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SURFICIAL GEOLOGY OF THE MAPLE VALLEY AND HOBART QUADRANGLES, WASHINGTON

by

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ABSTRACT

The Pleistocene sedimentary history of the Puget Lowland is one of alternate glacial and nonglacial deposition. The Maple Valley and Hobart quadrangles lie southeast of Seattle in the southeastern part of the lowland. Prior to the Fraser Glaciation, a lobe of the Cordilleran Glacier Complex advanced at least twice into the Puget Lowland as far south as the northwest quadrent of the Maple Valley quadrangle and deposited "undifferentiated drift", currently exposed along the walls of the Cedar River valley.

During the Vashon Stade of the Fraser Glaciation the Puget lobe flowed southeast across the Maple Valley-Hobart area. Vashon advance drift was deposited on the lowland drift plain and in proglacial lakes. Streamline molded forms were developed and a mantle of till deposited beneath the overriding glacier. At the glacier's maximum stand the entire mapped area was covered with ice except for that portion of Tiger Mountain above an altitude of about 2,740 feet, which emerged as an nunatak. Seven stages of ice recession are recognized on the basis of meltwater channels, terraces, ice-contact sediments, and sediments deposited in proglacial lakes. Sediments deposited during deglaciation are widespread and highly variable in thickness and extent.

During northward retreat of the Vashon glacier, a large ice-marginal stream deposited gravel over much of the southern part of the area and built several prominent terraces. Ice-dammed lakes formed during the retreat were the site of deposition of fine-grained lacustrine sediments and deltas. History of the recessional deposits is intimately related to various meltwater channels occupied as the retreating glacier successively exposed lower drainage routes.

Post-Fraser deposits include alluvium, organic sediments, colluvium, and landslide debris. Five postglacial climatic episodes have been recognized from pollen studies.

SURFICIAL GEOLOGY OF THE MAPLE VALLEY AND HOBART QUADRANGLES, WASHINGTON

INTRODUCTION

The Maple Valley and Hobart $7\frac{1}{2}$-minute quadrangles, with combined area of about 100 square miles, are located southeast of Renton in the Puget Sound lowland of Washington. The area may be divided into two physiographic units, a southwestern lowland and a northeastern mountainous area (fig. 1). Both units are covered by glacial drift, but exposures of underlying bedrock are almost entirely restricted to the mountainous area.

The lowland area is made up of a series of plateaus transected by the flat-floored but steep-sided Cedar River valley and abandoned melt-water channels. The plateaus consist of a rolling drift plain having low ridges and elongated hills with a relief of less than 200 feet. The plateaus vary in altitude from about 900 feet adjacent to the mountainous area in the southeast to 400 feet near Renton in the northwest. Many small lakes and peat bogs occupy depressions and poorly drained areas on the lowland surface. Flat plains and terraces are common along the southern margin of the area. Cedar River, the principal stream, heads in the Cascade Range to the east and flows generally northwest to Lake Washington at Renton. The river enters the southeastern boundary of the area at an altitude of 710 feet and leaves near the northwestern corner at an altitude of 150 feet; its average gradient is about 28 feet per mile.

The mountainous portion, which comprises about a third of the area, exhibits varied topography. Tiger Mountain, the highest peak, reaches

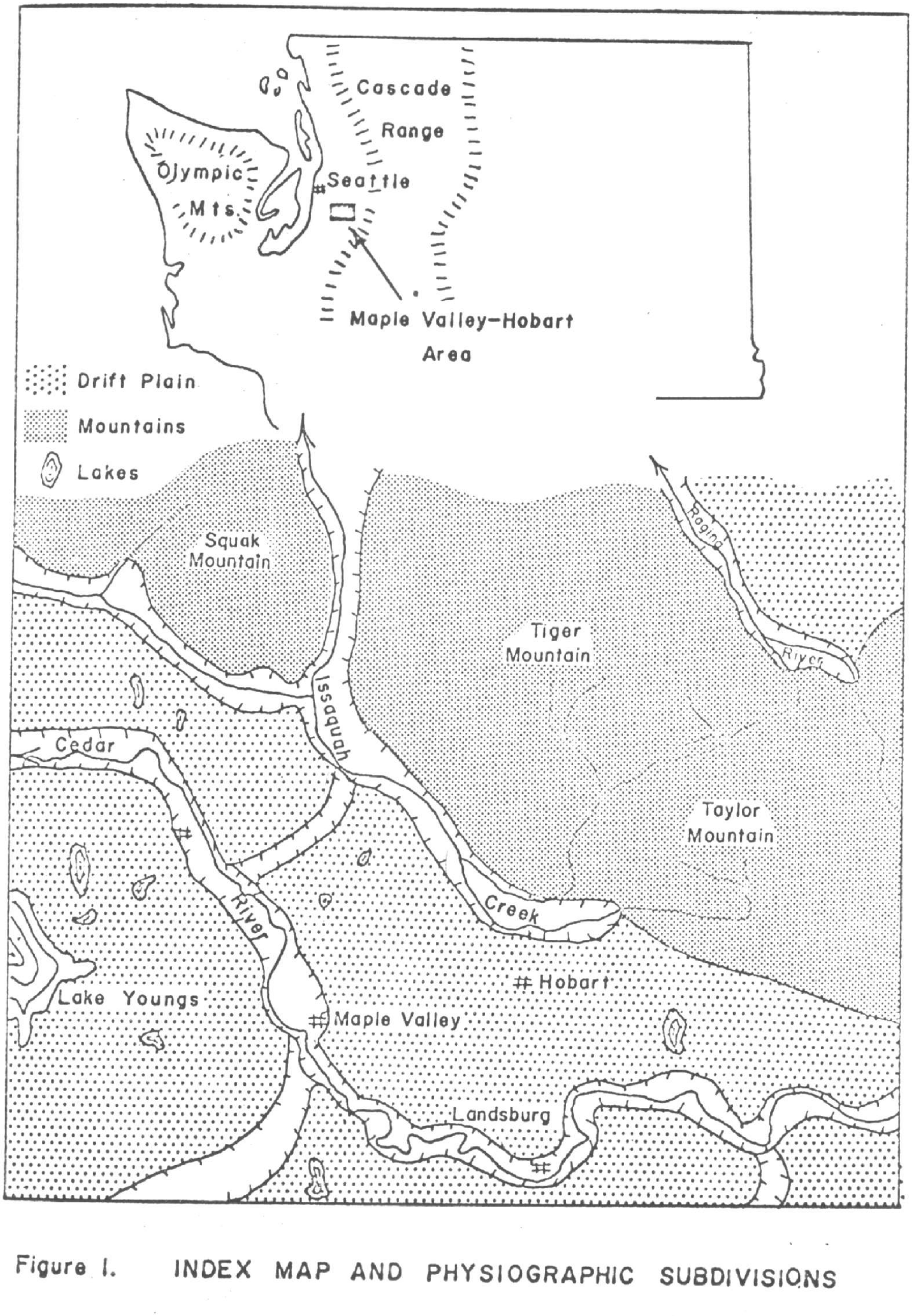


Figure I. INDEX MAP AND PHYSIOGRAPHIC SUBDIVISIONS an altitude of 3,004 feet whereas the principal valleys of Raging River and Issaquah Creek, on opposite sides of the mountain, are about 600 feet and 300 feet above sea level, respectively. The Echo Lake Road, completed in 1964, trends northeast through the mountainous area and fresh outcrops along it were an aid in reconstructing events during the Fraser Glaciation.

The climate in the Maple Valley-Hobart area is mild with most rain falling between the months of October and April. Annual precipitation in the western portion of the lowland is about 40 inches and increases towards the east. At Landsburg the precipitation is about 53 inches, and Tiger Mountain receives about 75 inches annually (Phillips, 1965). The mean annual temperature of the lowland area is around 50°F. July is the warmest month of the year with a mean temperature of about 65°F. The lowest mean monthly temperature occurs in January and is about 32°F. Seldom do the extreme annual temperatures exceed the limits of 0°F. and 100°F. The temperature in the mountainous area generally is 10°F. to 15°F. cooler than the prevailing temperature in the lowlands.

Vegetation in the area includes a varied flora as a result of the moist climate and varied geologic deposits and soil conditions. Except for farms and many recent suburban developments and home sites in the lowlands, most of the area is densely timbered. Douglas fir, Sitka spruce, hemlock and other conifers are dominant in the mountainous portion. A dense, thick second or third growth of Douglas fir is the predominant tree found on gravelly glacial outwash. Hardwoods, including maple, cottonwood, and alder, are interspersed among evergreens in forested areas and often a dense tangle of fern, holly, devil's club, and mosses cover the ground beneath large trees. Where outcrops are scarce, certain local flora may indicate possible geologic deposits when local topography is considered.

The purpose of mapping the surficial geology of the Maple Valley-Hobart quadrangles was two-fold. The primary purpose was to decipher the Pleistocene history with special emphasis on the recessional phase of the Vashon Stade of the most recent glaciation, the Fraser. Abandoned meltwater channels, terraces, deltas, lacustrine sediments and associated features are related to work done by others in adjacent areas to the north, west and south. Furthermore, surficial mapping of this area completes a block of nine $7\frac{1}{2}$-minute quadrangles in the southeastern portion of the Puget Sound lowland.

PREVIOUS STUDIES AND REGIONAL GLACIAL HISTORY

Pleistocene glacial deposits of the Puget Sound region have been studied and described by several geologists since the late 1900's. Bailey Willis (1898) made the first major contribution to the Pleistocene glacial history of the region in his study of the Tacoma area. He subdivided the Pleistocene deposits into three units which he named, from oldest to youngest, the Admiralty glacial, Puyallup interglacial, and the Vashon glacial. Bretz (1913) published a classic report on the "Glaciation of the Puget Sound Region" which remained unmodified until only recently (Crandell, Mullineaux, and Waldron, 1958). Bretz proved the existence of many proglacial lakes during the advance and retreat of the Vashon glacier, and established the position of the terminal moraine at the maximum advance of the Puget lobe. Through the use of meltwater channels, deltas, terraces, lacustrine sediments, and other associated features, Bretz reconstructed the position of the ice front and extent of proglacial lakes during several stages in the recession of the glacier. The glacial geology of the Snoqualmie-Cedar area, located about 5 to 10 miles northeast of the present study area, was published by J. H. Mackin in 1941. He identified two glacial stages which he named the "Embayment" and "Sallal". The Sallal stage is recognized as a recessional stand or minor readvance of the Vashon glacier during its retreat, while the Embayment stage was the period of maximum glacial advance. Mackin delineated a moraine for each stage, as well as glacial meltwater routes in the area.

A major revision of the Pleistocene glacial history of the Puget Sound region was published in 1958 by Crandell, Mullineaux, and Waldron. They redefined the Pleistocene stratigraphic sequence and recognized four glacial and three nonglacial intervals. These were named Orting glaciation (oldest), Alderton nonglacial interval, Stuck glaciation, Puyallup nonglacial interval, Salmon Springs glaciation, erosion interval, and Vashon glaciation. The term "Admiralty", which had been used for 60 years, was abandoned, because Crandell, Mullineaux, and Waldron found that deposits on which Willis based his Admiralty Glaciation are of different age from one locality to another. Another revision of the Pleistocene sequence was introduced by Armstrong and others (1965) when they changed the name of the latest glaciation from Vashon to Fraser, and reduced the term "Vashon" to stadial rank. Their complete subdivision of the Fraser Glaciation is as follows: Evans Creek Stade (oldest), Vashon Stade, Everson Interstade, and Sumas Stade. They also named the "erosional interval" of Crandell, Mullineaux, and Waldron (1958) the Olympia nonglacial interval.

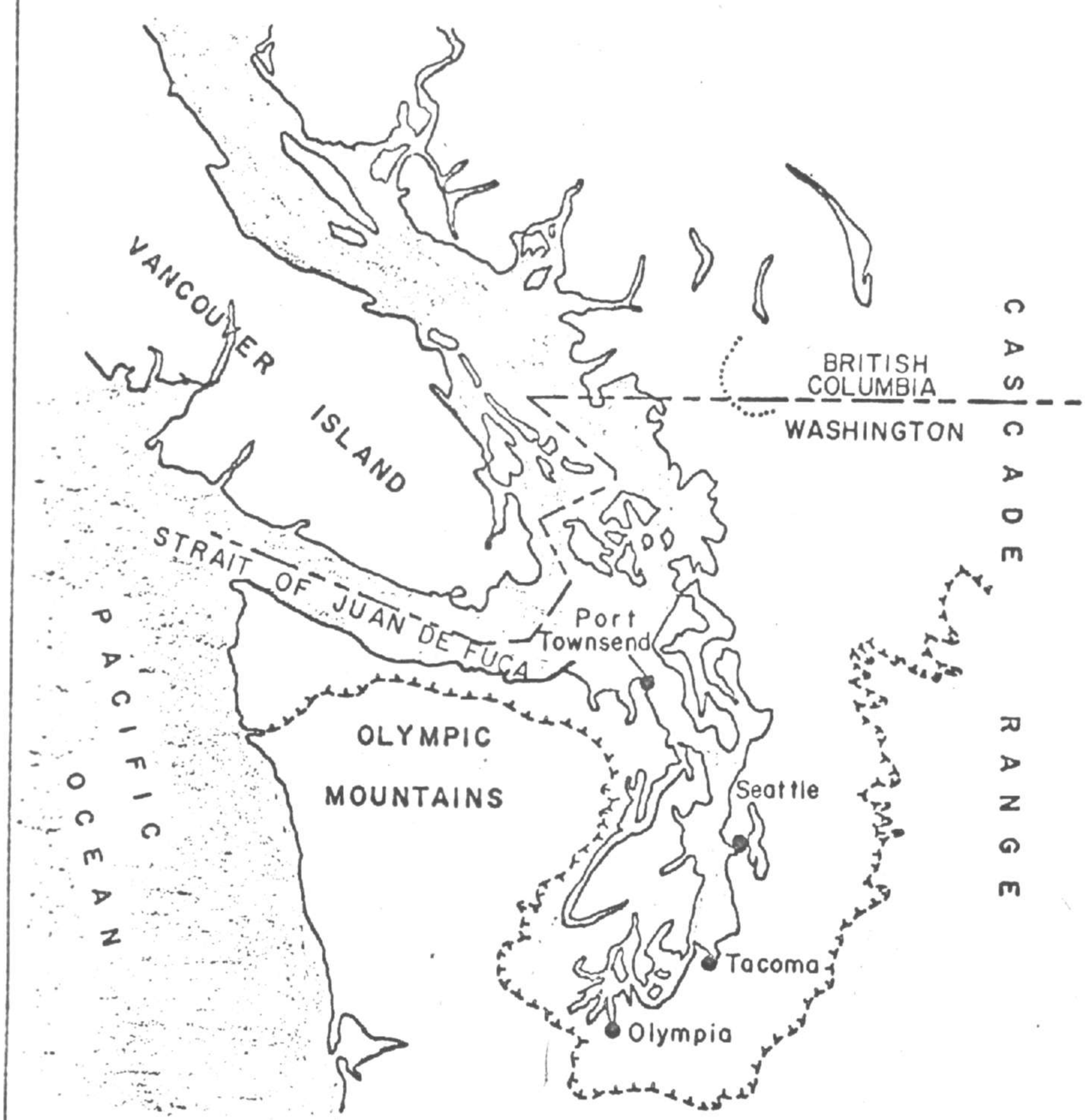
Detailed surficial geology adjacent to the present area of study has recently been completed. Mullineaux (1961) mapped the Renton, Auburn, and Black Diamond quadrangles in which Pleistocene deposits record at least four major glaciations and one nonglacial interval. Curran (1965) and Anderson (1965), from studies in the Issaquah and Fall City areas, respectively, identified nine phases of deglaciation. Drift which covers their areas is almost wholly Vashon and at only a few localities are pre-Vashon sediments exposed. A ground-water-resources study was performed in northwestern King County by Liesch, Price, and Walters (1963). However, no expansion or revision was made to the existing generalized Pleistocene history which Bretz published in 1913, for their work was limited in scope.

The Pleistocene sedimentary history of the Puget Sound lowland is one of alternate glacial and nonglacial deposition. During each of the four major glacial intervals a lobe of the Cordilleran Glacier Complex, originating in the mountains of British Columbia, advanced southward into the Puget Sound lowland. The history of the most recent glaciation is known in far greater detail than that of the three preceding ones and a brief summary of it is included here to establish a basic background for this report.

In early Fraser time (Evans Creek Stade) alpine glaciers formed in the Olympic and Cascade Mountains of Washington and in the Cascades of British Columbia. Glaciers grew in size and advanced down major stream valleys towards the lowland. Further expansion of alpine glaciers in British Columbia resulted in the formation of a mountain ice sheet while farther south in Washington glaciers were still restricted to mountain valleys. Continued growth of the ice sheet in British Columbia resulted in the southward advance of an ice lobe into the Puget lowland and contemporaneous retreat of alpine glaciers of Washington.

The Vashon Stade culminated with the advance of the Puget lobe of the Cordilleran Glacier complex into the lowland between the Olympics and Cascades. The advancing glacier scoured and deepened north-south trending valleys, and filled transverse valleys with drift. Advance stratified drift, consisting of gravels, sands, silts, and clays, were deposited in proglacial lakes that formed in front of the advancing Vashon glacier, and upon the higher parts of the Puget Lowland. At its maximum the Puget lobe extended from near Port Townsend to a point about 15 miles south of Olympia; it filled the lowland between the Olympics and the Cascades and extended several miles into the larger mountain valleys (fig. 2). The glacier remained at its maximum stand long enough to deposit an arcuate, somewhat fan-shaped terminal moraine. An extensive outwash plain, consisting of well-washed silts, sands, and gravels, was built beyond the moraine. Following the maximum stand, the Puget lobe began to recede out of the Puget Lowland, but not at a constant rate. Recessional stratified drift was deposited in proglacial lakes that developed in front of the retreating glacier, upon the freshly exposed drift plain, and the foothills of the Cascades. The sediments are very similar in appearence to advance stratified drift, but an intervening layer of till almost always separates the two deposits. Ice-marginal meltwater streams and (or) streams heading in the Cascades or Olympics, along with outlet streams from proglacial lakes carved meltwater channels into the drift plain. Successive channels were abandoned as lower drainage routes were exposed during the northward retreat of the ice front.

When the Puget lobe had retreated to a position near Port Townsend, marine waters invaded the large proglacial lake that occupied much of the Puget Lowland. The episode represented by the subsequent accumulation of glaciomarine, marine, and related sediments in the northern part of the lowland is named the Everson Interstade. During this interval



EXPLANATION

········ Maximum extent of glacier in Fraser Lowland during Sumas Stade.

ᐃᐃᐃᐃ Maximum extent of Cordilleran glacier in Washington during Vashon Stade, hachures on side toward glacier.

(after Armstrong and others, 1965)

10 0 20 40 miles

Figure 2. Map of southwestern British Columbia and northwestern Washington showing extent of glaciation.

the main ice lobe retreated into the southwestern highlands of British Columbia, but floating ice apparently was present upon the sea to the south (Easterbrook, 1964). The interstade ended when land rose with respect to sea level. During late stages of land emergence a valley glacier advanced through the Fraser Lowland of British Columbia and reached the International Boundary. The readvance is named the Sumas Stade. With disappearance of the Sumas Glacier, postglacial time began in the Puget Sound region.

ACKNOWLEDGEMENTS

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The writer also wishes to express his indebtedness to the Seattle Water Department for granting permission to work within the Cedar River Watershed and Lake Youngs Reservoir areas, and to the Weyerhaeuser Company for granting permission to work within the Tiger Mountain Timber Reserve area.

BEDROCK GEOLOGY

Bedrock crops out in about 10 percent of the mapped area, but less than two percent is found in the west half. The rocks consist of consolidated sediments and volcanics of Tertiary age with scattered bodies of igneous intrusives. Some of the significant bedrock investigations of the area were made by Evans (1910), Weaver (1916 and 1937), Warren and others (1945), and by Vine (1962), who mapped the bedrock geology of the Maple Valley and Hobart quadrangles to evaluate coal resources. The oldest exposed rock unit is the Raging River Formation, an epiclastic volcanic sandstone, siltstone, and conglomerate of marine origin. Its age is middle Eocene and probably it is at least 3,000 feet thick (Vine, 1962).

Conformably overlying the Raging River Formation is a sequence of nonmarine rocks which were named the "Puget Group" by White (1888, p. 446-447). The lower part of this sequence has been named the Tiger Mountain Formation and consists of 2,000 feet of continental arkosic sandstone, claystone, and interbedded shale and coal (Vine, 1962). Most of the sandstones have a clay matrix and are poorly cemented. The Tiger Mountain Formation (middle (?) and late Eocene) is overlain by the Tukwila Formation (late Eocene); the two formations are interstratified through about 800 feet. The Tukwila Formation, locally about 7,000 feet thick, is composed of epiclastic volcanic sandstone, tuffeceous siltstone, tuff breccia, volcanic conglomerate, and thin vesicular lava flows or sills (Vine, 1962). The Renton Formation conformably overlies the Tukwila Formation. It is the youngest formation recognized in the Puget Group of this area and may be of Late Eocene or earliest Oligocene age. It consists of arkosic sandstone, siltstone, carbonaceous claystone and coal that have an aggregate thickness of at least 2,250 feet (Vine, 1962).

A porphyritic igneous intrusive thought to be genetically related to volcanic rocks of the Tukwila Formation crops out on both sides of the canyon of Issaquah Creek in sec. 10, T.23N., R.6E. Intrusive rocks having a composition of calcic andesite crop out as resistant knobs and ledges along Fifteenmile Creek, on South Tiger Mountain, and along Raging River. They are believed to be Oligocene in age (Vine, 1962).

PRE-PLEISTOCENE GEOMORPHOLOGY

In middle and late Eocene time the Puget Sound lowland was part of a coastal plain in a subsiding basin that was being filled with detritus at about the same rate it was sinking. The Cascade Range did not exist in its present form and a coastal plain extended at least as far east as the position of the present Cascades. The climate was subtropical or temperate.

A marine embayment extended east as far as Tiger Mountain during part of middle Eocene time (Mullineaux, 1961). Sediments of the Raging River Formation were deposited in the embayment near Tiger Mountain. Subsequently, the sea retreated and nonmarine sediments of the Tiger Mountain Formation of the Puget Group were deposited over the Raging River marine sequence. Volcanic activity began during late Eocene time at an eruptive area located northeast of Renton, possibly in the vicinity south of Issaquah where intrusive igneous rock is found (Vine, 1962). The vocanic detritus derived from this eruptive area was deposited rapidly and forms the Tukwila Formation. Near the close of the Eocene Epoch volcanic activity ceased and continental sediments of the Renton Formation were deposited upon the Tukwila Formation. At this time the Puget Sound lowland was a continental coastal plain of low relief near sea level and the climate was subtropical. Over this coastal plain flowed rivers carrying bed loads of sand and in areas between the rivers abundant vegetation grew in swamps, lagoons, and shallow lakes.

By earliest Oligocene time deposition of the Renton Formation ceased. Volcanic activity and possible uplift in the vicinity of the present Cascade Range had begun along with a marked increase in rate of subsidence of the coastal plain at Renton (Mullineaux, 1961). During

Miocene time rocks in most of western Washington were deformed along northwesterly trending axes (Weaver, 1937) and the area of Puget Sound lowland was uplifted above sea level. This topographic high was eroded to a surface of low relief before the end of Miocene time. Near the close of the Miocene, uplift of the Cascade Range began. During the Pliocene Epoch the Olympic Mountains were uplifted, the Cascades experienced continued uplift, and the Puget Sound lowland came into existence (Snavely and Wagner, 1963). At first the lowland probably appeared as a somewhat featureless plain, but by the close of Pliocene time erosion had given it a topography similar to that of today.

SURFICIAL GEOLOGY

Glacial-Erosional Features

The major glacial-erosional features in the mapped area are streamline molded forms along the flanks of the mountainous area and on the lowland drift plain. The streamline molded forms consist of elongate hills and fluted surfaces, the former being more numerous. The elongate hills include both true drumlins and rock drumlins, while fluted surfaces are developed on drift. Rock drumlins are largely erosional; the true drumlins may also be chiefly erosional. The drumlins generally range in length from 2,000 to 4,000 feet, in width from 1,000 to 2,000 feet, and in height from 50 to 150 feet. An "ideal" drumlin is located about a mile west of Hobart and appears to consist entirely of drift. Two rock drumlins in the S$\frac{1}{2}$ sec. 31, T.23N., R.7E. show a thin discontinuous veneer of till. The fluted surfaces consist of parallel grooves with intervening ridges and generally range in length from 2,000 to 4,000 feet, in width from 200 to 400 feet, and height from 20 to 50 feet.

They are best developed just east of Shadow Lake in the southwestern lowland. Streamline forms offer minimum resistance to flow of fluids and are an expectable product of erosion and deposition by active glacier ice. In glaciated regions long axes of streamline molded forms provide good indicators of the ice-flow direction (Flint, 1957, p. 66-72). In the Maple Valley-Hobart area aligned topography indicates a southeast flow direction for the last glacier to pass over this part of the lowland (fig. 3).

Northwest-trending grooved topography is present about a mile north of Lake Desire along the south wall of the Cedar River valley, which trends west, transverse to the grooves. The grooves probably were excavated by the Vashon Glacier and now are occupied by small consequent streams.

Late-Glacial Morphologic Features

Significant late-glacial morphologic features of the Maple Valley Hobart area and from adjacent areas are described below according to mode or origin rather than age. Some may have formed contemporaneously. Altitudes were taken from $7\frac{1}{2}$-minute topographic quadrangles.

Five prominent glacial meltwater channels were excavated at various stages of retreat of the Vashon Glacier. The Cedar Spillway (Mackin, 1941) was the first to be occupied during recession of the glacier. It lies at the southeast end of Rattlesnake Mountain, about six miles south of North Bend. The southwest-trending channel is approximately six miles long, 0.75 mile wide, and its floor reaches an altitude of about 1,000 feet. Only the southwestern mile of the Cedar Spillway lies within the mapped area (sec. 22 and 23, T.22N., R.7E.). The southern portion of the channel grades into an outwash deposit.

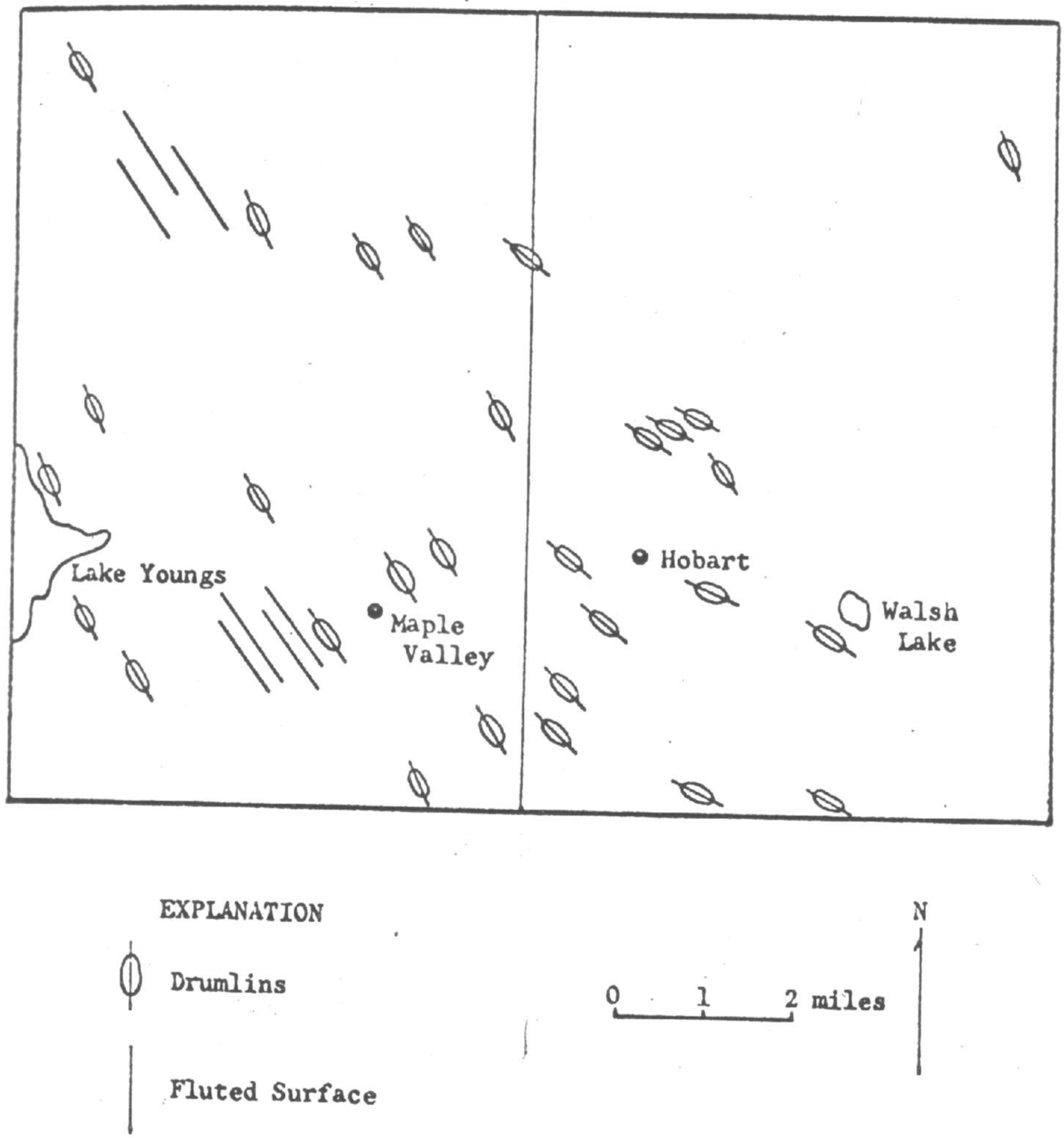


Figure 3. Sketch map of Maple Valley and Hobart Quadrangles showing location and trend of streamline molded forms.

A meltwater channel, here named the Georgetown Channel, is incised about 100 feet into the western portion of the outwash deposit below the Cedar Spillway. The channel trends south and then west in a arc-like path for approximately three miles. Only the upper half mile lies in the mapped area. The floor of the half-mile-wide channel lies at an altitude of about 730 feet and the western end terminates against outwash sediments.

The Covington Channel (Mullineaux, 1961, p. 111), a late-Vashon meltwater channel incised about 60 feet into a low sag in the drift plain, trends southwest from the vicinity of Maple Valley. Its floor is about 410 feet above sea level at its northeastern end and it terminates to the southwest in the Auburn Delta (Bretz, 1913) at a altitude of 250 feet. The northeasternmost three miles of the approximately 10-mile-long channel are in the mapped area. The channel is from 0.5 mile to 2 miles wide and is the largest of the five channels.

Another southwest-trending channel cuts the drift plain north of Maple Valley between the Issaquah Creek and the Cedar River valleys just northwest of Webster Lake. The channel, here named the Cedar Grove Channel, is just over two miles long, about 0.3 mile wide, and its floor lies about 150 feet below the drift plain at an altitude of 350 feet.

The Kennydale Channel (Curran, 1965) is a five-mile-long northwest trending valley having a swampy floor as much as 0.25 mile wide. It lies about a mile north of Lake Kathleen and Lake McDonald in the northwest portion of the mapped area. The maximum height of its floor is about 325 feet. The channel terminates northwest in the Kennydale Delta (Bretz, 1913), and all but the westernmost mile lies in the mapped area. Two underfit streams now occupy the channel floor.

Terraces are conspicuous features along the southern part of the area and are related to the Cedar Spillway, Georgetown, and Covington channels. Terraces east of the Cedar Spillway and the Georgetown Channel lie at altitudes of about 1580, 1140, 920, 860, and 780 feet; the lowest three are in the mapped area. Terraces on both sides of the Covington Channel reach altitudes of about 470 and 400 feet. Several other terraces, some minor, lie at altitudes of 720, 700, 640, 620, 600, and 505 feet between the Covington and Georgetown channels along the Cedar River valley.

Several deltas occur within the area, but few exhibit well-defined deltaic morphology. The only one mapped in the Hobart area, here named the Holder Creek Delta, is located about one mile south of South Tiger Mountain. It appears to have been built in three stages. The oldest segment lacks a well-defined top, but seems to reach an altitude of between 860 and 960 feet. Two level surfaces at altitudes of 830 and 760 feet are successively younger. Another delta, here named the Wilderness Delta, lies at the northwest end of the mile-long, 505-foot terrace on the south side of Cedar River a mile north of Lake Wilderness. Its upper surface reaches an altitude of about 520 feet. The southeastward extent of the delta could not be determined from topography, and exposures were not available. A compound delta at the southwest end of the Cedar Grove Channel is here named the Cedar Grove Delta. Its older southeast portion has a level top at about 425 feet and a younger northwestern portion lies at an altitude of about 400 feet. The Cedar Grove Channel divides the two delta segments and is incised more than 50 feet below the top of the delta. Another delta found near the eastern end of the Kennydale Channel is here named the Benson Road Delta. Its upper surface lies about 335 feet above sea level. A small delta, here named the Indian Delta, occurs on the south side of Cedar River valley near the community of Indian.

Its upper surface is poorly defined and reaches an altitude of about 410 feet. Another small delta, here named the Maple Valley Delta, is found on the east side of Cedar River valley at Maple Valley. Its upper surface is well-defined and lies at an altitude of about 410 feet.

A small terminal moraine, here named the Deep Creek Valley Moraine, crosses sec. 21, T.23N., R.7E. and is transected by the Echo Lake Road and Deep Creek. The moraine trends west of north and the upper surface of the 100-foot-high ridge reaches an altitude of about 1,340 feet. The moraine is best seen when looking southwest from the Echo Lake Road.

Stratigraphy

Unconsolidated sediments of the mapped area include silt, sand, gravel, and till, with minor amounts of clay and peat. These sediments have been assigned to the Vashon stade of the Fraser Glaciation, with the exception of two undifferentiated pre-Vashon units, peat, and modern alluvium.

Undifferentiated Pre-Vashon Sediments

Undifferentiated Drift

Pre-Vashon drift underlies Vashon drift in the walls of the Cedar River valley west of the small community of Indian. It was not possible to correlate these sediments with pre-Vashon units of Crandell and others (1958), but undoubtedly they are essentially comparable to "undifferentiated drift" in the Cedar River valley mentioned by Mullineaux (1961, p. 100). At least two till sheets, separated by about 50 feet of sand and sandy pebble-gravel, are included in the unit, which is about 200 feet thick. The gray till layers are about 15 feet thick, unoxidized, and very compact. The lower till is coarser than the upper, and overlying Vashon till is still coarser. Associated sand and gravel are of fluvial and lacustrine origin (Mullineaux, 1961). They are slightly oxidized above the lower till, but beneath the lower till oxidation is more widespread. A bed of sand and gravel exposed at the bottom of the unit in the NW$\frac{1}{4}$SW$\frac{1}{4}$sec. 20, T.23N., R.6E. has been strongly oxidized to a reddish-brown color. Although mapped as undifferentiated drift, this bed and others in the same stratigraphic position may be nonglacial in origin.

Undifferentiated Older Sediments

A unit of unconsolidated sediments which lacks till is exposed in the wall of the Cedar River valley between the communities of Cedar Mountain and Landsburg. Throughout the valley it is overlain by Vashon drift. Because correlation with units named by Crandell and others (1958) and Mullineaux (1961) was not possible, the designation "undifferentiated older sediments" is used. The upper part of the unit contains varying amounts of Vashon advance gravels and sands, but in most cases they were not differentiated on the map (plate I) because: (1) Vashon advance gravels are transitional into underlying sediments and (2) limited or discontinuous exposures and steep outcrops precluded mapping in many instances.

About 110 feet of undifferentiated older sediments are exposed in a steep cliff in the NE$\frac{1}{4}$NW$\frac{1}{4}$sec. 23, T.22N., R.6E. They are typical and consist of well-sorted sands, silts, cobble gravel, and pebble gravel that are strongly oxidized to a reddish-brown color. The sediments were deposited by a westward-flowing stream, as shown by the dip of small foreset and topset beds within sand layers.

Although exposures of the undifferentiated older sediments are restricted to the Cedar River valley probably they underlie throughout much of this part of the lowland. Despite absence of a recognizable weathering profile, the strong oxidation suggests that the unit was exposed for a considerable time before burial by Vashon drift. Future studies may show that the sediments were deposited during the Olympia nonglacial interval (Armstrong and others, 1965) that preceded the Fraser Glaciation.

Vashon Drift

Vashon drift was deposited by the Puget glacial lobe during the Fraser Glaciation. Two distinctive types of drift were formed during the advance and recession of this glacier: stratified drift, deposited by meltwater, and till, deposited at the base of the ice and ideally formed without the cooperation of water. However, no sharp dividing line exists between till and stratified drift. According to Flint (1957, p. 109) till is the non-size-sorted end member of a series whose opposite end member is well-size-sorted stratified drift; one grades into the other.

Identification of a deposit of stratified drift as belonging to the advance or recessional phase of the Vashon Stade is not always simple, for both deposits are similar in texture and composition. Typically the advance sediments are compact, appear fresh and unoxidized because they were overriden shortly after deposition and thickly mantled with till. On the other hand, recessional drift was laid down as the ice sheet retreated and has been exposed to weathering since deposition. Stratigraphic relationship of Vashon Till to stratified drift is in many cases the only means of classifying a deposit as advance or recessional drift. When till is not present, other criteria must be used. Advance drift is easily recognized when the deposit has a surface that obviously has been modified by overriding ice. Stratified drift that possesses a constructional surface in most cases is recessional. However, if a layer or lens of till was deposited during advance or recession of the glacier as flowtill, the associated stratified drift might inadvertently be mapped incorrectly.

Advance Stratified Drift

During advance of the Puget lobe across the Maple Valley-Hobart area stratified sediments were deposited in front of the ice sheet by meltwater streams. The sediments, which were laid down as proglacial outwash and glaciolacustrine sediments, consist of pebble and cobble gravel, sand, silt, and fine laminated clayey silt. Advance stratified drift is widespread but discontinuous, almost always being overlain by a thick mantle of till. Variations in thickness are due to the fact that it filled existing topographic lows, but only veneered the upper surface of the drift plain. Therefore, exposure of advance drift generally is restricted to localities which have been dissected by large streams that cross the Vashon drift plain.

Advance stratified gravels are exposed along the walls of the Cedar River valley and generally are less than 20 feet thick. In the vicinity of Maple Valley the gravels are about 50 feet thick, show very poor sorting and are almost devoid of stratification suggesting rapid deposition. The presence of thick advance gravels suggests a topographic low existed in the Maple Valley area prior to the advance of the Vashon glacier.

One of the finest exposures of Vashon drift occurs along the sides of Holder Creek valley just southeast of South Tiger Mountain between about 1,100 to 1,300 feet. Interbedded fluvial and lacustrine advance sediments comprise the lower 35 feet of this exposure. They consist of massive clayey silt, sand, and stratified pebble gravel. The clayey silt is compact and pale blue in color. Above is about 40 feet of additional advance lacustrine sediments which consist of compact finely laminated silts and clayey silts with several thin layers of coarse sand and pebble gravel (figs. 4 and 5). The laminae range from 1 mm to 10 mm in thickness and part readily along planes that separate layers of different grain size. Erratic stones, presumably ice-rafted, are common in the laminated sediments and many are faceted and a few have striations. Overlying the laminated sediments are about 25 feet of laminated silts with three intercalated lenses or layers of till also included as advance drift. The till layers range from 3 to 6 feet in thickness. The Overlying Vashon Till is considerably stonier than the lower till layers which consist of about 80 to 90 percent fine-grained matrix. The till layers may be flowtill derived from the surface of the advancing glacier. The underlying laminated silts apparently are undeformed and the layers of till generally were uniform in thickness across the width of exposure. Therefore, the direction from which the probable flowtill moved could not be determined.

In the NE$\frac{1}{4}$NE$\frac{1}{4}$sec. 15, T.23N., R.7E. on the south side of Raging River is an exposure of advance silts. The silts indicate that a proglacial lake occupied the Raging River valley during the advance of the Vashon glacier. The silts were deformed by overriding ice which advanced southeast up the valley. The base of the overlying Vashon Till has a very silty matrix as a result of incorporation of some of the silt.

A deposit of advance stratified gravels overlain by Vashon Till is well exposed along the Ditch Road in the Cedar River Watershed about 1.5 miles southwest of Walsh Lake. In the NE$\frac{1}{4}$NW$\frac{1}{4}$sec. 12, T.22N., R.5E., just southeast of Lake Youngs, a borrow pit exposes advance ice-contact gravels, sands, and silts which are discontinuously overlain by Vashon Till.

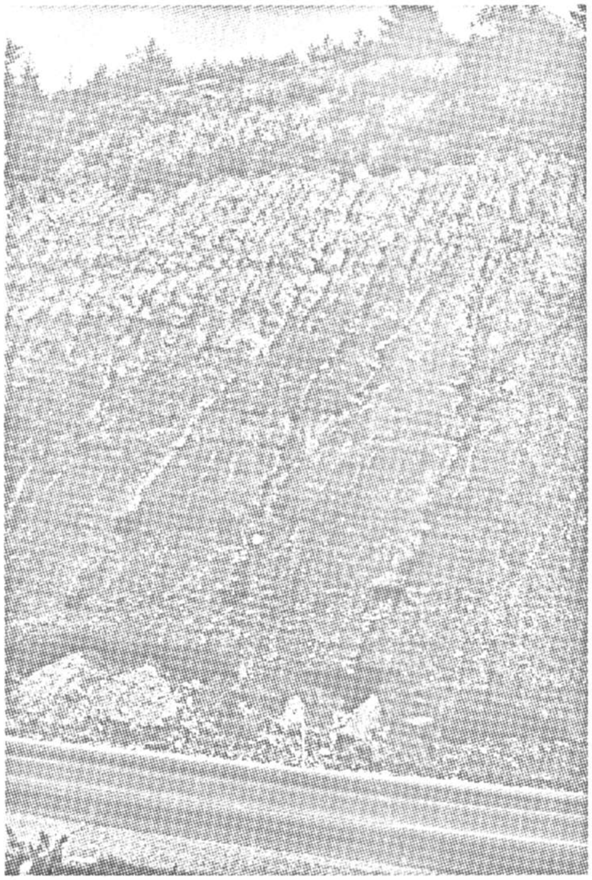


Figure 4. — Exposure in Holder Creek valley of Vashon advance stratified lacustrine sediments overlain by Vashon Till, and in turn capped by recessional lacustrine sands.

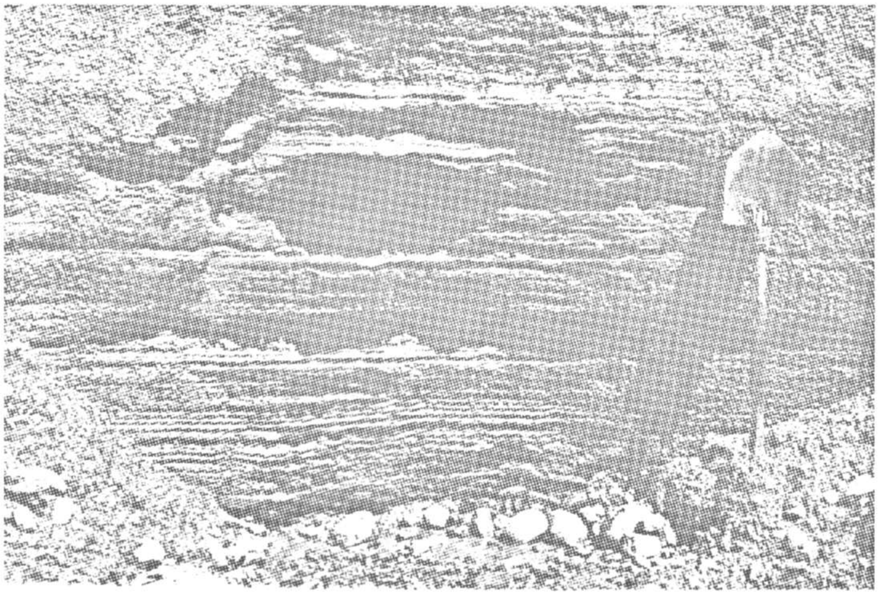


Figure 5. — Detail of lower stratified unit of figure 4.

Vashon Till

Vashon Till is the most extensively exposed unit in the mapped area and underlies most recessional stratified drift. Vashon drift includes only one till sheet in the mapped area, a condition typical of Fraser drift in the Puget Lowland. Vashon Till mantles preexisting topography, for it covers the walls of valleys, the drift plain, and bedrock hills, but where it also has an original constructional topography of its own it forms ground moraine (see p. 12).

Vashon Till has a fine-grained and generally structureless matrix in which are sparsely distributed pebbles, cobbles, and occasional boulders. However, the till in various parts of the mapped area has facies which vary widely in size range of component particles and in the amount of material in any one size class. In the mountainous area it generally contains more clay and silt in the matrix and larger cobbles and boulders than does till in the lowland. Lowland till generally has a silty sand matrix and contains a large number of pebbles and cobbles. Although the term till is properly applied only to nonstratified and nonsorted ice-laid materials (Pettijohn, 1957, p. 266), Vashon Till contains blocks and lenses of stratified drift and commonly shows thin partings termed fissility (Flint, 1957, p. 113). At the base of the Cedar Grove Delta, in the SE$\frac{1}{4}$NE$\frac{1}{4}$sec. 32, T.23N., R.6E., an exposure shows stratified gravel and sand incorporated within Vashon Till. A good exposure of till having fissility parallel to the ground surface occurs along the east side of Deep Creek in the SE$\frac{1}{4}$NE$\frac{1}{4}$sec. 15, T.23N., R.7E. Faceted and striated stones are uncommon in Vashon Till; most pebbles and cobbles are rounded rather than angular or tabular in shape. The numerous rounded stones common to the till probably is due to the stones having been derived largely from fluvial gravels in the Puget Sound Lowland during advance of the Vashon glacier, rather than to direct incorporation from bedrock outcrops in the path of the ice. Tabular stones are more common, however, in areas of bedrock outcrops. In the southeastern Puget Sound Lowland Vashon Till contains about 5 to 15 percent of rocks and minerals which can be shown to be of northern provenance (British Columbia and north Cascade origin), while the rest are of local Cascade provenance, having been derived from the east and southeast (Mullineaux, 1961, p. 107; Crandell, 1963, p. 36).

In the mapped area Vashon Till ranges in thickness from less than 2 feet to about 80 feet. Along the Cedar River valley the till averages about 25 feet thick. The thickest known occurrence is in the NW$\frac{1}{4}$sec. 9, T.22N., R.6E. where more than 70 feet are exposed without its base being seen. Vashon Till is also well exposed in the NW$\frac{1}{4}$sec. 29, T.23N., R.7E., on the east side of the Echo Lake Road where it is capped by at least 10 feet of recessional lacustrine sands (fig. 4). The highest exposure of till in the area lies at an altitude of about 2,740 feet on the east slope of Tiger Mountain.

Erratics resting on till within the mapped area consist mostly of foreign granitic rocks, but in the mountainous area locally derived volcanics are common erratics. Erratics are plentiful up to an altitude of about 2,700 feet and typically are six or more feet in diameter (fig. 6). Several granitic erratics have flat surfaces and a few have striations up to an eighth of an inch deep.

Fresh nonweathered Vashon Till is gray, compact, and coherent. The till is highly impermeable because of its compact clay and silt matrix, a feature typical of lodgment till. An overlying less-compact facies is regarded as ablation till (Flint, 1957, p. 120). Many shallow depressions on the drift plain are swampy as a result of inadequate subsurface

Figure 6. — Erratic resting upon Vashon Till near top of Brew Hill.

drainage through the impermeable till.

Weathering of the Vashon Till typically is restricted to the uppermost three feet, but under some conditions it may extend to a depth of about five feet. Generally, the uppermost 3 to 6 inches constitutes a dark brown to reddish brown soil which has variable amounts of organic matter in it. Beneath the soil, weathering has mainly involved oxidation and a film of iron oxide has formed about pebbles, sand grains, and cobbles. Where ablation till is 4 to 5 feet thick, or where the till matrix is rich in sand and coarser material, oxidation often extends to about five feet. Occasional granitic stones are thoroughly decomposed. Most likely such stones were weathered before being incorporated in the till.

Recessional Stratified Drift

Sediments deposited during northward shrinkage of the Puget Lobe are termed recessional stratified drift. Recessional sediments are widespread throughout the Maple Valley-Hobart area. The principal units, which include ice-contact sediments, outwash, deltaic sediments, and lacustrine sediments, are discussed individually.

Ice-Contact Sediments. Material deposited in, on, or against ice are termed ice-contact sediments. They may have distinctive morphology such as kames, kame terraces, eskers, and surfaces marked by numerous kettles. Ice-contact sediments generally consist of poorly sorted to well-sorted pebbly sand and sandy pebble-cobble gravel, with occasional boulders, included bodies of till, and layers of silt. Deformation, and extreme range and abrupt change in grain size are characteristic of the deposits.

Extensive deposits of stratified sands and gravels exposed on the southwest slopes of Tiger and Taylor mountains have been mapped as ice-contact sediments (pl. I). They were formed by deposition or partial filling of depressions between the Vashon glacier and adjacent slopes. Along the southwest slope of Taylor Mountain the sediments form well-developed kame terraces at several altitudes. Poorly developed kame terraces are found in the ice-contact unit 1 to 2 miles west of South Tiger Mountain and in the vicinity of Fifteenmile Creek in sec. 13, T.23N., R.6E. About one mile southwest of West Tiger Mountain on the east slope of Issaquah Creek valley a kame terrace was built during the last stages of ice recession from the Maple Valley-Hobart area. The kame-terrace deposits consist of poorly to fairly well-sorted coarse sand, pebble gravel, and cobble gravel with local silt lenses. The thickness of the Kame-terrace sediments is highly variable and ranges from a few feet to as much as 50 feet. The kame-terrace deposits are characterized by cut-and-fill stratification.

Ice-contact sediments in the form of irregular mounds are known as kames. A kame was deposited by meltwater in an embayment against the south face of Tiger Mountain in the NW$\frac{1}{4}$sec. 17, T.23N., R.7E. The upper surface of this feature lies at about 2,300 feet. The kame consists of a large mass of fairly well-sorted silt, sand, and pebbly cobble gravel; individual beds of stratified gravel are two feet thick. A few beds of massive silt are interbedded among the coarser sediments. A body of water which probably stood in the embayment during deposition of the sediments would explain the massive silt beds. Extensive collapse and slump occurred when the glacier melted and support was removed. The kame sediments can be traced down to about 1,900 feet, but much of the lower portion may be colluvium. Three small irregular mounds in the SW$\frac{1}{4}$sec. 4, T.22N., R.7E. also are interpreted as kames. Another small kame in the SE$\frac{1}{4}$SW$\frac{1}{4}$sec. 24, T.23N., R.6E. consists of poorly sorted sand and pebble gravel (fig. 7).

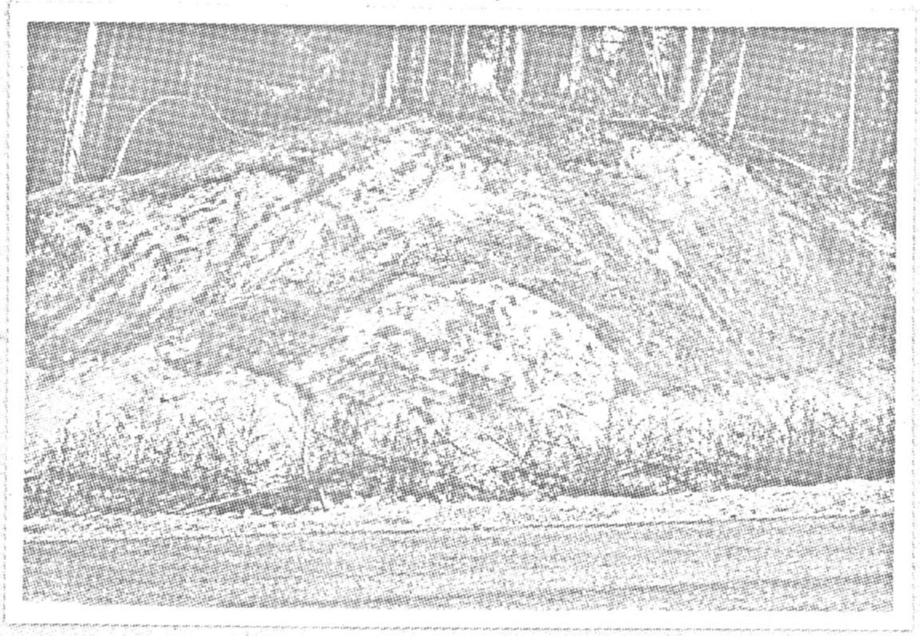


Figure 7.—— Section through a kame about one mile west of South Tiger Mountain showing poor sorting and abrupt change of grain size. G.I. shovel in left center indicates scale.

When a hummocky surface is associated with intermound depressions the feature is termed kame-and-kettle topography. One such area is located near Francis Lake and Webster Lake, 2 to 3 miles north of Maple Valley. A small ice-contact feature in the SE$\frac{1}{4}$sec. 11, T.22N., R.6E. may be an esker. The low sinuous ridge-like deposit consists of well-washed sandy pebble gravel and can be traced for about 200 yards.

An ice-contact collapse feature covering about a square mile and consisting of several kettles lies in the southeast part of the Hobart quadrangle in secs. 14 and 15, T.22N., R.7E. The kettles are close together and have sides that rise at about 30 degrees; a few are more than 100 feet deep. According to Flint (1957, p. 151) large deep kettles result from ablation of thick bodies of ice that project above accumulating stratified drift. The sediments of this feature consists of sand to large boulders and an included block of till was observed in one exposure.

Other recessional stratified drift has been mapped as ice-contact sediments in the area. A possible small end moraine, here named the Deep Creek Valley Moraine, is found in the central part of sec. 21, T.23N., R.7E. It consists mainly of compact pebble-, cobble-, and boulder gravel with included till and minor amounts of sand and silt. The moraine forms a north-trending ridge about 100 feet high across Deep Creek valley. It probably was deposited during a brief recessional stand or minor readvance of the glacier in the Deep Creek valley. Other ice-contact sediments are exposed on the west slope of Raging River valley, the north slope of Deep Creek valley, the south wall of the Kennydale Channel in secs. 11 and 12, T.23N., R.5E., and elsewhere in the area.

<u>Outwash.</u> Meltwater streams deposited sand and gravel in the form of valley trains, outwash plains, and channel deposits in spillways of glacial lakes in the Maple Valley-Hobart area. Along the southern bound-

ary of the area the surface is covered with outwash laid down by a large meltwater stream. The stream included meltwater from the Puget Lobe and water discharging through the Cedar Spillway (Mackin, 1941, p. 465). The ice-marginal stream occupied many channels and crossed the area known locally as "the Wilderness" (Willis, 1898, p. 134). In keeping with former usage (Mullineaux, 1961, p. 110) the river will herein be referred to as the "glacial Wilderness River".

Outwash laid down by the glacial Wilderness River varies considerably in thickness; locally it is very coarse. A valley train exposed on the south side of Cedar River near the center of sec. 22, T.22N., R.7E. consists of more than 100 feet of well-sorted sand and gravel with occasional boulders up to four feet in diameter. Lithologies of gravels in the valley train are predominately volcanic and sedimentary (Appendix A) and probably were derived mostly from Taylor Mountain. About 35 feet of outwash consisting of coarse gravel and sand is exposed in the SW$\frac{1}{4}$NW$\frac{1}{4}$sec. 23, T.22N., R.6E. on the east side of the railroad tracks. The deposit contains many boulders between 12 and 20 inches in diameter. Stratified deposits below the outwash show abrupt changes in grain size and little lateral continuity. Probably they represent older kame or ice-contact sediments. The largest valley train in the mapped area was deposited by the glacial Wilderness River in the Covington Channel. The Valley train fills a shallow sag in the drift plain between Maple Valley to Auburn and ranges from about half a mile to two miles wide. The valley train formed at several levels, for paired terraces occur on both sides of the channel. The upper terraces consist of pebble and cobble gravel as much as 50 feet thick and probably are remnants of a fill. The floor of the Covington Channel is underlain by sand and pebble gravel.

Outwash channel deposits consisting of sand and gravel cover the floor and sides of the Cedar Grove Channel to an altitude of about 450 feet. Toward the southwest end of the channel, the outwash merges with the drift plain. Outwash in and on the sides of the channel generally is less than 20 feet thick and consists of clean well-sorted pebble gravel and poorly sorted sandy pebble-cobble gravel. Strata in the Cedar Grove Channel deposits dip southwest towards the Cedar River valley. Another outwash channel deposit occurs along the floor of the Kennydale Channel and consists of fine silt covering the channel floor and well-washed gravels both beneath the silt and along the sides of the channel. Its thickness is not known. A small body of outwash occurs in sec. 10, T.23N., R.7E. on the east side of Raging River.

Weathering of Vashon outwash is restricted to oxidation which may extend the entire depth of a deposit. Oxidation forms an iron-oxide coating over sand- and stone-size particles which imparts a yellowish-brown color.

Deltaic Sediments. During recession of the Vashon glacier within the Maple Valley-Hobart area three major and three minor deltas were built.

The three major deltas are very well exposed and of these the Wilderness and Cedar Grove Deltas are actively being worked for their sand and gravel. The Wilderness Delta has well-developed foreset, bottomset and topset beds and the foreset beds dip slightly west of north (fig. 8). The delta is about 40 feet thick and bottomset beds lie on Vashon Till at an altitude of about 480 feet. Sediments of the Wilderness Delta are well sorted and consist of coarse sand and pebble-cobble gravel. The Cedar Grove Delta consists of two deposits separated by the Cedar Grove Channel (pl. I). The Cedar Grove Delta consists of poor- to fair-sorted sands and gravels with included blocks of silt (fig. 9). Foreset beds of the north-

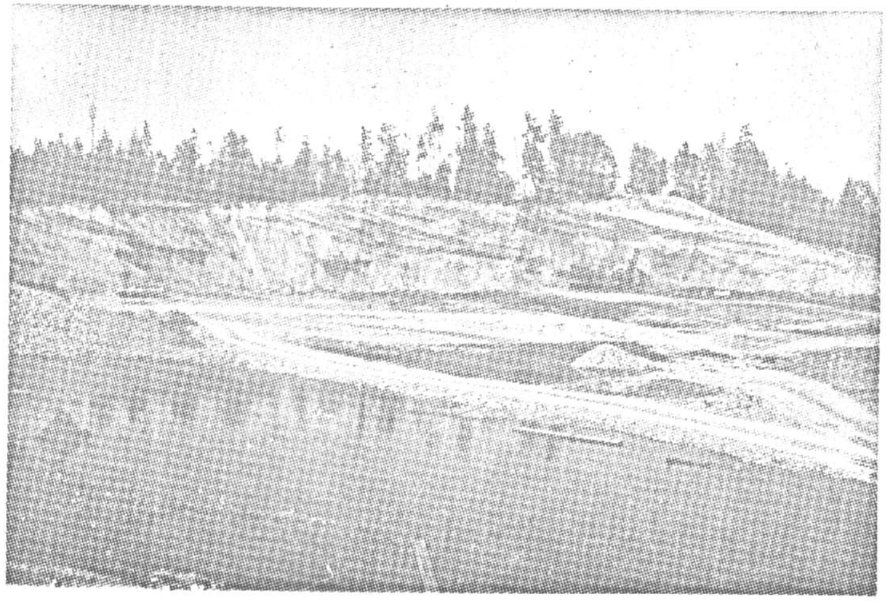


Figure 8.—— Wilderness Delta showing well-developed foreset, bottomset, and topset beds. View is toward west.

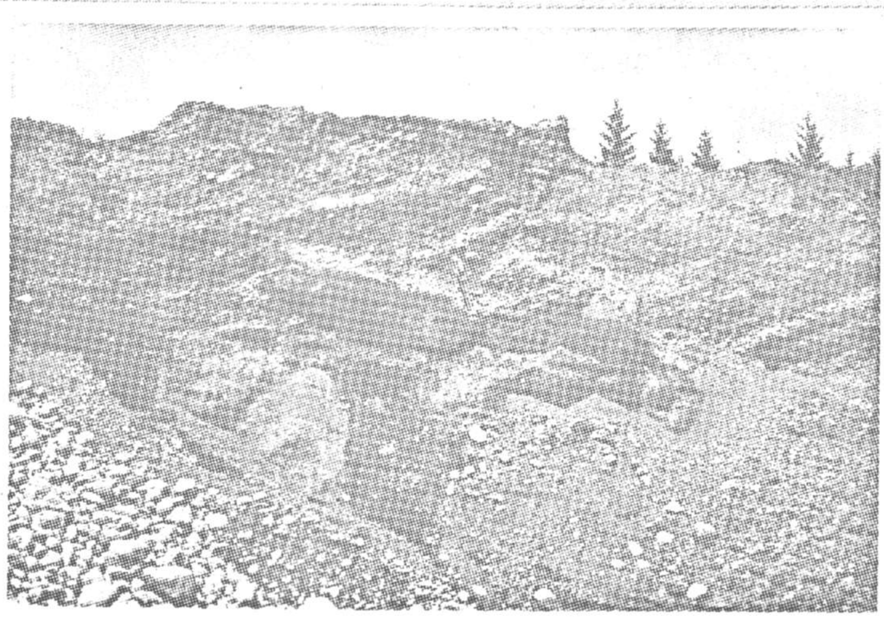


Figure 9. — Exposure of Cedar Grove Delta showing included block of silt. G.I. shovel in center indicates scale.

western most deposit dip west and beds on the southeast side of the channel dip south. The source of the sediments was the Cedar Grove Channel which was eroded by meltwater. The Holder Creek Delta consists of well-sorted gravels and sands in its upper portion and of poor- to well-sorted pebble-cobble gravel in its lower half. The upper portion of the mapped delta possesses some open-work gravels consisting of pebbles and fine cobbles with a fine silt and clay matrix. A bed of clean sand overlies the open-work gravel, and fines from the sand bed may have been washed down and collected in the voids of the gravel bed. The lower half of the Holder Creek Delta is exposed in a road across the east side of Holder Creek. The base of Holder Creek Delta lies on Vashon Till near the bottom of Holder Creek at an altitude of about 620 feet.

The minor Indian and Maple Valley Deltas were built by small streams flowing from the drift plain into the Cedar River valley and consist of well-sorted sandy pebble gravel. The upper surfaces of both deltas lie at an altitude of about 410 feet. The Benson Road Delta is poorly sorted and sediments range from sand to small boulders. Its foreset beds are thick and dip west.

Lithologies of gravels in Holder Creek, Wilderness, Benson Road, and Cedar Grove Deltas are given in Appendix A.

Lacustrine Sediments. Bodies of water ponded during recession of the Vashon glacier afforded conditions for lacustrine sediments to accumulate in several localities in the area. A lacustrine deposit at the summit of the Echo Lake Road in the Hobart Quadrangle has an upper surface at an altitude of about 1,380 feet. The deposit abuts against the Deep Creek Valley Moraine a quarter mile east of the summit; both deposits probably formed contemporaneously. The lacustrine deposit is about 40 feet thick with the lower 30 feet being fairly well laminated. The laminations range in thickness from 1 mm to 2 cm and consist of clayey silt and fine sand.

In the Raging River valley, well-exposed stratified lacustrine sands and silts with a few thin lenses of gravel are visible along the Echo Lake Road. The sediments are conformable on Vashon Till (fig. 10). In the SE$\frac{1}{4}$NE$\frac{1}{4}$sec. 15, T.23N., R.7E. on the east side of the Echo Lake Road the sediments locally are deformed. The deformation may have resulted from slumping subsequent to deposition of the unit or from melting of buried ice. The highest altitude within the Raging River valley that the sediments are found is about 900 feet. Other lacustrine sediments exposed at higher altitudes along Deep Creek canyon were deposited in small locally ponded waters (fig. 11).

The largest recessional lacustrine deposit in the area, covering about four square miles, occurs in the Issaquah Creek valley between Hobart and the base of Squak Mountain. A single body of water did not cover the entire area at any one time during deposition of the sediments, for they were deposited successively during retreat of the Vashon glacier. Half a mile east of Hobart nonstratified to poorly stratified sands represent the first sediments of this lacustrine unit to be deposited and are exposed up to an altitude of about 680 feet. As the unit is traced northwest the sediments become well stratified and the surface altitude of the deposit decreases. In the SW$\frac{1}{4}$NW$\frac{1}{4}$sec. 26, T.23N., R.6E. well-laminated clayey silt is exposed at an altitude of about 380 feet. A small extension of this large lacustrine unit is exposed at the northeast end of the Cedar Grove Channel and consists of nonstratified silt. A large ice-rafted boulder about 12 feet in diameter is partially exposed within it. The northernmost exposure of the deposit is on the east slope of Squak Mountain at an altitude of about 200 feet. At this locality the

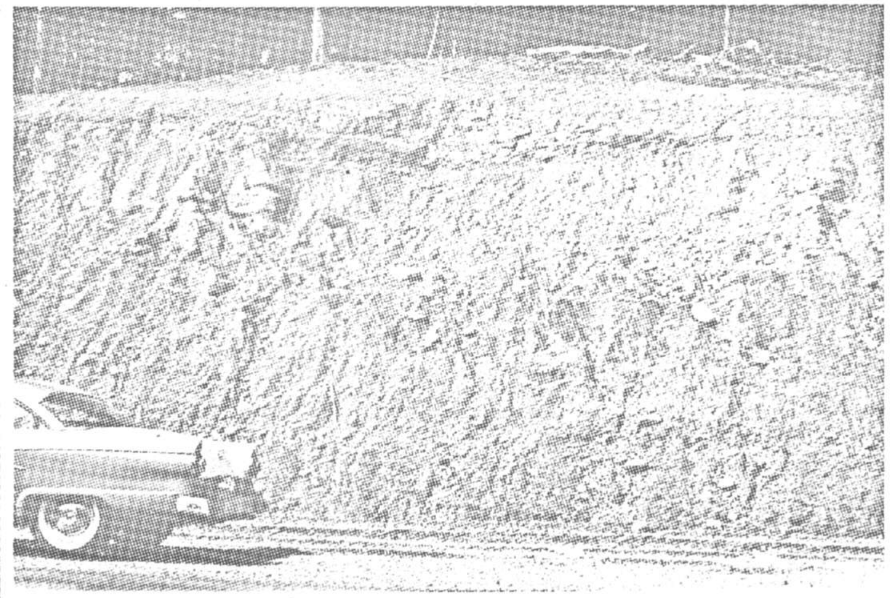


Figure 10.—— Recessional stratified sands and silts overlying Vashon Till in Raging River valley.

Figure 11.—— Recessional stratified sands and silts overlying bedrock in Deep Creek valley.

sediments are similar to those exposed to the south, for the lower portion consists of well-stratified clayey silts and silts, overlain by nonstratified sands. Along the Echo Lake Road about a mile northwest of Hobart, the lacustrine unit overlies ground moraine.

Lacustrine sediments, which cover about three-quarters of a square mile are exposed 1.5 miles northeast of Maple Valley. The proglacial lake in which the sediments were deposited probably was coextensive to the east with the larger body of water in which the lacustrine sediments near Hobart were deposited. Two marshy channels connect the separate lacustrine units at a altitude of about 500 feet. The lacustrine sediments of the smaller deposit consist of well-stratified silt covered by about five feet of nonstratified silt or sand.

Small local lacustrine deposits are exposed just east of Maple Valley at an altitude of about 440 feet. They have similar characteristics to those previously mentioned. In the western part of sec. 12, T.22N., R.6E. a poorly stratified to nonstratified lacustrine deposit consisting of medium-grained sand is exposed. Probably it formed in an ice-dammed lake, for the deposit occurs upon a topographic high on the drift plain. In one exposure the sand is overlain by a poorly sorted sandy pebble-cobble gravel about a foot thick. In Holder Creek valley east of South Tiger Mountain lacustrine sands with minor amounts of fluvial gravels overlie Vashon Till. The deposit is about 40 feet thick in some exposures along the east side of Echo Lake Road. The character of the deposit indicates the sediments were laid down in a shallow lake during ice retreat.

Most lacustrine deposits in the area have been oxidized and a rich soil commonly constitutes the upper six inches of any profile. Color ranges from yellowish-brown for sandy sediments to light-brown for silts.

Exposures of the lacustrine deposits typically are less than 20 feet thick, but are thicker in some localities in Issaquah Creek valley. In thick deposits the sediments are pale blue and unweathered. Several stratified recessional deposits could not be placed into the classifications used above and have been mapped as undifferentiated stratified recessional sediments (pl. I). They consist of silts, sands, and gravels laid down by meltwater streams that probably in most part existed only briefly. Portions of such deposits show characteristics common to ice-contact, outwash, deltaic, and (or) lacustrine sediments.

Postglacial Sediments

Peat

Peat deposits are widespread in the mapped area and consist of the remains of plants which have accumulated in water or wet localities. Four principal kinds of peat are found in the deposits: (1) moss peat, consisting of the remains of Sphagnum moss, usually forms the uppermost layer in the peat deposits in which it is found; (2) fibrous peat, the most abundant type, is composed principally of the remains of sedges (carex); (3) sedimentary peat, found as the lowermost layer in most peat bogs, is composed of aquatic plants such as diatoms, algae, bacteria, and of the skeletal remains and feces of small aquatic animals; (4) woody peat, made up of particles of partially decayed wood, is a minor constituent of many of the deposits (Rigg, 1958). Non-organic detritus, such as sand, silt, clay and volcanic ash, commonly are associated with peat deposits in the area. The volcanic ash is thought to have been derived principally from a catastrophic eruption of Mt. Mazama in southern Oregon about 6,600 years ago (Rigg and Gould, 1957; Wilcox and Powers, 1964).

Most peat deposits are found on the drift plain where depressions formed during recession of the Vashon glacier. A few are found in undrained or poorly drained meltwater channels, such as the Kennydale and Cedar Grove channels. The largest peat deposit lies adjacent to Walsh Lake in the Hobart quadrangle and covers about a third of a square mile. The best exposed peat deposit in the area lies in the NW$\frac{1}{4}$NW$\frac{1}{4}$sec. 13, T.23N., R.5E. and currently is being worked. Bore-hole data from peat deposits at Otter Lake, Shadow Lake, and the Cedar Mountain bog (sec. 30, T.23N., R.6E.) have been summarized by Rigg (1958). Thickness of peat is quite variable: the Cedar Mountain peat is only 10 feet thick, whereas the deposit at Otter Lake is about 42 feet thick.

Alluvium

The Cedar River valley is extensively floored with postglacial alluvium. Smaller deposits occur along Issaquah Creek and Raging River. Most alluvium in the lower reaches of Cedar River valley is derived locally even though the river heads near the crest of the Cascade Range. Cedar Lake, located seven miles east of the Hobart quadrangle, acts as a sediment trap for the bedload of the upper Cedar River. Therefore, alluvium within within the mapped area consists mainly of sediments derived from the Puget Group, Keechelus Andesite, and from Pleistocene deposits west of Cedar Lake. In the upper reaches of Cedar and Raging rivers in the mapped area alluvium consists of well-washed and sorted pebble-cobble gravel and coarse sand. Along the Cedar River below Maple Valley, and along Issaquah Creek, alluvium generally consists of interbedded pebble- and cobble gravel, pebbly sand, sand, and silt.

Colluvium

In the mountainous area and along the walls of the Cedar River valley colluvium is widespread and forms a discontinuous mantle over Vashon drift and pre-Vashon deposits. Because coluvium generally is thin and lacks lateral continuity, it was not mapped as a separate unit.

Landslide Sediments

Two landslides occurred within the Hobart quadrangle in postglacial time (Vine 1962). The most conspicuous of the two slides is on the west slope of Taylor Mountain in secs. 20 and 29, T.23N., R.7E. (fig. 12). The other slide is located on the south face of Brew Hill in sec. 35, T.23N., R.7E. Each slide covers an area of about a third of a square mile and is characterized by irregular hummocky topography and distinct breakaway scarps. Slide debris overlies Vashon till along the toe of each slide. Probably the principal factors promoting landslides in the in the Hobart quadrangle are the inherently incompetent rocks of the Tukwila Formation which constitutes most of the slide debris, heavy rainfall concentrated during the winter and spring months, and the steep mountain slopes.

PLEISTOCENE HISTORY

Pre-Fraser History

During pre-Fraser time sedimentary deposits of alternate glacial and nonglacial origin were laid down as a drift plain across the Puget Lowland. Among the few mountain spurs that rose above the drift plain was the northwest-trending bedrock ridge east of Seattle, of which Newcastle Hill and Squak Mountain are higher elements (Bretz, 1913, p. 14). During each of the major glacial episodes a Cordilleran glacier originating in the mountains of British Columbia advanced southward into the Puget Lowland. According to Mullineaux (1961), the distribution and character of the pre-Fraser glacial deposits indicate that the ice lobes were very similar to the Puget Lobe during the Fraser Glaciation.

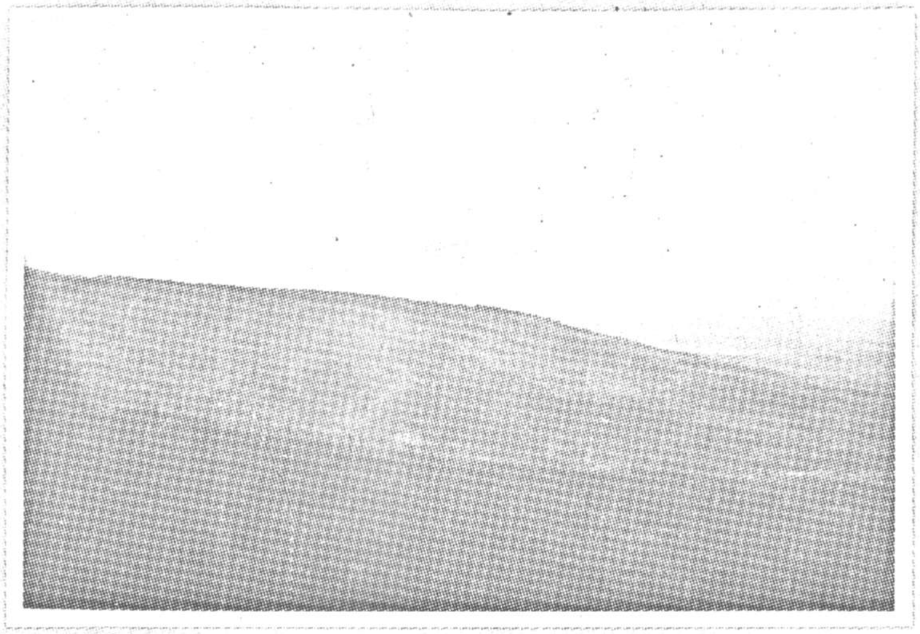


Figure 12. — View south from Tiger Mountain towards Taylor Mountain with Mt. Rainier in background. Note large landslide in right center of picture.

At least twice before the Fraser Glaciation, the Puget lobe advanced as far south as the community of Indian in the northwest part of the Maple Valley quadrangle. Undifferentiated glacial drift containing two till units lies beneath Vashon Drift along the walls of the Cedar River valley between Renton and Indian. Wood from the upper part of the sequence near Renton has been dated as older than 38,000 years (Mullineaux, 1961, p. 121). This places the undifferentiated drift older than the Fraser Substage of Armstrong and others (1965). However, the freshness of the undifferentiated deposits indicates that they have not undergone prolonged weathering. Probably the undifferentiated drift was laid down during the Salmon Springs Glaciation which has been dated as older than 38,000 years.

A topography of troughs and plateaus formed in the Puget Lowland during pre-Fraser time as a result of erosion by north-south trending consequent streams that formed upon the drift plain during nonglacial times. According to Bretz (1913, p. 188-197) the troughs and plateaus were formed by erosion of a drift plain built as part of an overall fill. However, he recognized only one pre-Fraser glaciation to build the fill and one nonglacial interval of erosion to form the troughs. Because the drift plain is now known to consist of several glacial and nonglacial units, the present system of troughs and plateaus may have segments that formed at different intervals during the Pleistocene Epoch. Changes as recent as Vashon time, including subsidence, glacial erosion, and stream erosion are needed to explain the manner in which the troughs branch, rejoin, and are drowned with sea water (Mullineaux, 1961 p. 149-153).

The pre-Fraser drainage system in the Maple Valley-Hobart area is not well known. Both the Cedar and Green Rivers flowed across the southeastern Puget Lowland at various times. Their exact locations are not known, but probably they were controlled by structure of northwest-trending bedrock ridges formed in Miocene time. According to Mackin (1941), the Cedar River in late-Tertiary time flowed northeast of the Rattlesnake Mountain bedrock spur and joined the Snoqualmie River (fig. 13). The river was diverted south across the bedrock spur into the Cedar Spillway during a glacial advance in pre-Fraser time. Whether or not the Cedar River stayed in the Cedar Spillway during subsequent pre-Fraser nonglacial intervals has not been determined. During a pre-Fraser glaciation the Green River was diverted from the north to the south side of a northwest-trending bedrock spur and now emerges about five miles south of its previous exit (fig. 13; Mullineaux, 1961, p. 157).

The Kennydale Channel was carved before Fraser time for Vashon Till is found covering the valley slopes down to the floor of the channel. Willis (1899) noted the existence of the channel and ascribed it to the work of Cedar River sometime during glacial retreat. The degree of development of the channel suggests that it was occupied by meltwater during more than one glacial retreat and (or) eroded during glacial advances. Issaquah Creek valley possesses similar characteristics and probably was carved by Pleistocene streams and glaciers.

Mullineaux (1961, p. 156) suggested that a shallow pre-Fraser valley lies between Maple Valley and Auburn, because thick Vashon advance drift is exposed along the walls of the Cedar River valley near Maple Valley and the Green River valley near Auburn; the Covington Channel sag occupies the drift plain between the two areas. Another pre-Fraser valley of limited extent probably existed along the Cedar Grove Channel. The drift plain to the north and south lies at an altitude of about 550 feet and is covered with Vashon Till. However, Vashon Till is found beneath the northeast and southwest ends of the channel at an altitude of about

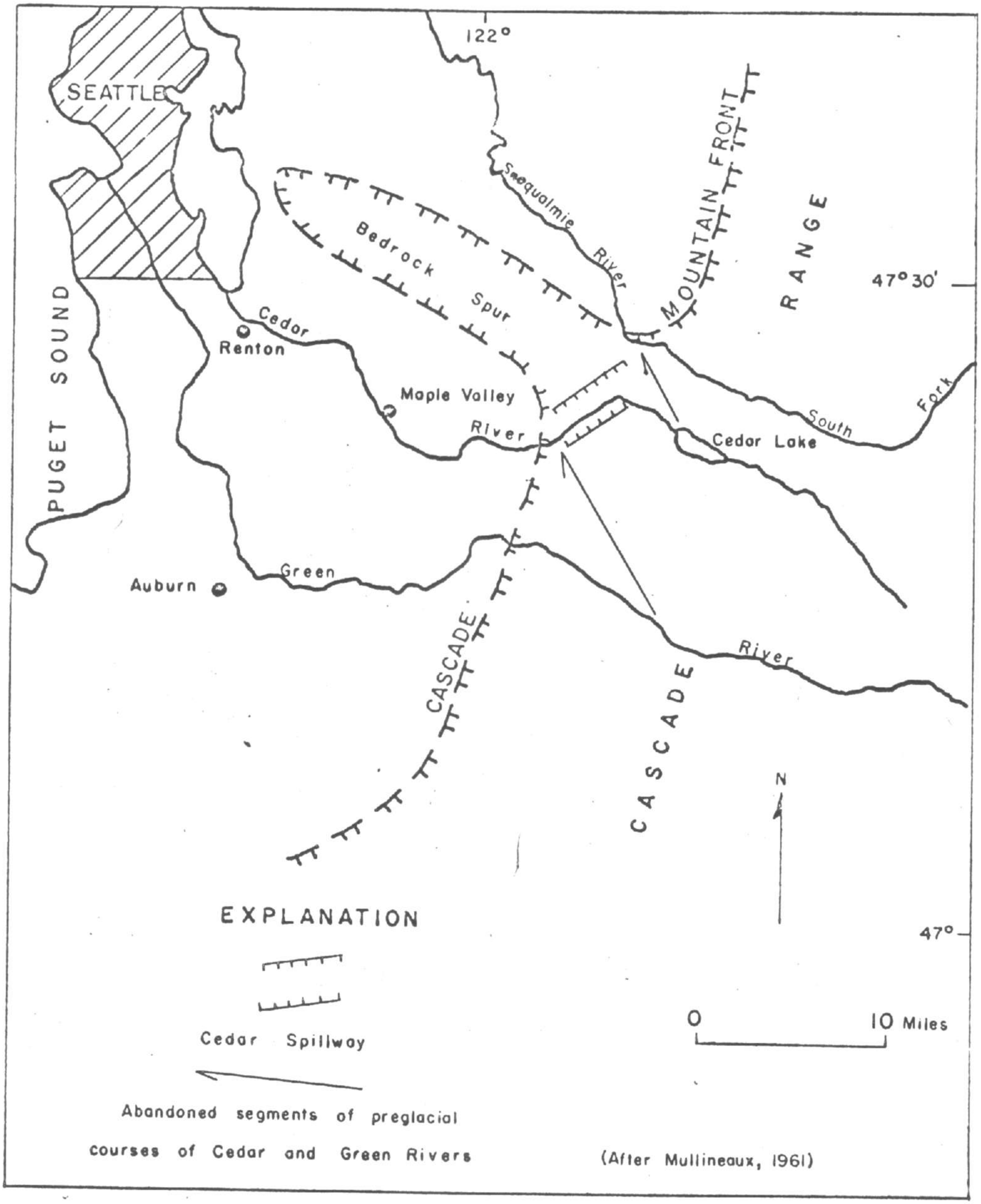


Figure 13. Location of pre-Fraser diversions of Cedar and Green Rivers near front of Cascade Range.

350 feet. According to Mullineaux, (1961, p. 158) a kame lies in the modern Cedar River valley about two miles east of Renton. Because it is improbable that the Vashon glacier eroded the west-trending Cedar River valley at this locality, the kame and the presence of Vashon Till well below the general surface of the drift plain suggests that a valley existed there before the Fraser Glaciation.

Fraser Glaciation

The onset of the Evans Creek Stade, also referred to as the Alpine phase, probably began by a decrease in temperature and increase in humidity resulting in a cool, moist climate advantageous for the building of alpine glaciers. At the maximum advance of the alpine glaciers in the Cascade Range the Puget Lobe of the Cordilleran Ice Sheet had not yet reached Everett, Washington. Cary and Carlston (1937) found that the Skykomish Valley glacier had substanially retreated from its westernmost advance before the Puget Lobe reached the area. Mackin (1941) and Crandell (1963) found similar evidence in the Snoqualmie and Carbon River drainages, respectively.

A climatic change probably caused retreat of alpine glaciers in the Cascade Range while the Puget Lobe continued to advance into the Puget Lowland. A possible explanation for their retreat is that the extensive Puget Lobe robbed the highlands of moisture they normally would receive (Porter, 1964).

The Vashon Stade of the Fraser Glaciation began with advance of the Puget Lobe into the Puget Lowland. After reaching its maximum stand an increase in temperature and resulting ablation caused the Puget Lobe to retreat north into British Columbia. The Vashon glacier uncovered the lowland south of Seattle more than 14,000 years ago (Mullineaux, 1961, p. 120). During the Sumas Stade a brief reversal of climatic conditions about 11,000 years ago caused a lobe of the Cordilleran Glacier to re-advance into the Fraser Lowland (Armstrong and others, 1965).

Sediments of Fraser age in the Maple Valley-Hobart area consist mainly of those deposited during the Vashon Stade. The stade will be discussed below in three segments: Vashon advance, Vashon maximum, and Vashon recession.

Vashon Advance

The Vashon glacier began its advance into the Puget Lowland about 23,000 years ago (Crandell and others, 1958). As the glacier flowed across the Maple Valley-Hobart area, thick deposits of sand and gravel were laid down in front of the ice. During advance of the glacier across the mountainous area, proglacial lakes formed in Raging River and Holder Creek valleys. Contemporaneously, thick deposits of advance drift accumulated in these ice-dammed lakes. Continued advance of the glacier obliterated the proglacial lakes and buried the proglacial drift with a thick cover of till. Northwest-trending valleys were scoured and bedrock hills molded into streamline forms by the Vashon glacier as it flowed southeast across the area. Much of the advance drift was reworked by the glacier and spread out upon the drift plain as ground moraine.

Vashon Maximum

At the climax of the Vashon glacier's southward advance into the Puget Lowland its terminus lay about 15 miles south of Olympia (Armstrong and others, 1965). In the mapped area, Tiger Mountain was the only exposed land and protruded above the ice mass as a nunatak. The upper limit of ice on the eastern slope of the mountain was about 2,740 feet and was determined from the upper limit of till and erratic stones. Puget ice blocked the valleys of the Snoqualmie River and the Cedar River about seven miles east of the mapped area and built a 700-foot-high moraine complex across their mouths. Temporary proglacial lakes formed beyond the moraine in the lower reaches of each valley.

Drainage from the Middle and South Forks of the Snoqualmie River and from Cedar River was diverted from its normal course. Meltwater flowed southward along the eastern margin of the Puget Lobe, then southeast along the abandoned route of the pre-Fraser Green River (Mackin, 1941). It entered the Green River near Eagle Gorge and from there flowed northwest along the present course until it encountered the Puget Lobe which extended up the valley about two miles from Kanasket (fig. 14). From this point ice-marginal meltwater flowed southwest between the glacier and the western foothills of the Cascade Range, ultimately reaching the Chehalis Valley, which was the principal outflow channel beyond the ice terminus.

Vashon Recession

Deglaciation of the Maple Valley-Hobart area is recorded by a series of meltwater channels that indicate successive positions of the ice front during retreat of the glacier. Extensive ice-contact deposits along the west slopes of Tiger and Taylor Mountains in conjunction with the deranged drainage pattern of small creeks provides evidence of the ice position along the mountain sides during ice recession. As the glacier retreated across the lowland, the upper surface of the drift plain were uncovered first, leaving small ice tongues in the southeast-trending valleys.

Seven stages in the recessional history of the Vashon glacier across the mapped area will be discussed. Each is not of equal significance, but all bear on the late-glacial history. Establishment of stages is based on meltwater channels, outwash, terraces, ice-contact sediments,

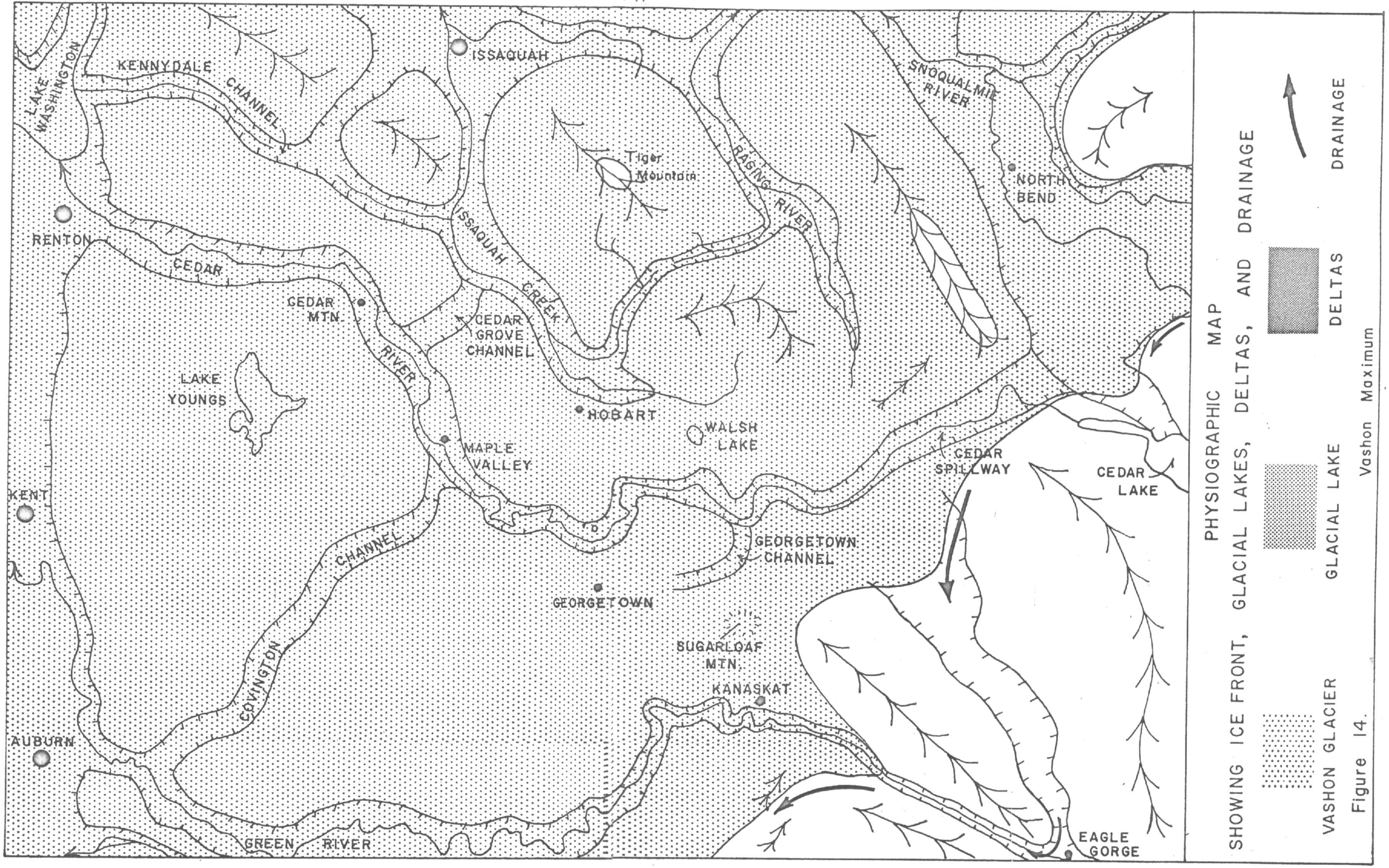


Figure 14. Vashon Maximum

deposits of proglacial lakes, and morphologic features indicative of stagnant ice.

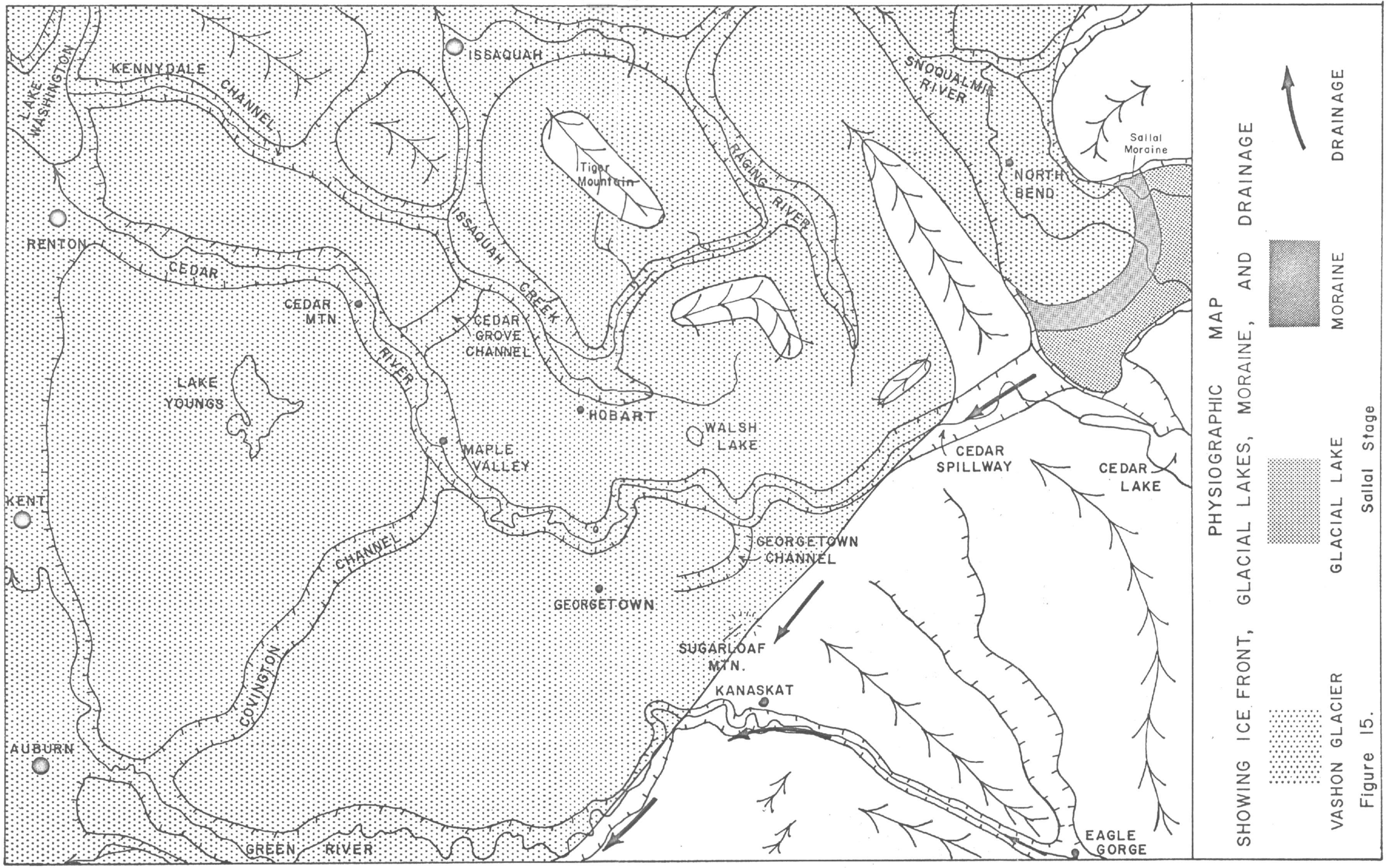
Sallal Stage

During initial deglaciation a large kame formed in an embayment on the south face of Tiger Mountain. Successive lower stands of the glacier are indicated by several deranged stream courses on the south slope of Taylor Mountain. As the eastern margin of the glacier retreated out of the valleys of the Cascade Range it made a major recessional stand or a minor readvance (Mackin, 1941). A broad, hummocky, morainal ridge in the Snoqualmie embayment is the basis for this stage, which Mackin called the "Sallal". The pre-Fraser Green River drainage course was abandoned, and the glacial Wilderness River (see p. 30) reexcavated the Cedar Spillway and flowed along the margin of the foothills. The ice front had retreated sufficently during this stage to open a lower ice-marginal outlet between Sugarloaf Mountain and the northwest-trending bedrock ridge two miles north of Kanasket (fig. 15). A broad bench which lies at an altitude of about 920 feet in sec. 23, T.22N., R.7E. was formed by the glacial Wilderness River during this stage.

Deep Valley Moraine Stage

As the Puget Lobe withdrew from the Sallal moraine, glacial Lake Snoqualmie formed in the embayment in front of the ice margin (Anderson, 1965, p. 45). The lake stood at an altitude of about 920 feet and drained south through the Cedar Spillway, becoming the main source of water for the glacial Wilderness River. The ice front had retreated to the west side of Sugarloaf Mountain and the glacial Wilderness River shifted its course to the newly exposed lower route.

The glacier probably made a short recessional stand at this time.



PHYSIOGRAPHIC MAP

SHOWING ICE FRONT, GLACIAL LAKES, MORAINE, AND DRAINAGE

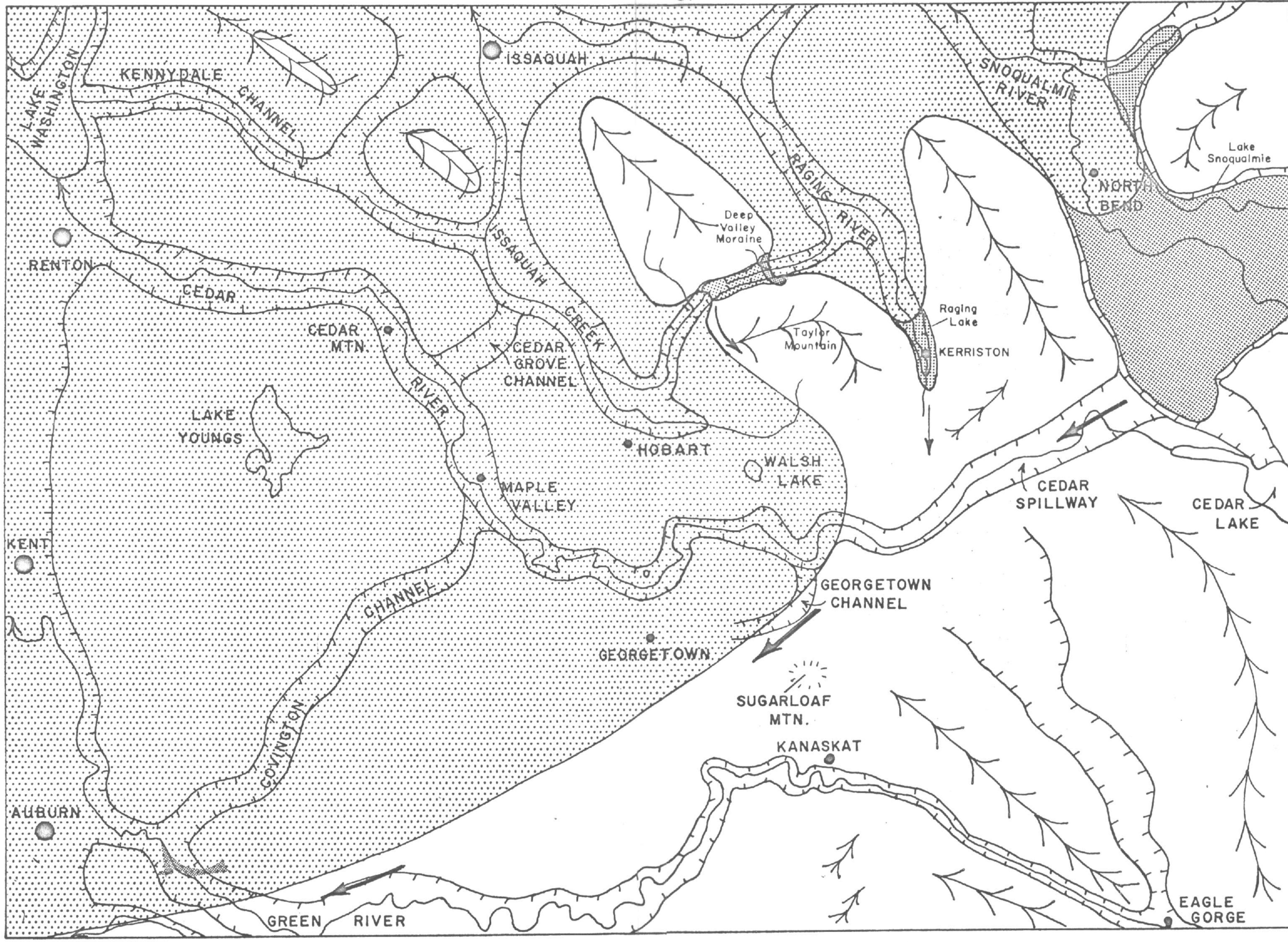
Figure 15. Sallal Stage

Ice lobes extended into the valleys of Holder and Deep Creeks and a lake formed between the two lobes at an altitude of about 1,360 feet. Sediments were deposited in the lake and a moraine was built across Deep Creek Valley. The lake drained by way of Holder Creek valley, the meltwater flowing southeast between the glacier and Taylor Mountain into the Cedar Spillway (fig. 16). Kame terraces and ice-contact deposits were built along the south side of Taylor Mountain between altitudes of 900 and 1,100 feet by this meltwater discharge (pl. I). A contemporaneous lake, known as Raging Lake (Anderson, 1965, p. 45), formed in the upper Raging River valley. Lacustrine sediments deposited in the lake are exposed near Kerriston. Initial drainage of Raging Lake was south through the small valley of Williams Creek to the Cedar Spillway.

An extensive outwash deposit was built during this stage by the glacial Wilderness River. It was built south from the lower portion of the Cedar Spillway to a position between Sugarloaf Mountain and the ice front. which lay about two miles west. A well-developed terrace at an altitude of about 860 feet approximately marks the surface of this outwash train in the lower part of the spillway. Outwash gravels consist largely of sedimentary and volcanic stones that probably were derived from the Puget Group of Taylor Mountain (Appendix A).

Holder Delta Stage

Continued downwasting of the glacier in the mountainous area caused the lake in Deep Creek valley to merge with Raging Lake. The outlet for this larger lake still lay by way of Holder Creek. Anderson (1965) believed that the drainage possibly flowed from Holder Creek northwest to the Kennydale Channel at this stage. However, evidence found during the present study in this area indicates that the drainage



PHYSIOGRAPHIC MAP

SHOWING ICE FRONT, GLACIAL LAKES, DELTAS, AND DRAINAGE

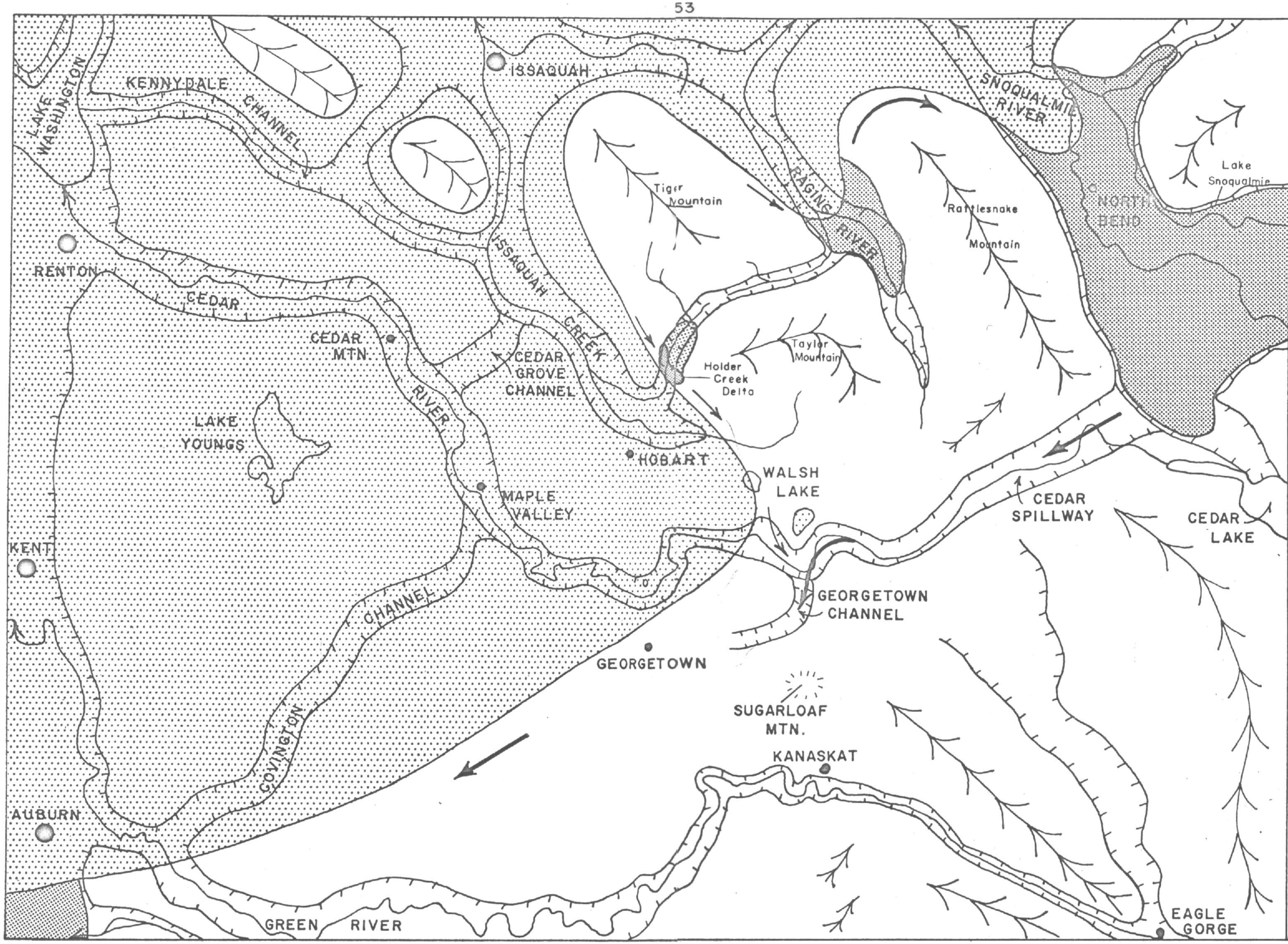
VASHON GLACIER — GLACIAL LAKE — DELTAS — DRAINAGE

Figure 16. Deep Valley Moraine Stage

was still southeast from Holder Creek towards the Cedar Spillway and that the glacier covered the lowland area to the northwest. Upon further retreat of the ice in Raging River valley the lake established a new outlet. Drainage abandoned the Holder Creek valley and followed the freshly exposed drift plain at the north end of Rattlesnake Mountain. Meltwater deposited a recessional outwash fan between bedrock knobs north of Echo Lake and entered Lake Snoqualmie which still was draining south through the Cedar Spillway (Anderson, 1965). Lacustrine sediments were deposited in the larger, but lower, Raging Lake, the surface of which lay at about 940 feet. A short-lived lake was formed in Holder Creek during down-wasting of the glacier and coarse lacustrine sediments were deposited in it at an altitude of about 1,280 feet.

As the glacier continued to downwaste on the west slope of South Tiger Mountain, meltwater deposited ice-contact sediments and spilled between low cols into the lower reaches of Holder Creek valley. Ice dammed the mouth of the valley forming a small lake, into which the Holder Creek Delta was built. Pebble counts from the delta show that about three-quarters of the stones are of sedimentary and volcanic origin (Appendix A). The lithology and structure of the delta indicate that the west slope of South Tiger Mountain was the probable source of gravel. Drainage from Holder Creek flowed southeast between the glacier and the southwest slope of Taylor Mountain towards the glacial Wilderness River and deposited sediments among residual ice masses along this course.

By this time the ice front in the lowland had retreated to a position just north of Georgetown. From there it passed northeast along the north side of a flat plateau to Walsh Lake (fig. 17). Several kettles and thick ice-contact sediments 1 to 2 miles southeast of Walsh



PHYSIOGRAPHIC MAP

SHOWING ICE FRONT, GLACIAL LAKES, DELTAS, AND DRAINAGE

VASHON GLACIER

GLACIAL LAKE

DELTAS

DRAINAGE

Figure 17. Holder Delta Stage

Lake are indicative of stagnant-ice conditions which persisted after the active ice front had retreated. Retreat of the glacier to this position exposed a lower route for ice-marginal meltwater between Holder Creek and the glacial Wilderness River at the southwest end of the Cedar Spillway. Subsequently, the glacial Wilderness River cut the Georgetown Channel by eroding outwash from the Cedar Spillway. The new course of the river lay along the south side of the flat plateau and through Georgetown to the area known locally as the Wilderness (Willis, 1898, p. 134), where it deposited large amounts of outwash (Mullineaux, 1961).

The Holder Delta Stage is equivalent to the early part of the Tokul Delta Stage of Anderson (1965).

Wilderness Delta Stage

Upon further retreat of the ice front, the Georgetown Channel was abandoned, and glacial Wilderness River flowed along the north margin of the flat plateau about two miles south of Walsh Lake. At that time the ice front extended northeast along the Covington Channel to Maple Valley, Hobart, and northwest along the east side of Issaquah Creek valley. An ice-marginal lake, here named Lake Covingtion, formed in the uncovered depression just south of Maple Valley. Its initial altitude was about 510 feet and its outlet was a narrow channel between two knolls half a mile southwest of Lake Wilderness. Lake Covington was a shallow body of water at this time and the deposits of glacial Wilderness River probably nearly filled the lake. The deposits consist of the Wilderness Delta and a broad gravel terrace on the north side of the Cedar River valley. Lithology of the delta gravels include more exotic glacial rocktypes than does the lower Cedar Spillway outwash (Appendix A). This is expectable because the glacial Wilderness River crossed about nine miles of drift plain east of the delta. Extensive outwash also was deposited upon the drift plain, and now forms gravel terraces at altitudes of 720, 700, 640, 620, 600, and 505 feet.

Another ice-marginal lake formed contemporaneously with Lake Covinton east of Hobart. The lake, here named Lake Hobart, initially lay at an altitude of about 700 feet. Sediments deposited in Lake Hobart are exposed hald a mile east of Hobart. Water discharged from the lake through a small channel to the south, about a mile west of Walsh Lake. Holder Creek valley was free of ice at this time and the stream emptied into Lake Hobart, incising itself into the Holder Creek Delta.

As the Covington Channel was exposed by ice retreat, the glacial Wilderness River ceased depositing material in Lake Covington and flowed southwest along the north side of the Wilderness Delta into the channel, finally flowing into Lake Tacoma (Bretz, 1913) which existed in the Duwamish Valley near Auburn. The Auburn Delta (Bretz, 1913, p. 134) was built into this lake by the river while it occupied the Covington Channel (Mullineaux, 1961, p. 114). Much of the earlier-formed deposits of Lake Covington were eroded and an extensive valley train was deposited in the channel. Lake Covington expanded northwest following the retreating ice front and extended a mile northeast of Maple Valley over newly exposed drift plain. The lake drained into the Covington Channel over a low col just southwest of Maple Valley at an altitude of about 490 feet. Lacustrine sediments exposed a mile northeast of Maple Valley were deposited at that time. Lake Hobart extended north up Issaquah Creek valley and abandoned its outlet to the south in favor of a lower channel that carried water west into Lake Covington (fig. 18). Ice-contact sediments on the west slope of South Tiger Mountain between the altitudes of about 500 and 800 feet probably were deposited contemporaneously.

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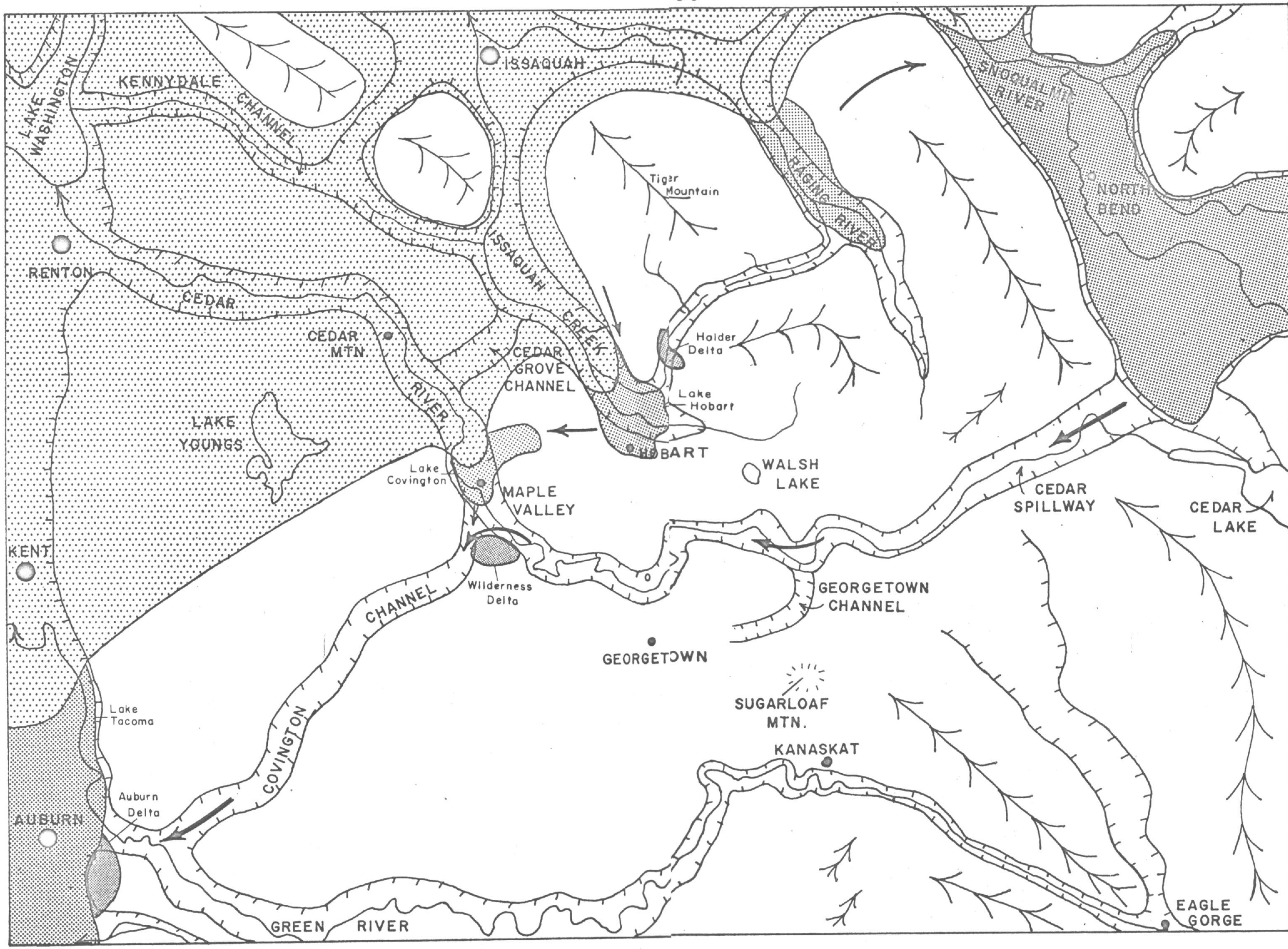


PHYSIOGRAPHIC MAP

SHOWING ICE FRONT, GLACIAL LAKES, DELTAS, AND DRAINAGE

VASHON GLACIER — GLACIAL LAKE — DELTAS — DRAINAGE

Figure 18. Wilderness Delta Stage

Cedar Grove Delta Stage

The early part of the Cedar Grove Delta Stage probably is approximately equivalent to the late part of the Tokul Delta Stage of Curran (1965) and Anderson (1965). However, an ice-front position and meltwater course different than that proposed by Curran is suggested here.

According to Curran (1965, p. 33-35), during the later part of the Tokul Delta Stage, glacial Lake Snoqualmie abandoned the Cedar Spillway as an outlet for a lower route to the north. He proposed that Lake Snoqualmie drainage flowed south through the Raging River spillway, then west beside the ice lobe in the East Fork valley of Issaquah Creek to a bedrock terrace at Lake Tradition. Meltwater then flowed south beside the Issaquah Creek valley ice lobe and then west through the Kennydale Channel, finally flowing into a proglacial lake which existed in the Lake Washington trough.

Field evidence found during the present study, along with altitudinal relationships of morphologic features in the area, indicate a somewhat different glacial recessional history for this stage.

Retreat of the glacier from the Wilderness Delta Stage uncovered the Cedar Grove Channel. The drift plain was nearly free of glacier ice near the channel at that time. Probably only ice lobes extended southeast in the valleys of Issaquah Creek, Kennydale Channel, and Cedar River. Blocks of stagnant ice remained upon the drift plain in various depressions. An ice block also existed in the Cedar Grove Channel, as evidenced by the presence of ice-contact sediments on its south and north walls. Drainage for Lake Snoqualmie was by way of the route described by Curran (1965), but instead of the meltwater flowing west through the Kennydale Channel it flowed south from the Issaquah Creek valley ice lobe and into Lake Hobart. The lake had expanded north down the Issaquah Creek valley to the east end of the Kennydale Channel which contained an ice lobe. Drainage for Lake Hobart was southwest through the recently exposed Cedar Grove Channel along both sides of the ice block at the channels southern end and into Lake Covington. The surface of Lake Hobart was about 460 feet above present sea level and was controlled by the ice block in the Cedar Grove Channel until it melted away. Ice-contact sediments at the south end of the channel were deposited contemporaneously.

Lake Covington extended down the Cedar River valley to about the community of Cedar Mountain. The glacial Wilderness River had eroded much of the sediments previously deposited in Lake Covington and the lake now drained into the Covington Channel just south of Maple Valley at an altitude of about 450 feet. East of the channel the glacial Wilderness River contained only water from the Cedar River drainage basin, because Lake Snoqualmie had abandoned the Cedar Spillway outlet to the south in favor of the lower channel to the north that carried water west into Lake Hobart. The surface of Lake Snoqualmie was about 550 feet above present sea level (Anderson, 1965, p. 48). When northward retreat of the glacier exposed the drainage route past the ice lobes that occupied narrow parts of the valleys of the East Fork of Issaquah Creek and Issaquah Creek, Raging Lake abandoned its previous outlet for this new route (Anderson, 1965). Shortly thereafter Raging Lake was drained completely.

According to Anderson (1965) the glacier probably made a brief recessional stand at that time. The Tokul Creek Delta and several morainal ridges near the Snoqualmie valley possibly were built contemporaneously with the south-sloping morainal (?) ridge at the east end of the Kennydale Channel. Exposures are scarce, but gravels and sands are present between altitudes of 250 and 520 feet in the V-slot cut into the deposit. The deposit may have been built by meltwater flowing southeast along the north side of the ice lobe which occupied the Kennydale Channel. At present, a small intermittent stream flows southeast upon its southern surface in sec. 21, T.23N., R.6E.

After withdrawal a short distance north the glacier again halted with its terminus standing west of Lake Kathleen. A lobe extended down the Cedar River valley close to the community of Indian. The ice block in the Cedar Grove Channel had melted away and meltwater from Lake Hobart eroded the channel and deposited the Cedar Grove Delta in Lake Covington. The delta was built over a period of time during which the Covington Channel was deepened by at least 25 feet, as evidenced by delta surfaces at two altitudes. Topset beds of the southeast portion of the delta are exposed in a borrow pit in the center of sec. 33, T.23N., R.6E. at an altitude of about 425 feet, which was about the level of Lake Covington at that time. As the level of the lake was lowered by erosion of Covington Channel, the northwest portion of the Cedar Grove Delta was deposited. Topset beds belonging to this segment are exposed in the large borrow pit in the NW$\frac{1}{4}$ sec. 33, T.23N., R.6E. at an altitude of about 400 feet. Two minor deltas, the Indian and Maple Valley deltas, were built into Lake Covington while its surface stood at about 410 feet. Both have topset beds exposed at an altitude of about 410 feet. Lacustrine sediments near Maple Valley at an altitude of between 400 and 440 feet also were deposited during this stage. The floor of the Covington Channel subsequently was eroded to an altitude of just over 400 feet at its northeast end. Terraces on both sides of the channel at altitudes of about 470 and 400 feet indicate two periods of valley-train formation. The Cedar Grove Channel lay at an altitude of about 410 feet during this phase.

Building of the Cedar Grove Delta probably occurred during the Issaquah Delta Stage of Curran (1965), when a stagnant block of ice occupied the Issaquah Creek valley between Squak Mountain and West Tiger Mountain (fig. 19). An ice dam is required at this point to permit Glacial Lake Sammamish to stand at an altitude of 450 feet, the altitude of the Issaquah Delta (Curran, 1965, p. 37). Drainage was south over or along the ice dam into Lake Hobart at an altitude of about 420 feet. Meltwater from the Kennydale Channel probably channeled the south sloping morainal (?) ridge and drained into Lake Hobart.

Cedar Grove Channel Stage

Upon further retreat of the glacier, a divide lower than the Covington Channel was opened along the Cedar River valley toward Renton. Another stand of the Vashon glacier probably occurred at this time. The ice margin extended along the east wall of the Lake Washington trough for a few miles south of Renton, and a lobe extended into the Kennydale Channel a short distance. Probably a small stagnant block of ice lay in a depression in the drift plain about two miles east of Renton (Mullineaux, 1961).

Lake Covington abandoned the Covington Channel outlet for a lower drainage route to the north through the Cedar River valley. The new drainage route emptied into a proglacial lake in the Lake Washington trough at Renton, which lay between the ice tongue and the eastern drift plain. Into this lake the Renton Delta was built. Topset beds of the delta are exposed at an altitude of about 290 feet in a borrow pit in the SW$\frac{1}{4}$NW$\frac{1}{4}$sec. 17, T.23N., R.5E. This portion of the Renton Delta is too high to be correlated with either Lake Tacoma or Lake

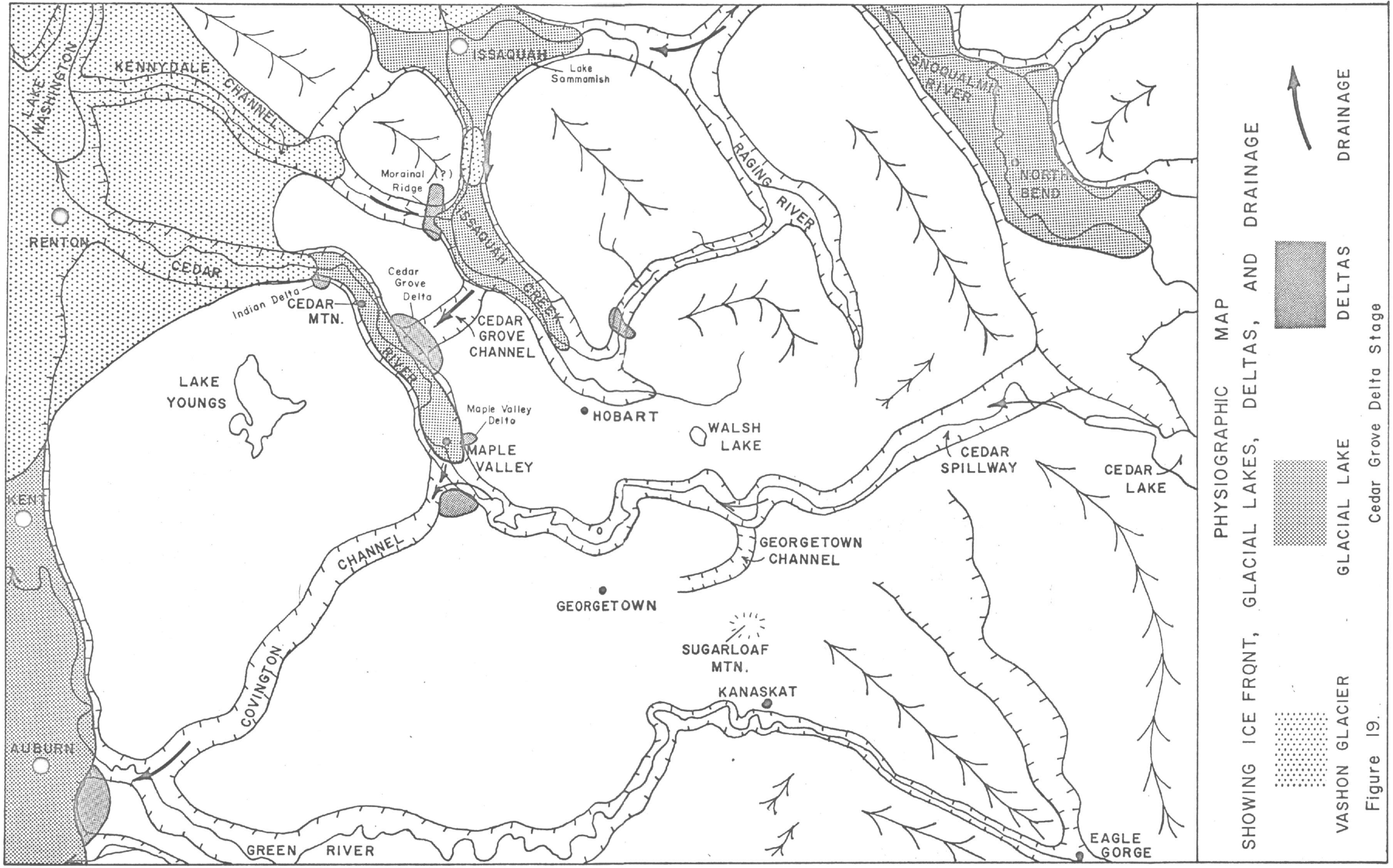


Figure 19. Cedar Grove Delta Stage

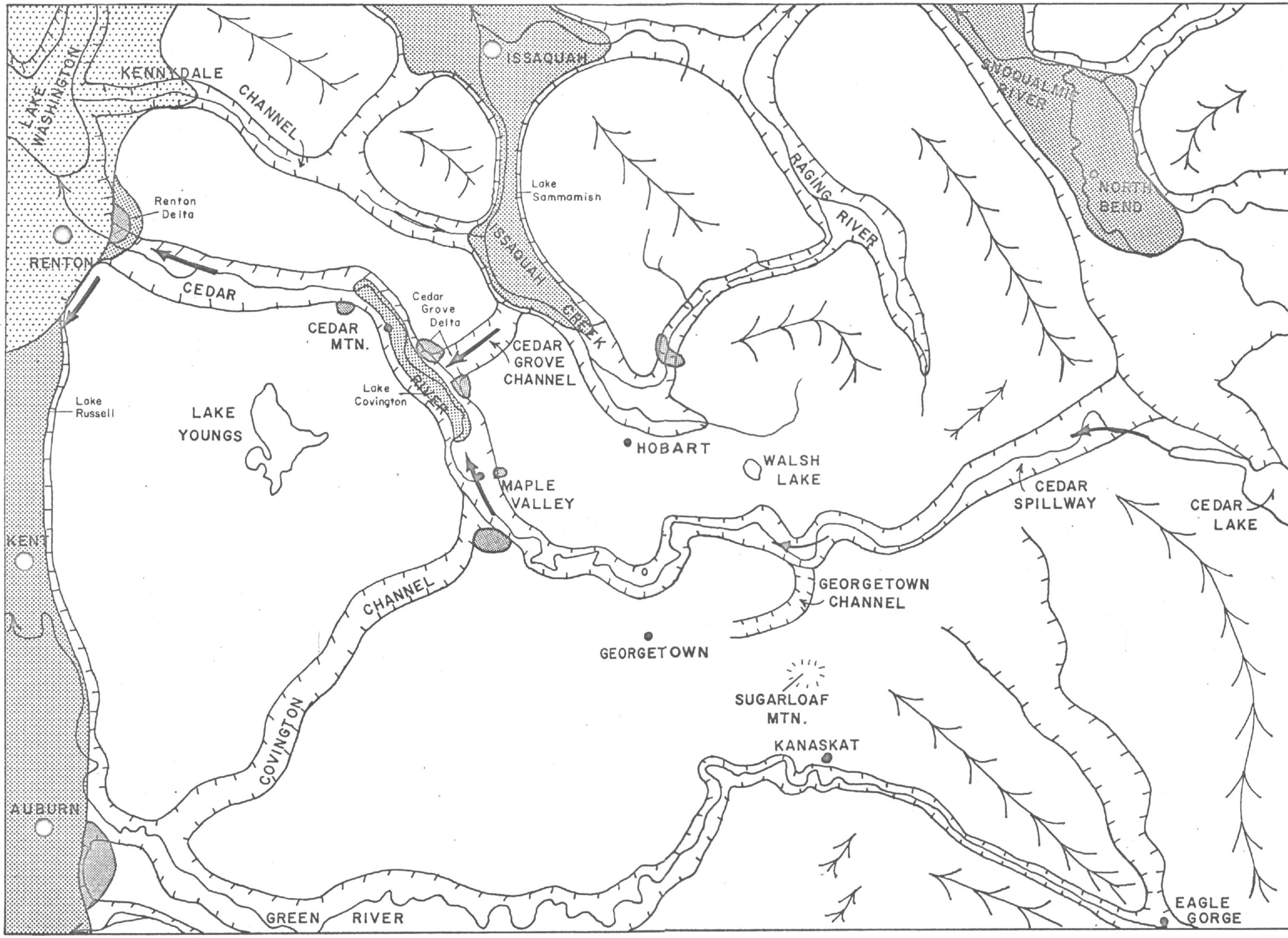
Russell of Bretz (1913). Outwash was deposited along the drainage route from Lake Covington to the Renton Delta contemporaneously. A broad bench which lies at an altitude of about 375 feet in the N$\frac{1}{2}$secs. 23 and 24, T.23N., R.5E. was formed by the drainage from Lake Covington during the early phase of this stage.

The level of Lake Covington rapidly dropped from its former altitude of about 400 feet to a new level at about 350 feet and became much smaller. The glacial Wilderness River abandoned the Covington Channel leaving it dry at its northeast end and flowed into Lake Covington. Contemporaneously with the lowering of the level of Lake Covington the Cedar Grove Delta was dissected by meltwater that flowed southwest through the Cedar Grove Channel. The floor of the channel subsequently was eroded to an altitude of about 350 feet.

The Cedar Grove Channel Stage most likely correlates with the Griffin Delta Stage of Curran (1965). The ice dam in Issaquah Creek valley had melted away and Lake Hobart had merged with Glacial Lake Sammamish (fig. 20). The altitude of the Lake surface was approximately 350 feet. Drainage from Lake Snoqualmie into Glacial Lake Sammamish built the lower Issaquah Delta at an altitude of 350 feet (Curran, 1965). Meltwater from Glacial Lake Sammamish drained by way of the Cedar Grove Channel.

<u>Kennydale Channel Stage</u>

Continued retreat of the glacier exposed a divide in the Kennydale Channel lower than the Cedar Grove Channel. The ice tongue in the Lake Washington trough stood at a position just north of Renton and the Maple Valley-Hobart area was free of ice. Meltwater from Glacial Lake Sammamish flowed west through the Kennydale Channel into a local lake



PHYSIOGRAPHIC MAP
SHOWING ICE FRONT, GLACIAL LAKES, DELTAS, AND DRAINAGE

VASHON GLACIER — GLACIAL LAKE — DELTAS — DRAINAGE

Figure 20. Cedar Grove Channel Stage

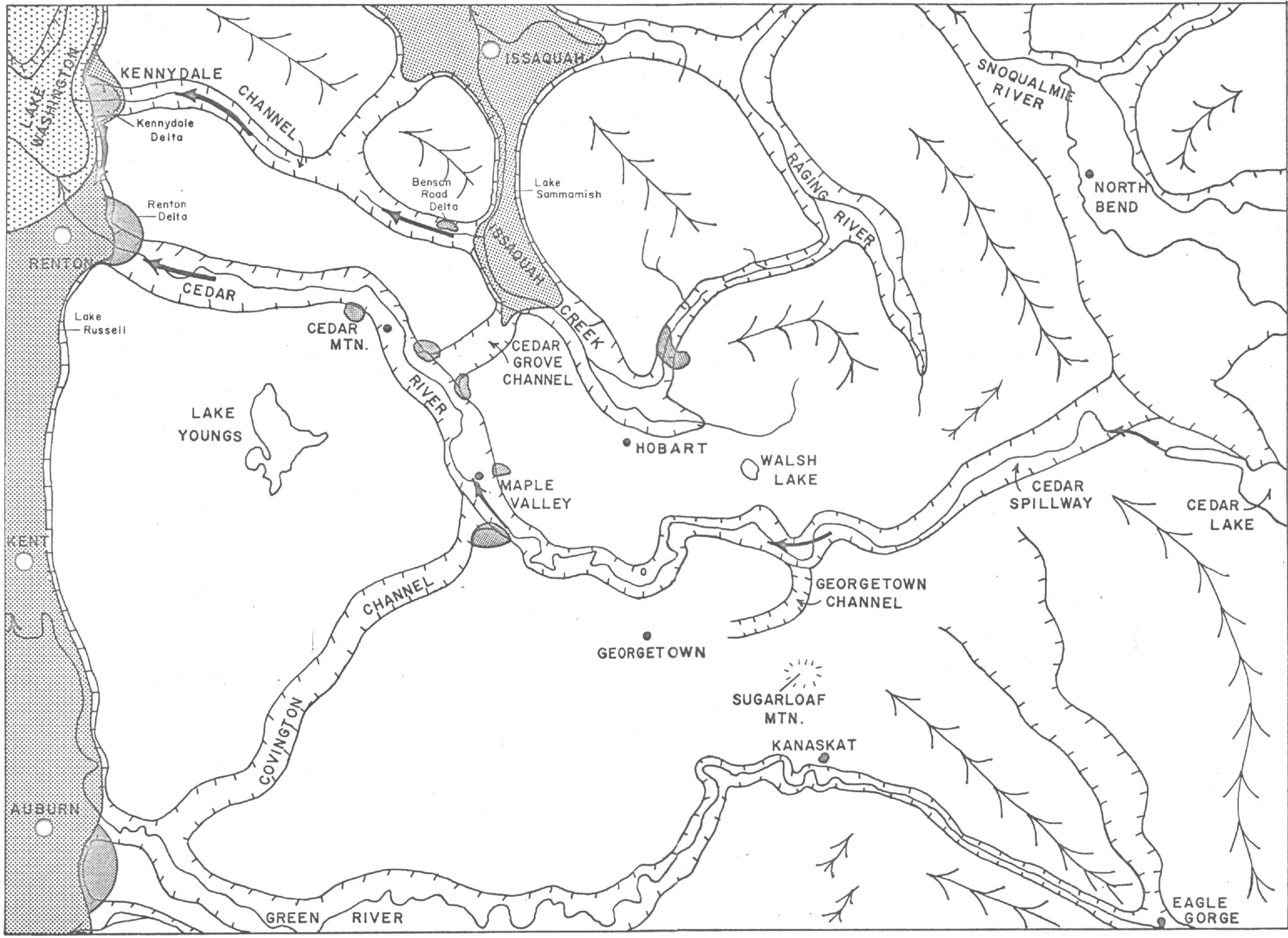
between the ice tongue of the Lake Washington trough and the eastern drift plain (Bretz, 1913, p. 136). Into this lake the Kennydale Delta was built. During an early phase when meltwater was flowing through the Kennydale Channel, the Benson Road Delta was built. Topset beds are exposed in a borrow pit at an altitude of about 335 feet in a small embayment near the east end of the channel. Subsequent erosion of the channel by meltwater removed the southern half of the delta.

The glacial Wilderness River was actively eroding deposits of Lake Covington, which by now had ceased to exist, and emptied into Lake Russell at Renton where the lower portion of the Renton Deltas was deposited (Bretz, 1913, p. 164) (fig. 21).

The Kennydale Channel Stage probably is equivalent to the Pine Lake Stage of Curran (1965). Glacial Lake Sammamish lay at an altitude of about 340 feet or a little less during this stage. It extended as far south as the northeast end of the Cedar Grove Channel. Lacustrine sediments which overlie outwash are exposed in the channel at an altitude of about 340 feet. Other contemporaneous lacustrine sediments are exposed in the Issaquah valley to the north.

Curran (1965) and Anderson(1965) have presented a detailed discussion of the recessional stages of the Vashon glacier north of the mapped area. A brief summary of the recessional events which followed the Kennydale Channel Stage is given here.

Continued retreat of the Vashon glacier finally opened the entire Sammamish Valley and its ponded water merged with an arm of glacial Lake Russel which occupied the Washington basin (Bretz, 1913, fig. 16). As the ice front reached the vicinity of Monroe, Lake Snoqualmie and ponded water in the Skykomish Valley merged to form an extensive water body which Bretz (1913) named Lake Snohomish. The outlet for the lake



PHYSIOGRAPHIC MAP

SHOWING ICE FRONT, GLACIAL LAKES, DELTAS, AND DRAINAGE

VASHON GLACIER — GLACIAL LAKE — DELTAS — DRAINAGE

Figure 21. Kennydale Channel Stage

lay to the south by way of the Redmond Channel into Lake Russell. The channel remained the outlet for the lake until the glacier reached the vicinity of Everett. When the ice reached a position just north of Everett, Lake Russell probably became an arm of the sea, for the Straits of Juan de Fuca very likely were ice-free by then. Lake Snohomish subsequently drained into the newly established Puget Sound. Invasion of marine water into Lake Russell and the lower Duwamish Valley occurred before about 13,500 years ago (Mullineaux, 1961, p. 184).

Postglacial History

Withdrawal of the Vashon glacier from the Puget Lowland probably was followed by reestablishement of vegetation upon the drift plain and accumulation of peat in many newly formed lakes. Cedar River alluvium blocked the Duwamish Valley at Renton impounding Lake Washington to the north, while the valley south of Renton remained an arm of Puget Sound. Basal peat from sediments in Lake Washington has a radiocarbon age of 13,650 years B.P., which establishes a minimum date for the retreat of the glacier from the vicinity of Renton (Rigg and Gould, 1957).

Five postglacial climatic episodes were recognized in the Puget Sound Lowland since glacial retreat by Hansen (1938). Studies of pollen from two peat bogs in the lowland led Hansen to identify a cool, dry interval following deglaciation, a warmer more humid period, a short xerothermic period, a period of greatly increased humidity, and a period of slightly decreased temperature and humidity similar to the present marine climate. A recent study by Heusser (1960) delineated a climatic sequence in the northwestern North America similar to that of Hansen.

Volcanic ash was spread widely over the Puget Lowland during the

Hypsithermal interval, and it became interbedded with sediments in the Duwamish Valley. The ash is found in most peat bogs in the area and was dated at about 6,600 years B.P. by Rigg and Gould (1957). They correlated the ash with an eruption of Glacier Peak, a Cascade volcanoe. However, recent work by Wilcox and Powers (1964) indicates that the volcanic ash was the product of a catastrophic explosion that destroyed Mt. Mazama and formed Crater Lake in south-central Oregon.

A large volcanic mudflow came down the White River valley from Mount Rainier about 4,800 years ago and spread out on the drift plain in the southeastern Puget Lowland. The White River subsequently dissected the mudflow and underlying drift plain, and deposited the reworked sediments in the Duwamish Valley. The valley floor was aggraded to a position above sea level north and south of Auburn by the heavily loaded river and an arm of Puget Sound that occupied the Duwamish Valley became a fertile valley.

Only minor modifications in the topography have occurred in the mapped area since the end of Fraser time. In relatively recent time, two landslides of moderate size have occurred on the slopes of Taylor Mountain. The Cedar River has incised itself sharply into the drift plain and developed a flat valley floor over half a mile wide below Maple Valley. Currently the river is widening its valley by meandering against the valley walls and undercutting its banks.

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PEBBLE COUNTS

APPENDIX A:

Holder Creek Delta

granite	20
basalt	28
andesite	12
crystalline metamorphics	6
sedimentary	28
mafic	6
	100%

Wilderness Delta

granite	29
basalt	25
andesite	17
crystalline metamorphics	8
sedimentary	16
mafic	5
	100%

Cedar Grove Delta (northwest)

granite	34
basalt	18
andesite	25
crystalline metamorphics	12
sedimentary	7
mafic	4
	100%

Cedar Grove Delta (southwest)

granite	32
basalt	27
andesite	17
crystalline metamorphics	11
sedimentary	10
mafic	3
	100%

Benson Road Delta

granite	34
basalt	13
andesite	26
crystalline metamorphics	3
sedimentary	19
mafic	5
	100%

Cedar Spillway Channel Outwash

granite	12
basalt	30
andesite	14
crystalline metamorphics	8
sedimentary	30
mafic	6
	100%

Standard sampling techniques were used, with 100 samples taken at each location, except Holder Creek Delta where 200 samples were taken.

Identifications were made from hand speciments. The basalt category may include some argillite and hornfels. Granitic rocks include all acidic crystalline plutonics. Andesities may include other volcanic types.

Plate I

Fall City Quad

SURFICIAL GEOLOGY OF THE MAPLE VALLEY AND HOBART QUADRANGLES, WASHINGTON

Geology by T.E. Rosengreen 1965

EXPLANATION

Pleistocene — Fraser Glaciation — post-Fraser

al — Alluvium

sl — Landslide Sediments

p — Peat

Pleistocene — Fraser Glaciation — Vashon Stade

vu | vsr | vic | vo | vrl | vd

Recessional Vashon drift
vu, undifferentiated, vsr, undifferentiated stratified recessional sediments, vic, ice-contact sediments, vo, outwash, vrl, recessional lacustrine sediments, vd, deltaic sediments

vt — Vashon Till

va | vl

Advance Vashon drift
va, undifferentiated, vl, lacustrine sediments

Pleistocene — pre-Fraser

uos | du

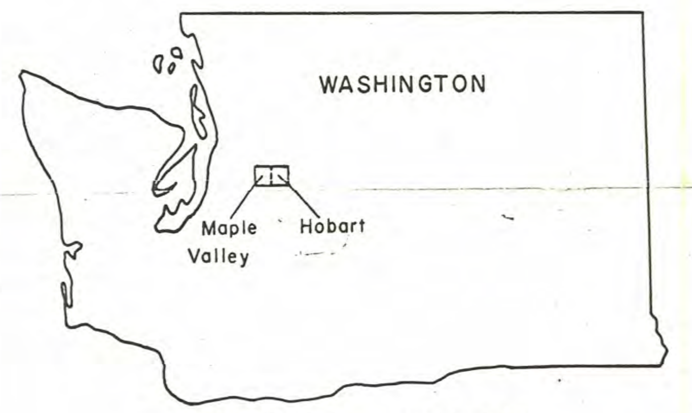
uos, undifferentiated older sediments, du, undifferentiated drift

pre-Pleistocene

br — Bedrock, undifferentiated

Contact, dashed where approximated

Scarps between Terraces



QUADRANGLE LOCATION

22°
true north
magnetic north

approximate mean declination 1950

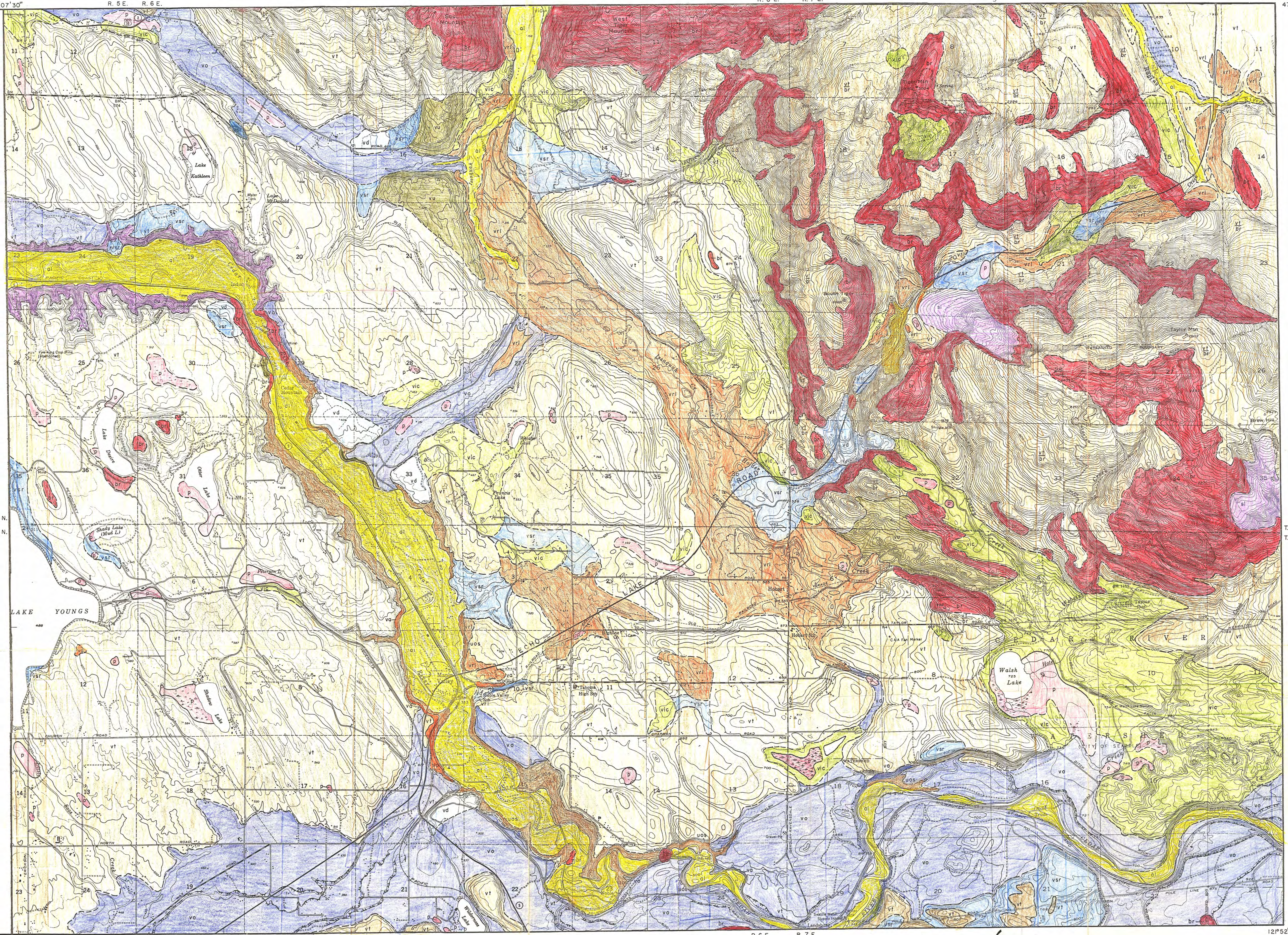
SCALE 1:24000

0 1/2 1 mile

Contour interval
Maple Valley 25 feet
Hobart 20 feet

datum is mean sea level

122°07'30" R. 5 E. R. 6 E. R. 6 E. R. 7 E. 121°52'30" 47°30'



T. 23 N. T. 22 N.

122°07'30" R. 5 E. R. 6 E. R. 6 E. R. 7 E. 47°22'30" 121°52'30"

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Plate I