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Glaciation in the Lower Lewis River Basin, Southwestern Cascade Range, Washington

Abstract

In pre-Fraser time, accumulation of ice in the upper Lewis River basin became so extensive that a large ice-tongue extended down valley and spread widely in the lower Lewis River Basin, reaching to within about 8 km of the present route of Interstate Highway I-5. The ice-tongue, more than 600 m thick at Cougar, spread across Chelatchie Prairie and into the East Fork Lewis River basin, extending down that valley to near Battle Ground. The ice also flowed up Canyon and Siouxon Creeks, and the East Fork Lewis River. Extensive deltaic and ponded outwash deposits were formed at many places. Other features of the glaciation include boulder trains, erratic boulders, and rock drumlins. Glacial-caused drainage changes include changes in the course of the East Fork Lewis River and Canyon Creek. Although more than one glacial advance may be represented, the majority of the deposits appear to represent a single glacial episode. Carbon-14 dating of wood from the ponded deposits indicates that they are more than 60,000 years old. The depth of weathering and rind thickness suggest that the glaciation occurred in late Pleistocene time, considerably before the Fraser glaciation.

Younger, Fraser-age glaciers originated in cirques with floors at altitudes of 825 to 915 m at the heads of many drainages in the Canyon and Siouxon Creek basins. These glaciers deposited till and moraine at altitudes ranging down to about 460 m.

Introduction

During the course of a ground-water investigation in Clark County, 1949-1954, deposits of glacial drift were mapped in the northern part of the county. The deposits are described briefly (Mundorff 1964), and their extent is shown on Plate 2 of that report. This paper gives the results of a much more detailed study of these glacial deposits.

The extensive glacial deposits in the lowlands of the Lewis River basin suggest that glaciers were widespread on the western slopes of the Cascades in southern Washington, yet there have been no previous detailed studies of glaciation in the area. In his summary of the glacial history of western Washington and Oregon, Crandell (1965), does not mention any glaciation in the area. In describing pyroclastic flows and lahars, Hyde (1975) briefly discusses Fraser-age glaciation on the south flank of Mount St. Helens. Since the beginning of the present study, Crandell (1979) has described a number of occurrences of Fraser-age and pre-Fraser age drift around the base of Mount St. Helens. Hammond (1980) shows six small areas of Hayden Creek Drift in the Canyon and Siouxon Creek drainages. However, the western limit of his map is longitude 122°18′45″ and it does not show the lower reaches of the Lewis River Basin.

Areal Extent and General Features of the Amboy Drift

Glacial drift including till, lacustrine and fluvial outwash deposits, ice-contact deposits, and boulder deposits occurs along the Lewis River valley, East Fork Lewis River valley,

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and on most of the interfluves between the two rivers (see Fig. 1). These glacial deposits are named the Amboy Drift for their characteristic exposure in the vicinity of the town of Amboy. The western margin of the till extends northwest from the East Fork Lewis River near Lewisville Park (altitude 90 m), to the south flank of Bald Mountain (altitude 275 m), around the east end of that mountain, and down the Lewis River to within 8 km of Interstate Highway I-5 (altitude 60 m). Generally the terminus

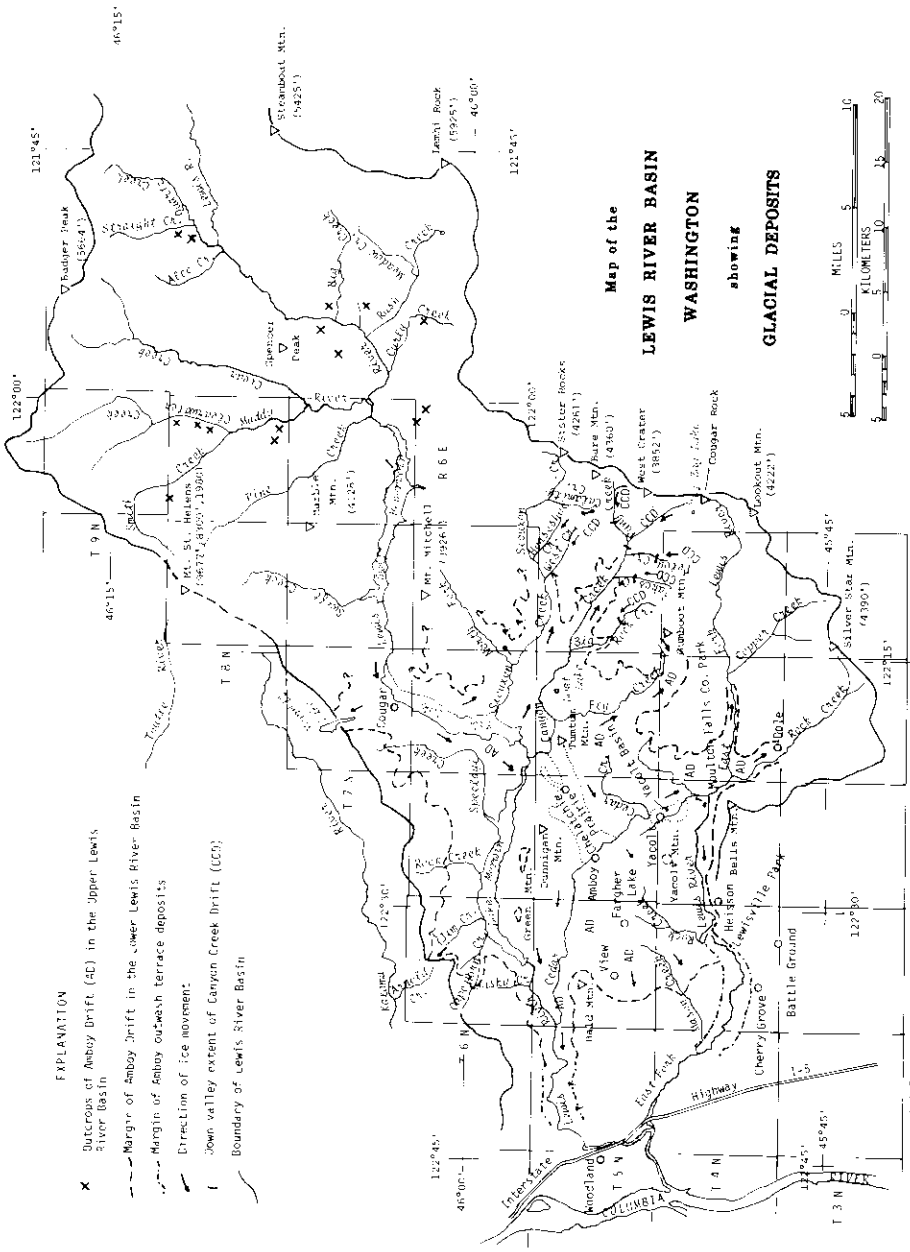

Figure 1. Map of the Lewis River Basin, Washington showing glacial deposits.

was deliniated on the basis of the westernmost exposures seen and, where till was not exposed, boulders in the soil were assumed to indicate that till underlay the surface.

Originating in the upper Lewis River Basin, a large ice tongue came down valley, reaching an altitude of about 760 m near Cougar. Down valley the ice spread widely; lobes of ice moved west, southwest, south, southeast, and east. Between the north flank of the Lewis River valley and the south side of the East Fork Lewis River valley, only the top of Yacolt Mountain and two small areas on Green Mountain were not overridden by the ice. The ice reached 560 m at the east end of Green Mountain and about 420 m on the north flank of Yacolt Mountain. A lobe of the glacier moved southeast and east up Canyon and Siouxon Creeks. Farther south one tongue of ice flowed down, and another flowed up the East Fork of Lewis River.

East of Chelatchie Prairie the ice over-rode the upland in the Cedar Creek drainage, reaching an altitude of about 610 m on the flanks of a steep hill 0.5 km north of Cedar Creek in sec 28, T 5 N, R 4 E. In the Fly Creek drainage, till was found at many places between altitudes of 550 and 640 m. Projection of inferred slopes of the drift margin suggest that the Amboy Drift could not have extended south along Fly Creek beyond about the southern boundary of T 5 N, at an altitude of about 565 m. Several excellent exposures of till and widespread boulders and cobbles are found farther south to altitudes of 640 m. The till is identical in appearance to the Amboy Drift, but is believed to have been deposited by a local glacier that may have originated on the southwest flank of Gumboot Mountain.

Ice extended up Canyon and Siouxon Creek valleys, and excellent exposures of drift are found at many places. Amboy age drift is exposed almost continuously up Canyon Creek to and beyond Pelvy Creek. However, considering the probable slope of the ice surface, it is unlikely that the Amboy ice lobe extended as far up valley as that creek. The drift in the reach above the mouth of Pelvy creek must have been deposited by contemperaneous local glaciers which occupied Canyon and tributary valleys. In some of these valleys there is an unglaciated section between the Amboy Drift deposited by the Lewis River ice lobe and the drift deposited by ice of local origin, but in the Canyon Creek valley ice from the two sources apparently merged. The two drifts are indistinguishable.

Exposures of till were found in Siouxon Creek valley at altitudes up to at least 730 m and possibly 850 m. Drift found above 580 to 600 m probably was deposited by ice moving down the Siouxon valley from sources in the headwaters of that drainage.

North of Lewis River, till is exposed at many places along highway 503. Glacial drift crops out in the drainage of Cape Horn Creek to an altitude of 490 m. Till also is exposed at several places along Dubois Road, near Jim Creek. The divide at the end of the road, between Jim Creek and Arnold Creek (which drains into Kalama River), is at an altitude of about 335 m; ice must have spilled through this gap. Eastward, in the Rock Creek and other drainages, till occurs to an altitude of 490 m. Considering the slope of the ice margin, the drift probably reached an altitude of about 550 m in that area. North of the town of Cougar, glacial drift is exposed along the road between Cougar and Merrill Lake, and on a bench east of the lake, at an atitude of 640 m. About 3.5 km southeast of Cougar, Amboy Drift occurs at an altitude of nearly 760 m and the ice probably reached that altitude in the vicinity of Merrill Lake. Because the present divide between the Lewis and Kalama Rivers is less than 490 m in altitude, ice either

moved north through the gap, or the Kalama valley was already occupied by an ice lobe and the two lobes merged. Amboy-age drift is exposed at several places on the west flank of Marble Mountain at altitudes of 900 to 1035 m; however, this drift was deposited by local ice.

Many outcrops of Amboy Drift, including several exposures along Clearwater Creek, were found in the Muddy River drainage. Outcrops of thin-bedded clays and sands were found at locations 180 to 240 m above the present valley floors, indicating temporary ponding.

Amboy Drift was found to altitudes of 760 m south of the head of Swift Reservoir; it probably extends considerably higher. East of the reservoir, drift was seen at many places both north and south of the Lewis River. Drift of two or more ages is represented; some of the deposits are Amboy Drift, but other exposures obviously are younger and probably are of Fraser age. The distribution of the exposures and of glacial lakes on the upland (see 7½-minute Lone Butte Quad.) indicates that nearly the entire upland south of the Lewis River was ice-covered and served as a gathering ground for the glacier that deposited the Amboy Drift in the lower Lewis River Basin.

Depositional Features of the Glacial Deposits

The Amboy Drift includes till, coarse deltaic outwash, fine-grained thin-bedded deposits that accumulated in ponds and as ice-contact deposits, boulder trains and nests, and individual boulders.

Till forms a discontinuous blanket over most of the area. The Amboy till varies considerably, but almost everywhere contains large amounts of pebbles, cobbles, and boulders in a clayey and gritty matrix. The unweathered till is blue or gray; the upper 1.5 to 2 m is weathered to various shades of brown. At many places the till is thin and is oxidized to the base. Till a few feet below the surface is tough and difficult to dig; fresh till is exceedingly tough.

Boulders commonly are 0.3 to 0.5 m in diameter, but boulders to 1 to 1.5 m were seen at many locations. The clasts comprise a wide variety of volcanic materials including fine- to medium-grained basalt and andesite, rhyolite, dacite, and gray porphyritic lava. Equigranular granitic and dioritic rocks were found in many outcrops.

In the uplands north and west of Yacolt Mountain, and in some other areas, some till outcrops have a much larger proportion of brown clayey material. As shown by soils in adjacent non-glaciated areas, there was a well developed pre-glacial soil 4.5 to 6 m deep in this area, and as the ice advanced, debris carried by the ice was mixed with this soil, giving the till a false appearance of a thick soil profile. For the last few miles of the glacial advance, west of Fargher Lake, the ice overrode the Troutdale Formation and incorporated material from that unit, including quartzite pebbles and some deeply weathered volcanic and granitic stones, into the till.

The thickest section of till, about 30 m, was measured on the north side of the East Fork Lewis River, about 6.5 km north of Battle Ground.

Because, at many places, especially at lower elevations, the ice incorporated such a large amount of pre-weathered material into the till, it is difficult to get an accurate idea of the depth and degree of weathering that has occurred since glaciation. Generally, the till appears to be much more deeply weathered than the Vashon till of the Puget Sound area; oxidation to depths of 1.5 to 2 m is usual. Some pebbles have weathered

rinds several mm thick, yet in the same outcrops many pebbles of the same types of rocks have rinds less than 1 mm thick.

Outwash deposits underlie much of the surface of Chelatchie Prairie and the Yacolt Basin. At an industrial supply well 1.5 km east of Chelatchie, the valley fill is 66 m thick, of which probably only the upper 20 to 30 m is of glacial origin. Another well, about 2.4 km down Cedar Creek from Amboy, penetrated 39 m of drift and alluvium before entering volcanic rock at an altitude of about 70 m. This well was drilled only about 180 m from a now abandoned and overgrown gravel pit in glacial outwash. (Mundorff 1964, Fig. 15)

Yacolt Basin, about 60 m higher than Chelatchie Prairie, also is underlain by outwash and till. Reworking of this material by glacial meltwater has left a lag covering of boulders over the basin. A well drilled for the town of Yacolt, on the west side of the basin, penetrated 35.4 m of glacial deposits and alluvium before entering volcanic rock at an altitude of about 178 m.

East Fork Lewis River occupies a flat-floored valley beginning at a point about 2.5 km west of the south end of the basin. The valley-floor deposits consist of glacial outwash and till. These deposits continue down valley to Lewisville Park, and an outwash terrace deposit extends downstream for another 8 km. The terrace deposit is well exposed along the south side of the East Fork Lewis River, northeast and northwest of Cherry Grove. Near the center of sec. 28, T 4 N, R 2 E, a borrow pit in the edge of the terrace exposes more than 9 m of poorly sorted, crudely stratified outwash containing a wide variety of rock materials ranging in size from sand to large boulders. One lens of iron-stained sand is 75 to 90 cm thick and about 12 m long. Exposures of the outwash terrace deposits were found downstream as far as Mason Creek.

The Amboy outwash terrace deposits overlie the Troutdale Formation along the East Fork Lewis River at elevations 24 to 27 m above the present floodplain. Similar outwash terrace deposits were found along Lewis River, where the base of the deposits also appears to be about 25 m above the present floodplain, and it seems probable that the local base level was that much higher in Amboy time than now.

A thick section of deltaic outwash is exposed in a road cut 7.5 to 9 m high along Canyon Creek in the SW¼ sec 1, T 6 N, R 4 E, at an altitude of 350 m, nearly 120 m above Canyon Creek. Thick sections of deltaic outwash are found at several other places along Canyon Creek, and also on the south flank of Dunnigan Mountain at an altitude of 340 m. Small lenses of stratified drift were seen at many other places in upland areas, usually overlain by till.

Thin-bedded lenticular deposits of stratified clay, silt, and fine- to medium-grained sand occur at many places. In some exposures the sediments are folded, apparently from loading by over-riding ice. A common feature is the presence of scattered pebbles, probably dropped from floating blocks of ice.

The deposits generally occur as lenses, at many places the complete lens can be seen entirely enclosed in till, but at other places only part of the lens is exposed. Lenses range from less than 0.3 m thick and 1 m long to 3 m thick and 12 to 15 m long.

The most extensive and thickest ponded deposits occur along Canyon Creek and are exposed in cuts along Forest Service Road N54. At least 10 such outcrops occur along the road, ranging in altitude from about 245 to more than 520 m, and from 60 to 150 m above present stream level. Thick outcrops begin at a point about 4.6 km east

of the first bridge across Canyon Creek and continue intermittently for 3.5 km as the road rises from an altitude of 270 to 385 m. Six separate outcrops, ranging from 3 to 9 m thick, were found in this interval. The deposits either were capped by till, or till was found at a higher level up valley. As the ice lobe moved up valley it blocked the Canyon Creek drainage at progressively higher levels, with ponds forming at the head of the ice tongue. A cumulative total of at least 33 m of finely laminated clay and sand was deposited in front of the ice in this 3.5 km reach. The deposits consist of alternating layers of clay and fine- to medium-grained sand. Clay layers range in thickness from 2 to 15 mm and average about 5 mm. The sand layers generally are 0.5 to 2 mm and rarely are more than 3 to 4 mm thick. In one 0.3 m interval 46 major pairs were counted. Some clay layers within the interval were further laminated with fine sand partings only one or two grains thick. Thin-bedded deposits were found at intervals up Canyon Creek to an altitude of more than 520 m, and the cumulative thickness of the deposits may exceed 60 m, suggesting that Canyon Creek was dammed by the Amboy ice for a very long time.

Similar deposits were found at many other places. In an outcrop along the Columbia Tie Road, on the south flank of Dunnigan Mountain, three lenses are interbedded in the till, the largest being 1.5 to 1.8 m thick and 12 to 15 m long.

Boulder trains formed as lag deposits on the floor of outwash channels at several places, including Yacolt basin. East Fork Lewis River contains a large concentration of boulders, especially in the reach downstream from the south end of the Yacolt basin and extending downstream to Lewisville Park. Rock Creek Valley, north of Lewisville Park, was floored with boulders in 1950; since that time most of the boulders have been removed during farming operations.

Boulders, occurring singly and in nests, are widely distributed, with many localities on ridges or hilltops. The boulders range from 0.3 to 3.5 m in diameter and boulders 1.5 to 2.4 m are common.

Erosional Features

Hundreds of low, rounded, elongated hills occur southeastward of Yale Lake. Topographic maps (15-minute Yacolt, and 7½-minute Amboy and Ariel quads.) show that most are elongated in the probable direction of ice movement; west down Lewis River Valley, southwest through Chelatchie Prairie, west along lower Cedar Creek west of Amboy, and southwest from Amboy toward Fargher Lake and Battle Ground.

Local direction of ice movement was controlled by major topographic features; Green Mountain, the uplands east of Chelatchie Prairie, and Yacolt Mountain exercised such local control. The hills are smoothly rounded, soil-mantled, and generally thickly covered with vegetation. A few are cut by roads that expose the till capping and the underlying rock core. In all, till and the underlying volcanic rock was seen on a score or more of these rock drumlins.

Drainage Changes

The most important drainage changes postulated are: 1) pre-glacial East Fork Lewis River flowed northwest through the Yacolt basin to Amboy, and thence down the present course of Cedar Creek to the Lewis River; and 2) pre-glacial Canyon Creek flowed southwest through Chelatchie Prairie to join the pre-glacial East Fork Lewis River at

Amboy. The present drainage and the postulated pre-glacial drainage are shown in Figure 2.

Beginning at the Dole Valley Bridge, East Fork Lewis River has incised a narrow gorge in the broader, pre-glacial valley. The pre-glacial valley floor is well exposed at the south end of the Yacolt basin in Moulton Falls County Park where it is about 0.15 km wide, with drift overlying basalt at an altitude of 183 to 186 m. Post-glacial East Fork Lewis River has cut a narrow gorge about 18 m deep at this point, where it turns from its pre-glacial course to flow westward toward Battle Ground. Figure 3 shows cross-sections of the pre-glacial and post-glacial valleys. Locations of the cross-sections are shown in Figure 2. The floor of the pre-glacial valley is at an altitude of 198 m at the Dole Valley Bridge, and about 185 m at the south end of the Yacolt Basin. It is at an altitude of about 178 m, 35 m below the land surface near the west edge of the Yacolt Basin, as shown by the log of a well for the Town of Yacolt, and probably is 8 or 10 m lower at the center of the basin. Downstream, the altitude of the valley floor was about 114 m at Amboy and 98 m, 2.4 km downstream. For the next 9.65 km, Cedar Creek flows in a broad valley underlain by drift. The gradient in this reach is about 5 m/km. At a point about 4.8 km from its mouth, Cedar Creek cuts through the drift

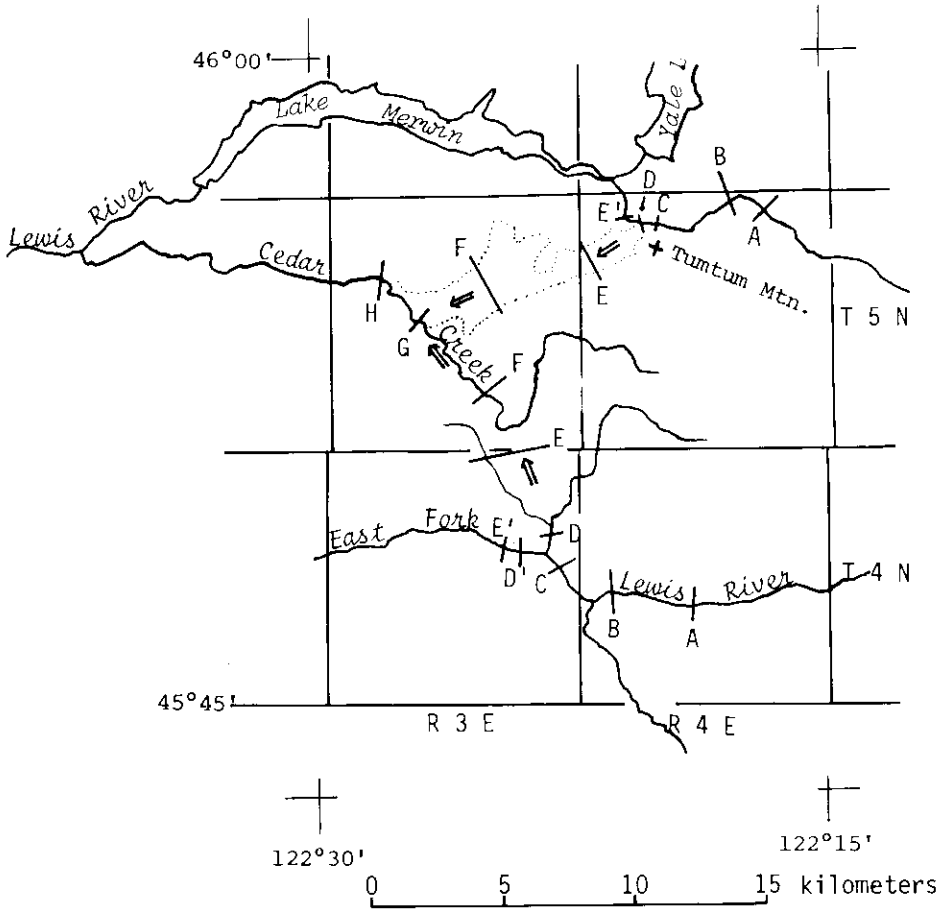

Figure 2. Map showing present and pre-glacial (arrows) drainage, and locations of cross sections.

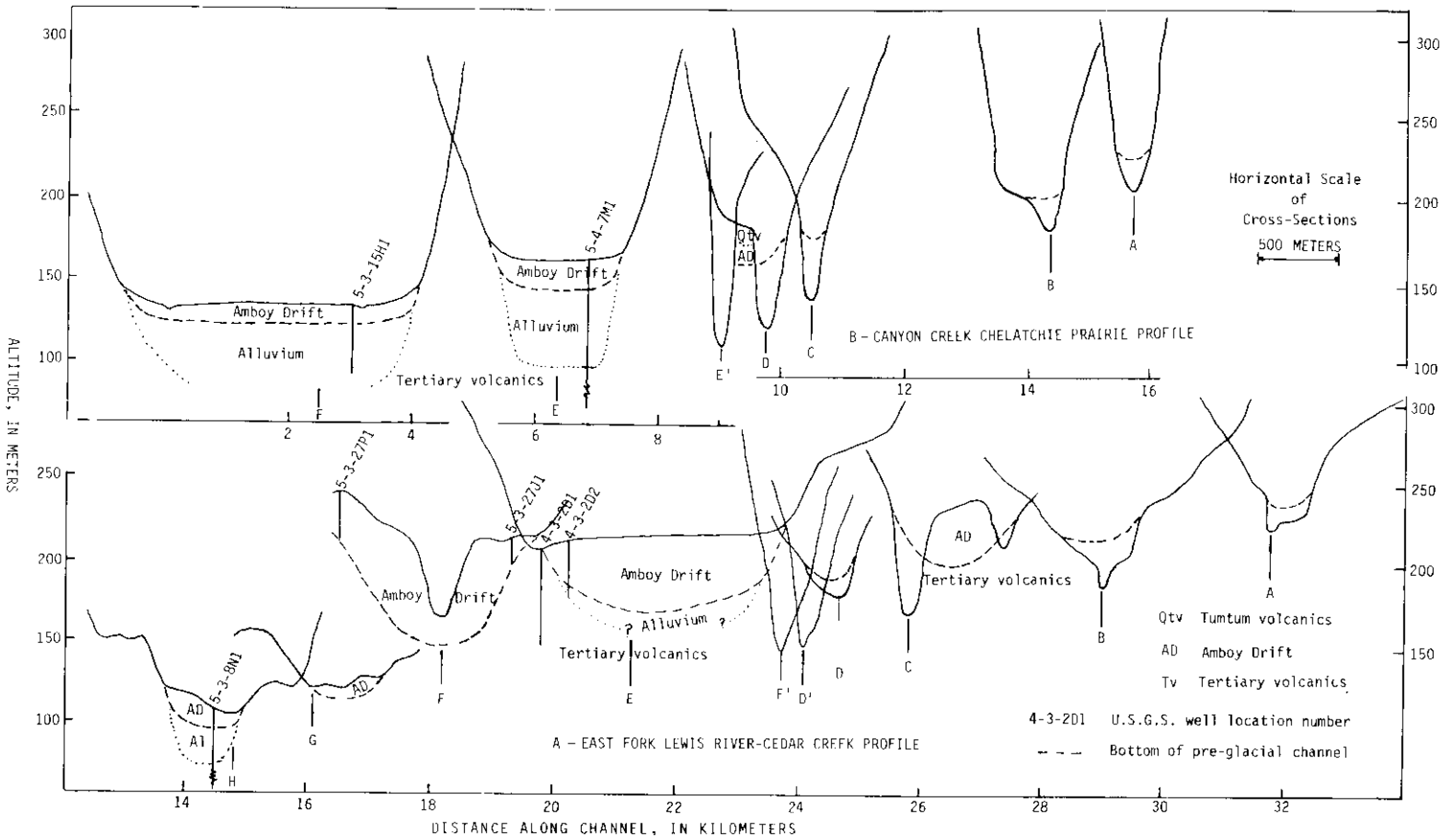

Figure 3. Cross sections and longitudinal profiles along: A—East Fork Lewis River, Yacolt basin and lower Cedar Creek, and B—Canyon Creek and Chelatchie Prairie, showing present profiles and reconstructed pre-glacial profiles. Cross sections have been rotated 90 degrees to plane of profile.

and the pre-glacial valley floor and flows in a canyon sharply incised into basalt. The gradient for the last 4.8 km is nearly 11.4 m/km. The sharply steepening gradient of Cedar Creek near its mouth appears to be further evidence of a change in base level of Lewis River as previously described. The profile of Cedar Creek, and the postulated profile of the pre-glacial East Fork Lewis River, are shown in Figure 4.

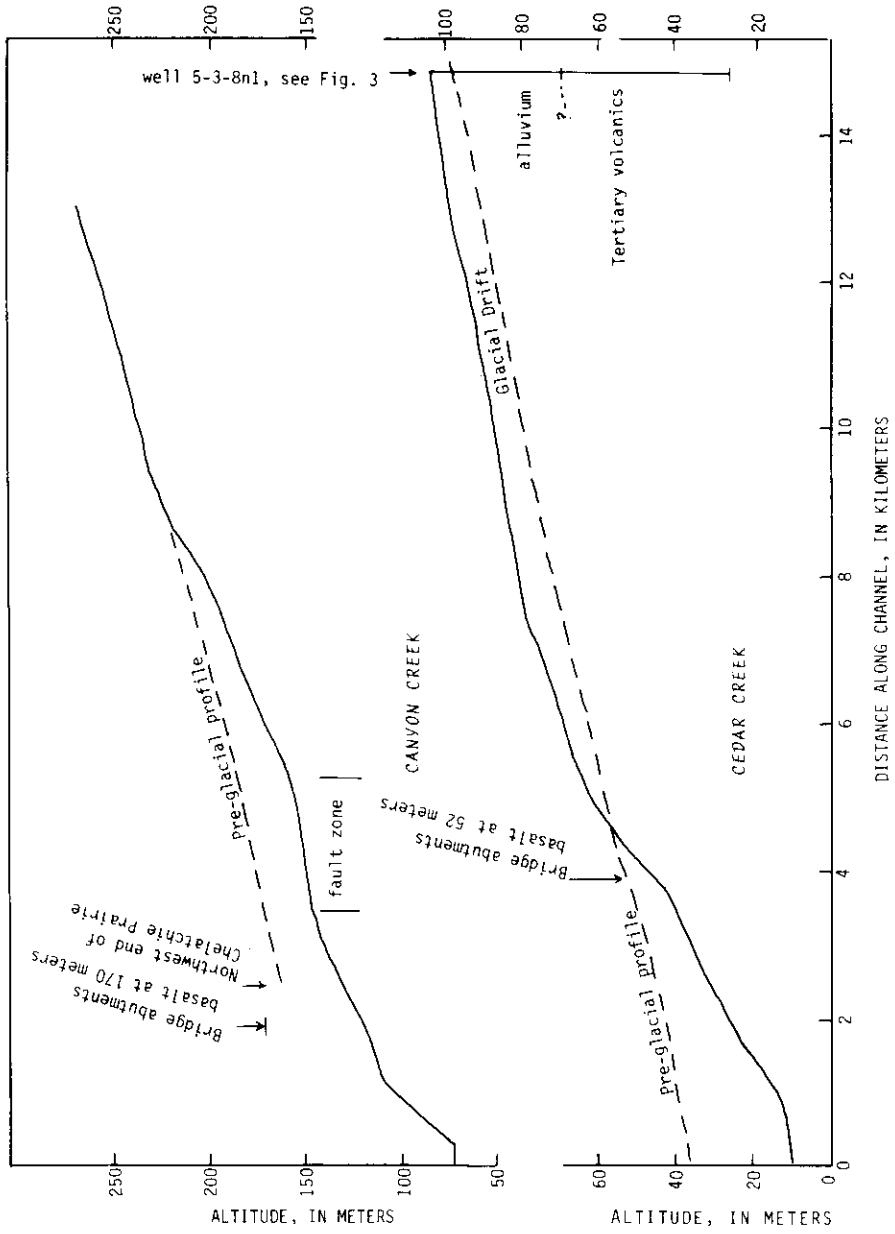

Figure 4. Present profiles, and postulated pre-glacial profiles of the lower reaches of Cedar and Canyon Creeks.

Canyon Creek also has a steeply increasing gradient (see Fig. 4), from a point 8.5 km upstream to its mouth, and the gradient is especially steep for the last 3.2 km. The creek is sharply incised in basalt beginning a km or two northeast of Tumtum Mountain. Both abutments of the bridge across the creek immediately north of the mountain are on basalt of Tertiary age, and till overlies the basalt at an altitude of 170 m. There are no glacial deposits in the downstream reach of the canyon, and it is obvious that this reach is post-glacial. A few hundred meters upstream from this bridge, a flow unit of late Quaternary Tumtum volcanics about 9 m thick overlies approximately 9 m of coarse bouldery Amboy Drift, which in turn overlies Tertiary basalt. The top of the basalt, at an altitude of about 162 m, apparently is the pre-glacial valley floor of Canyon Creek. Canyon Creek followed a course in the down-faulted basin (Mundorff 1964) containing Chelatchie Prairie, to enter the pre-glacial East Fork Lewis River at Amboy. Diversion of Canyon Creek to its present course probably was caused by blockage of its downstream reach by a large mass of ice on Chelatchie Prairie.

Age and Correlation of the Amboy Drift

Depth of weathering and thickness of weathered rinds indicate the relative age of the Amboy glacial deposits. However, the relation between these features and age can be obscured in several ways. At some places part of the surface material appears to have been removed by erosion, resulting in a reduced soil profile. At other places the soil profile has been thickened by soil creep, slope wash, or by deposition of wind-blown deposits. At about 15 outcrops Amboy till was overlain by 0.3 to 1.8 m of yellowish tephra. The tephra at one locality (SW¼ NW¼ sec. 8, T 5 N, R 5 E) was identified by D. R. Crandell (pers. comm.) as Tephra Horizon C from Mount St. Helens (Mulineaux 1978), which is dated as being 35,000 to 40,000 years old. Depth of the oxidized zone, measured at locations where it appeared that there was an undisturbed profile, ranged generally between 1.5 and 2 m, and average depth probably is a little less than 1.8 m. The clayey, less permeable till generally had a thinner profile, whereas sandier, more porous till was oxidized to a greater depth.

Weathering rinds were measured on more than a thousand stones from the upper part of the profile. These stones ranged from pebbles less than 2 cm to boulders more than 1.8 m in diameter. Weathered rinds ranged from less than 0.5 to more than 4 mm thick, but at many localities few or none of the stones had rinds exceeding 2 mm in thickness. It is believed that at most places stones with rinds more than about 2 mm thick are pre-weathered stones that were incorporated into the Amboy Drift from older deposits as the ice advanced over them. In the Fargher Lake-Battle Ground-View area ice overrode the deeply weathered Troutdale Formation. In this area many outcrops contained some pebbles with thick rinds. They also contained some completely rotted pebbles and some quartzite pebbles. The quartzite pebbles and the completely rotted granitic pebbles could have been derived only from the Troutdale, and it seems likely that the other pebbles with thick rinds also were derived from the Troutdale Formation. Pebbles with thick rinds were found side by side with pebbles of similar lithology that had only thin rinds.

The upland east of Amboy is underlain by deeply weathered basaltic and andesitic lavas. In some outcrops spheroidal weathering and exfoliation have produced rounded stones that, after smoothing by the ice, would resemble ice-rounded pebbles and cobbles.

Weathering rinds on 12 such stones ranged from 1.5 to 4 mm and averaged 3.1 mm in thickness. It seems likely that some of the stones with thick rinds, in the till on this upland, are pre-weathered stones derived from the underlying volcanic rock.

During the first part of the field work only the general range and estimated average thicknesses were noted. However, in the last field season individual descriptions were recorded for more than 550 clasts collected at 45 different locations in the Amboy till. Rind thicknesses for these sites, and for 15 sites in the Canyon Creek Drift, are shown in Table 1.

TABLE 1. Thickness of rinds on clasts.

Number of		Percent of rinds within given range (millimeters)							Ave. thickness	
Sites	Clasts	<0.5	0.5-1	1-1.5	1.5-2	2-2.3	3-4	>4	All Rinds	Rinds <2mm
					Amboy Drift					
Amboy-Battle Ground-View Area										
8	108	7.4	25.9	27.8	14.8	10.2	6.5	7.4	1.63	1.08
Yacolt Mountain Area										
2	25	0	32	48	16	4	0	0	1.26	1.17
Upland East of Amboy and Yacolt										
18	221	5.4	33.9	34.4	17.6	4.9	2.7	0.9	1.26	1.10
Lewis River Valley										
7	94	3.2	31.9	50.0	10.6	4.3	0	0	1.17	1.12
Canyon Creek Basin										
9	108	0	32.4	54.6	13.0	0	0	0	1.15	1.15
					Canyon Creek Drift					
15	172	48.3	33.2	15.7	2.3	0.6	0	0	0.60	

In the Amboy-Battle Creek-View area, where the ice overrode the Troutdale Formation, the average rind thickness was 1.63 mm. If the rinds thicker than 2 mm are assumed to be pre-weathered stones, the average thickness is 1.08 mm, about the same as for other areas.

An alternative explanation for the greater rind thickness in the Amboy-Battle Ground-View area would be that some of the outcrops represent an older glacial episode. However, most of the locations where clasts with thick rinds were found are at relatively low altitudes, near the terminus marking the maximum extent of ice. To reach these areas the ice would have had to reach maximum altitudes on the flanks of the Lewis River Valley and on the mountains in the lowland areas, such as Green, Dunnigan, and Yacolt mountains. Scores of outcrops were examined in those localites, and only rarely do the clasts have rinds thicker than 2 mm.

An average thickness of 1.10 to 1.15 mm appears to be a reasonable estimate for the Amboy Drift. This is slightly greater than the 1 mm thickness of rinds from the Hayden Creek Drift in the Mount Rainier region (Crandell and Miller 1974). However, if the percentage of pre-weathered clasts in the Amboy Drift were a bit higher than assumed, the average rind thickness would be nearly the same as for the Hayden Creek Drift.

A large fragment of wood was recovered from the thin-bedded clay along Canyon Creek road. Carbon-14 determination in the University of Washington Quaternary Laboratory showed that the material was older than 60,000 years (QL-1431, Minze Stuiver, pers. comm., 1980). The general appearance and this limiting age determination

suggest that the Amboy Drift is correlative with the Hayden Creek Drift and represents a geological event of early Wisconsin age.

Canyon Creek Drift

In tracing the advance of the Amboy galciation up Canyon Creek valley, it was found that both Amboy-age and a younger drift had originated in the headwaters of the drainage.

Cirques and emphitheaters are found at the head of Canyon Creek and its tributaries. Zig Zag Lake occupies a cirque on the west side of an amphitheatre at the head of Canyon Creek, and Canyon Creek Drift extends downstream to the mouth of Puny Creek, a distance of about 6.4 km. In the Puny Creek Valley, Canyon Creek Drift extends downstream nearly 5 km. In the Pelvy Creek Valley, a terminal morraine of Canyon Creek Drift is a prominent feature south of the center of sec. 5, T 5 N, R 5 E, at an altitude of about 780 m. In Jakes Creek Valley, Canyon Creek Drift extends to within 2 km of its junction with Canyon Creek. At the head of Big Rock Creek, two small streams have cut parallel channels on the east and west flanks of the valley, leaving a narrow ridge of Canyon Creek morraine several hundred meters long in the center of the valley. This morraine is well exposed where Forest Service Road N 525 cuts through the ridge. Canyon Creek Drift extends down valley for about 3.2 km beyond that point, to an altitude of about 490 m.

Canyon Creek Drift also was found along West, Horseshoe, and Calamity Creeks, all tributaries of Siouxon Creek. South of Zig Zag Lake, Canyon Creek Drift was found at the head of the East Fork Lewis River.

Cirque floors, occupied during the Canyon Creek glaciation, range in altitude from about 825 to 915 m. All these drainages trend north, northeast, or northwest, and the lowest cirque floors are in drainages opening directly north. The minimum altitude of about 825 m for the crique at the head of Big Rock Creek is considerably lower than the minimum reported (1000 m) for the Evans Creek glaciation in the Mount Rainier area (Crandell and Miller 1974).

The Canyon Creek till is very cobbly and bouldery, with a gray, sandy, and clayey matrix. At places the pebbles and larger stones are only moderately rounded. Generally, only 0.6 to 0.9 m of soil has developed on the till. The soil is medium to dark brown, grading downward through a yellowish subsoil into gray, unweathered till. Rinds range from less than 0.1 to about 1 mm, and average about 0.6 mm thick. A summary of rind thicknesses is given in Table 1. At some places on occasional stone with a thicker rind is found, probably reworked from older drift or other material. If the few stones with abnormally thick rinds are omitted, the average rind thickness is about 0.5 m.

The average depth of weathering on the Canyon Creek Drift, about 0.75 m, is somewhat greater than the depth on the Vashon till in the Tacoma area, and of the Evans Creek Drift in the Mount Rainier area (Crandell and Miller 1974). Also, according to that report, stones from the Evans Creek Drift generally lack discernable rinds. Rind thickness was measured on about 40 stones collected from the upper part of the soil formed on Vashon till in the Gig Harbor area: rinds ranged up to 1 mm in thickness, 90 percent were less than 0.5 mm, and average thickness was about 0.25 mm. On the basis of rind thickness, the Canyon Creek Drift appears to be older than the Vashon

and the Evans Creek Drifts. However, it is much younger than the Amboy Drift, and probably represents an early event during the Fraser glaciation.

Implications of the Glacial Deposits

The size of the Amboy ice lobe in the lower Lewis River Basin, the great distance it reached in its maximum extent, and the low altitude of its terminus suggest that glaciation was much more extensive on the western flank of the Cascade Mountains in southern Washington than generally recognized. East of the upper end of Swift Reservoir, much of the upland appears to have been glaciated, and most of the drainages heading at 900 m or more must have supported glaciers. The ice lobe in the Lewis River Valey must have been fed by scores of glaciers, and the entire area east of Swift Reservoir may have been covered by an ice cap.

Such extensive glaciation in the Lewis River Basin suggests that extensive glaciation must also have occurred in the Kalama and Toutle River Basins.

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