UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SURFICIAL DEPOSITS ALONG THE COWLITZ RIVER NEAR TOLEDO, LEWIS COUNTY, WASHINGTON

By

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Open-File Report 81-1043

INTRODUCTION

Löess-covered outwash terraces exposed along the Cowlitz River preserve a record of early (?) to latest Pleistocene glacial events in western Washington. During the Pleistocene Epoch glaciers repeatedly advanced from Mount Rainier, Mount Adams, and nearby alpine areas, coalescing in the Cowlitz River valley southwest of Mount Rainier. In at least two events, the resulting valley glacier extended as far west as the town of Silver Creek, 105 km from Mount Rainier. Extensive areas of weathered, löess-mantled outwash deposits are exposed along the Cowlitz River from Randal downstream to Toledo. Glaciofluvial terraces are well-developed between Silver Creek and Toledo, the area emphasized in this map, and included in an area mapped by Crandell and Miller (1974) at a scale of 1:250,000. The outwash terraces and associated löess caps along the Cowlitz River offer an unusual opportunity to study the development of soil sequences on andesitic parent material in a humid climate over an extended period of Quaternary time.

This map is the result of fieldwork performed in conjunction with detailed sampling of soil morphology and analysis of the physical and chemical properties of soils developed on Cowlitz River outwash deposits. Soil-sampling locations are noted on this map.

SETTING

The Cowlitz River heads at the Cowlitz Glacier on Mount Rainier and drains 3785 km^2 of mountainous terrain east of Toledo, Washington. The map area (plate 1) encompasses about 370 km^2 along the Cowlitz River consisting of flat to moderately dissected terraces separated by steep scarps and bounded on the south and east by rolling hills underlain by Tertiary bedrock (see Roberts, 1958; Snavely et al, 1958). Elevations range from 40 to more than 500 m, but most of the study area lies between 100 and 200 m. Mount Rainier, Mount Adams, and Mount St. Helens, all young Cascade volcanoes, dominate the landscape to the east of Toledo.

The climate of central Lewis County is cool, maritime, but it is more continental than climate in much of western Washington (Weigle and Foxworthy, 1962). Mean annual temperature averages about 10°C; summer temperatures average 15 to 17°C, while the winter mean is about 3 to 5°C. The frost-free season averages 165 days (Soil Conservation Service, 1954). Precipitation amounts range from 1250 mm at the western border of the map, to about 1550 mm at the east end of the study area (U.S. Weather Bureau, 1965). About 25 percent of the annual precipitation falls between April and the end of September, but June through August rainfall is usually less than 100 mm, forcing irrigation of crops during this period.

When white settlers arrived in the Toledo area in the 1840s, terrace areas were covered with a mixture of old-growth forest and prairie vegetation. The native vegetation in the forested areas (fir, hemlock, and red cedar with alder and maple in successional stands) has been cut, and second-growth stands are common. The prairies and cleared land have been used for pasture or cultivated since the mid-19th century.

Toledo is the only large town in the map area, but there are a number of small communities such as Mossyrock, Silver Creek, and Salkum. Agriculture and logging-related industries provide the economic base for these towns.

GEOLOGY AND SOILS

Snavely et al (1958) and Roberts (1958) described Tertiary volcanic and sedimentary rocks from the western part of the map area, whereas Erdmann and Bateman (1951) and Fisher (1957) discussed the stratigraphy of Eocene to Quaternary volcanic rocks exposed from Mossyrock to the Cascade crest. Crandell and Miller (1974) discussed the Quaternary stratigraphy and glacial history of the Mount Rainier region, and presented a map (scale 1:250,000) which includes the terraced area along the Cowlitz River. Weigle and Foxworthy (1962) mapped the geology of the terrace area, and provided extensive information on subsurface and ground-water hydrology. Roberts (1958) mapped bedrock geology to the south of the Cowlitz River and described selected Quaternary deposits.

Glacial outwash deposits form conspicuous terraces in the map area. The upper surface of terraces reflect the local base level of braided outwash streams which graded upstream to active glaciers during the Pleistocene. Most terrace surfaces probably formed from aggradation during glaciation of the Cowlitz River valley, followed by downcutting during and after deglaciation (Flint, 1971; Andrews, 1975). The major terraces most likely formed during major glaciations. Smaller and less extensive terraces may record minor still-stands, readvances during overall glacial retreat, or lateral erosion into older outwash material during downcutting. Terraces are generally capped by a layer of silt and fine sand, probably windblown material (löess) deposited during and following glaciations (Flint, 1971).

The terraces and their capping silt deposits range from slightly weathered Holocene alluvium to the deeply weathered Logan Hill Formation (Snavely et al, 1958), which is oxidized to depths greater than 10 m in most exposures. Terrace deposits are composed almost exclusively of andesitic material derived from Eocene-Quaternary bedrock which consists of unaltered to slightly metamorphosed flows, breccias, and tuffaceous rock.

Soils developed on the Logan Hill Formation and on the Wingate Hill deposits are brown to pale brown silty clay loams. The soils were classified as "brown lateritic" in the "old" soil classification (Soil Conservation Service, 1954), and are classified as Mesic, Xeric Haplohumults at present (Soil Conservation Service, 1980). The younger soils are pale brown silt loams to loams and were termed "brown podzolic" (Soil Conservation Service, 1954). At present, the Soil Conservation Service (1980) classifies these soils as Mesic, Typic Dystrondepts or Mesic, Ultic Haploxeralfs. All the soils are acidic, have low-cation exchange capacities, and require extensive fertilization for good crop yields. Local slopes on the terraces range from 0 to 3 percent. Detailed soil descriptions and selected soil analyses are presented by the Soil Conservation Service (1954; 1980).

METHOD

We mapped surficial deposits along the Cowlitz River during 1977-1979 by supplementing field observations with interpretation of aerial photographs (scale 1:76,000) which were taken in 1974. We compiled the location of the bedrock/Quaternary contact from Roberts (1958) and from Crandell and Miller (1974), the location of landslides and distribution of the Logan Hill Formation south of the Cowlitz River from Roberts (1958) and Weigle and Foxworthy (1962), and the extent of till, moraines, and morainal topography from Crandell and Miller (1974). We modified data from these sources with our field observations. We have drawn the contacts between outwash units at the break in slope at the base of the terrace riser.

Terrace-surface elevation points plotted on figure 1 were obtained from four sources: (1) elevations measured using an American Paulin M-1 altimeter on short loops from bench marks or road intersections with measured elevations, (2) bench marks or measured road intersections on terrace surfaces, (3) terrace surfaces shown on unpublished maps (scale 1:4,800) of Tacoma City Light with contour intervals of 5 or 10 feet, and (4) unpublished data of S. C. Porter (Porter, written communication, 1979) collected in 1964 on terraces that were inundated by waters from Mossyrock Dam. Terrace points and gradients in figure 1 are shown as far as 20 km east of the map boundary; most of these data were compiled from points measured on the Tacoma City Light maps. Terrace elevations were projected onto a line drawn along the axis of the Cowlitz River flood plain, now mostly inundated upstream from Silver Creek. With the exception of elevations on the Logan Hill surface, most elevation points lie less than two km from the line. The profile of the Cowlitz River was determined by plotting points where contour lines crossed the channel. Upstream from Mayfield Dam, large-scale Tacoma City Light maps were used, whereas U.S. Geological Survey 15' sheets were used downstream. These latter points could be in error by as much as 5 to 10 m; terrace elevations from the other sources are accurate to ±3 m (from repeated altimeter traverses) or ±0.5 m (bench marks).

Terraces were identified on the basis of topographic position; weathering characteristics such as depth of oxidation, thickness of weathering rinds on clasts, and degree of soil development supplement these observations. These methods were limited by the convergence of terraces downstream. Also, segments of the Evans Creek and Holocene terraces were inundated by the reservoirs behind Mayfield and Mossyrock Dams. We have drawn solid curves through terrace points in figure 1, but have chosen to dash the lines where some of the younger terraces converge near Toledo and where identification of isolated terrace remnants is difficult. Several terrace remnants near Toledo (heo) fall between the oldest Evans Creek and the younger Hayden Creek terraces; we show these terrace gradients as line segments. Younger Evans Creek deposits (eco_2) and Holocene outwash deposits (ho) do not form extensive terraces, and are shown mostly as short line segments, or as dashed lines.

RESULTS

Six distinct outwash terraces lie above the modern flood plain and Holocene terraces along the Cowlitz River between Silver Creek and Toledo, Washington. Terrace deposits are shown on the map, and terrace gradients upstream of Toledo are plotted on figure 1. Stratigraphic terminology follows Crandell and Miller (1974), but we have subdivided their Evans Creek and Hayden Creek units into "early" and "late" phases on the basis of topographic and weathering criteria, and have mapped undifferentiated Hayden Creek terraces (hco) and terraces (heo) which lie between Evans Creek and Hayden Creek deposits. We show the topographic relationship of the terrace deposits schematically in figure 2. The approximate ages of the terraces, and the map and profile relationships are discussed below.

Alpine glaciations originating at Mount Rainier remain poorly dated at present despite many years of fieldwork in the region (see Crandell, 1969; Crandell and Miller, 1974). Firm dates are not established for deposits older than Evans Creek age, and estimated ages for the oldest deposits (Wingate Hill and Logan Hill) are speculative. Holocene glaciers of the Winthrop Creek Glaciation of Crandell (1969) generally extended less than two km beyond the termini of present glaciers. Crandell (1969) described two phases of the Winthrop Creek Glaciation, the Garda Stade extending from 2200 to 100 years before present (YBP), and the Burroughs Mountain Stade (3000-2500 YBP), which contributed sediment to the low Holocene terraces found downstream along the Cowlitz River. The McNeely Drift, thought (Crandell, 1969) to be latest Pleistocene, extends only slightly farther downvalley.

The alpine stade of the Fraser (late Wisconsin) Glaciation, called the Evans Creek Stade, lasted from before 25,000 YBP to about 13,000 YBP in the Cowlitz River area (Barnosky, 1979). Palynologic studies from Davis Lake (15 km east of Mossyrock) suggest that significantly cooler periods occurred before 20,000 YBP, and between 15,000 and 13,000 years ago (Barnosky, 1979). Clague and others (1980) demonstrated that during the Fraser Glaciation the most significant alpine advance in the Cascades of British Columbia occurred between 25,800 and 18,700 YBP; major advances also occurred between 15,000 and 11,500 YBP. Porter (1976) suggests that the three phases of Lakedale Drift in the North Cascade Range probably span from 25,000 to about 11,100 YBP; the earliest (Bullfrog) drift is the most extensive.

The older Evans Creek (eco_1) surface heads at a moraine complex three km east of the edge of figure 1. The younger Evans Creek outwash (eco_2) surfaces head at moraines more than 10 km farther east (see Crandell and Miller, 1974). These terrace deposits are extensive, grade to morainal topography east of the map area, and are late Pleistocene in age (Crandell and Miller, 1974). We suggest that the older Evans Creek surface is about 22,000 years old, and that the younger surfaces are about 13,000 years old, as indicated by regional relationships (Porter, 1976; Clague and others, 1980) and radiocarbon dates at nearby Davis Lake (Barnosky, 1979).

Glaciers of Hayden Creek age responded to a snowline some 200 m lower than those of Evans Creek age, and advanced at least 30 km farther downvalley. Crandell and Miller (1974) tentatively correlated the Hayden Creek with the Salmon Springs Glaciation of the Puget lowland, but drift at the Salmon Springs type locality has recently been dated at about 840,000 YBP (Easterbrook and others, 1981). All pre-late Wisconsin correlations are thus uncertain. Hayden Creek drift mapped in upland areas south of Mount St. Helens (located about 40 km SE from the study area) predates the $\sim$38,000 YBP tephra of Mullineaux and others (1975). A log collected 70 km south of Mossyrock from advance outwash of the Hayden Creek glaciation (D. R. Crandell, written communication, 1980) is older than 60,000 ^{14}C years (QL-1431, M. Stuiver, personal communication, 1980). Heusser (1978) reports evidence of an alpine advance dated at about 60,000 radiocarbon years BP in the Olympic Range of western Washington, and Clague (1980) reports no evidence for major glaciation of nearby Vancouver Island between about 25,000 and $\geq$58,000 YBP. Crandell and Miller (1974) noted Hayden Creek (?) till beneath a pyroclastic deposit dated at $\geq$38,000 YBP on the slopes of Mount Rainier. Barnosky (1979) reports a radiocarbon date of 26,000 $\pm$1200 YBP in Davis Lake sediment which overlies gravel in an outwash channel that was last occupied during Hayden Creek time.

Hayden Creek outwash terraces are well-developed near Salkum. The older, higher terrace (hco_1) grades to an indistinct moraine complex near Silver Creek; the younger terrace can be traced to a moraine near Mossyrock. Moraines in similar topographic settings west of Morton are shown by Weigle and Foxworthy (1962). Weathering-profile development suggests that the hco_2 deposits are considerably younger than the hco_1 deposits, but it is possible that the younger deposits represent a significant stillstand or readvance related to deposition of the older terrace deposits. Two extensive terrace remnants (near Salkum and at Cowlitz Prairie) lie topographically between the principal Hayden Creek terraces, and cannot be clearly correlated with either surface. The terraces comprise coarse outwash gravels capped with silt, and they are designated hco on the map. Their origin remains uncertain, but they are not strath terraces and probably represent a stillstand, readvance, or complete glaciation during Hayden Creek time. The origin of the undifferentiated outwash deposits (heo) which form isolated remnants lying between hco_2 and eco_1 is also uncertain; they may be related to retreat of the Hayden Creek ice (see Erdmann and Bateman, 1951), degradation of the Hayden Creek deposits, or to an unmapped advance.

Colman (1977) studied weathering rinds on clasts from the older Hayden Creek till and suggested that it was probably a pre-Wisconsinan deposit. The hco_1 outwash may also date to this period, or it may have been deposited in early Wisconsinan time like Heusser's Olympic till. Fission-track dating of minerals from pumice incorporated in Hayden Creek till (D. J. Easterbrook, written communication, 1980) may help resolve some of these dating problems. We tentatively suggest that the younger Hayden Creek outwash is about 70,000 years old, and that the older Hayden Creek deposits formed 140,000 years before present, but both these deposits could be of pre-Wisconsinan age.

We recognized only one Wingate Hill outwash deposit (who) during field mapping, but relief on this terrace surface is sufficient (>10 m in places) to obscure the relationships that suggested differentiation of the younger deposits. The Wingate Hill outwash deposits apparently head one or two km west of the Hayden Creek terminal moraine (Crandell and Miller, 1974); no evidence of morainal features remains. No dateable material has been reported from these deposits, and regional correlations are speculative at present. The Wingate Hill outwash deposits are deeply weathered. Most deposits are oxidized to a depth of at least five meters, and most of the clasts in the upper two meters are completely weathered to clay. If the older Hayden Creek deposits are at least 140,000 years old, the weathering of the Wingate Hill deposits suggests that they are several hundred thousand years old, and possibly older.

The Logan Hill Formation (Snavely et al, 1958) is probably a glaciofluvial deposit comprising outwash units of early to mid-Pleistocene age. Deeply weathered exposures of till were noted beneath Wingate Hill deposits by Crandell and Miller (1974), and Snavely et al (1958) noted a deeply weathered diamicton exposed some 15 km west of the Wingate Hill till. The profile plotted in figure 1 cannot grade to this till, but could be related to some of the weathered till exposures noted by Crandell and Miller (1974). Woodward-Clyde (1978) suggest that the Logan Hill Formation is older than 630,000 years, and may be as much as 1 to 1.5 million years old (see also Washington Public Power Supply System, 1974). In the Cowlitz River area, the unit is oxidized to a depth of 10 m or more and most stones are wholly altered to clay to a depth of four meters below the surface. Local relief on the terrace or terrace remnants may be as much as 20 meters. Paleomagnetic determinations on the unit have been hampered by the degree of weathering, and by the absence of fine-grained interbeds. Because no dateable tephra has been recognized in the Logan Hill, and regional correlations are uncertain, we tentatively assign it to the early or mid-Pleistocene.

Terrace profiles (figures 1 and 2) support the stratigraphy proposed by Crandell and Miller (1974) and provide a basis for our subdivision of the Evans Creek and Hayden Creek deposits. The bulk of the Logan Hill Formation, the Wingate Hill outwash, and the older Hayden Creek outwash are preserved to the north of the Cowlitz River. Younger Hayden Creek outwash is best exposed to the south of the river, whereas the younger deposits are bisected by the present river. In some exposures we observed outwash deposits overlying surfaces cut into older units, but the lower contact of the older deposits was generally not exposed. With the exception of the younger Holocene deposits, the outwash surfaces are mantled with massive silt and fine sand units averaging one to three meters thick, and interpreted as windblown deposits. In a few exposures of older outwash, two or more löess sheets can be distinguished, but in most cases only one is apparent. During each deglaciation, the area upstream from Toledo probably consisted of broad surfaces of sand and gravel broken by the braided Cowlitz River, and marked by blowing dust.

All of the terraces show similar longitudinal profiles with gradients of 8-12 m/km adjacent to the moraines, decreasing to about 2.5 m/km near Toledo. As a result, the elevational difference between terrace surfaces decreases downstream. The terminal Evans Creek moraine lies three km east of the edge of figure 1, whereas other Evans Creek end moraines lie several tens of kilometers up the Cowlitz valley. Outwash terrace surfaces are easily distinguished near their respective moraines, but convergence of terrace surfaces near Toledo makes topographic separation of the Evans Creek and younger Hayden Creek terraces difficult. In most places weathering characteristics also allow separation of the terraces, but 14 km upstream from Toledo, isolated terrace segments with intermediate soil development are designated heo, and separation from the other terraces is difficult. The heo segments may represent a pre-Evans Creek event of magnitude comparable to that glaciation, but may simply record the dissection of hco_2 terraces in pre-Fraser time. The gradient of the Logan Hill terrace segment suggests a source tens of kilometers to the east, or the possibility of a non-glacial origin, but our data are not sufficient to support the latter possibility.

The locations of 11 soil sample pits are plotted on both the map and figure 1. Several of the pits plot above the average terrace gradients, probably because sites were selected on the highest, most stable portions of the terraces. Site C-7 was located on a terrace segment (heo) which lies four meters above the eco_1 terrace, and appears more weathered than the older Evans Creek deposits. Details of morphology, physical properties, and chemistry of soils are presently under investigation.

SUMMARY

At least six distinct outwash deposits, ranging in age from early (?) to latest Pleistocene, form terraces as much as 130 meters above Holocene alluvium and flood plain deposits along the Cowlitz River near Toledo, Washington. Outwash deposits of the Hayden Creek glaciation, the Wingate Hill glaciation, and the older Evans Creek outwash can be traced upstream to moraines, or to ice limits inferred from the extent of till. Terrace surfaces converge downstream, but in most places they can be distinguished by topography and weathering characteristics. The youngest deposits along the Cowlitz River are oxidized to a depth of only a few centimeters, and some exposures of the Logan Hill Formation are oxidized to depths of more than 10 meters. We have partly subdivided the stratigraphy proposed by Crandell and Miller (1974), who mapped at a scale of 1:250,000 and have modified the extent of their map units at a scale of 1:62,500. The sequence of löess-covered outwash terraces along the Cowlitz River above Toledo is probably the best-preserved record of alpine glacial events in the Pacific Northwest, and provides an excellent site to study soil development over an extended period of Quaternary time.

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