixing occurs when a truncated soil or a remnant eroded surface is incorporated into the next phase of soil development. Cryoturbation is mixing of the soil related to frost action (Soil Classification Working Group, 1998) that is associated with the presence of permafrost. Continued deposition is common in loess landscapes, where burial permits decomposition of organic matter in buried A horizons, rendering them morphologically indistinct from buried B horizons (Olson and Nettleton, 1998). When soils are buried by lava, the temperatures are high enough to convert iron oxides to hematite, creating a bright reddish hue. Another source of heat that alters paleosols is burning coal seams. Finally, relict soils or unburied paleosols formed under environmental conditions different than at present are altered by accumulating tropospheric dust. The dust adds carbonates, salts, and clay minerals to the surface, weakening the usefulness of those properties for paleosol classification (Olson and Nettleton, 1998).

Soils form on stable land surfaces through the interaction between environmental and sedimentary factors (Catt, 1990). Soils are a function of:

$$s=f(cl, o, r, p, t) \qquad \text{(Equation 1)}$$

where s is soil, cl is climate, o are organisms, r is topography, p is parent material, and t is time (Jenny, 1941). There are four general classes of soil forming processes: additions, losses, translocations, and transformations (Brady and Weil, 1999). Additions include organic matter at the surface, precipitation, and airborne particles. Transformations include weathering of primary minerals, organic matter decomposition, formation of secondary minerals, and mottles. Ions and solids are lost when they move in soil water downward through the soil profile. Mobile substances, such as Fe, Al, Si, bases, HCO_3^-, and organic compounds, readily move with percolating water until they precipitate out of solution. Silt and clay are translocated down the profile (Birkeland, 1999). Together, these factors and processes work together to create soils with unique combinations of morphological, chemical, and mineralogical properties (Catt, 1990; Brady and Weil, 1999).

1.3.3 Podzolic Soils

Podzols, common mineral soils in British Columbia, possess a distinct B horizon enriched in amorphous organic matter and Fe and Al oxides (Schaetzl and Isard, 1996) overlain by an eluviated A horizon. The A horizon is similar in appearance to ash and explains the name Podzol, which means “under ash” in Russian (Lundström et al., 2000; Sanborn et al., 2011). Podzols have an Ae – Bf – C horizon sequence (Sanborn et al., 2011). Podzolization is the downward movement of organic matter and soluble minerals, especially Fe and Al, in a soil profile. Podzolic soils typically form on coarse-textured parent materials, under a coniferous forest, with significant precipitation to facilitate the eluviation/illuviation processes that translocate material down the soil profile (Birkeland, 1999; Schaetzl and Isard, 1996).

Climatic conditions that favour podzolization in humid and perhumid climates are mean annual precipitation greater than 1200 mm, thick snowpacks, rain-on-snow events, high spring infiltration rates, and intense precipitation events (Schaetzl and Isard, 1996). These conditions promote eluviation and illuviation and the formation of Ae and Bf horizons. A thick snowpack prevents the soil from freezing during winter, which has the dual effects of allowing both snowmelt to infiltrate the soil during spring melt and decomposition of the acid-generating litter to continue during the winter (Schaetzl et al., 2015). Saturation due to snowmelt is significant since there is a steady supply of water to facilitate translocation of Fe and Al weathered from minerals and organic matter in upper soil horizons. The water is enriched with organic acids generated from the decomposing leaf and needle litter that facilitates weathering, further enhancing podzolization. The depth that the snowmelt reaches in the profile is controlled by intense, brief snowmelt conditions.

Soil parent material is an important factor for podzolization. Parent material imparts characteristics to the soil including texture, mineral composition, and drainage. Coarse soil textures enhance infiltration (Schaetzl and Isard, 1996; SCWG, 1998). In addition, coarse-textured soils tend to lack base cations (Lundström et al., 2000). Finally, coarse-textured soils are rapidly, well-, and moderately well-drained (Evans and Wilson, 1985).

The final factor that is critical for podzolization is vegetation. Podzols are associated with coniferous forests, heath, bog, and fen vegetation (Evans and Wilson, 1985; Lapen and Wang, 1999; Bockheim, 2011). Specifically, these vegetation types generate abundant acidic litter that accelerates weathering and chelation processes (Schaetzl and Isard, 1996). In addition, stemflow from trees increases podzolization, likely due to increased weathering and litter decomposition (Crampton, 1982).

Podzolization involves weathering of primary minerals, secondary mineral formation, leaching, eluviation/illuviation, and organic matter accumulation (Schaetzl and Isard, 1996; Birkeland, 1999). Fe and Al weather from primary minerals in the uppermost part of the soil profile (Lundström et al, 2000) and form complexes with organic acid derived from the breakdown of litter that subsequently moves down through the soil profile (Blume and Schwertmann, 1969; Lundström et al., 2000). Soluble forms of Fe, Al, and organic matter are translocated from an upper A horizon to a lower B horizon.

The ions released by weathering (Fe, Al, Si) react with other material in the soil, adsorb to soil colloids, and move down the soil profile by leaching (Birkeland, 1999). Formation of secondary Fe minerals depends on pH and Eh conditions. Eh is a measure of the ability of the environment to foster oxidation or reduction (McBride, 1994). Under oxidizing conditions, Fe^{2+} released from primary minerals during weathering becomes Fe^{3+}. The resulting products are insoluble at normal soil pH values so they immediately precipitate. Under reducing conditions, Fe^{2+} is stable and can migrate some distance from the weathering site before precipitating. Reducing conditions are generally associated with an aquic (saturated) soil moisture regime (Birkeland, 1999).

In the illuvial Podzolic B horizon, Al takes the form of imogolite, proto-imogolite, and allophane (Farmer et al., 1980; Evans and Wilson, 1985). Proto-imogolite forms the mobile Al fractions that are responsible for the downward migration of Al in Podzols because they are stable at $pH < 5$ (Farmer et al., 1980). Imogolite-type material (ITM) may be the source of Si and Al found in cemented horizons (Farmer et al., 1980).

Fe occurs in Podzols in noncrystalline form (ferrihydrite), as crystalline goethite, and as organically bound free Fe (Evans and Wilson, 1985). Ferrihydrite is the iron material that imparts the distinct bright colours of the Podzolic B horizon (Birkeland, 1999).

Amorphous aluminosilicates in soils are noncrystalline and are present in low concentrations (Birkeland, 1999). Pedogenic Fe and Al occur as thin films on soil particles and are consequently difficult to recognize by visual means therefore chemical extractants are used to indicate their presence (Birkeland, 1999). Selective dissolution methods are used to extract different forms of secondary Fe, Al, and Si in soils (Parfitt and Childs, 1988; Birkeland, 1999). Three treatments are used to dissolve Fe and Al: dithionite-citrate (d), oxalate (o), and pyrophosphate (p) (Parfitt and Childs, 1988). Dithionite-citrate extracts crystalline (goethite and hematite), amorphous (ferrihydrite), and organically-bound Fe; oxalate extracts amorphous (ferrihydrite) and organically bound Fe; and pyrophosphate extracts Fe complexed with organic matter (Evans and Wilson, 1985; Parfitt and Childs, 1988). Dithionite and oxalate extract Al bound in amorphous allophane and imogolite (Gustafsson et al., 1999); and pyrophosphate extracts organically bound Al (Evans and Wilson, 1985).

Concentrations of each element provide a measure of the amount, form, and source of pedogenic Fe and Al in the soil (Blume and Schwertmann, 1969; Parfitt and Childs, 1988; Birkeland, 1999). For example, pyrophosphate extracts organically bound Fe and oxalate extracts Fe on both amorphous inorganic (ferrihydrite) and organically bound forms (Parfitt and Childs, 1988). Table 1-4 summarizes ratios that provide additional insight into the form of Fe and Al in Podzolic soils.

Table 1-4: Extractant ratios and their significance.

Extractant ratio	Significance	Reference
$1.7(Fe_o)$	Concentration of ferrihydrite	Parfitt and Childs, 1988
Fe_d- Fe_o	Crystalline Fe oxides (e.g., goethite, hematite)	Parfitt and Childs, 1988
Fe_p and Al_p	Organically complexed Fe and Al	McKeague, 1967
Fe_o/Fe_d	Proportion of extractable Fe that is ferrihydrite; index of crystallinity	Evans and Wilson, 1985
Al_o-Al_p	Al in imogolite and allophane	Evans and Wilson, 1985
$(Al_o-Al_p)/Si_O$	Al:Si ratio of allophanic materials	Evans and Wilson, 1985

The Fe activity ratio (Fe_o/Fe_d) is a measure of amorphous pedogenic Fe (i.e., ferrihydrite) as a proportion of the extractable secondary forms of Fe (Evans and Wilson, 1985) and measures the crystallinity of free Fe oxides. The ratio is high in Podzolic horizons due to the high organic matter content that inhibits crystallization (Blume and Schwertmann, 1969). A study of Canadian Podzols found an average activity ratio of 0.87, indicating amorphous Fe in the soils (Evans and Wilson, 1985).

Placic horizons are thin (<1 cm), indurated horizons that are impermeable to water (SCWG, 1998). They can be a single layer or a series of thin layers. They are hard, impervious, generally vitreous, and are dark reddish brown to black coloured (Campbell and Schwertmann, 1984; SCWG, 1998). A placic horizon usually has a wavy form, lies nearly parallel to the soil surface, commonly within 40 cm of surface. Fe, Al-organic complexes, hydrated Fe oxides, or a mix of Mn and Fe oxides cements the horizon (SCWG, 1989).

Placic horizons form by downward and lateral translocation of Fe with Fe_o values ten times greater than overlying horizons. They generally have large Fe_o/Al_o ratios (Pinheiro et al., 2004). The iron-rich minerals in placic horizons are ferrihydrite, goethite, and lepidocrite (Campbell and Schwertmann, 1984; Pinheiro et al., 2004). Ferrihydrite and goethite minerals are dominant in placic horizons, suggesting they are the cementing agents (Valentine, 1969; Bockheim, 2011). Lepidocrite indicates hydromorphic conditions, perhaps caused by the cemented horizon. This mineral was found in 66% of placic horizons in one study (Campbell and Schwertmann, 1984).

The genesis of placic horizons is not fully understood, but they form when Fe precipitates. Precipitation may be caused by slight changes in soil texture, which creates a perched watertable, or a change in porosity allowing enrichment in organic matter. In both cases, Fe precipitates due to higher oxidation potential (Eh) or pH at depth (Lapen and Wang, 1999; Bockheim, 2011).

Placic horizons are important indicators of the soil-forming climate conditions. Specifically, they are associated with mean annual precipitation between 2400 and 3900 mm/yr with an average of 3200 mm/yr (Bockheim, 2011). They are associated with conifers, tropical montane, or bog vegetation (Lapen and Wang, 1999; Bockheim, 2011). Placic horizons are found on the east coast of Haida Gwaii, the east coast of Newfoundland, and the west coast of Vancouver Island – all areas with high precipitation, coarse textured parent material and forest or bog vegetation that ensures an acidic soil pH (Valentine, 1969; Lavkulich et al., 1971). The parent material in the described profile on the west coast of Vancouver Island is sandy gravelly outwash deposits, the climate is mild with an annual precipitation of 3450 mm, and the vegetation is coastal coniferous forest (Lavkulich et al., 1971).

1.3.4 Macrofossils

Macrofossils are fossils that are large enough to see without a microscope and are preserved in sediment (Birks, 2001). They are the remains of plants, insects, and animals and are representative of the local environment at the time of deposition when they can be identified to the genus and species level (Birks, 2001). Plant macrofossils provide a more precise indication of past vegetation than pollen alone, but they may poorly represent regional conditions (Birks, 2001). Coniferous needles are well preserved as macrofossils and are useful for identifying tree species (Dunwiddie, 1987).

Dunwiddie (1987) found a strong correlation between the coniferous tree species in a source forest and macrofossils recovered from nearby ponds. Macrofossil percentage data had a 1:1 relationship when compared to the basal area for each tree species along his topographic transect on Mount Rainier in Washington. Basal area is the area of land occupied by tree trunks, with diameters measured at breast height expressed as a percentage of the total forest composition. The relationship between macrofossil percentage data and basal area has been used at other sites in the Pacific Northwest to describe the forest composition approximately 18,000 years ago (Hicock et al., 1982). Here, plant macrofossils indicated that there was a cold humid continental climate approximately 18,000 years ago similar to the modern Engelmann spruce subalpine fir (ESSF) Biogeoclimatic Ecosystem Classification (BEC) zone.

Insect macrofossil analysis is less commonly used for reconstructing past environments. However, insect macrofossils can improve or refine paleoenvironmental reconstructions. Beetle macrofossils were collected at the Port Moody and Mary Hill sites in sediment dated at 18,300 and 18,700 ^{14}C years BP (Miller et al., 1985). The assemblages proved useful for augmenting the existing paleoclimatic interpretations. Miller et al. (1985) found several beetle species that live in alpine or subalpine forests. *Notiophilus sylvaticus* Eschscholtz is a ground beetle associated with gravel sediments and open subalpine forest. *Micropeplus laticollis* Mäklin is a rove beetle that lives on the forest floor of a subalpine forest composed of fir, pine, and spruce. *Phloeotribus lecontei* Scedl is a Douglas-fir bark beetle. *Bembidion* sp. are ground beetles that live on bare soil or at the edges of standing or slowly flowing water.

1.4 Thesis Objectives and Organization

Several sites in Chehalis Valley expose sediment deposited in the Late Pleistocene during the transition from non-glacial to glacial conditions. This study is based on an examination of three exposures, with the objective of testing the regional nature of the Late Pleistocene stratigraphy. Paleoenvironments are reconstructed from stratigraphy, paleosol interpretation, and plant and insect macrofossil evidence.

Research methods and results derived from paleopedology and macrofossil analysis are described and presented, respectively in Chapters 2 and 3. New radiocarbon dates that constrain the timing of the shift from nonglacial to glacial conditions are presented in Chapter 3. The paleoenvironmental reconstruction and its regional significance are discussed in Chapter 4. Conclusions from this study and recommendations for future research are presented in Chapter 5.

Chapter 2. Methods

Information from the two paleosols found in the valley provides some information about the local climate. This information is supplemented by plant and insect macrofossil data. The macrofossil evidence comes from two datasets, an older data set collected between 1998 and 2001 and a set that I collected between 2012 and 2014. The earlier macrofossils were sent to a laboratory for analysis, but were never fully interpreted. All macrofossil samples were processed and identified in the same laboratory.

2.1. Stratigraphy

The stratigraphic framework for Chehalis Valley is based on interpreting the sediments exposed at three sites (Figure 1-2). The sites were selected because they were known to have paleosols, were accessible, and had sediment from the time of interest.

At each exposure, the sediment was described from a distance to identify the most obvious units and to measure the height and width of the exposure using a laser range finder. Once the main units were identified, the units that either had a paleosol, as at CH01, or were likely to have been deposited during the Fraser Glaciation were examined in greater detail. Bed thickness, grading, sorting, texture, colour, and relationship to adjacent strata were described. Drawings were made and photographs taken. Samples of organic matter for radiocarbon dating or macrofossil analysis were collected, with the location within the unit and on the exposure recorded.

Macrofossil samples were sent to Alice Telka of Paleotec Services, for processing and radiocarbon dating. Ms. Telka sent the samples to the W. M. Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory (UCIAMS) at the University of California Irvine for radiocarbon analysis. Samples from the earlier sampling period were sent to several laboratories for radiocarbon dating, specifically, IsoTrace, University of Toronto, Toronto, Ontario; National Science Foundation, Arizona AMS Facility, University of Arizona, Tucson, Arizona; and Waterloo Environmental Isotope Laboratory, Waterloo, Ontario.

A systematic error in radiocarbon age determination was tested by sending samples from a single piece of wood to four different laboratories (B. Ward, personal communication, 2016). The range in age for the piece of wood was 19,600 ± 170 to 17,290 ± 130 ^{14}C years BP, suggesting that some of the age results were not reliable. The results were compared to those determined by the Lawrence Livermore National Laboratory in Livermore, California to determine which were reliable. The radiometric ages from the Waterloo Environmental Isotope Laboratory at the University of Waterloo, were found to reliably date the piece of wood. Therefore, radiocarbon ages from the Waterloo laboratory most accurately date the sediment from the previous study.

2.2. Paleopedological Methods

Paleosols were described from the surface down, and samples were collected from each horizon for laboratory analysis. Descriptions follow the protocols in the Field Manual for Describing Terrestrial Ecosystems (Province of BC, 2010). Each paleosol horizon was measured, described, and sampled (Table 2-1). Approximately 500 mL of soil from each horizon was placed in labeled and sealed plastic bags. The samples were stored in a cool room before being sent to the BC Ministry of Environment's Analytical Chemistry Laboratory for the following analyses:

- Al, Fe, Mn, Si, extractable: sodium pyrophosphate extraction, acid ammonium oxalate extraction, and dithionite - citrate extraction
- Particle size analysis
- Total C and N: combustion elemental analysis

Paleosols were classified according to the Canadian System of Soil Classification (SCWG, 1998) based on the field descriptions and laboratory analyses. The classification was then used to infer the soil-forming environment.

Table 2-1. List of soil samples.

Sample ID	Lab ID	Description
CH01 paleosol		
Chehalis Section 1 A	1	Silty, massive, top of paleosol
Chehalis Section 1 B	2	Upper paleosol horizon, could be mixed with sample A
Chehalis Section 1 C	3	Upper portion of B horizon, more red than lower in profile
Chehalis Section 1 D	4	Lower half of B horizon
Chehalis Section 1 E		Charcoal, not sent for soil analysis
Chehalis Section 1 F		Dark stained material, placic horizon, not sent for analysis
Chehalis Section 1 G	5	C horizon of paleosol
CH26-01	6	Placic material
CH26-02	7	Placic material
CH26-03	8	Placic material
ST03 paleosol		
ST03-060314 Soil 1	1	Upper soil horizon (A)
ST03-060314 Soil 2	2	Lower soil horizon (B)

2.3. Macrofossil Methods

Each macrofossil sample comprised approximately one litre of sediment. Samples were collected based on the likelihood of extracting abundant well-preserved macrofossils. The location of each sample in the sections was recorded.

The samples were sent to Paleotec Services where macrofossils were isolated. The extraction procedure differed according to the sample density and volume (Telka, 2000a). For very dense and large samples, the first step was to isolate macrofossils visible under magnification from the surface of the sample. The entire sample was then washed in warm water to separate the organic macrofossils from the clastic sediment. The organic matter floating on the surface of the water was decanted to a 100 mesh Tyler sieve (0.15 mm opening). The remaining sediment was passed through nested 5, 20, and 40 mesh (4.0 mm, 0.85 mm, and 0.425 mm) sieves. All organic material larger than 0.425 mm was examined with a binocular microscope to recover plant and animal macrofossils. When the samples were not dense or small in volume, they were first processed with warm water and then treated as above.

The recovered samples were then classified to identify which family, genus, and/or species, depending on the size and preservation of the macrofossils. The results were reported as lists of recovered samples with either a count or an indication of amount (abundant, few) where counts were not possible.

In order to relate a fossil plant assemblage to an ecosystem, each fossil must be considered as an individual environmental indicator as well as a component of the ecosystem (Hicock et al., 1982). Macrofossils preserved in sediment represent between 18% and 48% of the former local flora and there is a 1:1 relationship between conifer needle percentage macrofossil data and the tree basal area of the surrounding forest (Dunwiddie, 1987). These numerical relationships are used to recreate the composition of the surrounding coniferous forest at the time of deposition.

Using Dunwiddie's (1987) method, the contribution of each needle and needle equivalent, by species, compared to the total of all needle and needle equivalents approximates the basal area composition of the source forest. I divided the needle fragment count by three to estimate the needle equivalent based on the assumption that needle equivalents were composed of three needle fragments, representing the tip, middle, and end of a whole needle. Modern contaminants found in macrofossil samples were excluded from counts. The macrofossil reports sometimes indicated the presence of a macrofossil as abundant or present in the sediment rather than as a specific count. These uncounted macrofossils were considered equivalent to one needle or needle fragment when determining needle equivalents.

The insect macrofossil assemblage from Chehalis was compared to the Port Moody coleopteran assemblage (Miller et al., 1985) to determine if there are similarities between the two that can be attributed to the regional climate. The Port Moody assemblage came from organic sediments that are approximately 1000 years younger than the Chehalis sediments but, since both come from similar ecosystems, they are comparable.

Chapter 3. Results

In this chapter, the stratigraphy is described, interpreted, and correlated to the earlier stratigraphy to provide a framework for interpreting the paleosol and macrofossil evidence. Paleosols and macrofossils are analyzed to reconstruct the paleoenvironment.

3.1. CH01 Exposure

In this area, a series of exposures along the road cut were the focus of the Ward and Thomson (2004) study. They are becoming obscured by vegetation and colluvium, but the CH01 exposure was cleared when the bridge was replaced in the winter of 2007 to 2008. It is similar to S9, the most downstream Statlu section described by Ward and Thomson (2004).

The elevation at the base is 150 m above mean sea level. The exposure is approximately 30 m wide and 20 m high. Access is difficult because the exposure is nearly vertical. Pleistocene sediments rest on Harrison Lake Formation bedrock. There are four major stratigraphic units (Figures 3-1 and 3-2).

3.1.1. Unit 1

Unit 1 drapes bedrock and is composed of moderately sorted and ungraded cobble to pebble gravel and coarse sand (Figure 3-3A) with a 10 cm thick bed of massive silt near the top. The rocks are round to subround granitic clasts. There are some nearly horizontal coarse sand lenses within the gravel. The unit ranges in thickness from a few centimetres to approximately 2 m. Some granitic clasts are highly weathered and disintegrated during sample collection, but most remained intact. A paleosol is present at the top of this unit. No macrofossils were found in Unit 1.

Unit 1 represents fluvial deposition based on the shape, size, sorting, the presence of nearly horizontal sand lenses, and its location adjacent to Statlu Creek. The position at the base of the exposure, with a paleosol at the top, suggests that this sediment was deposited during non-glacial conditions and was exposed for some period of time.

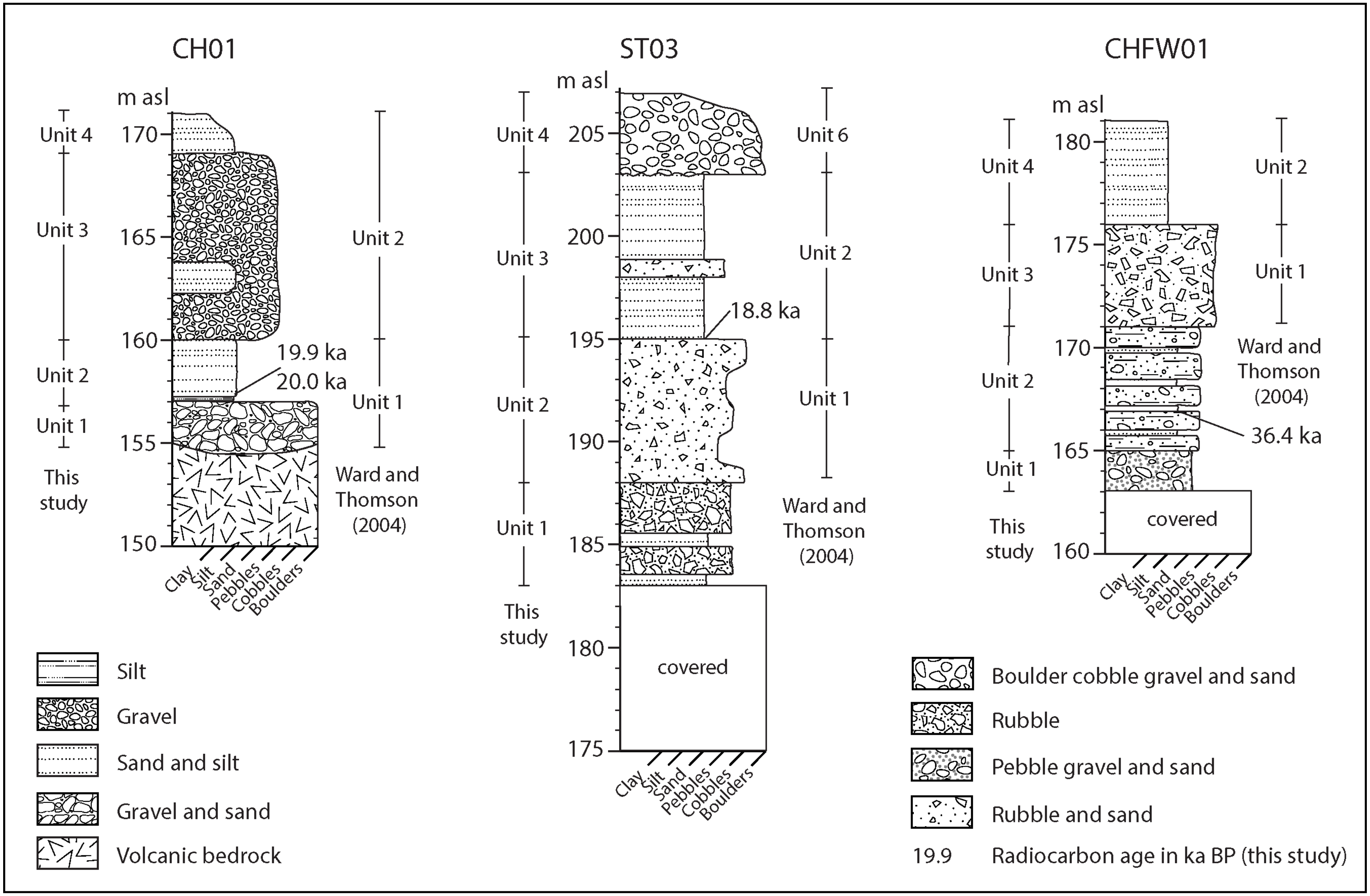

Figure 3-1. Stratigraphic log showing correlation to the previously described stratigraphic units.

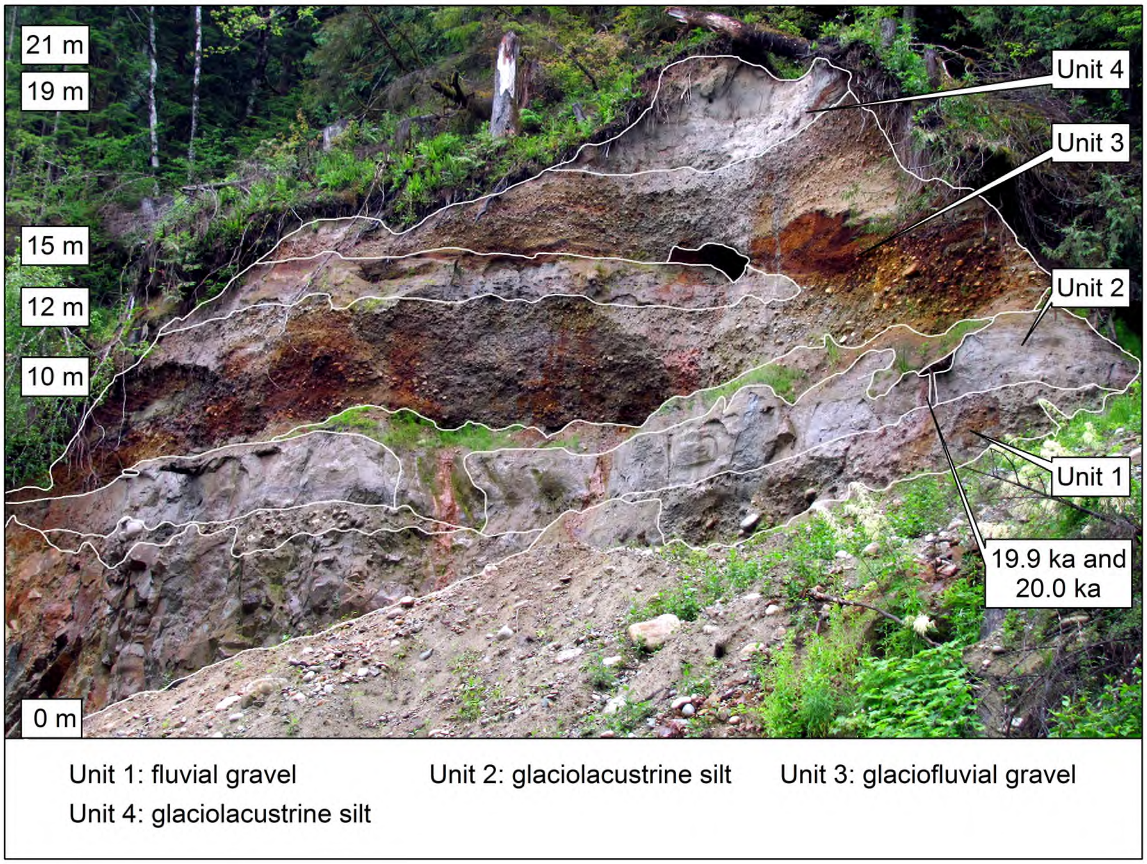

Figure 3-2. Chehalis Mainline CH01. Approximate height above the base of the exposure is on the left.

3.1.2. Unit 2

Unit 2 is cohesive and compact and consists of rhythmically laminated to finely bedded silt and fine sand (Figure 3-3B). The fine beds are thin, ranging from a few millimetres to centimetres in thickness. The lower beds, immediately above the massive silt, contain abundant intact conifer needles, root fragments, small seeds, and insect parts. The lower contact is sharp, and nearly level to slightly undulating. Several large (10 cm diameter) wood pieces lie parallel to the bedding within this unit. A root fragment from the lower organic-rich bed returned a radiocarbon age of 19,980 ± 70 ^{14}C years BP (UCIAMS 126600) and a bark fragment is 19,880 ± 60 ^{14}C years BP (UCIAMS 126601) old (Table 3-1). These fragments are both detrital and therefore provide a maximum age for the sediment enclosing them.

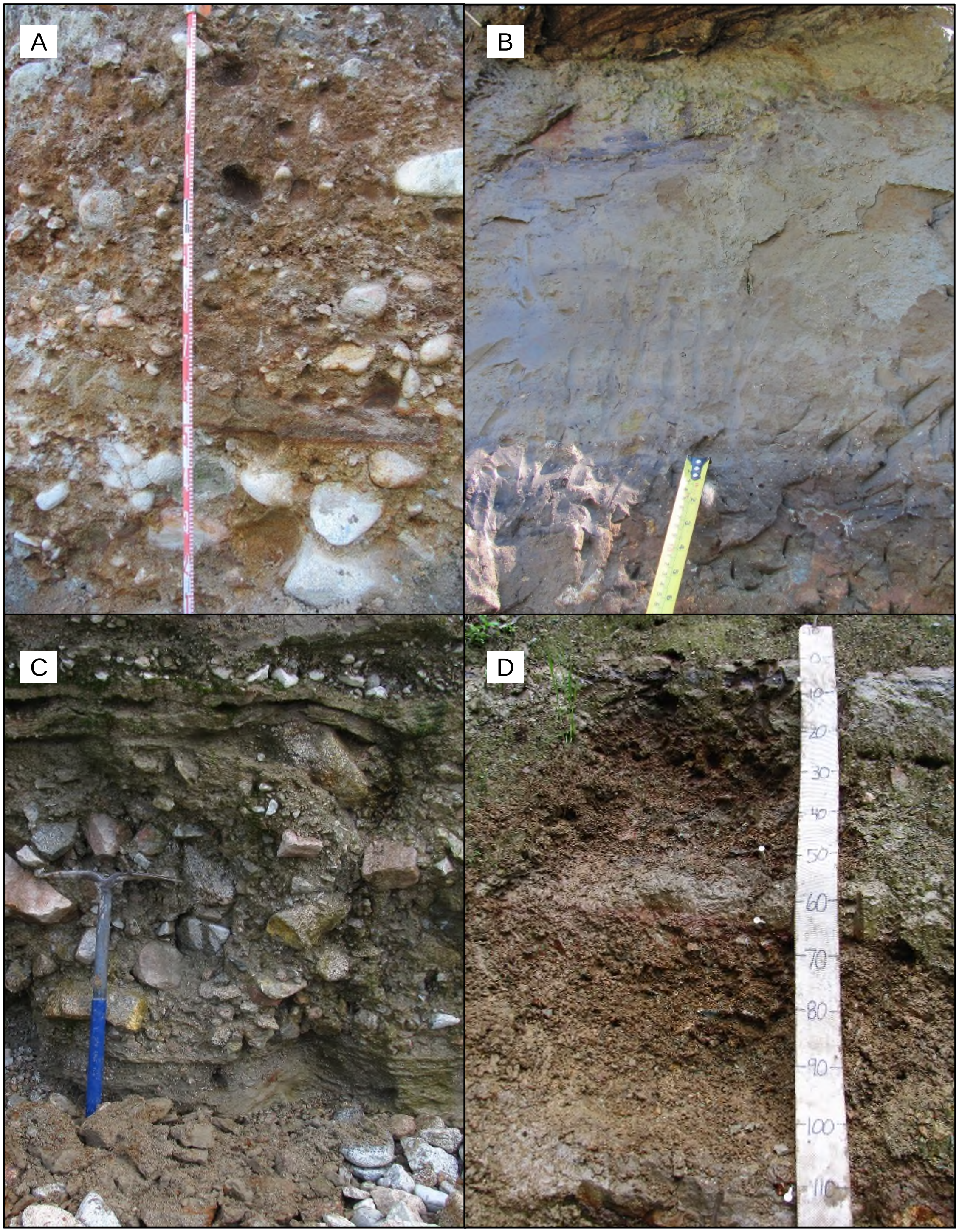

Figure 3-3. A: Unit 1 at CH01: note the sand lens near the middle of the photo. B: Upper part of Unit 1 and lower part of Unit 2 at CH01: the paleosol A horizon is near the top of the tape measure. C: Unit 1 at ST03: coarse angular clasts surrounded by a sandy matrix with interstratified silt and sand. D: Unit 2 at the CHFW02: charcoal from this unit was dated at 36,410± 530 ^{14}C years BP (UCIAMS 138099).

Unit 2 represents low energy suspension settling. This is interpreted as glaciolacustrine deposition in a lake impounded by ice in the Fraser Lowland. There are several mechanisms that can form a lake in a narrow valley similar to Chehalis Valley. The first mechanism is blockage of the mouth of Chehalis Valley by advancing glaciers in the Fraser Lowland. The second is a local glacial advance in a tributary blocking the mainstem valley. The third is a local blockage, such as a landslide or large debris deposit in the valley. Ward and Thomson (2004) originally preferred the explanation that a landslide blocked Chehalis Valley to deposit the fine grained sediments. That explanation was discarded in favour of glaciers in the Fraser Lowland blocking the mouth. The characteristic of the sediment, with sand beds capped by thin silt beds, the presence of occasional lonestones (Figure 3-4), and sedimentary structures suggest that these sediments were deposited in an ice dammed lake.

Figure 3-4. Glaciolacustrine sediment with lonestones and paired bedding from Chehalis Valley, tool handle is 9 cm in length.

Table 3-1. Radiocarbon dates for samples collected in Chehalis Valley.

Lab Number	Age (years BP)	$\delta^{13}C$	Material	Section	Sample Number	Geographic Coordinates[a]
UCIAMS 126600	19,980 ± 70	-25.6	Root fragment	CH01	061513CH01-M02	10U 570995 5466701
UCIAMS 126601	19,880 ± 60	-23.5	Bark fragment	CH01	061513CH01-M03	10U 571037 5466714
UCIAMS 138099	36,410± 530	-26.7	Charcoal	CHFW01	CHFW01-M01	10U 574893 5464646
UCIAMS 142764	18,790 ± 45	n/a	Compact bark	ST03	ST03 060314-SED01	10U 570212 5466204

[a]Datum is NAD 83.

3.1.3. Unit 3

Unit 3 is composed of interstratified gravel and sand with few pebbles with an interfingered bed of rhythmically laminated to finely bedded silt and fine sand. The unit ranges in thickness from 5 to 9 m. The gravel is moderately sorted with weak normal grading and rounded to subrounded clasts. The gravel is stained orange, brown, and black. The lower contact is erosional, sharp, and nearly horizontal with slight undulations.

Unit 3 represents subaerial deposition after the glacial lake temporarily drained when glaciers in the Fraser Lowland retreated. The interpretation is based on sediment sorting, clast shape, and the presence of the interfingered bedded silt and sand lens.

The combination of Units 2 and 3 represents oscillation of the glacier that dammed the mouth of Chehalis Valley. First the glacier advanced, blocking the mouth and forming a lake. It retreated and the lake drained, depositing Unit 3 sediments. It then readvanced and the lake reformed.

3.1.4. Unit 4

Unit 4 is composed of rhythmically laminated to finely bedded silt and sand with a modern soil at the surface. The unit does not extend across the exposure. This unit represents glaciolacustrine deposition based on bedding and texture.

3.2. ST03 Exposure

The ST03 exposure, on the south bank of Statlu Creek (Figures 3-1 and 3-5), is nearly 100 m wide and more than 30 m tall. It is difficult to describe the sediment because access is only possible when the exposure is dry, late in the summer, with rope support. Portions of the exposure are covered with colluvium, horsetail, and shrubs. There are four sedimentary units at ST03.

3.2.1. Unit 1

Unit 1 (Figure 3-3C) is 8 to 10 m thick and is composed of interstratified beds of angular granitic rubble within a sandy matrix and thin silt and sand beds. The rubble is moderately sorted with weak reverse grading.

Grading, interstratification, and clast shape indicate that the sediment is a colluvial deposit. The reverse grading and presence of fine-grained beds separating rubble beds suggests that it originated as a series of debris flows from steep slopes above Statlu Creek.

3.2.2. Unit 2

Unit 2 is up to 18 m thick. It is composed of angular fragments within a silty sandy matrix. There are rip-up clasts of laminated sediment near the contact with Unit 3. The unit has weak grading and stratification, with the blocky clasts sorted into nearly horizontal beds. The lower contact is obscured by vegetation and is partially covered with material ravelled from higher in the exposure. There is a weakly expressed paleosol at the contact between Units 2 and 3. A piece of compacted bark recovered from above this unit was dated at 18,790 ± 45 ^{14}C years BP (UCIAMS 142764), providing a maximum age for the enclosing sediment.

Unit 2 is interpreted to be colluvium based on clast shape, stratification, grading, and stratification. The combination of Units 1 and 2 suggest that the landform was a debris flow fan at the time of deposition.

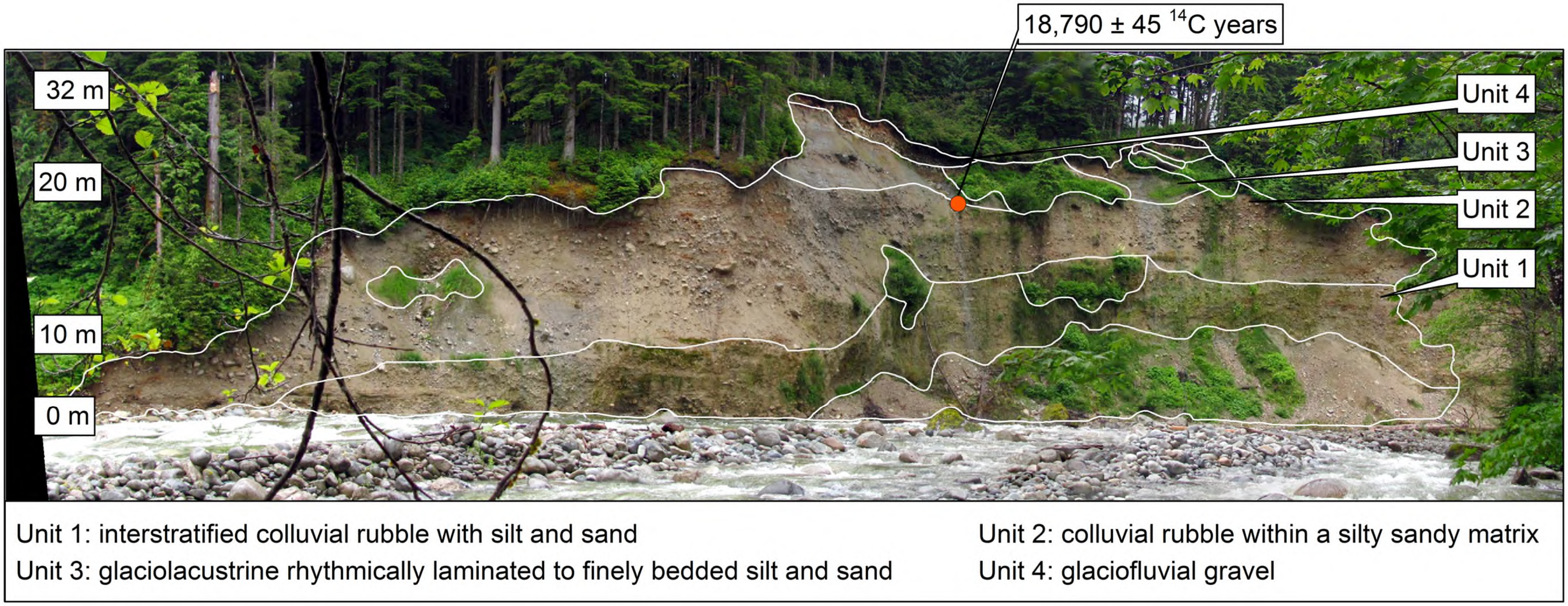

Figure 3-5. ST03 exposure and stratigraphy. The paleosol location is at the contact between Units 2 and 3. A piece of compacted bark from this location is aged 18,790 ± 45 ^{14}C years BP (UCIAMS 142764).

3.2.3. Unit 3

Unit 3 is approximately 10 m thick and is composed of compact, rhythmically laminated to finely bedded silt and sand conformably draping Unit 2. The beds range from a few millimetres to 3 cm thick, with ripples in many of the thicker beds. The beds are brown to reddish brown. The unit is very compact. A rounded, granitic lonestone, 10 cm in diameter, was noted within the unit with sediments draping the upper surface. A discontinuous bed about 1 m thick near the middle of the unit contains angular fragments, silt, and sand and has sediment similar to those in Unit 2

This unit is interpreted to be a glaciolacustrine deposit, based on the bedding, texture, and presence of a lonestone. The lonestone and the coarse-textured bed suggest the glacial lake was ice contact. It is likely coeval with other glaciolacustrine deposits located throughout Chehalis valley (e.g., Units 2, 3, and 4 at CH01) and it correlates to Ward and Thomson's (2004) Unit 2 (Figure 3-1).

3.2.4. Unit 4

Unit 4 is up to 4 m thick and comprises boulder cobble gravel and sand. The clasts are rounded to subrounded and mostly granitic. The lower contact is sharp, undulating, and erosional. A modern soil has formed at its upper surface. This unit is a glaciofluvial deposit dating to soon after the end of the Fraser Glaciation, when base level in the area was higher than today.

3.3. CHFW01 Exposure

The CHFW01 exposure (Figures 3-1 and 3-6) is located on the east side of Chehalis River below an old forest road that is no longer drivable. The exposure lies in a washout created when a woodbox culvert on the road failed possibly less than 50 years ago. The top of this exposure was destroyed during road construction and subsequent failures of the woodbox culvert.

Figure 3-6: Part of the CHFW01 exposure showing Unit 2 in the centre of the photos with the sharp lower contact with Unit 1. The sample location that yielded a date of 36,410± 530 ^{14}C years BP (UCIAMS 138099) is indicated with a blue dot.

3.3.1. Unit 1

Unit 1, near the creek at the base of the exposure, is a thick deposit of rounded to subrounded gravel and sand. The sediment is clast-supported near the base of the unit and becomes matrix-supported near the upper contact. Much of the unit is covered with colluvium and vegetation.

This unit is interpreted to be a glaciofluvial or fluvial deposit, based on the shape of the clasts. It is most likely fluvial because it lies beneath a unit that was probably deposited during MIS3.

3.3.2. Unit 2

Unit 2 is composed of interstratified silt and fine sand beds with rubble and sand beds (Figure 3-3D). The finer-textured beds are about 20 cm thick and the coarser-textured beds are up to 1 m thick. The lower contact is sharp and nearly horizontal. Charcoal from this unit returned a radiocarbon age of 36,410 ± 530 ^{14}C years BP (UCIAMS 138099). The interstratification and the repeating sequence of beds suggests this deposit is the result of a repeated, episodic sedimentation, possibly subaerial deposition on a fan.

3.3.3. Unit 3

Unit 3 is normally graded rubble and blocks with some sand and silt. The lower contact is sharp and nearly horizontal. No material suitable for radiocarbon dating was found in this deposit. This sediment represents subaerial deposition or colluvial sedimentation from the valley sides.

3.3.4. Unit 4

Unit 4 is composed of rhythmically laminated to finely bedded silt and fine sand beds with a few rounded to subrounded lonestones. The beds range from 1 to 5 cm thick. Some of them are stained rust orange. This unit is a glaciolacustrine deposit, based on the bedding and the presence of lonestones. The sediment is similar to Unit 4 at CH01 and Unit 3 at ST03.

3.4. Stratigraphic Correlation

CH01 most closely matches Ward and Thomson's (2004) S9 exposure (Figure 1-4) because of its location and stratigraphy. CH01 Unit 1 correlates to their Unit 1, based on sedimentology, and it represents fluvial deposition. Unit 2 correlates to the fine-grained lens in their Unit 1 because both units have similar sediments and radiocarbon ages from both are both about 20,000 ^{14}C years BP. They interpreted this lens as a local event, such as a landslide blocking the river; however, they did suggest the possibly that it represented glacial blockage at the mouth of Chehalis Valley. It is more likely that Unit 2 represents the initial blockage of Chehalis Valley by glaciers in the Fraser Lowland.

Unit 3 either correlates to the upper part of Ward and Thomson's (2004) Unit 1 or a coarse grained facies of Unit 2. It is more likely that it represents a return to subaerial conditions as the glacier in the Fraser Lowland retreated briefly and allowed the lake in the Chehalis Valley to drain. Unit 4 correlates to the base of their Unit 2, representing continuous blockage of the mouth of the Chehalis. This occurred about 19,400 ^{14}C years BP, approximately 500 radiocarbon years after the initial blockage recorded in Unit 2.

Ward and Thomson (2004) did not describe the ST03 exposure nor did they describe a unit similar to ST03 Unit 1. ST03 Unit 2 could represent deposition coeval with their Unit 1 but it may be older. The paleosol at the top indicates a short period of stability before flooding indicated by Unit 3. ST03 Unit 3 correlates to their Unit 2 and represents flooding of the valley by glacier blockage at the mouth. The age of 18,700 ^{14}C years BP could indicate that this lake persisted for several hundred years after the initial flooding event at about 19,400 ^{14}C years BP. ST03 Unit 4 correlates to their Unit 6.

CHFW01 is similar to Ward and Thomson's (2004) CH1 exposure (Figure 1-4). CHFW01 Unit 1 does not correlate because it is older than the units they describe and it represents deposition during MIS 3. CHFW01 Unit 2 also represents deposition during MIS 3. CHFW01 Unit 3 correlation is problematic because there was no dateable material recovered and it represents a different depositional environment, but based on its location below the glaciolacustrine unit, it could correlate to their Unit 1. CHFW01 Unit 4 correlates to their Unit 2 or Unit 5a, based on sedimentology but since it does not overlie diamicton, it probably correlates to Unit 2.

The unit names first published by Ward and Thomson will be used to organise the macrofossil data and to simplify discussion. The radiocarbon ages from their Units 1 and 2 suggest they were deposited during the period that is the focus of this study.

3.5. Paleosols

Two paleosols found within the Chehalis Valley study area were described and analyzed. Both paleosols are on the bank of Statlu Creek, approximately 3 km apart (Figure 1-2). The sediments above them have been dated (Figure 3-1 and Table 3-1). The first is at the CH01 exposure, at the top of Unit 1; I refer to it informally as Chehalis paleosol. The second paleosol is at the ST03 exposure at the top of Unit 2, and is referred to as the Statlu paleosol.

3.5.1. Chehalis Paleosol

The Chehalis paleosol comprises five soil horizons that are distinguished by colour, coarse fragment content, and soil textural class (Table 3-2 and Figure 3-7). The parent material is sand and gravel with a silt and sand cap. The uppermost soil horizon is overlain by stratified silt and sand.

Soil horizons are named according to definitions provided in the Canadian System of Soil Classification (SCWG, 1998). The Roman numeral prefix indicates a change in parent material or a lithological discontinuity. The uppercase letter indicates the major soil horizon and the lowercase suffixes are used to describe the soil-forming processes.

The Ahb horizon is a dark brown silt loam that developed in massive silts. The second horizon, IIBfjb, developed in fluvial gravel and nearly meets the morphological criteria of a Bf horizon (SCWG, 1998), but does not meet the chemical criteria or thickness requirement of a diagnostic Podzolic B horizon. The underlying IIBfb horizon meets these requirements. It has slightly fewer, but larger coarse fragments, is up to 45 cm thick, and the colour becomes yellower with depth. Underneath, there is a 2.0 to 2.5 cm thick placic horizon (IIBfjcb). It is hard, impervious, and dark reddish brown (Figure 3-8). The horizon is wavy and nearly parallel to the soil surface. At the base of the soil, the IIC horizon is highly weathered, coarse gravelly sand with more coarse fragments than the upper horizons.

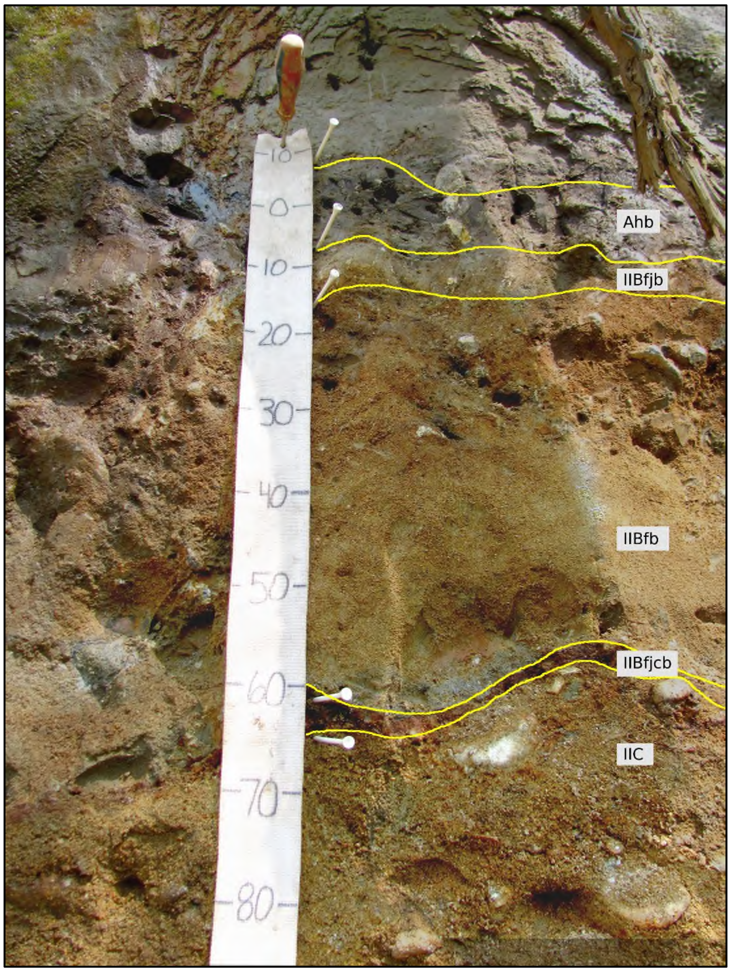

Figure 3-7. Chehalis paleosol with horizon boundaries marked. The placic horizon is near the 60 cm mark on the scale.

Samples of the Chehalis paleosol soil horizons were analyzed for properties used to identify podzolization and for classification (Table 3-3 and Appendix A). The amount of carbon and pyrophosphate-extractable iron and aluminum in the second B horizon of the soil are sufficient to meet the criteria for Podzolic B horizon (SCWG, 1998). The total carbon component is assumed to be organic C because the soil lacks other sources. Carbon concentration decreases with depth, especially beneath the placic horizon, clear evidence of pedogenesis (Figure 3-9).

Table 3-2. Chehalis paleosol soil profile description.

Horizon	Depth (cm)	Description
Ahb	0-15	Dark brown (10YR 3/3 m); silt loam; massive structure that breaks to moderate, medium, angular to subangular blocky; very firm when moist; 10% coarse fragments with rare round granitic cobbles; gradual, smooth boundary; 12-15 cm thick.
IIBfjb	15-23	Brown (10YR 4/3 m); sandy loam; massive structure that breaks to weak, fine to moderate subangular blocky; very firm when moist; 30% coarse fragments primarily rounded weathered granitic cobbles; clear, wavy boundary; 0-8 cm thick.
IIBfb	23-68	Dark yellowish brown (10YR 3/6 m) becoming yellowish brown (10YR 5/6 m); sand to coarse sand; massive structure, breaks to moderate coarse and medium subangular blocky; firm when moist, 20% coarse fragments, rounded cobbles; wavy boundary; 0-45 cm thick.
IIBfjcb	68-73	Dark reddish brown (5YR 3/3m) sand; cemented (placic); abrupt, wavy boundary; 2-2.5 cm thick.
IIC	73-140+	Dark yellowish brown (10YR 4/6 m) coarse gravelly sand; massive structure breaks to weak subangular blocky; 50% coarse fragments with rounded cobbles; 67 cm and thicker.

Table 3-3. Chehalis paleosol diagnostic chemical properties.

Horizon	Depth (cm)	C (%)	Fe_p (%)	$Fe_p + Al_p$ (%)	$Fe_p + Al_p$:Clay	C:Fep
Ahb	0-15	3.5	0.3	1.0	0.2	12.0
IIBfjb	15-23	2.2	0.1	0.5	0.2	15.6
IIBfb	23-68	1.7	0.1	1.6	0.2	13.0
IIBfjcb	68-73	0.7	0.1	0.3	0.2	5.9
IIC	73-140+	0.7	0.0	0.2	0.2	21.8

Figure 3-8. The placic horizon is thin, vitreous, and nearly flat, and is located above the top of the knife. Knife handle is 11 cm in length.

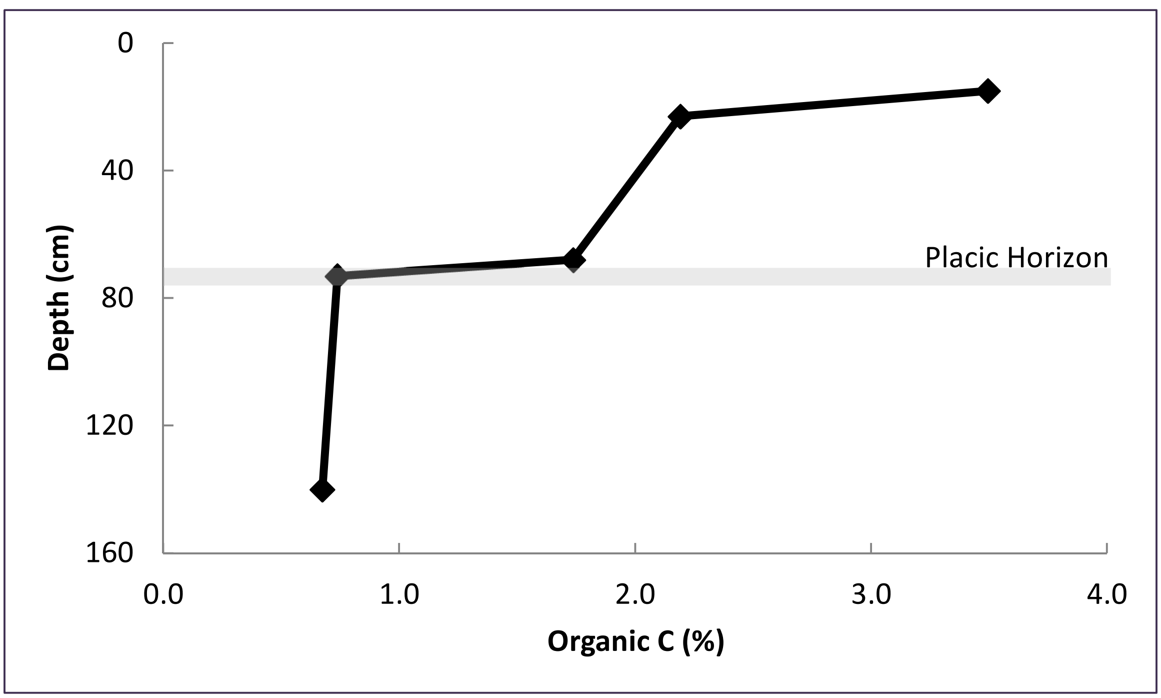

Figure 3-9. Organic matter as a function of depth in the Chehalis paleosol.

The iron, aluminum, and silicon contents indicate the forms of these elements in the soil (Table 3-4). The placic horizon (IIBfcb) has a high concentration of ferrihydrite compared to the other horizons. It has a lower Fe activity ratio, an indication that the placic horizon has less amorphous Fe than the nearby horizons. The cementing agent in the placic horizon is not crystalline Fe oxides, unlike that found by other researchers (e.g., Valentine, 1969; Bockheim, 2011).

Table 3-4. Fe, Al, and Si in the Chehalis paleosol.

Horizon	Depth (cm)	Fe Activity Ratio (Fe_o/Fe_d)	Ferrihydrite [$1.7(Fe_o)$] (%)	Organic-complexed Fe and Al [$Fe_p + Al_p$] (%)	Crystalline Fe Oxides [$Fe_d - Fe_o$] (%)	Al in Imogolite and Allophane [Al_o-Al_p] (%)	Al:Si Ratio Allophanic Materials [$(Al_o-Al_p)/Si_O$] (%)
Ahb	0-15	1.0	1.4	1.0	-	3.1	1.4
IIBfjb	15-23	1.1	0.9	0.5	-	2.5	1.4
IIBfb	23-68	1.2	0.9	0.6	-	2.5	1.4
IIBfjcb	68-73	1.0	5.9	0.3	0.1	1.6	1.5
IIC	73-140+	1.2	0.6	0.2	-	1.4	1.6

The increase in oxalate- and pyrophosphate-extractable iron at the top of the placic horizon is a characteristic associated with placic horizons in soils, which can have a 10-fold increase in oxalate-extractable iron (Figure 3-10) and a large Fe_o/Al_o ratio (Lapen and Wang, 1999).

3.5.2. Statlu Paleosol

The Statlu paleosol formed on parent material composed of a mix of sand and gravel with subangular to angular granitic fragments (Figure 3-10). The paleosol is weakly expressed compared to the Chehalis paleosol and only two horizons were described and sampled for classification (Tables 3-5 and 3-6). The uppermost Ahb horizon is a gray silt loam with 20% angular coarse fragments by volume. The lower boundary with the Bmb horizon is abrupt. The Bmb horizon is brown sandy loam with 50% rubbly coarse fragments.

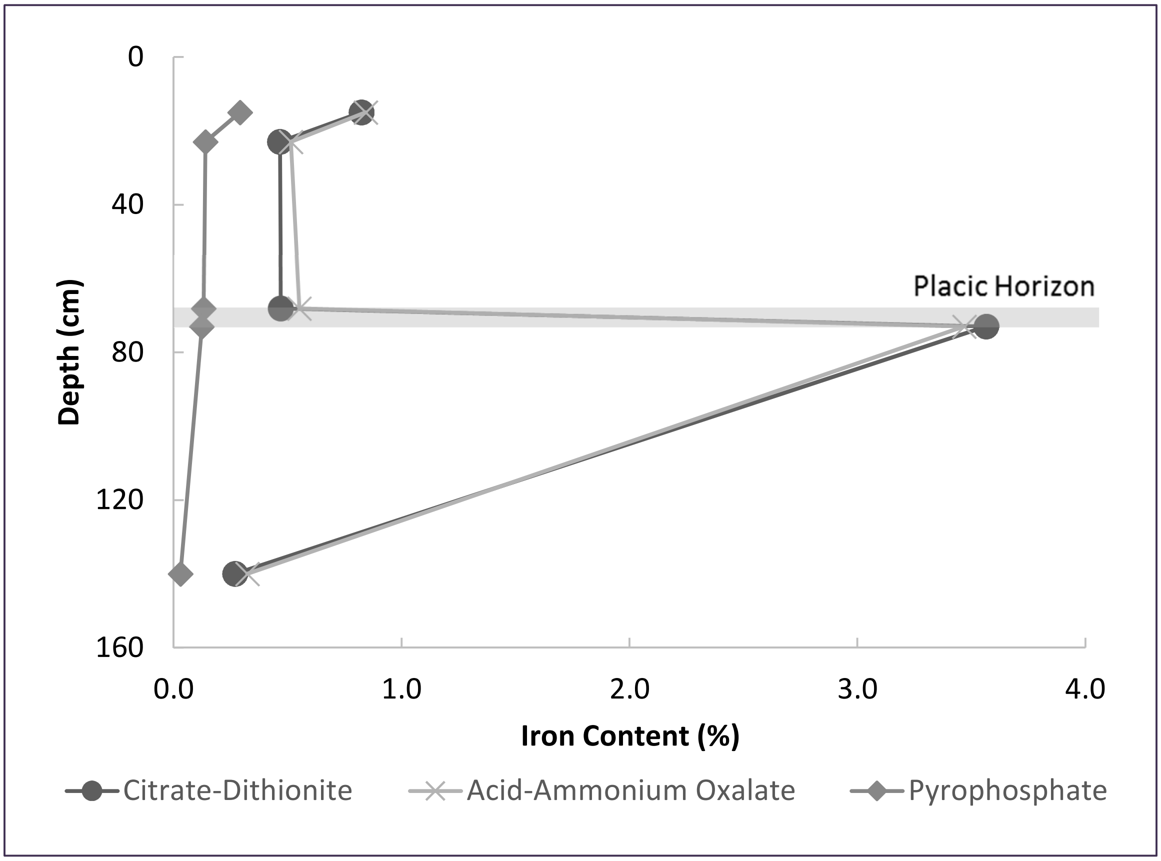

Figure 3-10: Iron content, by extraction method, in the Chehalis paleosol.

Table 3-5. Statlu paleosol profile description.

Horizon	Depth (cm)	Description
Ahb	0-13	Gray (10YR 5/1 m); silt loam; strong, medium angular blocky structure; firm when moist; 20% rubbly coarse fragments; abrupt, smooth boundary.
Bmb	13-30+	Brown (10YR 4/3 m); sandy loam; weak, medium angular blocky structure; very firm when moist; 50% rubbly coarse fragments.

Table 3-6. Statlu paleosol chemical properties. (See Appendix B).

Horizon	Depth (cm)	C (%)	Fep (%)	Fep + Alp (%)	Fep + Alp : Clay	C : Fep
Ahb	0-13	1.7	0.1	0.4	0.0	11.8
Bmb	13-30+	0.6	0.2	0.4	0.1	2.8

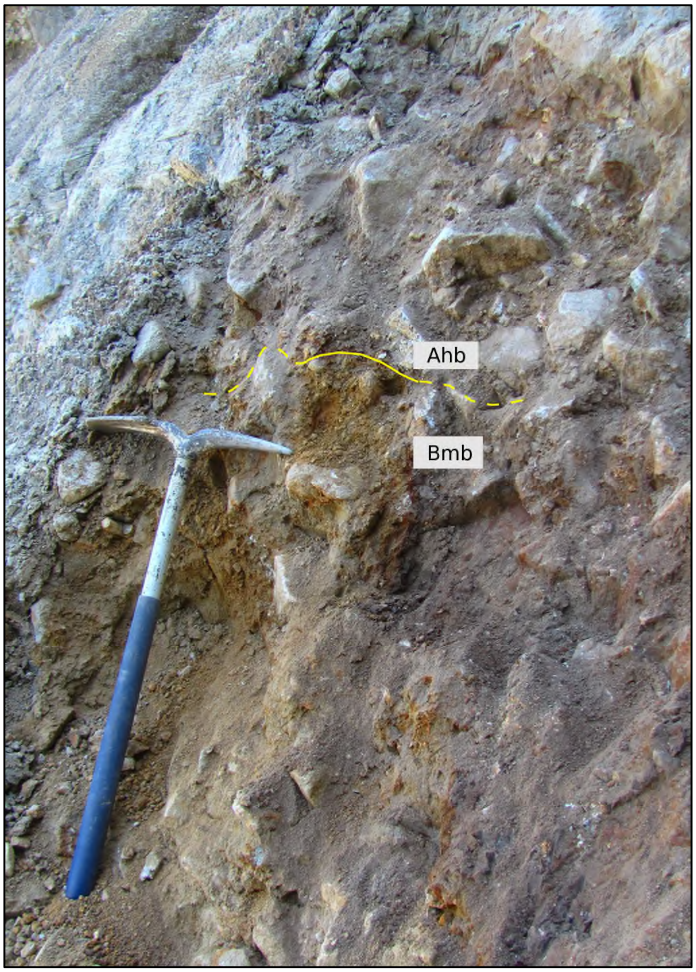

Figure 3-11: The Statlu paleosol. Yellow marks show the boundary between the Ahb and Bmb horizons; dashed where uncertain. The pick handle is 64 cm long.

3.5.3. Soil Classification

The Chehalis paleosol is a Placic Humo-Ferric Podzol, according to the Canadian System of Soil Classification (SCWG, 1998). The pyrophosphate extractable Fe and Al and organic C content of the B horizon and the presence of a placic cemented horizon at 68 cm are the classifying characteristics. The Statlu paleosol is classified as an Orthic Sombric Brunisol based on the brown colour in the Bmb horizon and the lack of evidence of podzolization (SCWG, 1998). Brunisolic soils are associated with forest vegetation and they are named after the characteristic brown B horizon.

Since placic horizons are not found locally, its presence in the Chehalis paleosol suggests that the climate under which it formed was different from today's climate. In contrast, Podzolic and Brunisolic soils are common in modern Chehalis Valley, indicating climatic similarities.

Post-burial alteration, in particular oxidation of organic matter, may have modified the Statlu paleosol. Such alteration could reduce the amount of Fe_p and Al_p relative to other forms of Fe and Al in the B horizon (Olson and Nettleton, 1998). The horizon could be misclassified because the classification of podzols depends on the amount of Fe_p and Al_p in the B horizon. The weakness of using a modern soil classification system for buried paleosols is that strict horizon designations and classifications do not account for post-burial alterations.

3.6. Macrofossils

3.6.1. Plant Macrofossils from 1998, 2000, and 2001 Samples

The composition of the plant macrofossil samples for all sites sampled by Ward and Thomson in 1998, 2000, and 2001 is summarized below and in Appendix C. Plant macrofossils present in samples from each lithostratigraphic unit at each section, including all plant families and species that could be identified, are listed in tables. Common names were verified using the E-Flora BC website (E-flora BC, 2015). The macrofossil dataset was not partitioned since the samples were recovered from specific stratigraphic units, which represent a narrow timeline in the Late Pleistocene history of Chehalis Valley.

Ward and Thomson's (2004) Unit 1 sediments contain fewer macrofossils (Table 3-7) than the overlying unit. Those present are parts of coniferous trees (hemlock and spruce). The sediments lack macrofossils from understory vegetation and insects. There is a paleosol at the top of Unit 1 at the CH01 exposure. It is possible that normal soil-forming processes resulted in decomposition of some or all of the vegetation, reducing macrofossil preservation. Alternatively, the sediment may have been deposited in a stream, as suggested by the fluvial nature of the sediment.

Table 3-7. Plant macrofossil data from Unit 1 sediment from upstream of CH01 (samples BCW250500-M4 and BCW250500-M3) (Telka, 2000b).

Scientific Name	Common Name	Item(s) Found
Fungal Remains		~5 fungal sclerotia
Vascular plants		
Pinaceae (undifferentiated)	Pine Family	
Picea sp.	Hemlock species	1 charred needle fragment
Tsuga sp.	Spruce species	1 modern needle base fragment (contaminant)
Other		
	Charcoal	Abundant large and small fragments
	Wood	Partially charred fragments
	Charred twig	3 fragments
	Unknown	Soft organic? fragments with opaque brown and caramel gold colours
	Modern contaminants	3 plant fragments and 1 plant rootlet

Tables 3-8, 3-9, 3-10, and 3-11 list macrofossils recovered from Unit 2 sediments. The data are presented by section and by age. The sample presented in Table 3-8 was collected from Unit 2 and the sample presented in Table 3-9 was collected in the uppermost part of Unit 2 at sections close to CH01 (Telka, 2001a). Table 3-10 represents Unit 2 at Section S4, 220 m from CH01. Table 3-11 lists the macrofossils from Unit 2 at Section CF2.

Table 3-8. Plant macrofossil data from Unit 2 (BCW160500-M1) at Statlu section.

Scientific Name	Common Name	Item(s) Found
Fungal Remains		~20 fungal sclerotia, some flattened
Non-vascular plants		
Bryophytes	Mosses	18 fragments representing few types, 5 leaves
Sphagnum sp.	Sphagnum species	1 leaf
Vascular plants		
Pinaceae (undifferentiated)	Pine family	
Abies sp.	Fir species	2 twig terminals Some poorly preserved needle fragments
Tsuga sp. (modern)	Hemlock species	1 complete needle
Picea sp.	Spruce species	Poorly preserved needle fragments

Scientific Name	Common Name	Item(s) Found
Gramineae	Grass family	1 seed
Cyperaceae	Sedge family	
Carex sp.	Lenticular type	5 seeds 1 perigynium with seed
Carex sp.	Trigonous type	4 seeds
Salicaceae	Willow family	
Salix sp.	Willow species	11 twig fragments with persistent buds 13 persistent buds
	Unidentified plant taxa	Small capsules?
Other		
	Charcoal	19 fragments, including one larger piece
	Coal?	1 fragment
	Amber-like resin	More opaque fragments
	Wood	Compressed fragments, most without bark Larger pieces (10 cm by 2.5 cm)
	Twig	1 modern contaminant with no bark
	Bark? with nodules	Small and large pieces
	Net-veined leaves	8 fragments

Table 3-9. Plant macrofossil data from Unit 2 from (Samples BCW280401-M3 and BCW280401-M4) collected from a section near CH01 dated to 20,060 ± 190 ^{14}C years BP (AA50799).

Scientific Name	Common Name	Item(s) Found
Fungal Remains		166 fungal sclerotia
Non-vascular plants		
Bryophytes	Mosses	3 fragments 2 fruiting bodies Abundant stem fragments with leaves (2 types)
Vascular plants		
Selaginellaceae	Spikemoss family	
Selaginella selaginoides (L.) Link	Mountain-moss or spike clubmoss	1 megaspore
Pinaceae (undifferentiated)	Pine family	4 seed wing fragments
Abies sp.	Fir species	6 needle fragments ~40 twig terminal fragments (poorly preserved, bark)
Picea spp.	Spruce species	8 needle fragments

Scientific Name	Common Name	Item(s) Found
Poaceae (or Gramineae)	Grass family	38 seeds
Cyperaceae	Sedge family	
Carex sp.	Lenticular type	374 seeds 3 pergynium with seed Seed fragments
Carex sp.	Trigonous type	126 seeds
Eriophorum sp.	Cottongrass species	406 seeds Some seed fragments
Juncaceae	Rush Family	
Juncus/Luzula type	Wood-rush type	9 seeds
Brassicaceae (or Cruciferae)	Mustard family	1 seed
Salicaceae	Willow family	
Salix sp.	Willow species	11 seed capsules, 13 persistent buds 3 twigs with persistent buds, ~6 twigs
Chenopodiaceae or Caryophyllaceae undifferentiated	Orache or sandwort	20 seeds
Violaceae	Violet family	
Viola sp.	Violet species	1 seed , 2 seed fragments
Rosaceae	Rose family	
Potentilla sp.	Cinquefoil species	5 seeds
Caprifoliaceae	Honeysuckle family	
Sambucus sp.	Elderberry species	1 seed
Asteraceae (Compositae)	Aster Family	8 seeds
	Unidentifiable plant taxa	13 unknown flat seeds 4 unknown seeds Hollow plant stem? fragments
Other		
	Fungal/yeast mats	
	Charcoal	~13 fragments
	Amber-like resin and nodules	Fragments (more opaque)
	Unknown bark? With nodules	Abundant small and large pieces

Scientific Name	Common Name	Item(s) Found
	Wood	Abundant compressed (flattened) fragments, most without bark
	Twigs	~10 fragments, one larger poorly preserved flattened twig (6.5 cm by 1 cm)
	Nodules with unknown bark?	Opaque, dark-coloured fragments
	Net-veined leaves	2 thick fragments

Table 3-10. Plant macrofossil data from Unit 2 at Section S4, 220 m from CH01 (Samples BCW 071101-M1A and BCW071101-M1B) dated to 19,400 ± 120 ^{14}C years BP (WAT-4168) (Telka, 2001c).

Scientific Name	Common Name	Item(s) Found
Fungal Remains		32 fungal sclerotia
Non-vascular plants		
Bryophytes	Mosses	28 stem fragments with leaves 4 stem fragments (few types)
Vascular plants		
Selaginellaceae	Spikemoss family	
Selaginella selaginoides (L.) Link	Mountain-moss or spike clubmoss	2 megaspores
Pinaceae (undifferentiated)	Pine family	3 seed wing fragments 67 needle fragments
Abies sp.	Fir species	12 needles, 108 needle fragments 8 twig terminal fragments
Picea spp.	Spruce species	19 needles, 63 needle fragments 25 twig terminal fragments
Poaceae (or Gramineae)	Grass family	2 seeds
Cyperaceae	Sedge family	1 seed
Carex sp.	Lenticular type	2 seeds
Brassicaceae (or Cruciferae)	Mustard family	1 seed
Salicaceae	Willow family	
Salix sp.	Willow species	1 persistent bud
	Unidentified plant taxa	1 poorly preserved seed
Other		
	Modern contaminants	3 moss fragments and needles
	Amber-like material	~4 crumbly fragments

Scientific Name	Common Name	Item(s) Found
	Net-veined leaves	~21 fragments
	Wood	~5 block shaped fragments, 2 fragments
	Twigs	6 fragments with no bark 3 larger pieces 10 cm and 14 cm long
	Bark	Few fragments
	Peds	Fe-stained, rust-coloured silt cemented fragments
	Iron precipitate	Abundant flattened fragments 1 cm in size
	Organics with iron precipitate	

Table 3-11. Plant macrofossil data from Unit 2 (Samples BCW 010600-M1, BCW 050601-M2, BCW280201-M3, BCW 220300-M2, BCW 220300-M3, BCW 160698-M1, and BCW 160698-M2) collected from the Chehalis-Fleetwood CF2 exposure dated to 19,150 ± 110 (WAT-4169) (Telka, 2000a).

Scientific Name	Common Name	Item(s) Found
Fungal Remains		80 fungal sclerotia, some flattened
Non-vascular plants		
Bryophytes	Mosses	32 fragments with leaves (few types) 1 leaf 3 fruiting bodies
Sphagnum sp.	Sphagnum species	4 leaves
Vascular plants		
Pinaceae (undifferentiated)	Pine family	3 cone scale fragment (one has ~4 scales and seed wing) 8 needle fragments 11 cone scales (3 are frayed with worn edges), 2 cone scale bracts 14 seed wings 12 seed wing fragments 2 conifer seeds
Abies sp.	Fir species	11 needle fragments 21 twig terminal bark fragments 1 seed wing fragment 1 seed
Abies lasiocarpa (Hook.) Nutt.	Subalpine fir	Abundant needles and needle fragments
Picea sp.	Spruce species	~29 needle fragments ~11 twig terminals
Tsuga sp.	Hemlock species	1 needle

Scientific Name	Common Name	Item(s) Found
Cupressaceae	Cypress family	
Thuja plicata Donn ex D. Don	Western redcedar	1 leafy shoot 1 upright shoot
Poaceae (or Gramineae)	Grass family	2 seeds 1 lemma and palea
Cyperaceae	Sedge family	4 seeds
Carex	Lenticular type	40 seeds
Carex	Trigonous type	1 seed
Carex sp.	Sedge species	2 seeds
Eriophorum sp. or *Cyperus* sp.	Cottongrass or cyperus	37 seeds 2 seed fragments
Juncaceae	Rush family	
Juncus/Luzula type		3 seeds
Chenopodiceae	Goosefoot family	4 seeds 4 half seeds 28 seed fragments
Chenopodium sp.	Goosefoot species	3 seeds 11 seed fragments
Chenopodiceae or Caryophyllaceae (undifferentiated)	Goosefoot or Sandwort family	1 seed
Ranunculaceae	Crowfoot family	
Ranunculus macounii/pensylvanicus type	Macoun's or Pennsylvania-type Buttercup	1 seed
Ranunculus sp.	Buttercup species	1 seed
Caprifoliaceae	Honeysuckle family	1 seed
Sambucus sp.	Elderberry	6 seeds, 6 seed fragments
Violaceae	Violet family	
Viola sp.	Violet species	2 half seeds
Ericaceae	Heath family	1 seed 1 leaf
Salicaceae	Willow family	
Salix sp.	Willow species	3 twigs with bark
	Unidentified plant taxa	2 seed fragments, all poorly preserved 7 seeds (one poorly preserved)
Other		

Scientific Name	Common Name	Item(s) Found
	Modern contaminants	Paper fragments and plant rootlets
	Stem fragments	Many fragments similar to *Equisetum* sp.
	Amber-like material	Fragments
	Unknown bark? with nodules	Many chunks and fragments
	Nodules from unknown bark	Fragments
	Charcoal	5 fragments
	Wood	Many compressed and block shaped pieces, some ~12 cm long Abundant compressed (flattened) fragments including large 15 cm by 5 cm pieces, most without bark
	Coal	1 fragment
	Twigs	Many flattened fragments with and without bark

3.6.2. Insect Macrofossils from 1998, 2000, and 2001 Samples

No insect macrofossils were recovered from Unit 1 in samples (BCW250500-M3 and BCW250500-M4). The samples collected from Unit 2 sediments on the north side of Statlu Creek are BCW071101-M1A, BCW071101-M1B, BCW280401-M2, BCW280401-M3, BCW280401-M4, and BCW160500-M1.

Insect macrofossils from Unit 2 samples BCW071101-M1A and BCW071101-M1B are sparse but include Coleoptera (beetle), Diptera (fly), and Arachnida (mites and spiders) remains. The macrofossils that could be classified to the subfamily level include Carabidae (ground beetles), Staphylinidae (rove beetles), Chironomidae (midges), and Oribatei/Acari (mites).

The insect macrofossil assemblage in samples BCW280401-M2, BCW280401-M3, and BCW280401-M4 collected from Unit 2 sediments include ground, rove, and scarab beetles; weevils; flies; wasps and ants; and mites. The macrofossils could not be identified to genus level, except for the ground beetles *Bembidion sp.* and *Notiophilus sp.,* the scarab beetle *Aegialia sp.*, and the ant genus *Myrmica.*

The Unit 2 insect macrofossils from the high road cut exposure close to CH01 (sample BCW160500-M1) include ground, rove, and scarab beetles, weevils, and caddisflies. The macrofossils could not be identified to the family level, with the exception of the ground beetle genus *Bembidion sp.* and the rove beetle subfamilies Omaliinae and Aleocharinae.

The samples collected from Unit 2 sediments at the Chehalis-Fleetwood exposure are BCW010600-M1, BCW220300-M2, BCW220300-M3, BCW160698-M1, BCW160698-M2, BCW280201-M2, BCW280201-M3, and BCW050601-M2. The insect macrofossils in these samples include mayflies, beetles, weevils, flies, craneflies, wasps, ants, midges, and mites. The species diversity in these sediments is greater than at the other Chehalis sites.

The fossils that could be identified to the species level include ground beetles (*Notiophilus sylvaticus* Eschscholtz and *Bembidion grapei* group), rove beetles (*Micropeplus laticollis* Mäklin and *Olophrum consimile* Gyllenhall), and bark beetles (*Phloeotribus lecontei* Scedl, and *Ips Tridens* Mannerheim). Taxa identified only to the genus level include the ground beetles (*Nebria sp., Notiophilus sp., Bembidion sp., Scaphinotus sp.,* and *Pterostichus sp.*), rove beetles (*Tachinus sp., Phlaeopterus sp., Olophrum sp.,* and *Stenus sp.*), and bark beetles (*Carphoborus sp., Pityophthorus sp.,* and *Ips sp.*). The sample included fossils from small carrion beetles, round fungus beetles, scarab beetles, and leaf beetles that could not be classified beyond the family level.

3.6.3. Plant Macrofossils from 2011, 2012, and 2013 Samples

The more recent sampling at the CH01 (Table 3-12) and ST03 (Table 3-13) exposures was conducted to refine the earlier analysis and to complement the new paleosol information (Appendix D). No macrofossils were recovered from the Chehalis-Fleetwood CHFW-01 exposure.

Table 3-12. Macrofossils recovered from Unit 2 at CH01 dated to 19, 980 ± 70 (UCIAMS 126600) (Telka, 2015b).

Scientific Name	Common Name	Item(s) Found
Fungal Remains		28 fungal sclerotia, some flattened
Non-vascular plants		
Bryophytes	Mosses	1 fragment
Vascular plants		
Pinaceae (undifferentiated)	Pine family	
Abies lasiocarpa (Hook.) Nutt.	Subalpine fir	Needles: 136 tips, 56 bases, 252 fragments 1 partial seed and remnants of attached wing
Tsuga heterophylla (Raf.) Sarg.	Western hemlock	1 whole needle, modern contaminant
Poaceae	Grass family	1 seed
Cyperaceae	Sedge family	
Carex sp.	Lenticular type	153 seeds of few species
Carex sp.	Trigonous type	15 seeds
Cyperus sp.	Flatsedge species	28 seeds
Salicaceae	Willow family	
Salix sp.	Willow species	10 persistent buds
Rosaceae	Rose family	
Potentilla sp.	Cinquefoil	2 seeds, 1 half seed
Brassicaceae	Mustard family	1 seed
	Unidentified plant taxa	12 seeds (same type)
Other		
	Charcoal	1 fragment
	Wood	Many fragments, mostly flattened thin strips
	Bark	Fragments
	Fe-stained (orange) cemented silt peds	Fragments
	Manganese peds	2 fragments

Table 3-13. Macrofossils recovered from Unit 2 at ST03 dated to 18,790 ± 45 (UCIAMS 142764) (Telka, 2015a).

Scientific Name	Common Name	Item(s) Found
Fungal Remains		34 fungal sclerotia
Non-vascular plants		
Bryophytes	Mosses	3 fragments
Vascular plants		
Selaginellaceae	Spikemoss family	
Selaginella selaginoides (L.) Link	1 megaspore	
Pinaceae (undifferentiated)	Pine family	
Abies sp.	Fir	6 needle tips and bases, some fragments 5 twig terminal fragments
Picea sp.	Spruce	10 needle tips and bases, some fragments 1 twig terminal fragment
Cyperaceae	Sedge family	
Carex sp.	Lenticular type	4 seeds of few species
Salicaceae	Willow family	
Salix sp.	Willow species	1 twig with persistent bud, 2 persistent buds
Other		
	Charcoal	3 fragments
	Wood	Many fragments with abrupt ends
	Bark	Fragments
	Amber-coloured nodules	Many

3.6.4. Insect Macrofossils from 2011, 2012, and 2013 Samples

Insect macrofossils were recovered from Unit 2 at CH01 and Unit 2 at ST03 (Table 3-14). Raw data are provided in Appendix D.

Table 3-14. Insect macrofossils Unit 2 at CH01 and Unit 2 at ST03 (Telka, 2015a).

Scientific Name	Common Name	Item(s) Found
Coleoptera	Beetle Order	6 sternites, 3 articulated sternites, 1 sternum, 2 articulated legs, 7 femurs, 3 tibiae, 1 scutellum, 1 adult mandible
Carabidae	Ground beetles	2 elytral fragments

Scientific Name	Common Name	Item(s) Found
Pterostichus punctatissimus Rand.		1 half elytron
Notiophilus aquaticus L.		1 elytron
Dyschirioides sp.		1 elytron
Staphylinidae	Rove beetles	2 half elytra
Olophrum sp.		1 head
Tachinus sp.		1 elytron
Omaliinae		1 head, I pronotum
Scarabaeidae	Scarab beetles	
Aegialia sp.		4 heads, 2 pronota, 2 half pronota, 9 elytra, 1 half elytron, 8 elytral fragments
Diptera	Fly Order	1 pupa fragment
Chironomidae	Midges	1 adult thoracic fragment
Hymenoptera	Wasp and Ant Order	
Ichneumonoidea	Ichneumons and braconids	
Ichneumonidae	Ichneumon wasps	1 thoracic fragment

3.6.5. Percentage Plant Macrofossil Data

Percentage plant macrofossil data for Unit 2 sediments has been stratified according to section and approximate age to see if there was any difference in forest composition across the study area or through time. The needle count from Unit 1 sediment was insufficient to apply Dunwiddie's forest reconstruction method.

The tree types in the macrofossils collected from Unit 2 sediments at one of the Statlu sections presented in Table 3-8 could not be used to determine the basal area of the forest because the needles were not reported as counts. However, the forest must have contained some fir and spruce species because their macrofossils were recovered from the sediment. Similarly, the Unit 2 macrofossils presented in Table 3-9 describe a forest with 43% fir and 57% spruce species, although other conifer genera were present but uncounted in the data.

The S4 section results, shown in Table 3-15, record a forest with ~30% undifferentiated members of the Pine family, which includes fir and spruce, ~45 %

Abies sp. (unspecified fir), and ~25% *Picea* sp. (unspecified spruce). A piece of *Abies* sp. wood from this unit was dated to 19,400 ± 120 ^{14}C years BP (WAT-4168) (Ward and Thomson, 2004).

Table 3-15. Percent Basal Area by Species, Unit 2 at S4.

Tree Type	Needle Count[a]	Needle Fragment Count	Needle Equivalent*	Needle Equivalent (%)	Basal Area (%)
Pinaceae family	0	67	22	**28**	**28**
Abies sp.	12	108	36	**46**	**46**
Picea sp.	19	63	21	**26**	**26**
Total	**31**	**238**	**79**	**100**	**100**

[a]In cases where needle and needle fragment counts were reported as abundant or present, they were counted as one whole needle or one fragment. This means that some species are underrepresented in the resultant basal area. *One needle equivalent was assumed to be three fragments representing two ends and the middle part of a single needle.

The macrofossils from Unit 2 at the CF2 section underrepresent the amount of *Abies lasiocarpa* because the needle count and needle fragment count was reported as abundant and not quantified. However, the macrofossils record a forest dominated by spruce and fir, with some hemlock present. Radiocarbon dates from this unit range from 19,150 ± 110 ^{14}C years BP (WAT 4169) to 17,380 ± 130 ^{14}C years BP (TO-9158) (Ward and Thomson, 2004).

The percentage plant macrofossil data for Unit 2 sediments at CH01 records a forest composed of only *Abies lasiocarpa*, although uncounted remains of undifferentiated members of the Pine family were present. This sediment dates from about 19,900 ^{14}C years BP. Macrofossils from ST03 record a forest with 40 % *Abies* sp. and 60% *Picea* sp.at approximately 18,790 ^{14}C years BP.

The forest composition recorded in the Unit 2 sediments that span the time period between approximately 20,000 and 18,800 ^{14}C years BP is consistent. All macrofossil samples contained evidence of *Abies* sp. and *Picea* sp. with remnants of other conifers that could not be identified beyond the Pinaceae family level in the classification hierarchy.

Chapter 4. Discussion

Paleosol and macrofossil evidence provides insight into the paleoenvironment in Chehalis Valley during the period before a glacier blocked the mouth about 20,000 ^{14}C years BP. The evidence indicates that vegetation in this low-elevation valley was similar to the ecosystem found at treeline in BC today. Stratigraphy places the soil and macrofossil-bearing sediments in a local and regional context, while the paleosol and macrofossils allow for paleoenvironmental reconstruction.

4.1. Paleosol Evidence

Development of the Chehalis and Statlu paleosols shows that podzolization was the most significant soil-forming process. The Chehalis developed from sandy gravelly parent material derived from felsic volcanic and granitic rocks. The combination of parent material, climate, and vegetation lead to development of a cemented placic horizon in the Chehalis paleosol. Such horizons form in very coarse sandy gravelly parent materials, under acid-producing coniferous or heath vegetation, in areas that receive in excess of 2400 mm of annual precipitation (Bockheim, 2011). The Statlu paleosol has a weakly expressed B-horizon and lacks morphological or chemical properties that support a detailed paleoenvironmental reconstruction.

The difference between the two soils is likely a function of landscape differences. The Statlu paleosol formed on debris flow or fan deposits. The Statlu paleosol may have had a shortened time to develop owing to the possibility that it formed on an unstable land surface. It did not have the same amount of time to develop the morphological expression of pedogenesis to the same degree as the Chehalis paleosol.

The range in Podzolic soil forming intervals in Canada reported in a review of Canadian soil chronosequences is approximately 400 years to 6800 years (Sanborn, 2015). The range reflects diversity in the factors governing the rate of soil formation. For example, the fastest forming Podzol developed in fewer than 400 years in coastal British Columbia under mild and wet climatic conditions with a coastal temperate rainforest. At other sites, the rate of podzolization was slowed by subarctic climates, calcareous parent material, and vegetation.

The soil-forming interval for the Chehalis paleosol is limited by the age of the sediment it formed on. The youngest age for the parent material is provided by a piece of charcoal recovered Unit 1 sediment at 26,150 ± 330 ^{14}C years BP (AA44046) (Ward and Thomson, 2004). The end of the soil-forming interval is provided by the ages of the lowermost beds of Unit 2. The age of this sediment ranges from 20,060 ± 190 ^{14}C years BP (AA50799) to 19,880 ± 60 ^{14}C years BP (UCIAMS 126601). The longest possible soil forming interval possible is ~6,300 radiocarbon years. Given the influence of climate, vegetation, and parent material on the rate of soil forming summarized in the chronosequence review, the soil-forming period in Chehalis Valley is likely shorter than the maximum possible because the climate, vegetation, and parent material would increase the formation rate. The placic horizon provides a minimum limit because similar horizons were found to form in approximately 2,000 years (Sanborn and Massicotte, 2010). The soil-forming interval was at least 2,000 years and at most 6,300 years.

The soil evidence indicates an environment with coniferous forest, bog, or heath vegetation with high precipitation and a thick snowpack. The soil-forming time interval could have been as short as 2000 years (Sanborn and Massicotte, 2010). This short period, combined with a general lack of paleosols in sediments spanning the last part of MIS 3 in the Chehalis Valley implies that 1) they were not found, 2) they were eroded or degraded as climate transitioned from interstadial to glacial conditions, 3) climate during MIS 3 was unstable and surfaces were not stable enough for well-developed soils to form, or 4) a combination of the above.

The use of a soil to interpret the ecological conditions under which it formed requires observations across the landscape to account for the inherent natural variability that is characteristic of pedogenesis. In Chehalis Valley, the paleosol distribution is limited, thus other evidence must support interpretation of the ecological factors influencing pedogenesis. Plant and insect macrofossil evidence supports the paleosol evidence that there was a subalpine environment.

4.2. Macrofossils

The assemblage of coniferous species recorded in the percentage macrofossil data is similar to that of the modern Engelmann Spruce Subalpine Fir (ESSF) forest ecosystem. Modern ESSF ecosystems are composed of the climax coniferous species *Picea engelmanii* and *Abies lasiocarpa,* with minor occurrences of whitebark pine, lodgepole pine, and mountain hemlock and abundant heath, meadow plants, and grassland at higher elevations (Coupe et al., 1991; Meidinger and Pojar, 1991). The upper elevations of the ESSF consist of subalpine parklands characterized by clumps of coniferous trees with areas of heath, meadow, and grassland (Coupe et al., 1991). The understory vegetation includes an ericaceous shrub layer, a sparse herb layer, and dense moss.

The plant macrofossil data, recovered from Unit 2 sediments, indicate a coniferous forest composed of *Picea* sp. (spruce), *Abies* sp. (true fir), and undifferentiated conifers of the pine family, which includes the tree genera spruce, pine, and fir. Abundant sedge, rush, and willow dominate the shrub species. Other vegetation includes members of the grass, violet, rose, honeysuckle, mustard, and aster families.

The beetle assemblage in similar-aged sediments at the Port Moody and Mary Hill sites include several species that live in alpine or subalpine forests, including *Notiophilus sylvaticus* Eschscholtz, *Micropeplus laticollis* Mäklin. *Phloeotribus lecontei* Scedl, and *Bembidion* sp. (Miller et al., 1985). The Chehalis Valley beetle assemblage is similar to the Port Moody assemblage, with all the species described above present in the samples collected from Unit 2 sediments. This fossil beetle assemblage includes members of three beetle families that are associated with forest ecosystems (Telka, 2000a). The rove beetles family (Staphylinidae), including the species *Micropeplus laticollis* Mäklin*,* inhabit forest floor ecosystems. Many species within this family live in deciduous leaf litter associated with stream and pond edges. *M. laticollis* inhabitat the forest floor of a subalpine forest composed of fir, pine, and spruce. The ground beetle (Carabidae) family is associated with running water, small creeks, and gravel banks with sparse vegetation. The bark beetle family (Scolytidae) assemblage includes *Prionus lecontei*, which is associated with *Pseudotsuga menziesii* and *Abies lasiocarpa*. Carphobrus beetles are associated with *Picea engelmanii*, *Pseudotsuga menziesii*, *Pinus ponderosa,* and *Pinus contorta*. The beetle assemblage suggests a forested ecosystem, with subalpine conifer tree species, wet areas, and running water.

4.3. Paleoenvironment

The paleoenvironment recorded by the late Fraser Glaciation sediments in the Chehalis Valley is similar to the modern ESSF ecosystem. In southwest BC, the ESSF occurs at 1200 m to 2100 m elevation, mainly in mountainous terrain. The climate is cold and moist with cool, short growing seasons and long, cold winters. The mean annual temperatures range from -2 °C to 2 °C. Precipitation is variable because of the orographic effects of the mountains, but mean annual precipitation in southwest BC is up to 2200 mm with 50% to 70% of precipitation falling as snow. The snowpack depths range from 1 m to 4 m (Coupe et al., 1991; Meidinger, 1998).

4.4. Regional Context

The macrofossil evidence from Chehalis Valley shows that there was a forest similar to the modern ESSF when ice advanced and blocked the mouth of the valley. The blockage impounded a lake in which glaciolacustrine sediments were deposited. Dates from these samples suggest that this forest existed 1000 to 2000 years earlier than that found at locations to the west (*i.e.,* Port Moody, Lynn Valley, and Mary Hill). The implications of the potential diachronous nature of similar forests suggest that there were regional differences in glacier advances and that the Coquitlam Stade and the Port Moody Interstade were not driven by regional climate change.

There is no evidence of glaciers affecting the Chehalis Valley when the Coquitlam Stade type sections were initially covered by glaciers, at approximately 21,700 ^{14}C years BP. At this time in the Chehalis Valley, a paleosol with a placic horizon was forming under a coniferous forest; this soil represents at least a few thousand years of a stable land surface. Radiocarbon ages of 20,000 ^{14}C years BP immediately above the soil indicate both the end of soil formation and the first flooding of the valley (Figure 4-1). This represents the first evidence of glaciation in the area, and corresponds to approximately the middle of the Coquitlam Stade at sites further west. There is evidence of at least one oscillation of the ice front, with the main flooding event occurring a few hundred years later, about 19,500 to 19,300 ^{14}C years BP. The timing of complete glacier cover of the Chehalis is unclear because of the range in radiocarbon ages obtained from the glaciolacustrine sediments. If the age from ST03 is accurate at 18,790 ± 45 ^{14}C years BP (UCIAMS 142764), the lake could have persisted almost 1000 ^{14}C years.

Macrofossils in organic sediments, similar to Port Moody sediments, from the glaciolacustrine deposits in Chehalis Valley indicate there was a forest similar to the ESSF. The Port Moody Interstade occurs from 18,500 to 17,500 ^{14}C years BP further west, while Chehalis Valley organic sediments existed from about 20,000 ^{14}C years BP to at least 18, 000 ^{14}C years BP. Thus, the Port Moody sediments do not represent a true interstade because a similar environment existed for a much longer period of time in Chehalis Valley. A true climatically driven interstade should be regional and synchronous. It now appears that glaciers in the western part of the Fraser Lowland were advancing into a forested environment and the sites with Port Moody sediment represent this forest reoccupying sites after Coquitlam glaciers retreated.

It is unclear why Coquitlam glaciers retreated. It could be related to some sort of internal ice dynamics, or possibly relative sea level rise. Further study is necessary to determine the cause of Coquitlam ice retreat. Mathews (1979) suggests that between 15 km and 50 km of continental shelf on the west side of Vancouver Island would have been exposed during the last glacial maximum (LGM) as a result of eustatic sea-level decrease, with shoreline approximately 200 km west of the Fraser Lowland 18,000 years ago (Hicock et al., 1982). An analysis of relative sea level change in the area during the Late Pleistocene indicates that the crust responded rapidly to ice-sheet loading and unloading (Clague et al., 2005). Marine fossils found 18 m above present sea level, when combined with estimates of eustatic sea level, imply isostatic depression of approximately 100 m at 24,800 ^{14}C year BP. During deglaciation, relative sea level was approximately 200 m higher than present at about 13,000 ^{14}C year BP. Relative sea level could not have been lower than at present about 20,000 years ago, suggesting the shoreline was closer than Mathews (1979) estimated.

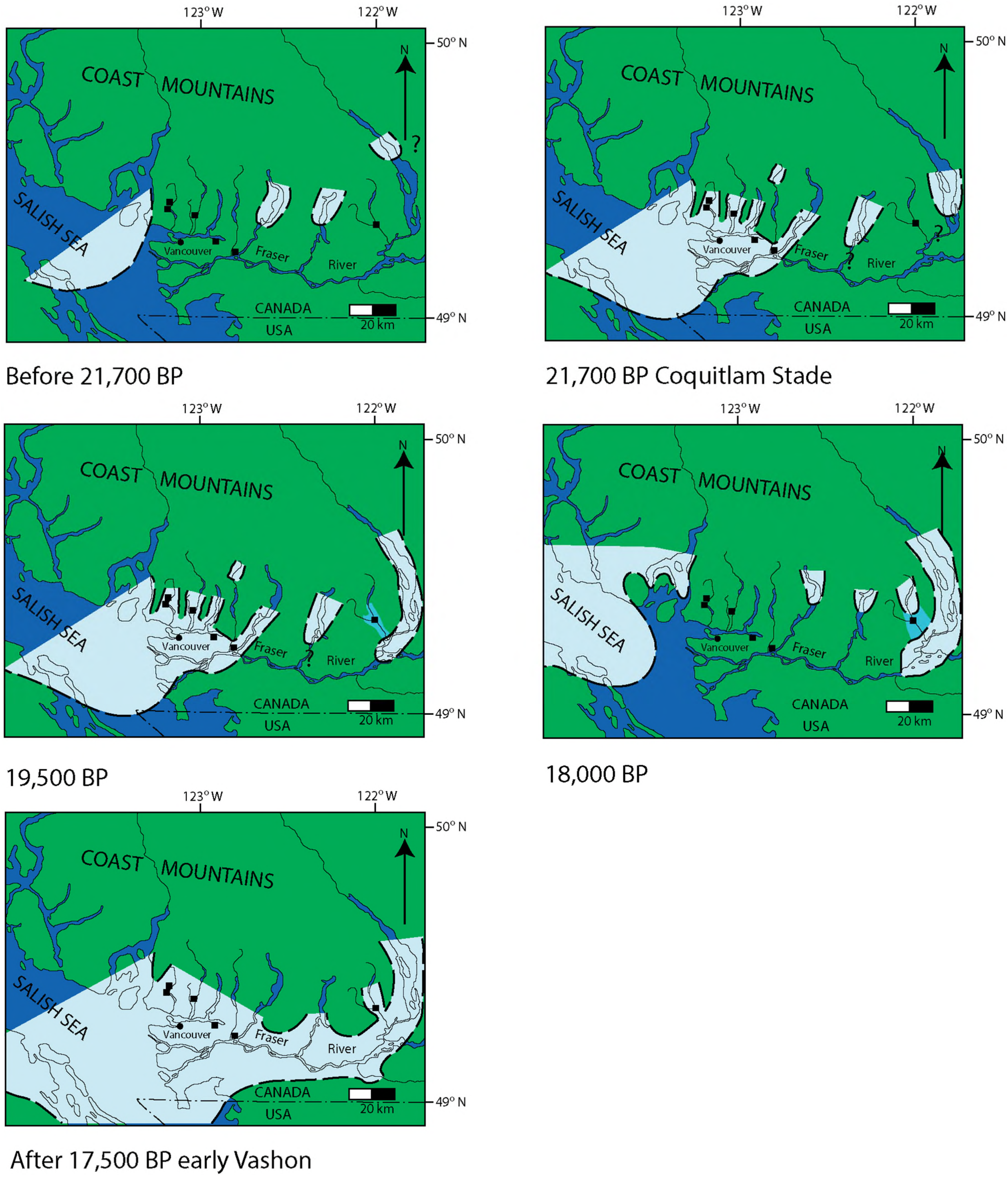

Figure 4-1: Suggested glacier cover in the Fraser Lowland. Black squares are the locations that provide chronological control. (Modified from Ward and Thomson, 2004).

Differences in effective precipitation for the source areas of glaciers that covered southwest British Columbia could contribute to ice sheet expansion or retraction. The Insular Mountains of Vancouver Island and the western ranges o of the Coast Mountains could have received precipitation and created a rainshadow over the source areas for ice that covered Chehalis Valley if shoreline was further west. A drier climate might have suppressed significant ice sheet growth, accounting for ice-free conditions in Chehalis Valley when other areas of southwestern British Columbia were covered by ice (Ward and Thomson, 2004).

Chapter 5. Conclusion

The stratigraphy preserved in Chehalis Valley records an end to non-glacial conditions about 20,000 ^{14}C year BP. The record lacks Coquitlam Stade equivalent glacial sediments. The sediments similar to Port Moody Interstade sediments appear approximately 1000 years earlier here than at type sections to the west. This appears to indicate that the Coquitlam and Port Moody events are local and do not represent regional climate change.

The paleosols in the Chehalis Valley study area indicate that the climate was colder and wetter than present conditions before 20,000 ^{14}C year BP. The presence of a well-developed placic horizon in the Chehalis paleosol is a significant indicator of a wet climate while the evidence of podzolization indicates both a forest dominated by coniferous trees and a wet climate. Soil development indicates that there was a period between 2,000 and 6,300 years long with a stable landscape that ended around 20,000 ^{14}C year BP.

Plant macrofossils include coniferous tree species commonly found in modern subalpine environments. The macrofossil plant data confirms a forest dominated by *Abies lasiocarpa* (subalpine fir) and *Picea engelmanii* (Engelmann spruce), with sedge, willow, and rush understory vegetation. This forest was present from before 20,000 ^{14}C years BP until possibly 18,500 ^{14}C years BP. Although this forest appears identical to that reconstructed from Port Moody Interstade sediments further west, it pre-dates it by at least a thousand radiocarbon years.

The paleoclimate in Chehalis Valley between 20,000 and 18,000 ^{14}C years BP was likely similar to one supporting the ESSF. The ESSF today is restricted to high elevation and is characterized by cold, wet, continental climates.

5.1. Future Research

The Norrish, Stave, Pitt, and Alouette valleys are all large north-south trending valley on the southern flank of the Coast Mountains. There has been little research in those valleys related to Late Pleistocene glacier advance and retreat patterns. Sediments in these valleys should be studied to test the regional nature of the Coquitlam Stade and Port Moody Interstade events. Additional potential sites include the east side of Hatzic Valley near Pattison Creek, 20 km southwest of the study area. Sediments are exposed in a large landslide scarp and could contain up to four sedimentary units (D. Brayshaw, personal communication 2016). Some small drainages on the west side of Harrison Lake contain thick sediments that might be as old as the Late Pleistocene.

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Appendix A.

Soil Chemical Data for the Chehalis Paleosol

Analysis Report

Ministry of Forests & Range
Competetiveness and Innovation Division
Research, Innovation & Knowledge Management Branch

Requisition # S1288
Submitter Eryne Croquet / Dr. Brent Ward
Office: SFU Department of Earth Sciences
Project Chehalis Section 1 soil samples
Date In: 2012/09/13
Date Out: 2012/10/03
* all results reported on oven-dry basis

		Citrate-Dithionite Extractable				*Acid-Ammonium Oxalate Extractable*			
Sample	**Horizon**	**Al %**	**Fe %**	**Mn %**	**Si %**	**Al %**	**Fe %**	**Mn %**	**Si %**
1	**Ahb**	3.074	0.825	0.028	1.418	3.820	0.843	0.027	2.283
2	**IIBfjb**	1.441	0.468	0.014	0.679	2.906	0.515	0.016	1.827
3	**IIBfb**	0.993	0.472	0.008	0.473	2.923	0.553	0.010	1.722
4	**IIBfjb**	0.609	0.261	0.004	0.301	1.816	0.357	0.006	1.051
5	**IIC**	0.317	0.271	0.005	0.158	1.597	0.324	0.007	0.868
6	**IIBfjcb**	0.743	2.923	0.059	0.471	1.602	2.878	0.100	1.155
7	**IIBfjcb**	0.633	3.565	0.049	0.442	1.468	3.469	0.085	1.126
8	**IIBfjcb**	0.387	3.187	0.162	0.363	1.258	2.635	0.162	0.880

Analysis Report

Ministry of Forests & Range

Competetiveness and Innovation Division

Research, Innovation & Knowledge Management Branch

Requisition # S1288
Submitter Eryne Croquet / Dr. Brent Ward
Office: SFU Department of Earth Sciences
Project Chehalis Section 1 soil samples
Date In: 2012/09/13
Date Out: 2012/10/03
* all results reported on oven-dry basis

		Pyrophosphate Extractable				*Total N and C*	
Sample	**Horizon**	**Al**	**Fe**	**Mn**	**Si**	**N**	**C**
		%	**%**	**%**	**%**	**%**	**%**
1	**Ahb**	0.727	0.292	0.026	0.075	0.165	3.496
2	**IIBfjb**	0.395	0.141	0.014	0.040	0.089	2.192
3	**IIBfb**	0.435	0.134	0.008	0.045	0.053	1.737
4	**IIBfjb**	0.252	0.062	0.004	0.025	0.026	0.887
5	**IIC**	0.198	0.031	0.002	0.026	0.021	0.675
6	**IIBfjcb**	0.183	0.126	0.021	0.025	0.021	0.765
7	**IIBfjcb**	0.144	0.125	0.021	0.026	0.020	0.738
8	**IIBfjcb**	0.140	0.076	0.015	0.019	0.023	0.695

Analysis Report

Ministry of Forests & Range
Competetiveness and Innovation Division
Research, Innovation & Knowledge Management Branch

Requisition # S1288
Submitter Eryne Croquet / Dr. Brent Ward
Office: SFU Department of Earth Sciences
Project Chehalis Section 1 soil samples
Date In: 2012/09/13
Date Out: 2012/10/03
* all results reported on oven-dry basis

Sample	Horizon	*Soil Texture* Sand %	Silt %	Clay %	Sample Collection ID	Field Notes
1	Ahb	43.0	51.7	5.3	Chehalis Section 1 A	A horizon
2	IIBfjb	62.1	35.3	2.6	Chehalis Section 1 B	B
3	IIBfb	84.3	13.1	2.6	Chehalis Section 1 C	Upper B
4	IIBfjb	89.6	9.1	1.3	Chehalis Section 1 D	Lower B
5	IIC	92.4	6.4	1.3	Chehalis Section 1 G	C
6	IIBfjcb	n/a	n/a	n/a	Chehalis Section 1 CH26-01	placic
7	IIBfjcb	93.6	5.1	1.3	Chehalis Section 1 CH26-02	placic
8	IIBfjcb	n/a	n/a	n/a	Chehalis Section 1 CH26-03	placic

Appendix B.

Soil Chemical Data for the Statlu Paleosol

Analysis Report

Ministry of Forests & Range
Competetiveness and Innovation Division
Research, Innovation & Knowledge Management Branch

Requisition # S1432
Submitter Eryne Croquet / Dr. Brent Ward
Office: SFU Department of Earth Sciences
Project ST03-060314 Soil 1 and Soil 2 (Mineral Soil)
Date In: 2014/06/10
Date Out: 2014/07/31
* all results reported on oven-dry basis

		Citrate-Dithionite Extractable				***Acid-Ammonium Oxalate Extractable***			
Sample	**Horizon**	**Al**	**Fe**	**Mn**	**Si**	**Al**	**Fe**	**Mn**	**Si**
		%	**%**	**%**	**%**	**%**	**%**	**%**	**%**
1	**Ahb**	0.412	0.503	0.032	0.233	0.843	0.416	0.032	0.530
2	**Bmb**	0.507	1.117	0.065	0.341	0.892	0.985	0.067	0.589

Analysis Report

Ministry of Forests & Range
Competetiveness and Innovation Division
Research, Innovation & Knowledge Management Branch

Requisition # S1432
Submitter Eryne Croquet / Dr. Brent Ward
Office: SFU Department of Earth Sciences
Project ST03-060314 Soil 1 and Soil 2 (Mineral Soil)
Date In: 2014/06/10
Date Out: 2014/07/31
* all results reported on oven-dry basis

		Pyrophosphate Extractable				***Total N and C***	
Sample	**Horizon**	**Al**	**Fe**	**Mn**	**Si**	**N**	**C**
		%	**%**	**%**	**%**	**%**	**%**
1	**Ahb**	0.222	0.141	0.015	0.069	0.091	1.657
2	**Bmb**	0.212	0.209	0.010	0.055	0.037	0.578

Analysis Report

Ministry of Forests & Range
Competetiveness and Innovation Division
Research, Innovation & Knowledge Management Branch

Requisition # S1432
Submitter Eryne Croquet / Dr. Brent Ward
Office: SFU Department of Earth Sciences
Project ST03-060314 Soil 1 and Soil 2 (Mineral Soil)
Date In: 2014/06/10
Date Out: 2014/07/31
* all results reported on oven-dry basis

		Soil Texture			
Sample	**Horizon**	**Sand %**	**Silt %**	**Clay %**	**Sample Collection ID**
1	**Ahb**	31.3	58.6	10.2	ST03-060314 Soil 1
2	**Bmb**	55.5	40.7	3.8	ST03-060314 Soil 2

Appendix C.

Plant and Insect Macrofossil Reports, 1998 to 2001

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-49

Sample No.: BCW 250500-M3 & M4 Unit 1

Lab No.: 5-59, 5-60

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N Longitude: 49º 21' W Elevation: 110 m

Collector: B. Ward, collected May 25, 2000

Submitter: B. Ward

Material: fine grained lens of organics in gravel

Site description: High roadcut above forestry road in a gravel sequence directly on bedrock. BCW 250500-M4 and BCW 250500-M3 are from a pebbly diamicton lens 0.5 m and 2.0 m (respectively) above bedrock contact. Glaciolacutstrine sequence abruptly caps gravel and large tree at base yielded a date of 19,400 (Wat 4168).

Sample volume: ~1.6 L (M4); ~7.0 L (M3)

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	~5
Vascular Plants:		
Pinaceae ...."pine family"		
Picea sp.	+	charred needle fragment: 1
Tsuga sp.	+	modern contaminant: needle base fragment: 1
Other:		
charcoal	+++	fragments (large and small)
wood	+	partially charred wood fragments
charred twig	+	fragments: 3
unknown	+	soft organic? fragments (opaque colours of brown and caramel gold)
modern contaminants	+	plant fragments: 3, plant rootlet?: 1

ANIMAL MACROFOSSILS:

No animal macrofossils.

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

continued…

Comments:

Six bulk samples of varying volumes collected by Brent Ward from the Chehalis Statlu Section were submitted for macrofossil analyses. As requested by the submitter, samples BCW 110698-M1 and M2 (previously sieved by a student of B. Ward) and sample BCW 250500-M1 were not analyzed at this time. Of the remaining three samples from this section, BCW 250500-M3 and M4 are from the same Unit 1 gravel, therefore, for the purpose of discussion, this report is based on the combined fossil contents of both these samples. To view the macrofossil content of each individual sample see MFRPT 00-45 (BCW 250500-M3) and MFRPT 00-44 (BCW 250500-M4). The remaining sample from this section is discussed in macrofossil report MFRPT 00-48.

Both BCW 250500-M3 and M4 required a more diligent method of processing based on the amount of material submitted (BCW 250500-M3, 6.5 Kg), denseness of the sediment and presence of abundant gravel. Processing the samples therefore involved two techniques. Initially the samples were hand separated manually by breaking apart large sediment 'blocks' and each separated surface examined under a microscope. Any observable fossils were delicately extracted. The second technique involved combining the examined layers along with any remaining loose sediment and processing with warm water. Organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). The sample was then swirled in water in order to isolate the organic material from the gravel component. This swirled organic concentrate was sieved through nested 5, 20 and 40 mesh Tyler sieves (mesh openings: 4.0 mm, 0.85 mm and 0.425 mm respectively). All organic material greater than 0.425 mm (Tyler 40 mesh sieve) was examined using a binocular microscope and plant and animal fossil remains were isolated for identification.

Although a large amount of material was examined from Unit 1 (total volume ~8.6 L), M3 and M4 yielded very little organic material. The non-identifiable organic component consists of abundant well-preserved charcoal including large and small fragments along with charred and partially charred wood fragments and three unidentifiable charred twigs. Macrofossil remains are rare represented by one charred spruce (*Picea*) needle fragment. A few modern contaminants were observed in M3 and M4 including a needle fragment of hemlock (*Tsuga* sp), three plant fragments and what appears to be a plant rootlet. Samples M3 and M4 contain no insect fossil remains.

Based on the small numbers of fossils recovered from both Unit 1 samples, no meaningful interpretation can be made regarding the depositional environment of M3 and M4. The presence of abundant charred remains more than likely indicates a fire occurred in the region.

Two samples from Unit 1 have been submitted to Isotrace for AMS radiocarbon dating:

1) charcoal/charred wood fragment (BCW 250500-M3, TO-9160)
2) conifer charcoal fragment (BCW 250500-M4, TO-9161)

Caution should be used in interpreting the AMS radiocarbon dating results on charcoal/charred wood. Charcoal is very buoyant and easily floats. The possibility that the charred remains are rebedded from older sediments cannot be ruled out. However, I feel quite confident that they are not reworked and do represent the depositional age of the diamicton. In both cases, the selection of charred remains for dating were obtained by 'hand excavating' the fragments from the surrounding sediment within the bulk samples. More than likely, the charred remains were rapidly incorporated and deposited within the diamicton which would account for the good preservational state of the charcoal showing no visible signs of wear or degration.

Alice Telka

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December 18, 2000

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-45

Sample No.: BCW 250500-M3 Unit 1

Lab No.: 5-60

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N   Longitude: 49º 21' W   Elevation: 110 m

Collector: B. Ward, collected May 25, 2000

Submitter: B. Ward

Material: fine grained lens of organics in gravel ~2 m above bedrock contact

Site description: High roadcut above forestry road in a gravel sequence directly on bedrock. Sample is from a pebbly diamicton lens ~2.0 m above base. Glaciolacutstrine sequence abruptly caps gravel and large tree at base yielded a date of 19,400 (Wat 4168).

Sample volume: ~7.0 L (6.5 Kg)

PLANT MACROFOSSILS:

Vascular Plants:		
Pinaceae ...."pine family"		
Picea sp.	+	charred needle fragment: 1
Other:		
charcoal	+++	fragments (large and small)
wood	+	partially charred wood fragments
modern contaminants	+	plant rootlet?: 1

ANIMAL MACROFOSSILS:

No animal macrofossils.

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

<u>Comments:</u>

See marcrofossil report MFRPT 00-49 for comments.

Two samples from Unit 1 have been submitted to Isotrace for AMS radiocarbon dating:

1) charcoal/charred wood fragment (BCW 250500-M3, TO-9160)
2) conifer charcoal fragment (BCW 250500-M4, TO-9161)

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December 1, 2000

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-44

Sample No.: BCW 250500-M4 Unit 1

Lab No.: 5-59

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N Longitude: 49º 21' W Elevation: 110 m

Collector: B. Ward, collected May 25, 2000

Submitter: B. Ward

Material: fine grained lens organics in gravel 50 cm above bedrock contact

Site description: High roadcut above forestry road in a gravel sequence directly on bedrock. Sample is from a pebbly diamicton lens 0.5 m above base. Glaciolacutstrine sequence abruptly caps gravel and large tree at base yielded a date of 19,400 (Wat 4168).

Sample volume: ~1.6 L

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	~5
Vascular Plants:		
Pinaceae ...."pine family"		
Tsuga sp.	+	modern contaminant: needle base fragment: 1

No plant macrofossils.

Other:		
charcoal	+++	fragments (large and small)
charred twig	+	fragments: 3
modern contaminants	+	plant fragments: 3
unknown	+	soft organic? fragments (opaque colours of brown and caramel gold)

ANIMAL MACROFOSSILS:

No animal macrofossils.

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

Comments:

See marcrofossil report MFRPT 00-49 for comments.

Two samples from Unit 1 have been submitted to Isotrace for AMS radiocarbon dating:

1) charcoal/charred wood fragment (BCW 250500-M3, TO-9160)
2) conifer charcoal fragment (BCW 250500-M4, TO-9161)

Alice Telka

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December 1, 2000

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-48

Sample No.: BCW 160500-M1

Lab No.: 5-62

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N Longitude: 49º 21' W Elevation: 110 m

Collector: B. Ward, collected May 16, 2000

Submitter: B. Ward

Material: organic rich sediment

Site description: High roadcut above forestry road in a gravel sequence directly on bedrock. Exposed in gully at downstream portion of section. Organic rich sediment directly overlies oxidized gravels (Unit 1). Unsure of stratigraphic context.

Sample volume: ~3.5 L

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	~20 (some are flattened)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments: 18 (few types), leaves: 5
Sphagnum sp	+	leaf: 1
Vascular Plants:		
Pinaceae ...."pine family"		
Abies sp.	+	needle fragments (poorly preserved), twig terminals: 2
Picea sp.	+	needle fragments (poorly preserved)
Tsuga sp. (modern)	+	modern contaminant: complete needle: 1
Gramineae? ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"		
Carex lenticular type	+	seeds: 5, perigynium and seed: 1
Carex trigonous type	+	seeds: 4
Salicaceae ...."willow family"		
Salix sp.	+	twig fragments with persistent buds: 11, persistent buds: 13
Unidentifiable plant taxa	+	small capsules?
Other:		
amber-like resin	+	fragments (more opaque)
charcoal	+	fragments: 19 (including one larger piece)
wood	+	compressed (flattened) fragments (most without bark), including larger pieces (4' long x 1" wide)
twig	+	modern contaminant (no bark): 1
bark? with nodules	+	small and large pieces
net-veined leaves	+	fragments: 8
coal?	+	fragment: 1

continued…

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	elytral fragments: ~3 (poorly preserved, thin, pitted surfaces), femurs: 3, sternites: 6, mandible: 1
Carabidae ...."ground beetles"	+	half pronotum: 1 (poorly preserved)
Bembidion sp.	+	elytron: 1
Staphylinidae ....."rove beetles"	+	elytron: 1, articulated pro & mesosternum: 1
Omaliinae	+	elytron: 1
Aleocharinae	+	pronotum: 1
Scarabaeidae ......"scarab beetles"	+	tibia: 1
Curculionidae ....."weevils"	+	pronotal fragment: 1, elytral fragment: 1
TRICHOPTERA ...."caddisflies"	+	mineral larval case: 1, fragments: 2
Other:		
Immature insects	+	fragment: 1

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

Comments:

Six bulk samples of varying volumes collected by Brent Ward from the Chehalis Statlu Section were submitted for macrofossil analyses. As requested by the submitter, samples BCW 110698-M1 and M2 (previously sieved by a student of B. Ward) and sample BCW 250500-M1 were not analyzed at this time. Of the remaining three samples from this section, BCW 250500-M3 and M4 are from the same Unit 1 gravel and are discussed in MFRPT 00-49. To view the macrofossil content of each individual sample see MFRPT 00-45 (BCW 250500-M3) and MFRPT 00-44 (BCW 250500-M4). This report discusses the remaining sample from this section.

The procedure for isolating macrofossils for analyses was similar to the method used for the Chehalis Fleetwood Section samples. The starting volume for each was approximated using wet displacement technique. The entire sample, excluding a small archive was initially soaked in warm water and the organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). The remaining sample was swirled in water in order to isolate the organic material from the fine silt component. The swirled organic concentrate was sieved through nested 5, 20 and 40 mesh Tyler sieves (mesh openings: 4.0 mm, 0.85 mm and 0.425 mm respectively). All organic material greater than 0.425 mm (Tyler 40 mesh sieve) was examined using a binocular microscope and plant and animal fossil remains were isolated for identification.

The organic content of BCW 160500-M1 is large compared to the other two samples examined from Chehalis Statlu Section. The non-identifiable organic fraction consists mainly of compressed, flattened wood including larger pieces (~4” long x 1” wide), charcoal, and the same bark? with nodules seen from the Chehalis Fleetwood Section samples. Some of these nodules (separated from the bark) were also observed in the organic residue ‘encrusted’ in opaque, amber-like resin.

Fossil preservation in this sample is poor. A majority of the fossils had fine sediment adhering to their surfaces making identification difficult. As such, the conifer needles could not be identified beyond the genus level. Some of the insect fragments display postmortem ‘punctures’ on the surfaces with thin worn edges. This is typical of fossils from sands or sediments exposed to prolonged weathering.

Plant macrofossils in BCW 160500-M1 consists mostly of conifer remains of fir (*Abies* sp.) and spruce (*Picea* sp.) as well as twigs and persistent buds of willow (*Salix* sp.). A few types of mosses (Bryophytes) were recovered with *Sphagnum* sp. being rare. Only a small number of macrofossil

continued…

seeds were isolated from BCW 160500-M1, being represented by one genus, sedges (*Carex* sp.). This sample contains two modern contaminants including one hemlock (*Tsuga* sp.) needle and one twig.

Insect fossil remains are not abundant with most of the beetle fragments being non-identifiable. Only the ground beetle (*Bembidion* sp.) and rove beetles (Staphylinidae) could be identified. *Bembidion* is hygrophilous often inhabiting bare soil or sparsely vegetated areas on the border of standing and slow running water. Rove beetles occur in a variety of habitats, but are most often seen about decaying materials including leaf litter. Two fragments of an aquatic larval caddisfly (Trichoptera) case composed of silt grains were also recovered in this sample.

Plant macrofossil evidence suggests a partly forested environment comprised of fir and spruce trees with shrubs of willow. Mosses and sedges are growing in the more poorly drained areas. Insect fossil evidence, although rare, suggests an aquatic environment of possibly slow moving water or a temporary wet depression.

The organic and fossil content of BCW 160500-M1 is more similar to BCW 160698-M1 & M2 (Chehalis Fleetwood Section) from the other side of the valley. Although I have not looked at BCW 110698-M1 & M2 Unit 2 (previously processed by student), from the Chehalis Statlu Section, I suspect it also will be similar to BCW 160500-M1. More than likely, this sample represents Unit 2.

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April 28, 2001

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-46

Sample No.: BCW 010600-M1, BCW 220300-M2 and BCW 220300-M3

Lab No.: 5-52, 4-91 and 4-93

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, near Aggazzi, British Columbia

Latitude: 121º 81' N   Longitude: 49º 20' W   Elevation: ~140 m

Collector: B. Ward

Submitter: B. ward

Material: organic rich glaciolacustrine sediment

Site description: Small landslide scar below forestry road at the base of a thick, advance glaciolacustrine sequence.

Sample volume: ~2.3 L

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	(some are flattened)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments with leaves (few types)
Sphagnum sp.	+	leaves: 3
Vascular Plants:		
Pinaceae ...."pine family"	+	cone fragments: 2 (one has ~4 scales and seed wing), cone scales: 11 (3 are frayed, worn edges), cone scale bract: 2, seed wings: 14, seed wing fragments: 10, conifer seeds: 2
Abies lasiocarpa (Hook.) Nutt.	+++	needles (complete and fragments)
Abies sp.	+	seed and wing: 1, seed: 1, twig terminals: ~15 (some with lateral buds)
Picea sp.	++	needles (complete and fragments), twig terminals: ~11 (some with lateral buds)
Tsuga sp.	+	needle: 1
Gramineae ...."grass family"	+	seed: 1, lemma and palea (floret): 1
Cyperaceae ...."sedge family"	+	seeds: 3
Carex lenticular type	+	seeds: 2
Carex sp.	+	seeds: 2
Chenopodiaceae ...."goosefoot family"	+	seed: 1, seed fragment: 1
Chenopodium sp.	+	seeds: 3, seed fragments: 11
Ranunculaceae ....."crowfoot family"		
Ranunculus Macounii/pensylvanicus type	+	seed: 1
Ranunculus sp.	+	seed: 1
Violaceae ...."violet family"		
Viola sp.	+	half seeds: 2
Ericaceae ...."heath family"	+	seed: 1, leaf: 1
Caprifoliaceae ...."honeysuckle family"	+	seed: 1
Sambucus sp.	+	seed: 1
Unidentified plant taxa	+	seeds: 3 (one is poorly preserved)

continued…

Other:		
amber-like resin	+	fragments
charcoal	+	
wood	+++	abundant compressed (flattened) fragments including large pieces (6' long x 2" wide), most without bark
twigs	++	many flattened fragments with and without bark
bark? with nodules	+	many 'chunks'
coal	+	fragment: 1

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA	+	abdomen: 1
EPHEMEROPTERA ...."mayflies"	+	immature mandible: 1
COLEOPTERA ...."beetles"	+	elytral fragment: 1, pronotal fragment: 1, half pronotum: 1, metasternum: 1, femur: 1, coxae: 1, trochanters: 2, sternites: 4
Carabidae ...."ground beetles"	+	metasternum: 1, femur: 1
Nebria sp.	+	half pronota: 2, pronotal fragment: 1, elytral fragment: 1
Bembidion grapei group	+	elytron: 1
Scaphinotus sp.	+	half elytron: 1
Pterostichus sp.	+	head: 1
Staphylinidae ....."rove beetles"	+	elytra: 4, elytral fragment: 1, mesosternum: 1
Micropeplus laticollis Mäklin	+	elytron: 1
Phlaeopterus sp	+	elytron: 1, half pronotum: 1
Olophrum sp.	+	elytron: 1
Olophrum consimile Gyll.	+	pronota: 2
Stenus sp.	+	elytron: 1
Tachinus sp.	+	elytra: 2
Aleocharinae	+	pronotum: 1, elytron: 1
Leptodiridae? ......"small carrion beetles"	+	elytron: 1
Leiodidae? ...."round fungus beetles"	+	half elytron: 1, pronotum: 1
Scarabaeidae ......"scarab beetles"		
Aegialia? sp.	+	elytral fragment: 1
Chrysomelidae ....."leaf beetles"		
Chrysolina sp.	+	elytron: 1
Curculionidae ....."weevils"	+	elytron: 1
Scolytidae ...."bark beetles"		
Phloeotribus lecontei Schedl*	+	elytra: 3
Carphoborus sp	+	elytron: 1
Pityophthorus sp.*	+	pronotum: 1
DIPTERA ...."flies"	+	adult thorax: 1, puparial fragments: 4
Tipulidae ...."crane flies"		
Tipula sp.	+	heads: 1.5
Chironomidae ......"midges"	+	larval head capsules: 4.5
ARACHNIDA		
Oribatei/Acari ...."mites"	+	6
Other:		
soft-bodied/immature insects	+	fragments: 2

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
*Identified by D.E. Bright, Department of Agriculture, Ottawa

continued…

Comments:

Five bulk samples of varying volumes collected by Brent Ward from the Chehalis Fleetwood Section were submitted for macrofossil analyses. Three samples, BCW 220300-M2 and BCW 220300-M3, collected on Mar. 22/00 and BCW 010600-M1 collected on June 1/00 are from the same horizon therefore, for the purpose of discussion, this report is based on the combined fossil contents of all three samples. To view the macrofossil content of each individual sample see MFRPT 00-42 (BCW 220300-M2), MFRPT 00-43 (BCW 220300-M3) and MFRPT 00-39 (BCW 010600-M1). The remaining two samples from this section are discussed in MFRPT 00-47.

The procedure for isolating macrofossils for analyses was similar for all three samples. The starting volume for each was approximated using wet displacement technique. Only half of sample BCW 010600 (1.8 L) was analyzed due to the large volume of organic material recovered. The entire sample, excluding a small archive was initially soaked in warm water and the organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). The remaining sample was swirled in water in order to isolate the organic material from the fine silt component. The swirled organic concentrate was sieved through nested 5, 20 and 40 mesh Tyler sieves (mesh openings: 4.0 mm, 0.85 mm and 0.425 mm respectively). All organic material greater than 0.425 mm (Tyler 40 mesh sieve) was examined using a binocular microscope and plant and animal fossil remains were isolated for identification.

The large volume of organic matter in this sample consists of mostly flattened, compressed wood fragments (some being very large, i.e. 6" long x 2" wide), twigs and large pieces of what resemble bark with internal yellow sacs/nodules (**Fig. 1** and **Fig. 2**). These nodules, seen separated from the bark were also prevalent in the organic residue. Examination of five slides containing smears of the nodules by Thane Anderson (retired palynologist, Geological Survey of Canada) revealed the absence of pollen suggesting they are not pollen sacs. Some of the nodules were encased by amber-like resin (**Fig. 3**). Fragments of this amber-like resin were observed throughout the organic residue (mostly in the float fraction) and were initially identified as reworked amber from older deposits. After a thorough examination of many nodules it was determined that the source of the amber is probably from the unknown bark? with nodules. Interestingly, this sample contains one fragment of coal.

Overall, fossil preservation in this sample is fair to good. The majority of plant macrofossil remains were flattened and covered in fine silt making identification difficult. Larger 'felted' layers of organics, interspersed with fine silty clay and cemented silt were separated by hand. Careful examination of these layers under the microscope provided isolation of the better preserved fossils. Many complete conifer needles of *Abies* and *Picea* sp. were delicately excavated with the aid of water wash bottle and set aside for potential AMS dating (**Fig. 4** and **Fig. 5**).

Plant macrofossils from Chehalis Fleetwood Section are abundant, dominated by conifer remains including needles, partial cones, cone scales, seed wings and terminal twigs. Although a species could not be assigned to the *Picea* (spruce) based on external needle characteristics, the number of stomata on all four surfaces indicate they are probably Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) or white spruce (*Picea glauca* (Moench) Voss. However, the fir (*Abies*) fossil needles could be identified based on external features and they belong to the species *Abies lasiocarpa* (Hook.) Nutt., known as subalpine fir. Hemlock (*Tsuga* sp.) is rare represented by one fossil needle. The absence of macrofossil remains of pine *(Pinus*), *Alnus* (alder) and rare occurrence of *Tsuga* (hemlock) is noteworthy. Pollen analyses on this section is recommended.

Many of the plant macrofossil seeds recovered at Chehalis Fleetwood Section are either annual or perennial herbs, which can be found growing in moist meadows, thickets and low woods. These include grasses (Gramineae), sedges (*Carex* sp.), buttercups (*Ranunculus* sp.), violets (*Viola* sp.) and goosefoot (*Chenopodium* sp.). Shrubs and small trees are represented by single seed occurrence of elderberry (*Sambucus* sp.). Mosses (Bryophytes) comprise a minor component of the floral assemblage with *Sphagnum* sp. being rare.

continued…

The insect fossils isolated from Chehalis Fleetwood Section consist mostly of members from three families. The dominant group is the rove beetles (Staphylinidae) followed by ground beetles (Carabidae) and bark beetles (Scolytidae). Staphylinidae live in a wide variety of habitats, most being hygrophilous and often associated with decaying materials. The rove beetle *Olophrum consimile* can be found in deciduous leaf litter along streams or at the edges of ponds or in moss growing in shallow water or in clumps of *Carex* (Campbell, 1983). Other rove beetles such as *Tachinus* are also found in decaying organic matter including dead leaves as well as living in cool, wet habitats in moss or leaf litter along streams (Campbell, 1973). Many species of the rove beetle *Stenus* are semi-aquatic often occurring abundantly in marshes, wet meadows, wet moss and along the margins of ponds, lakes and streams (Hatch, 1957). Of interest is the rove beetle *Micropeplus laticollis*, which inhabits soil and conifer duff, specifically spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*) and pine (*Pinus poderosa* and *P. contorta*) duff (Campbell, 1968). Insect fossils recovered from Chehalis Fleetwood Section have similar components to the fossil insect analyses done by Miller et al. (1985) from Port Moody. Staphylinidae, Carabidae, Curculionidae and Scolytidae were the four main families of beetles recovered from this site indicating an open forest-floor community existed at Port Moody about 18000 years ago. Fossil insect evidence also suggests standing water and flowing water were present. Although Miller et al. (1985) looked at a much larger volume of sediment (85 kg) from Port Moody, the small insect fossil assemblage recovered from Chehalis Fleetwood Section is very similar.

The second most abundant family from this section, fossil ground beetles (Carabidae) are represented by *Nebria* sp., *Bembidion grapei* group, *Scaphinotus* sp. and *Pterostichus* sp. Both *Nebria* and *Bembidion* are strongly hygrophilous ground beetles living near water. They are often collected at the border of running waters or small creeks on sterile gravel banks where vegetation is sparse. *Scaphinotus* species from British Columbia inhabit forested areas, some living near margins of brooks under bark and moss of dead standing or fallen trees in shady places or among stones and trunks on thick humus layer.

The third component of the faunal assemblage at Chehalis Fleetwood Section is bark beetles the family (Scolytidae). Bark beetles are boreal forest insects that feed and reproduce in the cambium region of dying, injured, or fallen trees and shrubs. They are host specific feeding on select trees. *Phloeotribus lecontei* prefers mainly *Pseudotsuga menziesii* (Douglas-fir) but can also be found associated with *Abies* spp. (Bright, 1976). Species of *Carphoborus* in southern British Columbia have conifer host trees including *Picea engelmanni* (subalpine fir), *Pseudotsuga menziesii* (Douglas-fir), *Pinus ponderosa* (Ponderosa pine) and *P. contorta* (Lodgepole pine) (Bright, 1976).

The fossil plant evidence from this section suggests a forested environment dominated by subalpine fir and spruce. Although pollen recovery was sparse from two Chehalis samples examined by R. Mathewes, they do contain well-preserved *Picea* and *Abies* pollen, agreeing with macrofossil evidence of at least partly forested conditions (pers. Comm., Jan./01). Subalpine fir (*Abies lasiocarpa)* is a high-altitude tree found growing at elevations of 600 to 2000 m existing in pure stands or more often with mixed species. Its main associate is Engelmann spruce, but it can also be seen growing with mountain hemlock, subalpine larch, lodgepole pine, white birch and trembling aspen (Farrar, 1995). Engelmann spruce grows on mountain slopes at elevations between 1000 and 2000 m but can also be found along streams at lower elevations. Both subalpine fir and Engelmann spruce are well adapted to severe climatic conditions of long cold winters with short cool growing seasons tolerating extended periods of frozen ground. Subalpine fir frequently colonizes newly exposed ground. The occurrence of abundant plant fossil remains of subalpine fir in combination with *Picea* cf. *engelmannii* from Chehalis Fleetwood Section more than likely indicates climatic conditions similar to those found in the subalpine zone today. This suggests that tree line was probably lower than it is today. Similar results were obtained by Hicock et al (1982) from pollen and macrofossil analyses at Port Moody and Mary Hill, British Columbia (northwestern Fraser Lowland). Examination of organic silt from post-Coquitlam Quadra sand from these sites revealed that an *Abies lasiocarpa* – *Picea* cf. *engelmannii* forest and parkland grew there about 18000 years ago. Climate was probably cold with short, dry, frost-free summers and long, cold, wet winters. Temperatures were depressed by 8°C and tree line was probably 1200-1500 m lower than today. A recent reassessment by Lian et al. (in press) of the environmental conditions that existed during PMI (Port Moody Interstade) infer cool and moist summers as opposed to a dry growing season. Numerical comparisons of analogues and pollen

continued…

evidence indicate temperatures were more than likely 3.5°C lower than the mean annual temperatures around 18 ka but may have been as much as 8°C suggested by Hicock et al. (1982).

Although the predominant environment at Chehalis Fleetwood Section is forested, it also contains herbaceous type plants and mosses suggesting an open forest environment with plants such as sedges, grasses, violets, buttercups and goosefoot growing in the openings.

Fossil insects support the plant macrofossil evidence of a forested environment. Among the forest floor in conifer duff are inhabitants of the rove beetle *Micropeplus laticollis* as well as other rove beetles that live in litter from trees. The ground beetle *Scaphinotus*, a forest inhabitant, can be found under bark and moss of dead standing or fallen trees. Boreal forest insects such as bark beetles (Scolytidae) are living among trees where they attack dying, injured and fallen trees and shrubs. Fossil insect evidence also suggests that both standing and flowing water were present. Members of the families' Staphylinidae (rove beetles) and Carabidae (ground beetles) are semi-aquatic/hygrophilous living near water. The rove beetles *Olophrum consimile, Tachinus,* and *Stenus* inhabit leaf litter and moss along streams or at the edges of ponds. The ground beetles, *Nebria* sp., *Bembidion grapei* group inhabit sterile gravel banks or sparsely vegetated areas along borders of standing and slow running waters or small creeks.

The combined plant and insect fossil evidence from Chehalis Fleetwood Section suggests an open forest community dominated by subalpine fir and spruce. Herbaceous type plants are growing in openings or along the borders of standing and flowing water. The occurrence of abundant plant fossil remains of subalpine fir probably indicates climate was similar to that found in the subalpine zone near tree line today where temperatures are cool and rainfall low to moderate.

All of the fossils listed in this report have modern representatives living in southern British Columbia today.

Report Update (December 4, 2000):

Two samples from BCW 010600-M1 have been submitted to Isotrace for AMS C14 radiocarbon dating:

1) macrofossil needles of *Abies lasiocarpa* (BCW 010600-M1A, TO-9157)
2) one fossil *Picea* twig terminal (BCW 010600-M1B, TO-9158). A radiocarbon date on wood 11-12 m higher in the sequence has yielded an age of 19,150.

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November 24, 2000

Fig. 1. Three pieces of bark? with nodules. Chehalis Fleetwood Section, BCW 220300-M3.

Fig. 2. Enlarged view of cross-section of bark? with nodules. Chehalis Fleetwood Section, BCW 220300-M3.

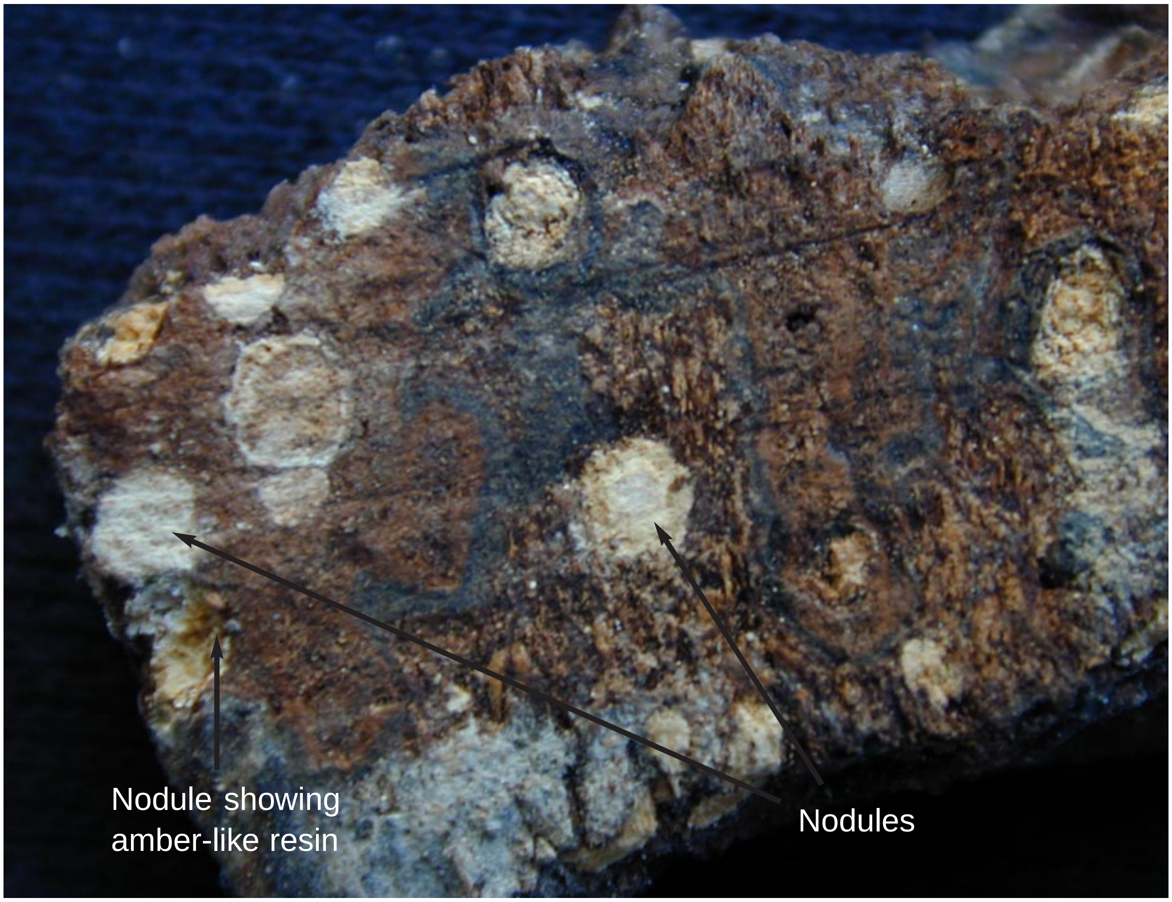

Fig. 3. Close up of Fig. 2 nodules showing amber-like resin. Chehalis Fleetwood Section, BCW 220300-M3.

Fig. 4. *Abies lasiocarpa* (subalpine fir) macrofossil needles. Chehalis Fleetwood Section, BCW 220300-M2. Needles have been cleaned with an ultrsonic bath.

Fig. 5. Close up of *Abies lasiocarpa* (subalpine fir) macrofossil needles. Chehalis Fleetwood Section, BCW 220300-M2. Needles have been cleaned with an ultrsonic bath.

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-39

Sample No.: BCW 010600-M1

Lab No.: 5-52

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, near Aggazzi, British Columbia

Latitude: 121º 81' N Longitude: 49º 20' W Elevation: ~140 m

Collector: B. Ward, collected June 1, 2000

Submitter: B. ward

Material: organic rich glaciolacustrine sediment

Site description: Small landslide scar below forestry road at the base of a thick, advance glaciolacustrine sequence.

Sample volume: 1.8 L

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	~25 (some are flattened)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments with leaves (few types)
Vascular Plants:		
Pinaceae ...."pine family"	+	cone fragment: 1 (~4 scales and seed wing), cone scales: 3 (frayed worn edges), cone scale bract: 1, seed wings: 8, seed wing fragments: 10, conifer seed: 1
Abies lasiocarpa (Hook.) Nutt.	+++	needles (complete and fragments)
Abies sp.	+	twig terminals: ~15 (some with lateral buds)
Picea sp.	++	needles (complete and fragments), twig terminals: ~7 (some with lateral buds)
Gramineae ...."grass family"	+	seed: 1, lemma and palea (floret): 1
Cyperaceae ...."sedge family"	+	seed: 1
Carex lenticular type	+	seeds: 2
Carex sp.	+	seed: 1
Chenopodiaceae ...."goosefoot family"	+	seed: 1
Chenopodium sp.	+	seed fragments: 4
Ranunculaceae ....."crowfoot family"		
Ranunculus Macounii/ pensylvanicus type	+	seed: 1
Ericaceae ...."heath family"	+	seed: 1, leaf: 1
Caprifoliaceae ...."honeysuckle family"	+	seed: 1
Unidentified plant taxa	+	seed: 1 (poorly preserved)
Other:		
amber-like resin	+	fragments
charcoal	+	
wood	+++	abundant compressed (flattened) fragments including large pieces (6' long x 2" wide), most without bark
twigs	++	many flattened fragments with and without bark
bark? with nodules	+	many 'chunks'

continued…

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-39

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA	+	abdomen: 1
COLEOPTERA ...."beetles"	+	metasternum: 1, femur: 1, coxae: 1, trochanter: 1, sternites: 2
Carabidae ...."ground beetles"	+	femur: 1
Nebria sp.	+	half pronota: 2, pronotal fragment: 1, elytral fragment: 1
Bembidion grapei group	+	elytron: 1
Scaphinotus sp.	+	elytron: 1
Pterostichus sp.	+	head: 1
Staphylinidae ....."rove beetles"	+	elytron: 1, elytral fragment: 1
Micropeplus laticollis Mäklin	+	elytron: 1
Olophrum consimile Gyll.	+	pronotum: 1
Tachinus sp.	+	elytron: 1
Aleocharinae	+	pronotum: 1, elytron: 1
Leptodiridae ......"small carrion beetles"	+	elytron: 1
Leiodidae? ...."round fungus beetles"	+	half elytron: 1, pronotum: 1
Scarabaeidae ......"scarab beetles"		
Aegialia? sp.	+	elytral fragment: 1
Curculionidae ....."weevils"	+	elytron: 1
Scolytidae ...."bark beetles"		
Pityophthorus sp.*	+	pronotum: 1
Phloeotribus lecontei Schedl*	+	elytron: 1
DIPTERA ...."flies"	+	adult thorax: 1, puparial fragments: 4
Chironomidae ......"midges"	+	larval head capsules: 1.5
ARACHNIDA		
Oribatei/Acari ...."mites"	+	1

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
*Identified by Don Bright, Department of Agriculture, Ottawa

<u>Comments:</u>

See macrofossil report MFRPT 00-46 for comments.

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-42

Sample No.: BCW 220300-M2

Lab No.: 4-91

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, near Aggazzi , British Columbia

Latitude: 121º 81' N Longitude: 49º 20' W Elevation: ~140 m

Collector: B. Ward, collected March 22, 2000

Submitter: B. ward

Material: organic rich glaciolacustrine sediment

Site description: Small landslide scar below forestry road at the base of a thick, advance glaciolacustrine sequence.

Sample volume: ~200 mL

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	
Non Vascular Plants:		
Bryophytes ...."mosses"	+	(few types)
Sphagnum sp.	+	leaves: 3
Vascular Plants:		
Pinaceae ...."pine family"	+	cone scales: 4, cone scale with bract: 1, seed wing: 1
Abies lasiocarpa (Hook.) Nutt.	+++	needles: (whole and fragments)
Abies sp.	+	seed and wing: 1, seed: 1
Picea sp.	++	needles: (whole and fragments), twig terminal: 1
Gramineae? ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"	+	seeds: 1
Carex sp.	+	seed: 1
Chenopodiaceae ...."goosefoot family"	+	seed fragment: 1
Chenopodium sp.	+	seed: 1, seed fragments: 4
Violaceae ...."violet family"		
Viola sp.	+	half seed: 1
Caprifoliaceae ...."honeysuckle family"		
Sambucus sp.	+	seed: 1
Unidentified plant taxa	+	seeds: 2
Other:		
amber-like resin	+	fragments
wood	++	fragments are flattened, compressed, worn edges
charcoal	+	fragments
bark? with nodules	+	fragments: ~20

continued…

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	elytral fragment: 1, sternite: 1, pronotal fragment: 1
Carabidae ...."ground beetles"	+	metasternum: 1
Nebria sp.	+	pronotal fragment: 1
Staphylinidae ....."rove beetles"	+	elytron: 1, mesosternum: 1
Phlaeopterus sp	+	elytron: 1 (verify)
Olophrum sp.	+	elytron: 1 (verify)
Olophrum consimile Gyll.	+	pronotum: 1
Stenus sp.	+	elytron: 1
Tachinus sp.	+	elytron: 1
Chrysomelidae ....."leaf beetles"		
Chrysolina sp.	+	elytron: 1
Curculionidae? ....."weevils"	+	elytral fragment: 1
Scolytidae ...."bark beetles"		
Phloeotribus lecontei Schedl*	+	elytra: 2
DIPTERA ...."flies"		
Tipulidae ...."crane flies"		
Tipula sp.	+	heads: 1.5
Chironomidae ......"midges"	+	larval head capsule: 1, half capsule: 3
ARACHNIDA		
Oribatei/Acari ...."mites"	+	3
Other:		
soft-bodied insects	+	fragments: 2

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
*Identified by Don Bright, Department of Agriculture, Ottawa

Comments:

See macrofossil report MFRPT 00-46 for comments.

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-43

Sample No.: BCW 220300-M3

Lab No.: 4-93

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, near Aggazzi, British Columbia

Latitude: 121º 81' N Longitude: 49º 20' W Elevation: ~140 m

Collector: B. Ward, collected March 22, 2000

Submitter: B. ward

Material: organic rich glaciolacustrine sediment

Site description: Small landslide scar below forestry road at the base of a thick, advance glaciolacustrine sequence.

Sample volume: ~300 mL

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	some are ‘flattened’
Non Vascular Plants:		
Bryophytes ...."mosses"	+	few types
Vascular Plants:		
Pinaceae ...."pine family"	+	seed: 1, seed wings: 5, cone scales: 4, half cone: 1
Abies lasiocarpa (Hook.) Nutt.	++	needles: (whole and fragments)
Picea sp.	++	needles: (whole and fragments), twig terminals: 3
Tsuga sp.	+	needle: 1
Cyperaceae ...."sedge family"	+	seed: 1
Chenopodiaceae ...."goosefoot family"		
Chenopodium sp.	+	seeds: 2, seed fragments: 3
Ranunculaceae ....."crowfoot family"		
Ranunculus sp.	+	seed: 1
Violaceae ...."violet family"		
Viola sp.	+	half seed: 1
Unidentified plant taxa	+	seeds: 3
Other:		
amber-like resin	+	fragments
charcoal	+	fragments
wood	+++	fragments are flattened, no bark, worn, some fragments are ‘wafer’ thin
coal	+	fragment: 1
bark? with nodules	+	fragments

continued…

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
EPHEMEROPTERA ...."mayflies"	+	immature mandible: 1
COLEOPTERA ...."beetles"	+	half pronotum: 1, trochanter: 1, sternite: 1
Staphylinidae ....."rove beetles"	+	elytra: 2
Phlaeopterus sp	+	half pronotum: 1
Scolytidae ...."bark beetles"		
Phloeotribus lecontei Schedl*	+	elytron: 1
Carphoborus sp*	+	elytron: 1
DIPTERA ...."flies"		
Chironomidae ......"midges"	+	larval head capsules: 0.5
ARACHNIDA		
Oribatei/Acari ...."mites"	+	2

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
*Identified by Don Bright, Department of Agriculture, Ottawa

Comments:

See macrofossil report MFRPT 00-46 for comments.

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-47

Sample No.: BCW 160698-M1 and BCW 160698-M2

Lab No.: 5-54 and 5-55

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, British Columbia

Latitude: 121º 81' N Longitude: 49º 20' W

Collector: B. Ward

Submitter: B. ward

Material: organic rich glaciolacustrine sediment

Sample volume: ~300 mL

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	12 (some are compressed)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments with leaves (few types): ~27
Sphagnum sp.	+	leaf: 1
Vascular Plants:		
Pinaceae ...."pine family"		
Abies lasiocarpa (Hook.) Nutt.	++	needles: (whole and fragments)
Abies sp.	+	twig terminals: 4
Picea sp.	+	needles: (whole and fragments)
Cyperaceae ...."sedge family"	+	seed: 1
Carex trigonous type	+	seed: 1
Carex lenticular type	+	seeds: 3
Salicaceae ...."willow family"		
Salix sp.	+	twigs with bark: 3 (no persistent buds), persistent bud: 1
Unidentified plant taxa	+	seed: 1
Other:		
charcoal	++	
amber like resin	+	fragments
wood	+	'strips' of flattened wood
twigs	+	compressed twigs with bark

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	prothorax: 1
Staphylinidae ....."rove beetles"	+	mesosternum: 1
Omaliinae	+	elytron: 1
Curculionidae ....."weevils"	+	elytron: 1
HYMENOPTERA ...."wasps and ants"	+	thorax: 1
ARACHNIDA		
Oribatei/Acari ...."mites"	+	3

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

continued…

Comments:

Five bulk samples of varying volumes collected by Brent Ward from the Chehalis Fleetwood Section were submitted for macrofossil analyses. Three samples collected 11-12 m lower in the section are discussed in MFRPT 00-46 (BCW 010600-M1, BCW 220300-M2 and BCW 220300-M3). This report covers the remaining two samples, BCW 160698-M1 and BCW 160698-M2. To view the macrofossil content of each individual sample see MFRPT 00-40 (BCW 160698-M1) and MFRPT 00-41 (BCW 160698-M2). Both samples are from a dated interval in which an age of 19,150 was obtained on unidentified wood.

The procedure for isolating macrofossils for analyses was similar for both samples. The starting volume for each was approximated using wet displacement technique. The entire sample, excluding a small archive was initially soaked in warm water and the organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). The remaining sample was swirled in water in order to isolate the organic material from the fine silt component. The swirled organic concentrate was sieved through nested 5, 20 and 40 mesh Tyler sieves (mesh openings: 4.0 mm, 0.85 mm and 0.425 mm respectively). All organic material greater than 0.425 mm (Tyler 40 mesh sieve) was examined using a binocular microscope and plant and animal fossil remains were isolated for identification.

Samples BCW 160698-M1 and M2 are small subsamples (volumes: 50 mL and 250 mL respectively) from the same level a date of 19,150 was obtained. The non-identifiable organic fraction in the samples consists mostly of compressed wood fragments (most without bark), flattened twigs and the same unknown bark? with nodules seen in lower samples examined from this section. Amber-like resin was also observed in the organic residue. Overall fossil preservation is fair to poor. Many of the macrofossils are flattened i.e. spherical fungal sclerotia were observed as discs. Fossil identification was difficult since most of the surfaces were covered in fine silt. Felted layers of organics, interspersed with fine silt and rust coloured cemented silt had to be separated manually. These layers were examined individually under the microscope and exposed fossils were carefully extracted.

Although samples BCW 160698-M1 and M2 are small compared to BCW 010600-M1, both contain the same fossil elements as the larger sample. Conifer remains including abundant needle fragments of subalpine fir (*Abies lasiocarpa*) dominate the plant macrofossil assemblage. Spruce (*Picea* sp.) is also present but not as abundant as alpine fir. Unlike BCW 010600-M1, BCW 160698-M2 contains fossil twigs and persistent bud of willow (*Salix* sp.). Macrofossil seeds are rare, represented by one genus, *Carex* sp. (sedges). A few types of mosses (Bryophytes) are present including *Sphagnum,* which is rare.

Insect fossil fragments in the two samples are sparse represented by rove beetles (Staphylinidae) and weevils (Curculionidae).

Although insect fossil evidence is lacking, plant macrofossil evidence suggests subalpine fir and spruce are growing in the area. Willow and sedges are more than likely growing in open areas.

All of the fossil listed in this report can be found living in southern British Columbia today. For a more comprehensive discussion of Chehalis Fleetwood Section, see MFRPT 00-46.

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November 23, 2000

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-40

Sample No.: BCW 160698-M1

Lab No.: 5-54

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, British Columbia

Latitude: 121º 81' N Longitude: 49º 20' W

Collector: B. Ward

Submitter: B. ward

Material: organic rich glaciolacustrine sediment

Sample volume: ~50 mL

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	7 (flattened spheres)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments with leaves (few types): 7
Sphagnum sp.	+	leaf: 1
Vascular Plants:		
Pinaceae ...."pine family"		
Abies lasiocarpa (Hook.) Nutt.	+	needle fragments: ~20
Picea sp.	+	needle fragments: 3
Cyperaceae ...."sedge family"		
Carex lenticular type	+	seeds: 3
Other:		
charcoal	++	
wood	+	‘strips’ of flattened wood, no bark:~10

ANIMAL MACROFOSSILS:

ARTHROPODA		
ARACHNIDA		
Oribatei/Acari ...."mites"	+	3

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

Comments:

See macrofossil report MFRPT 00-47 for comments.

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November 23, 2000

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 00-41

Sample No.: BCW 160698-M2

Lab No.: 5-55

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, British Columbia

Latitude: 121º 81' N   Longitude: 49º 20' W

Collector: B. Ward

Submitter: B. ward

Material: organic rich glaciolacustrine sediment

Sample volume: ~250 mL

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	5 (some are compressed)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments with leaves (few types): ~20
Vascular Plants:		
Pinaceae ...."pine family"		
Abies lasiocarpa (Hook.) Nutt.	++	needles: (whole and fragments)
Abies sp.	+	twig terminals: 4
Picea sp.	+	needles: (whole and fragments)
Cyperaceae ...."sedge family"	+	seed: 1
Carex trigonous type	+	seed: 1
Salicaceae ...."willow family"		
Salix sp.	+	twigs with bark: 3 (no persistent buds), persistent bud: 1
Unidentified plant taxa	+	seed: 1
Other:		
amber like resin	+	fragments
wood	+	'strips' of flattened wood
twigs	+	compressed twigs with bark

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	prothorax: 1
Staphylinidae ....."rove beetles"	+	mesosternum: 1
Omaliinae	+	elytron: 1
Curculionidae ....."weevils"	+	elytron: 1
HYMENOPTERA ...."wasps and ants"	+	thorax: 1

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

continued…

Comments:

See macrofossil report MFRPT 00-47 for comments.

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November 23, 2000

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-46

Sample No.: BCW 280201-M3

Lab No.: 6-55

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, near Aggazzi, British Columbia

Latitude: 121º 81' N   Longitude: 49º 20' W   Elevation: ~140 m

Collector: B. Ward

Submitter: B. ward

Material: laminated to finely bedded silt and clay with minor sand

Site description: Lacustrine sequence from an old landslide scar exposure from the opposite side of the gully.

Sample volume: ~800 mL; ~4.6 Kg (dry)

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	23 (some are flattened)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments with leaves: 2
Vascular Plants:		
Pinaceae ...."pine family"	+	seed wing fragment: 1, needle (base) fragment: 1
Picea sp.	+	needle fragments: 4
Cyperaceae ...."sedge family"		
Carex lenticular type	+	seeds: 7
Carex sp. check Eriophorum or Cyperus	+	seeds: 4
Juncaceae ...."rush family"		
Juncus/ Luzula type	+	seeds: 2
Chenopodiaceae ...."goosefoot family"	+	seed fragments: 6
Other:		
modern contaminant	+	plant rootlets
unknown bark? with nodules	++	‘chunks’ and fragments
nodules from unknown bark?	+	fragments
charcoal	+	fragments: 3
wood	++	compressed (flattened) fragments (most without bark), ‘block shaped’
twigs	+	few flattened fragments without bark

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	head: 1, half elytron: 1, femur: 1, sternites: 5, articulated sternites: 1, larval head capsule: 1
Carabidae ...."ground beetles"	+	prosternum: 1
Notiophilus sylvaticus Eschz.	+	elytron: 1

continued…

Notiophilus sp.	+	head: 1, half pronotum: 1
Bembidion sp.	+	head: 1, elytra: 3
Staphylinidae ....."rove beetles"	+	elytra: 6, elytral fragment: 1, pronota: 2, half pronotum: 1, articulated pro & mesosternum: 1
Micropeplus laticollis Mäklin	+	pronotum: 1, elytron: 1
Scarabaeidae ......"scarab beetles"	+	articulated prosternum & pronotum: 1, articulated leg: 1
Aegialia sp.	+	pronotal fragment: 1
Byrrhidae ...."pill beetles"	+	pronotum: 1
Scolytidae ...."bark beetles"	+	pronotum: 1, half elytron: 1
Phloeotribus lecontei Schedl	+	elytra: 2
TRICHOPTERA ...."caddisflies"	+	larval frontoclypeal apotome: 1
DIPTERA ...."flies"	+	adult head: 1, puparial fragments: 3
Tipulidae ...."crane flies"		
Tipula sp.	+	larval head capsule: 1
HYMENOPTERA ...."wasps and ants"		
Formicidae ...."ants"	+	thorax: 1
ARACHNIDA		
Oribatei/Acari ...."mites"	+	10, half mites: 4

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
Note: The term seed is used generically to include all forms of seeds including achenes, nutlets etc.

Comments:

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-47

Sample No.: BCW 050601-M2

Lab No.: 6-47

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, near Aggazzi, British Columbia

Latitude: 121º 81' N   Longitude: 49º 20' W   Elevation: ~140 m

Collector: B. Ward

Submitter: B. ward

Material: laminated to finely bedded silt and clay with minor sand

Site description: Lacustrine sequence from an old landslide scar exposure from the opposite side of the gully.

Sample volume: ~1.5 L; ~4.7 Kg (dry)

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	~20 (some are flattened)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	mostly stem fragments, fragments with leaves: 3, leaf: 1, fruiting bodies: 3
Vascular Plants:		
Pinaceae ...."pine family"	+	seed wing fragment: 1, cone scale fragment: 1, needle fragments: 7
Abies sp.	+	needle fragments: 11, twig terminal bark fragments: 2
Picea sp.	+	needle fragments: ~25
Cupressaceae ......"cypress family"		
Thuja plicata Donn ex D. Don ......"cedar"	+	leafy shoot: 1, upright shoot: 1
Poaceae (Gramineae) ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"		
Carex lenticular type	+	seeds: 28
Carex sp. check Eriophorum or Cyperus	+	seeds: 33, seed fragments: 2
Juncaceae ...."rush family"		
Juncus/ Luzula type	+	seed: 1
Salicaceae ...."willow family"	+	persistent bud: 1
Chenopodiaceae ...."goosefoot family"	+	seeds: 3, half seeds: 4, seed fragments: 21
Chenopodiaceae/ Caryophyllaceae undiff.	+	seed: 1
Caprifoliaceae ...."honeysuckle family"		
Sambucus sp.	+	seeds: 5, seed fragments: 6
Unidentified plant taxa	+	seeds: 3, seed fragments: 2 (all are poorly
	+	preserved)
Other:		
modern contaminants	+	paper fragments (from label inside of bag)
stem fragments	+	many fragments (similar to *Equisetum*)
unknown bark? with nodules	+	‘chunks’ and fragments
nodules from unknown bark?	+	fragments
charcoal	+	fragments: 2

continued…

Other (cont'd):		
wood	++	compressed (flattened) fragments (most without bark), 'block shaped', some longer pieces (~12 cm long)
twigs	+	few flattened fragments without bark

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA	+	wing fragment: 1
HOMOPTERA	+	head fragments: 2
COLEOPTERA ...."beetles"	+	pronotum: 1,pronotal fragment: 1, half elytron: 1, elytral fragments: 10, articulated elytra: 1, articulated prothorax: 1, femurs: 3, tibia: 2, articulated femur & tibia: 1, sternites: 15
Carabidae ...."ground beetles"	+	head: 1, prosterna: 1, half prosterna: 2, articulated sternites: 1
Nebria sp.	+	pronotum: 1
Notiophilus sp.	+	half pronotum: 1
Bembidion sp.	+	articulated pronotum & prosternum: 1, pronota: 2, half pronota: 2, heads: 3 (one head with mandibles intact), elytra: 7,half elytra: 2
Staphylinidae ....."rove beetles"	++	heads: 3, elytra: 15, half elytra: 2, articulated elytra: 4, pronota: 4, prosternum: 1, mesosternum: 1, articulated pro & mesosterna: 3, articulated sternites: 1
Micropeplus laticollis Mäklin	+	elytra: 2
Tachinus sp.	+	elytra: 2
Byrrhidae ...."pill beetles"	+	half elytron: 1
Chrysomelidae ....."leaf beetles"	+	elytron: 1, articulated elytra including pro, meso, metasternum and sternites: 1
Curculionidae ....."weevils"	+	elytra: 3, half elytra: 3, elytral fragments: 3, articulated elytra: 3, articulated prothorax: 1, pronota: 2, mesosternum: 1
Scolytidae ...."bark beetles"	+	pronota: 3, elytral fragment: 1
Carphoborus sp	+	elytron: 1
Pityophthorus sp.	+	articulated elytra: 1
Ips tridens (Mannerheim)	+	half elytron: 1
Ips sp.	+	pronotum: 1
TRICHOPTERA ...."caddisflies"	+	larval frontoclypeal apotomes: 3, misc. fragments: 4
DIPTERA ...."flies"	+	pupae: 3, half pupae: 3, puparial fragments: 4
Tipulidae ...."crane flies"	+	larval head capsules: 2, half head fragments: 4
HYMENOPTERA ...."wasps and ants"	+	head: 1
Ichneumonoidea .."ichneumons and braconids"	+	thoraces: 3
ARACHNIDA		
Oribatei/Acari ...."mites"	+	24, half mites: 5
Cepheoidea		
Cepheus type	+	1
Other:		
modern contaminants	+	Collembola (springtail): 1
puparial fragment	+	1

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-47

immatures	+	fragment: 3
larval head capsule	+	1.5
small mammal feces	+	pellets: 7, half pellet: 1

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
Note: The term seed is used generically to include all forms of seeds including achenes, nutlets etc.

<u>Comments:</u>

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-48

Sample No.: BCW 050601-M2 & BCW 280201-M3

Lab No.: 6-47, 6-55

Locality: Chehalis Fleetwood Section, Chehalis Valley, north side of the Fraser Valley, just to the west of Harrison Lake, near Aggazzi, British Columbia

Latitude: 121º 81' N Longitude: 49º 20' W Elevation: ~140 m

Collector: B. Ward

Submitter: B. ward

Material: laminated to finely bedded silt and clay with minor sand

Site description: Lacustrine sequence from an old landslide scar exposure from the opposite side of the gully.

Sample volume: ~2.3 L; ~9.3 Kg (dry)

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	~43 (some are flattened)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	mostly stem fragments, fragments with leaves: 5, leaf: 1, fruiting bodies: 3
Vascular Plants:		
Pinaceae ...."pine family"	+	seed wing fragments: 2, cone scale fragment: 1, needle fragments: 8
Abies sp.	+	needle fragments: 11, twig terminal bark fragments: 2
Picea sp.	+	needle fragments: ~29
Cupressaceae ......"cypress family"		
Thuja plicata Donn ex D. Don ......"cedar"	+	leafy shoot: 1, upright shoot: 1
Poaceae (Gramineae) ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"		
Carex lenticular type	+	seeds: 35
Carex sp. check Eriophorum or Cyperus	+	seeds: 37, seed fragments: 2
Juncaceae ...."rush family"		
Juncus/ Luzula type	+	seeds: 3
Salicaceae ...."willow family"	+	persistent bud: 1
Chenopodiaceae ...."goosefoot family"	+	seeds: 3, half seeds: 4, seed fragments: 27
Chenopodiaceae/ Caryophyllaceae undiff.	+	seed: 1
Caprifoliaceae ...."honeysuckle family"		
Sambucus sp.	+	seeds: 5, seed fragments: 6
Unidentified plant taxa	+	seeds: 3, seed fragments: 2 (all are poorly
	+	preserved)
Other:		
modern contaminants	+	paper fragments (from label inside of bag), plant rootlets
stem fragments	+	many fragments (similar to *Equisetum*)
unknown bark? with nodules	++	'chunks' and fragments
nodules from unknown bark?	+	fragments
charcoal	+	fragments: 5

continued…

Other (cont'd):		
wood	++	compressed (flattened) fragments (most without bark), 'block shaped', some longer pieces (~12 cm long)
twigs	+	few flattened fragments without bark

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA	+	wing fragment: 1
HOMOPTERA	+	head fragments: 2
COLEOPTERA ...."beetles"	+	head: 1, pronotum: 1,pronotal fragment: 1, half elytra: 2, elytral fragments: 10, articulated elytra: 1, articulated prothorax: 1, femurs: 4, tibia: 2, articulated femur & tibia: 1, sternites: 20, articulated sternites: 1, larval head capsule: 1
Carabidae ...."ground beetles"	+	head: 1, prosterna: 2, half prosterna: 2, articulated sternites: 1
Nebria sp.	+	pronotum: 1
Notiophilus sylvaticus Eschz.	+	elytron: 1
Notiophilus sp.	+	head: 1, half pronota: 2
Bembidion sp.	++	articulated pronotum & prosternum: 1, pronota: 2, half pronota: 2, heads: 4 (one head with mandibles intact), elytra: 10, half elytra: 2
Staphylinidae ....."rove beetles"	++	heads: 3, elytra: 21, half elytra: 2, articulated elytra: 4, pronota: 6, half pronotum: 1, prosternum: 1, mesosternum: 1, articulated pro & mesosterna: 4, articulated sternites: 1
Micropeplus laticollis Mäklin	+	pronotum: 1, elytra: 3
Tachinus sp.	+	elytra: 2
Scarabaeidae ......"scarab beetles"	+	articulated prosternum & pronotum: 1, articulated leg: 1
Aegialia sp.	+	pronotal fragment: 1
Byrrhidae ...."pill beetles"	+	half elytron: 1, pronotum: 1
Chrysomelidae ....."leaf beetles"	+	elytron: 1, articulated elytra including pro, meso, metasternum and sternites: 1
Curculionidae ....."weevils"	+	elytra: 3, half elytra: 3, elytral fragments: 3, articulated elytra: 3, articulated prothorax: 1, pronota: 2, mesosternum: 1
Scolytidae ...."bark beetles"	+	pronota: 4, half elytron: 1, elytral fragment: 1
Phloeotribus lecontei Schedl	+	elytra: 2
Carphoborus sp	+	elytron: 1
Pityophthorus sp.	+	articulated elytra: 1
Ips tridens (Mannerheim)	+	half elytron: 1
Ips sp.	+	pronotum: 1
TRICHOPTERA ...."caddisflies"	+	larval frontoclypeal apotomes: 4, misc. fragments: 4
DIPTERA ...."flies"	+	adult head: 1, pupae: 3, half pupae: 3, puparial fragments: 7
Tipulidae ...."crane flies"	+	larval head capsules: 2, half head fragments: 4
Tipula sp.	+	larval head capsule: 1
HYMENOPTERA ...."wasps and ants"	+	head: 1
Ichneumonoidea .."ichneumons and braconids"	+	thoraces: 3
Formicidae ...."ants"	+	thorax: 1
ARACHNIDA		
Oribatei/Acari ...."mites"	+	34, half mites: 9
Cepheoidea		
Cepheus type	+	1

Other:

modern contaminants	+	Collembola (springtail): 1
puparial fragment	+	1
immatures	+	fragment: 3
larval head capsule	+	1.5
small mammal feces	+	pellets: 7, half pellet: 1

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
Note: The term seed is used generically to include all forms of seeds including achenes, nutlets etc.

Comments:

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October 23, 2001

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-43

Sample No.: BCW 280401-M2

Lab No.: 6-52

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N Longitude: 49º 21' W Elevation: 110 m

Collector: B. Ward, collected April 28, 2001

Submitter: B. Ward

Material:

Site description: This site is downstream from the site where date of 19.4 ka was obtained.

Sample volume: ~2.5 L (3.2 Kg)

PLANT MACROFOSSILS:

No plant macrofossils.

Other:

blackened/charred organics	++	
'peds'	++	
unknown	+	soft organic? fragments (opaque colours of brown and caramel gold)

ANIMAL MACROFOSSILS:

No animal macrofossils.

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)

Comments:

Three bulk samples collected by Brent Ward from the Chehalis Statlu 'downstream' Section were submitted for macrofossil analyses. All three samples are presumed to be from Unit 2. BCW 280401-M4 (MFRPT 01-42) is from the uppermost portion of unit 2, ~1 m above BCW 280401-M3 (MFRPT 01-41). BCW 280401-M2 (this report) is from the lower 30 cm of Unit 2 just slightly below M3. The examination of these three samples is a continuation of macrofossil analyses from Chehalis Statlu Section on three previously examined samples from Unit 1. See associated macrofossil report, MFRPT 00-49 (BCW 250500-M3 & M4) and MFRPT 00-48 (BCW 160500-M1).

The procedure for isolating macrofossils for analyses varied depending upon the type of material submitted. Based on the denseness of the sediment and amount of material submitted, processing involved two techniques. The entire sample, excluding a small archive was initially hand separated manually by breaking apart large sediment 'blocks' and each separated surface examined under a microscope. Any observable fossils were delicately extracted. The second technique involved combining the examined layers along with any remaining loose sediment and processing with warm water. Organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). The remaining sample was sieved through nested 5, 20 and 40 mesh

continued…

Tyler sieves (mesh openings: 4.0 mm, 0.85 mm and 0.425 mm respectively). All organic material greater than 0.425 mm (Tyler 40 mesh sieve) was examined using a binocular microscope and plant and animal fossil remains were isolated for identification.

From the large sample volume examined (~2.5 L; 3.2 Kg), BCW 280401-M2 yielded only a small amount of organic material, all in the form of charcoal and/or blackened organic fragments. Better preserved fragments of charcoal/blackened organics were isolated by manual separation of the material and careful extraction of the fragments from split bedding planes. A few fragments have been set aside for potential AMS dating. No observable plant or animal fossils were recovered from BCW 280401-M2, not even charred ones. Of the charcoal/blackened organic fragments examined, none appear to belong to conifers. This sample also contains an unknown seen before from the Chehalis Statlu Section in sample BCW 250500-M4. Small fragments (also seen as very thin layers within the sediment) of opaque, caramel gold coloured, soft organic? unknown material were observed. Many 'peds' which could not be broken down also occur in BCW 280401-M2. These peds vary in colour from dark brown to lighter gray.

Based on the absence of fossils within this sample, no meaningful interpretation can be made in regards to the depositional environment. However, the organic content, lack of macrofossils and sediment type suggests it is more similar to BCW 250500-M3 & -M4 from Unit 1 of the 'Upstream' site than Unit 2.

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October 5, 2001

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-41

Sample No.: BCW 280401-M3

Lab No.: 6-40

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N   Longitude: 49º 21' W   Elevation: 110 m

Collector: B. Ward, collected April 28, 2001

Submitter: B. Ward

Material:

Site description: This site is downstream from the site where date of 19.4 ka was obtained.

Sample volume: ~2.6 L (3.8 Kg)

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	116
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments: 3
Vascular Plants:		
Selaginellaceae...."spikemoss family"		
Selaginella selaginoides (L.)Link	+	megaspore: 1
Pinaceae ...."pine family"	+	seed wing fragments: 4
Abies sp.	+	needle fragments: 6, twig terminal fragments (poorly preserved, mostly bark fragments): ~40
Picea sp.	+	needle fragments: 8
Poaceae (Gramineae) ...."grass family"	+	seeds: 37
Cyperaceae ...."sedge family"		
Carex lenticular type	++	seeds: 133, perigynium and seed: 2
Carex trigonous type	+	seeds: 11
Eriophorum sp.	+++	seeds: 356
Juncaceae ...."rush family"		
Juncus/Luzula type	+	seeds: 8
Salicaceae ...."willow family"		
Salix sp.	+	persistent buds: 3
Chenopodiaceae/ Caryophyllaceae undiff.	+	seeds: 20
Rosaceae ...."rose family"		
Potentilla sp.	+	seeds: 2
Violaceae ...."violet family"		
Viola sp.	+	seed: 1, seed fragments: 2
Unidentifiable plant taxa	+	unknown 'flat' seeds?: 13, unknown seeds: 3
Other:		
wood	++	compressed (flattened) fragments (most without bark
twigs	+	fragments: ~10
charcoal	+	fragments: ~11
unknown bark? with nodules	++	small and large pieces
amber-like resin and nodules	+	fragments (more opaque)

continued…

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	elytral fragments: 6, prosternum:1, mesosternal fragment: 1, scutellum: 4, trochanters: 2, femurs: 3, tibia: 2, sternites: 17, mandible: 1
Carabidae ...."ground beetles"	+	heads: 2 (poorly preserved, thin edges, pitted surface), elytron: 1, half elytra: 2 (one is poorly preserved), prosterna: 4, metasternum: 1, metaepisterna: 2
Notiophilus sp.	+	head: 1, pronotum: 1
Bembidion sp.	+	head: 1, pronota: 2, elytra: 9
Staphylinidae ....."rove beetles"	+	pronotum: 1, articulated pro & mesosternum: 1, elytra: 3, prosternum: 1
Omaliinae		
Phlaeopterus? sp CHECK	+	elytral fragment: 1
Aleocharinae		
Scarabaeidae ......"scarab beetles"		
Aegialia sp.	+	elytron: 1, half elytra: 3, elytral fragments: 2
Curculionidae ....."weevils"	+	elytral fragments: 2
DIPTERA ...."flies"	+	pupae: 2, puparial fragments: 5
HYMENOPTERA ...."wasps and ants"		
Formicidae ...."ants"		
Mrymica type	+	heads: 2
ARACHNIDA		
Oribatei ...."oribatid mites"	+	1, half fragments: 3
Other:		
larval head capsules	+	half fragments: 6

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
Note: The term seed is used generically to include all forms of seeds including achenes, nutlets etc.

Comments:

Three bulk samples collected by Brent Ward from the Chehalis Statlu Section were submitted for macrofossil analyses. All three samples are presumed to be from Unit 2. BCW 280401-M4 (MFRPT 01-42) is from the uppermost portion of unit 2, ~1 m above BCW 280401-M3 (this report). BCW 280401-M2 (MFRPT 01-43) is from the lower 30 cm of Unit 2 just slightly below M3. The examination of these three samples is a continuation of macrofossil analyses from Chehalis Statlu Section on three previously examined samples from Unit 1. See associated macrofossil report, MFRPT 00-49 (BCW 250500-M3 & M4) and MFRPT 00-48 (BCW 160500-M1).

The procedure for isolating macrofossils for analyses varied depending upon the type of material submitted. Based on the denseness of the sediment and amount of material submitted, processing involved two techniques. The entire sample, excluding a small archive was initially hand separated manually by breaking apart large sediment ‘blocks’ and each separated surface examined under a microscope. Any observable fossils were delicately extracted. The second technique involved combining the examined layers along with any remaining loose sediment and processing with warm water. Organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). The remaining sample was sieved through nested 5, 20 and 40 mesh Tyler sieves (mesh openings: 4.0 mm, 0.85 mm and 0.425 mm respectively). All organic material greater than 0.425 mm (Tyler 40 mesh sieve) was examined using a binocular microscope and plant and animal fossil remains were isolated for identification.

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-41

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-42

Sample No.: BCW 280401-M4

Lab No.: 6-50

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N Longitude: 49º 21' W Elevation: 110 m

Collector: B. Ward, collected April 28, 2001

Submitter: B. Ward

Material:

Site description: This site is downstream from the site where date of 19.4 ka was obtained.

Sample volume: ~1650 mL (2.4 Kg)

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	~50 (few are compressed)
Non Vascular Plants:		
Bryophytes ...."mosses"	++	stem fragments with leaves: two types, fruiting bodies: 2
Vascular Plants:		
Poaceae? (Gramineae) ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"	+	seeds: 10, seed fragments
Carex lenticular type	+++	seeds: 241, perigynium and seed: 1, seed fragments
Carex trigonous/'heart shape' type	++	seeds: 115
Eriophorum sp. or *Cyperus* VERIFY	+	seeds: 50, seed fragments
Juncaceae ...."rush family"		
Juncus/Luzula type	+	seed: 1
Salicaceae ...."willow family"		
Salix sp.	+	seed capsules: 11, persistent buds: 10, twigs with persistent buds: 3, twigs: ~6
Brassicaceae (Cruciferae) ...."mustard family"	+	seed: 1
Rosaceae ...."rose family"		
Potentilla sp.	+	seeds: 3
Violaceae ...."violet family"		
Viola sp.	+	seeds: 4, half seeds: 4, seed fragments: 2
Caprifoliaceae ...."honeysuckle family"		
Sambucus sp.	+	seed: 1
Asteraceae (Compositae)	+	seeds: 8 [see 6b]
Unidentifiable plant taxa	+	unknown seed: 1, 'hollowed' plant stem? fragments
Other:		
fungal/yeast 'mats'	+	
wood	+	few fragments
twigs	+	fragments (mostly small fragments, some with bark), one larger poorly preserved 'flattened' twig (6.5 cm x 1 cm)

continued…

Other (cont'd):		
charcoal	+	fragments: 2
unknown bark? with nodules	+	small fragments
nodules from unknown bark?	+	fragments (opaque, dark coloured)
net-veined leaves	+	'thick' fragments: 2
ANIMAL MACROFOSSILS:		
ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	elytral fragment: 1, prosternal fragment:1, mesosternum: 1, femurs: 6 (two are poorly preserved), tibia: 3, sternites: 18, articulated sternites: 3
Carabidae ...."ground beetles"	+	elytral fragment: 1, mandible: 1
Staphylinidae ....."rove beetles"		
@Scarabaeidae ......"scarab beetles"		
Aegialia sp.	+	
@Curculionidae ....."weevils"		
DIPTERA ...."flies"	+	half pupa: 1, puparial fragment: 1
HYMENOPTERA ...."wasps and ants"		
Formicidae? ...."ants"	+	half head: 1
ARACHNIDA		
Oribatei ...."oribatid mites"	+	7
Other:		
larval head capsules	+	half fragments: 3

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
Note: The term seed is used generically to include all forms of seeds including achenes, nutlets etc.

Comments:

Three bulk samples collected by Brent Ward from the Chehalis Statlu Section were submitted for macrofossil analyses. All three samples are presumed to be from Unit 2. BCW 280401-M4 (this report) is from the uppermost portion of unit 2, ~1 m above BCW 280401-M3 (MFRPT 01-41). BCW 280401-M2 (MFRPT 01-43) is from the lower 30 cm of Unit 2 just slightly below M3. The examination of these three samples is a continuation of macrofossil analyses from Chehalis Statlu Section on three previously examined samples from Unit 1. See associated macrofossil report, MFRPT 00-49 (BCW 250500-M3 & M4) and MFRPT 00-48 (BCW 160500-M1).

The procedure for isolating macrofossils for analyses varied depending upon the type of material submitted. Based on the denseness of the sediment and amount of material submitted, processing involved two techniques. The entire sample, excluding a small archive was initially hand separated manually by breaking apart large sediment 'blocks' and each separated surface examined under a microscope. Any observable fossils were delicately extracted. The second technique involved combining the examined layers along with any remaining loose sediment and processing with warm water. Organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). The remaining sample was sieved through nested 5, 20 and 40 mesh Tyler sieves (mesh openings: 4.0 mm, 0.85 mm and 0.425 mm respectively). All organic material greater than 0.425 mm (Tyler 40 mesh sieve) was examined using a binocular microscope and plant and animal fossil remains were isolated for identification.

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-53

Sample No.: BCW 071101-M1A

Lab No.: 7-15

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N Longitude: 49º 21' W Elevation: 110 m

Collector: B. Ward, collected Nov. 7/01

Submitter: B. Ward

Material: glaciolacustrine sediment

Site description: High roadcut above forestry road in a gravel sequence directly on bedrock. Glaciolacustrine sequence abruptly caps gravel and a large tree at base yielded a date of 19,400 (Wat 4168). Samples BCW 071101-M1A & M1B) taken from lower 15 cm of Unit 2, directly above Unit 1gravel.

Sample volume: ~950 mL

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	26
Non Vascular Plants:		
Bryophytes ...."mosses"	+	stem fragments with leaves: 28, stems fragments only: 4, (few types)
Vascular Plants:		
Selaginellaceae...."spikemoss family"		
Selaginella selaginoides (L.)Link	+	megaspores: 2
Pinaceae ...."pine family"	+	seed wing fragments: 2, needle fragments: 67
Abies sp.	+	needles: 12, fragments: 108, twig terminal fragments: 4
Picea spp.	+	needles: 19, fragments: 63, twig terminal fragments: 7
Poaceae (Gramineae)? ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"	+	seed: 1
Brassicaceae (Cruciferae)? ...."mustard family"	+	seed: 1
Unidentified plant taxa	+	seed: 1 (poorly preserved)
Other:		
modern contaminants	+	moss fragment: 1
net-veined leaves	+	fragment: 1
wood	+	‘block shaped’ fragments: ~5
twigs	+	fragments: 4 (no bark), one larger pieces (~10 cm long)
bark	+	few fragments
peds	+	Fe (rust coloured) stained silt cemented fragments
iron precipitate	+	many flattened fragments (some ~1cm in size)
organics with iron precipitate	+	

continued…

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA	+	wing fragments: 2
COLEOPTERA ...."beetles"	+	articulated abdomen: 1, sternites: 2, femur: 1
DIPTERA ...."flies"	+	thoraces: 2, head: 1, half pupa: 1
Chironomidae ......"midges"	+	larval head capsules: 24, half head capsules: 2
Orthocladiinae	+	larval head capsules: 1
ARACHNIDA		
Oribatei/Acari ...."mites"	+	13 (few types)
Other:		
immatures	+	misc. fragments: 6, mandible: 1
larval head capsule	+	1

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
Note: The term seed is used generically to include all forms of seeds including achenes, nutlets etc.

Comments:

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November 19, 2001

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 01-51

Sample No.: BCW 071101-M1B

Lab No.: 6-74

Locality: Chehalis Watershed-Statlu Creek Section, near Aggazzi, British Columbia

Latitude: 122º 01' N Longitude: 49º 21' W Elevation: 110 m

Collector: B. Ward, collected Nov. 7/01

Submitter: B. Ward

Material: glaciolacustrine sediment

Site description: High roadcut above forestry road in a gravel sequence directly on bedrock. Glaciolacustrine sequence abruptly caps gravel and a large tree at base yielded a date of 19,400 (Wat 4168). Samples BCW 071101-M1A & M1B) taken from lower 15 cm of Unit 2, directly above Unit 1gravel.

Sample volume: ~1450, weight: ~3200 grams

PLANT MACROFOSSILS:

Fungal Remains:		
fungal sclerotia	+	6 (some are flattened)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	stems with leaves, stems only (few types)
Vascular Plants:		
Pinaceae ...."pine family"	+	seed wing fragment: 1
Abies sp.	+	mostly complete needles, some fragments, twig terminal fragments: 4
Picea sp.	+	mostly complete needles, some fragments, twig terminal fragments: 18
Poaceae (Gramineae)? ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"		
Carex lenticular type	+	seeds: 2
Salicaceae ...."willow family"		
Salix sp.	+	persistent bud: 1
Unidentified plant taxa	+	seed: 1 (poorly preserved)
Other:		
modern contaminants	+	moss fragments (2) and needles (id them)
amber-like material	+	crumbly fragments: ~4
net-veined leaves	+	fragments: ~20
wood	+	fragments: 2
twigs	+	fragments: 2 (no bark), two larger pieces (~14 cm long)
bark	+	fragments
peds	+	Fe (rust coloured) stained silt cemented fragments
iron precipitate	++	many flattened fragments (some ~1cm in size)
organics with iron precipitate	+	

continued…

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	sternites: 2
Carabidae ...."ground beetles"		
Bembidion sp.	+	elytron: 1
Staphylinidae ....."rove beetles"	+	pronotum: 1 (poorly preserved)
DIPTERA ...."flies"	+	articulated adult thoraces and abdomens: 6, fly thorax: 1, puparial fragment: 1
Chironomidae ......"midges"	+	
Chironominae		
Sergentia sp.	+	larval head capsules: 5
Orthocladiinae	+	larval head capsules: ~7
ARACHNIDA		
Oribatei/Acari ...."mites"	+	11
Hydrozetidae		
Hydrozetes type	+	1
Other:		
immatures	+	misc. fragments: 14

Key: +=taxon present, +++=taxon is abundant
Report based upon examination of organics greater than 425 microns (0.425 mm)
Note: The term seed is used generically to include all forms of seeds including achenes, nutlets etc.

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November 19, 2001

continued…

Appendix D.

Plant and Insect Macrofossil Reports, 2011 to 2013

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 15-07

Sample No.: 060513 CH01 M04

Lab No.: 15-88

Locality: Chehalis-Fleetwood Watershed-Statlu Creek, British Columbia

Material:

Sample volume: ~435 ml (dry)

PLANT MACROFOSSILS:

Fungal remains:		
fungal sclerotia	+	28 (discontinued counts in fine fraction)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragment: 1
Vascular Plants:		
Pinaceae ...."pine family"		
Abies lasiocarpa (Hook.) Nutt.	++	needles: tips-136, bases-56, fragments-252, partial seed and remnants of attached wing: 1
Tsuga heterophylla (Raf.) Sarg.	+	whole needle: 1 (young contaminant)
Poaceae ...."grass family"	+	seed: 1
Cyperaceae ...."sedge family"		
Carex lenticular type	++	seeds: 153 (few species)
Carex trigonous type	+	seeds: 15
Cyperus sp.	+	seeds: 28
Salicaceae ...."willow family"		
Salix sp.	+	persistent buds: 10
Rosaceae ...."rose family"		
Potentilla sp.	+	seeds: 2, half seed: 1
Brassicaceae ...."mustard family"	+	seed: 1
Unidentifiable/unknown macrofossil taxa	+	seeds: 12 (all the same type)
Other:		
charcoal	+	fragment: 1
wood	++	many fragments (mostly flattened, thin 'strips')
bark	+	fragments
Fe stained (orange) cemented silt peds	+	fragments
Manganese peds	+	fragments: 2

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	misc. parts: sternites-6, articulated sternites-3, sternum-1, articulated legs-2, femurs-7, tibiae-3, scutellum-1, adult mandible-1,
Carabidae ...."ground beetles"	+	elytral fragment: 1
Notiophilus aquaticus L.	+	elytron: 1
Dyschiriodes sp.	+	elytron: 1
Staphylinidae ....."rove beetles"	+	half elytron: 1
Olophrum sp.	+	head: 1
Tachinus sp.	+	elytron: 1

continued…

Scarabaeidae ......"scarab beetles"		
Aegialia spp.	+	head: 1, pronota: 2, half pronotum: 1, elytra: 3, elytral fragments: 2
Elateridae ...."click beetles"	+	elytron: 1, prosternal spine: 1
Cerambycidae ......"longhorn beetles"	+	larvae mandibles 13
Curculionidae ....."weevils"		
Trichalophus alternatus?	+	pronotum: 1, half rostrum: 1, elytral fragment: 1, sternum: 1, articulated sternites: 1
DIPTERA ...."flies"	+	pupa: 1, half pupa: 1, pupa fragments: 4
Xylophagidae		
Xylophagus sp.	+	larva head: 1
ARACHNIDA		
Oribatida ...."oribatid mites"	+	mites: 2

Key: +=taxon present, +++=taxon is abundant
Note: The term seed is used generically to include all forms of seeds including achenes, carpels, nutlets etc.
Report based upon examination of organics greater than 425 microns (0.425 mm)
If the information provided above proves critical for the submitter's work, A. Telka should be consulted concerning the possibility of more detailed determinations or updates on the validity of the original conclusions.

Comments:

The procedure for isolating macrofossils for analyses involved the standard technique of sieving in water (Warner, 1990; Birks, 2001) with slight modifications. Modifications included dividing and dispersing the sediment on an aluminum tray with subsequent drying at 80° F in a drying oven. The dried sample was weighed and a starting volume approximated using water displacement technique. The entire sample, excluding a small archive was soaked in warm water and the organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). In order to concentrate the organics from the silt/sand component, the sample was sieved in warm tap water using a swirling technique, decanting the organic portion onto nested sieves of 12, 20, 40 and 60 mesh Canadian Standard Tyler series (mesh openings: 1.4 mm, 0.85 mm, 0. 425 mm, and 0.250 mm respectively). All material greater than 0.425 mm was examined using a binocular microscope and plant and animal fossil remains were isolated for identification. The finest fraction (0.425 to 0.250 mm) was briefly scanned for macrofossils.

A large amount of organic matter was recovered from this sample amounting to approximately half (46%) of the original volume processed (435 ml, dry). The organic component predominantly consists of abundant wood and bark fragments. Most of the wood fragments are flattened, flake-like shaped with angled/rounded edges. Some wood is block-shaped with abrupt ends. Mosses are rare with only one fragment being recovered.

Subalpine fir (*Abies lasiocarpa*) is the dominant plant macrofossils recovered in this sample being represented by abundant fragmented needles and one seed with partial attached wing. No other conifers were isolated except for one complete needle of western hemlock (*Tsuga heterophylla*). This one needle is a younger contaminant based of the fresh appearance of the complete needle in terms of preservation (not flattened) whereas the subalpine fir needles are aged and flattened. Deciduous plants in this sample are represented by small tree/shrubs of willow (*Salix* sp., 10 persistent buds). Next abundant are seeds of sedges (*Carex* lenticular type) with 153 achenes represented by a few species (spp.). *Carex* is a large genus with close to 2000 species within the family Cyperaceae. While some achenes of *Carex* are identifiable, most others require an intact diagnostic perigynum (outer seed coat) for identification. None of the achenes in 060513-CH01-M04 had intact perigynia and could not be identified to species. In general, these grass-like perennial herbs can be found in wetlands such as marshes, calcareous fens, bogs, peatlands, ponds, stream banks, riparian zones, alpine tundra and turfy places (Jermy et al., 2007). Another sedge, flatsedge, *Cyperus* sp. also occurs in this sample. Of the native species occurring in southern British Columbia, *Cyperus erythrorhizos* (redroot flatsedge) occurs on moist to wet lakeshores in the steppe zone and *Cyperus squarrosus* (bearded flatsedge) can be found

 continued…

growing in moist to wet, often sandy sites in the lowland and steppe zones (E-flora of B.C: Electronic Atlas of the Flora of British Columbia, http://linnet.geog.ubc.ca).

Minor occurrences of other plants include grasses (Poaceae), cinquefoil (*Potentilla* sp.), mustard family (Brassicaceae) and unidentifiable seeds of a single macrofossil taxon. Preservation of these minor plant occurrences is poor (bleached and worn seeds) resulting in identification to the Family level only.

Insect fossil remains, similar to plant macrofossils are not that diverse but do contain some interesting finds. Some of the insects in this sample are associated with decaying vegetation and dying trees in forest habitats. Long-horned beetles (Cerambycidae) larvae (**Figure 1**) infest severely weakened and dying trees as well as felled logs (Triplehorn and Johnson, 2005). The adults lay their eggs in crevices in the bark, and the larvae bore into the wood creating tunnels (**Figure 1**). Thirteen larval mandibles occur in this sample. Another beetle whose larvae occur in rotting logs are click beetles (Elateridae). The adults are phytophagous occurring on flowers, under bark, or on vegetation (Triplehorn and Johnson, 2005). Larvae of the fly *Xylophagus* live in decaying vegetation, under bark, or in decaying wood. They are often predatory, consuming other insect larvae living in wood (Arnett, 2000) (**Figure 2**). The rove beetle *Tachinus* is associated with decaying leaf litter or animal matter. The weevil *Trichalophus alternatus* is found in boreomontane forest habitats (Bright and Bouchard, 2008).

Insect fossils that are associated with water bodies but are not truly aquatic include the scarab beetle *Aegialia*, ground beetle *Dyschiriodes*, and rove beetle *Olophrum*. *Aegialia* can be found on the sandy-muddy and gravelly shores of streams, rivers and ponds (Gordon & Cartwright, 1988). Species of *Dyschiriodes* are primarily subterraneous, digging burrows in soil with sparse or no vegetation, usually near water (Lindroth, 1961-1969). *Olophrum* is usually found on poorly drained sites (Campbell, 1983).

The ground beetle *Notiophilus aquaticus* occurs in open bare ground that may or many not be covered with short, sparse vegetation. Its habitat consists of gravelly, well-drained ground (Lindroth, 1961-1969).

The fossil plant evidence from this section suggests a forested environment dominated by subalpine fir (*Abies lasiocarpa*). Subalpine fir is a high-altitude tree found growing at elevations of 600 to 2000 m existing in pure stands or more often with mixed species (Farrar, 1995). Subalpine fir frequently colonizes newly exposed ground. The occurrence of abundant plant fossil remains of subalpine fir from site CH01 more than likely indicates climatic conditions similar to those found in the subalpine zone today. This suggests that tree line was probably lower than it is today situated closer to 150 m (CH01 site elevation).

Although the predominant environment at CH01 is forested, it also contains herbaceous type plants suggesting an open forest environment with sparse vegetation of sedges, grasses, cinquefoil, and the mustard family growing in openings.

Fossil insects support the plant macrofossil evidence of a forested environment. Weevil beetles, *Trichalophus alternatus* inhabit boreomontane forest and both long-horned (Cerambycidae) larvae and fly larvae (*Xylophagus*) are infesting dying/weakened wood. Fossil insect evidence also suggests flowing water with scarab beetles (*Aegialia*), ground beetles (*Dyschiriodes*) and rove beetles (*Olophrum*) being found on/near shorelines.

The combined plant and insect fossil evidence from CH01 section suggests an open forest community dominated by subalpine fir. Herbaceous type plants are growing in forest openings or along the border of flowing water. The occurrence of abundant plant fossil remains of subalpine fir indicates climate was similar to that found in the subalpine zone near tree line today where temperatures are cool and rainfall low to moderate.

continued…

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Date: November 30, 2015

Figure 1. Top: Photo of long-horned beetle (Cerambycidae) larva. Inset: SEM photo of long-horned beetle larva mandibles. Thirteen mandibles were isolated in 060513-CH01-M04. . Long-horned beetles larvae infest severely weakened and dying trees as well as felled logs. Bottom: Photo of long-horned beetle galleries. A female beetle deposits multiple eggs along the central chamber. Each “branch” stemming from it is formed by an individual larva.

Figure 2. Photo of fly larva, *Xylophagus*. Inset: close-up showing larva head. Larvae of the fly *Xylophagus* live in decaying vegetation, under bark, or in decaying wood. They are often predatory, consuming other insect larvae living in wood.

PALEOTEC SERVICES

PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 15-06

Sample No.: 060513 CH01-M01

Lab No.: 15-87

Locality: Chehalis Watershed-Statlu Creek section, British Columbia

Material: glaciolacustrine sediment

Stratigraphic unit: collected immediately above the upper surface of a paleosol

Sample volume: ~510 ml (dry); Sample weight: 1091 grams (dry)

PLANT MACROFOSSILS:

No plant macrofossils

Other:

charcoal	+++	fragments (large and small)

ANIMAL MACROFOSSILS:

ARTHROPODA
ARACHNIDA

Oribatei/Acari ...."mites"	+	oribatid mites: 10

Key: +=taxon present, +++=taxon is abundant
Note: The term seed is used generically to include all forms of seeds including achenes, carpels, nutlets etc.
Report based upon examination of organics greater than 425 microns (0.425 mm)
If the information provided above proves critical for the submitter's work, A. Telka should be consulted concerning the possibility of more detailed determinations or updates on the validity of the original conclusions.

Comments:

The procedure for isolating macrofossils for analyses involved the standard technique of sieving in water (Warner, 1990; Birks, 2001) with slight modifications. Modifications included dividing and dispersing the moist sediment on an aluminum tray with subsequent drying at 80^{o} F in a drying oven. The dried sample was weighed and a starting volume approximated using water displacement technique. The entire sample, excluding a small archive was soaked in warm water and the organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). In order to concentrate the organics from the silt/sand/rock component, the sample was sieved in warm tap water using a swirling technique, decanting the organic portion onto nested sieves of 20, 40 and 60 mesh Canadian Standard Tyler series (mesh openings 0.85 mm, 0. 425 mm and 0.250 mm respectively). All material greater than 0.425 mm was examined using a binocular microscope and plant and animal fossil remains were isolated for identification. The finest fraction (0.425 to 0.250 mm) was briefly scanned for macrofossils.

Although a large amount of material was examined from this sample (dry volume ~510 ml; dry weight 1.091 kg), 060513 CH01-M01 yielded very little organic material. The non-identifiable organic component consists of abundant well-preserved charcoal including large and small fragments along with a small amount of finely comminuted plant material. Plant macrofossils are absent and animal fossils include tiny arachnids of oribatid (Oribatida) mites. Oribatida, also known as 'beetle' or 'box' mites are found in nearly all terrestrial ecosystems and are actively involved in decomposition of organic matter, in nutrient cycling and in soil formation. They feed on a wide variety of material including living and dead plant and fungal material, lichens and carrion; some are predaceous but none are parasitic (Behan-

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(Pelletier, 1997). The role of oribatid mites in soil formation, especially in northern regions is particularly important since large invertebrates such as earthworms, isopods, myriapods normally associated with soil formation are absent. This is especially important in colder climates where oribatid mites are the dominant soil microarthropods (Behan, 1978). The small number of mites in this sample may be part of the underlying paleosol if this sample indeed was collected directly above the paleosol.

Based on the small number of animal fossils recovered and absence of plant macrofossils from this sample, no meaningful interpretation can be made regarding the depositional environment. The presence of abundant charcoal more than likely indicates a fire occurred in the vicinity of the sampling site.

References:

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 15-04

Sample No.: ST03 060314 SED04

Lab No.: 15-37.5

Locality: Chehalis-Watershed-Statlu Creek, British Columbia

Material: Sediment matrix surrounding ST03 060314 SED01 bark

Sample volume: ~300 ml (dry); Sample weight: 656 grams (dry)

PLANT MACROFOSSILS:

Fungal remains:		
fungal sclerotia	+	34 (discontinued counts in fine fraction)
Non Vascular Plants:		
Bryophytes ...."mosses"	+	fragments: 3
Vascular Plants:		
Selaginellaceae...."spikemoss family"		
Selaginella selaginoides (L.)Link	+	megaspore: 1
Pinaceae ...."pine family"		
Abies sp.	+	needles: tips & bases: 6, fragments: +; twig terminal fragments: 5
Picea sp.	+	needles: tips & bases: 10, fragments: +; twig terminal fragments: 1
Cyperaceae ...."sedge family"		
Carex lenticular type	+	seeds: 4 (few species)
Salicaceae ...."willow family"		
Salix sp.	+	twig with persistent bud: 1, persistent buds: 2
Other:		
charcoal	+	fragments: 3
wood	+	many fragments with abrupt ends
amber coloured nodules	+	many nodules

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	misc. parts: sternites, femurs, tronchanter, adult mandibles
Carabidae ...."ground beetles"		
Pterostichus punctatissimus Rand.	+	half elytron: 1
Staphylinidae ....."rove beetles"	+	half elytron: 1
Omaliinae	+	head: 1, pronotum: 1
Scarabaeidae ......"scarab beetles"		
Aegialia spp.	+	heads: 3, half pronotum: 1, elytra: 6, half elytron: 1, elytra fragments: 6
DIPTERA ...."flies"	+	pupa fragment: 1
Chironomidae ......"midges"	+	adult thoracic fragment: 1
HYMENOPTERA ...."wasps and ants"		
Ichneumonoidea ...."ichneumons and braconids"		
Ichneumonidae	+	thoracic fragment: 1

continued…

Key: +=taxon present, +++=taxon is abundant
Note: The term seed is used generically to include all forms of seeds including achenes, carpels, nutlets etc.
Report based upon examination of organics greater than 425 microns (0.425 mm)
If the information provided above proves critical for the submitter's work, A. Telka should be consulted concerning the possibility of more detailed determinations or updates on the validity of the original conclusions.

Comments:

The procedure for isolating macrofossils for analyses involved the standard technique of sieving in water (Warner, 1990; Birks, 2001) with slight modifications. Modifications included dividing and dispersing the sediment on an aluminum tray with subsequent drying at 80^{o} F in a drying oven. The dried sample was weighed and a starting volume approximated using water displacement technique. The entire sample, excluding a small archive was soaked in warm water and the organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). In order to concentrate the organics from the silt/sand component, the sample was sieved in warm tap water using a swirling technique, decanting the organic portion onto nested sieves of 5, 20, 40 and 60 mesh Canadian Standard Tyler series (mesh openings: 4.0 mm, 0.85 mm, 0.425 mm and 0. 250 mm, respectively). All material greater than 0.425 mm was examined using a binocular microscope and plant and animal fossil remains were isolated for identification. The finest fraction (0.425 to 0.250 mm) was briefly scanned for macrofossils.

This sample represents the sediment matrix associated with ST03 060314 SED01 bark (**Figure 1**). The organic content of ST03 060314 SED04 is small (16% by volume) compared to the original volume of material that was sieved (300 ml dry). The non-identifiable organic fraction consists mainly of wood fragments (largest fragment ~3 cm long by 4 mm wide) containing abrupt ends, bark fragments with resin nodules (Figure 1). Many individual resin nodules (amber-coloured 'dots'), separated from the bark were also observed in the organic residue. This sample contains a lot of mineral grains (100 ml by volume).

Fossil preservation in this sample is poor with many of the conifer needles and beetle parts being fragmented. A majority of the fossils had fine sediment adhering to their surfaces making identification difficult. As such, the conifer needles could not be identified beyond the genus level.

Plant macrofossils in ST03 060314 SED04 consist mostly of conifer remains of fir (*Abies* sp.) and spruce (*Picea* sp.) comprising needle and twig terminal fragments. Shrubs include twigs and persistent buds of willow (*Salix* sp.). Mosses (Bryophytes) are rare (3 fragments) and only a small number of macrofossil seeds were isolated from ST03 060314 SED04, being represented by sedges (*Carex* sp.) and northern spike-moss (*Selaginella selaginoides*). *Carex* (lenticular type) is a large genus with close to 2000 species within the family Cyperaceae. While some achenes are identifiable, most others require an intact diagnostic perigynum (outer seed coat) for identification. None of the sedge achenes in this sample contained an intact perigynum for species identification. In general, these grass-like perennial herbs can be found in wetlands such as marshes, calcareous fens, bogs, peatlands, ponds, stream banks, riparian zones, alpine tundra and turfy places (Jermy et al., 2007). Northern spike-moss can often be found growing in damp areas near water including stream banks and lakeshores (Flora of North America Editorial Committee, eds, 1993+) (eflora.org).

Insect fossil remains are not abundant in this sample with most of the beetle fragments belonging to the scarab beetle, *Aegialia* spp. In order to identify this genus to species, the prothorax is needed and only one fragment of a prothorax occurs in this sample. Based on the number of differing elytra and heads, more than one species is present (spp.). *Aegialia* can be found on the sandy-muddy and gravelly shores of streams, rivers and ponds (Gordon & Cartwright, 1988). Another interesting fossil beetle is the ground beetle *Pterostichus punctatissiumus*. This forest beetle occurs in coniferous or mixed forests being found usually under bark and moss on tree-stumps (Lindroth, 1969).

continued…

Plant macrofossil evidence suggests a forested environment comprised of fir and spruce trees with shrubs of willow. Sedges and northern spike-moss are growing in the more poorly drained areas or on the wet reaches of shoreline water bodies. Insect fossil evidence supports the plant macrofossil evidence of a forested environment where the ground beetle *Pterostichus punctatissiumus* is living under bark on tree-stumps. The abundant number of scarab beetles *Aegialia* spp. imply flowing water such as a river or stream.

References:

Birks, H.H., 2001. Plant macrofossils. In: Tracking environmental change using lake sediments. Vol. 3: Terrestrial, Algal, and Siliceous Indicators. Eds. Smol, J.P., H.J.B. Birks and W.M. Last, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 49-74.

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Figure 1. Opposite views of ST03 060314 SED01 bark. Note resin nodules (round, amber-coloured circular dots) on the surface of upper photo.

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PLANT MACROFOSSIL & FOSSIL ARTHROPOD REPORT: MFRPT 15-05

Sample No.: CHF-W01-M03

Lab No.: 15-86

Locality: Chehalis Fleetwood Watershed, Chehalis River section, British Columbia

Material: interstratified silty sand and coarse angular beds

Sample volume: ~75 ml; Sample weight: 197 grams

PLANT MACROFOSSILS:

No plant macrofossils

Other:

charcoal	+++	fragments (large and small)

ANIMAL MACROFOSSILS:

No animal/insect fossils

Key: +=taxon present, +++=taxon is abundant
Note: The term seed is used generically to include all forms of seeds including achenes, carpels, nutlets etc.
Report based upon examination of organics greater than 425 microns (0.425 mm)
If the information provided above proves critical for the submitter's work, A. Telka should be consulted concerning the possibility of more detailed determinations or updates on the validity of the original conclusions.

Comments:

The procedure for isolating macrofossils for analyses involved the standard technique of sieving in water (Warner, 1990; Birks, 2001) with slight modifications. Modifications included dividing and dispersing the moist sediment on an aluminum tray with subsequent drying at 80^{o} F in a drying oven. The dried sample was weighed and a starting volume approximated using water displacement technique. The entire sample, excluding a small archive was soaked in warm water and the organic material floating on the surface was gently decanted into a 100 mesh Tyler sieve (mesh opening 0.15 mm). In order to concentrate the organics from the silt/sand/rock component, the sample was sieved in warm tap water using a swirling technique, decanting the organic portion onto nested sieves of 20, 40 and 60 mesh Canadian Standard Tyler series (mesh openings 0.85 mm, 0. 425 mm and 0.250 mm respectively). All material greater than 0.425 mm was examined using a binocular microscope and plant and animal fossil remains were isolated for identification. The finest fraction (0.425 to 0.250 mm) was briefly scanned for macrofossils.

This small sample (dry volume ~75 ml; dry weight 197 g) yielded no plant macrofossils and no animal (insect) fossils. It does contain abundant charcoal including large and small fragments. Charred macrofossils of plants and insects were not observed; only non-identifiable charcoal fragments. Based on the small sample size, absence of plant macrofossils and animal fossils very little can be said about the depositional environment of the sample except that a fire occurred locally/regionally.

References:

Birks, H.H., 2001. Plant macrofossils. In: Tracking environmental change using lake sediments. Vol. 3: Terrestrial, Algal, and Siliceous Indicators. Eds. Smol, J.P., H.J.B. Birks and W.M. Last, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 49-74.

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