THE GLACIAL GEOLOGY OF THE HAMMA HAMMA VALLEY AND ITS RELATION TO THE GLACIAL HISTORY OF THE PUGET SOUND BASIN

by

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TABLE OF CONTENTS

LIST OF FIGURES

THE GLACIAL GEOLOGY OF THE HAMMA HAMMA VALLEY AND ITS RELATION TO THE GLACIAL HISTORY OF THE PUGET SOUND BASIN

The region to be described is situated on the southeastern border of the Olympic Mountains in western Washington. The area, shown on the southeastern part of the Mount Constance topographic sheet, includes the valley of the Hamma Hamma River and the lowland between the mountain front and Hood Canal south and north as far as shown on the Mount Constance sheet. (See Figs. 1 and 2)

Two elements of the topography are of primary importance: frist, the mountain mass of the Olympics rising steeply to above 3000 feet in most of the summits; and second, a constructional flat, made up largely of glacial drift, between 500 and 700 feet in elevation, extending outward from the base of the mountains. The flat is interrupted eastward by Hood Canal which makes a steep-sided trench 1000 to 1200 feet deep in it. (500 to 700 feet above, plus 500 feet below sea level.) East of Hood Canal the flat is again excellently preserved.

These two surfaces: the mountain mass and the 500-to-700-foot flat, make up the major part of the area studied.

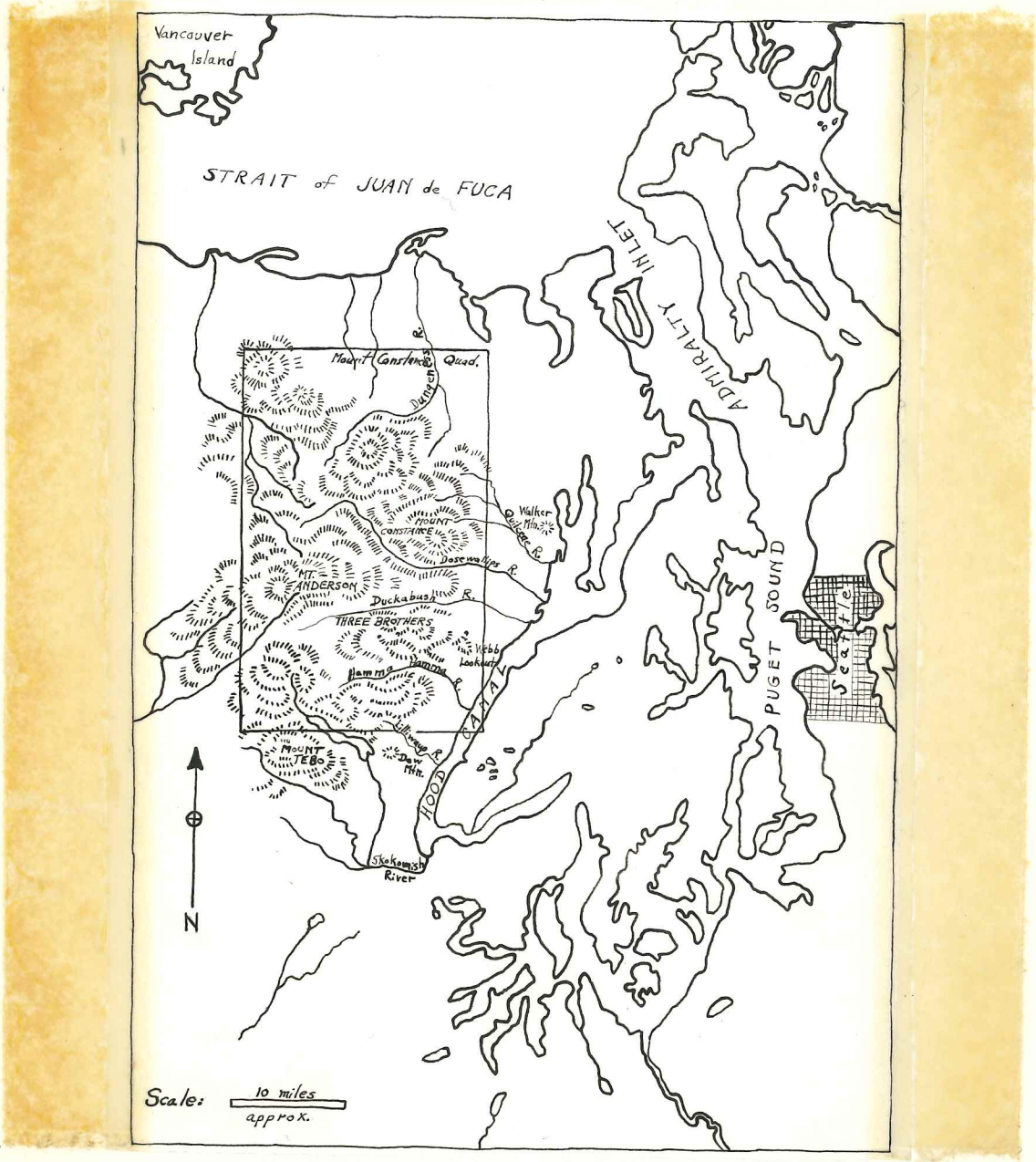

Figure 1. INDEX MAP

Figure 2.

PART OF MOUNT CONSTANCE SHEET SHOWING THE HAMMA HAMMA VALLEY

Valleys are cut deeply into the mountain mass and extend through the flat to reach Hood Canal.

Along the west shore of Hood Canal at low elevations there are outcrops of bedrock. The lower course of the Hamma Hamma River has a two-mile north-south section where the river flows in a narrow gorge in bedrock. Several irregular knobs of bedrock project out of the 500-to-700-foot flat near the mountain front. These occurrences of bedrock suggest the presence of foothills only thinly buried under the ground moraine, gravels, and deltas associated with glaciation.

The study was made under the direction of Prof. J. H. Mackin of the University of Washington. The writer wishes to express sincere gratitude and appreciation for the help given by him both in the field work and in the preparation of this paper.

EARLIER WORK

ON GLACIATION OF PUGET SOUND BASIN IN GENERAL

The Pleistocene history of the Puget Sound Basin was first described by Willis (1) and Bretz (2). Two epochs of glacial advance, an older, the Admiralty, and a younger, the Vashon, separated by the Puyallup interglacial epoch, were recognized and named by Willis. Following is a brief statement of the glacial history of the Puget Sound Basin according to Bretz and later workers.

During the Admiralty epoch, the Puget Sound Basin was occupied by a glacier lobe which moved southward from gathering grounds in British Columbia to a terminal moraine along the low divide between Puget Sound and Chehalis River drainage. The lobe filled the Puget Sound Basin, even lapping up over the foothills of the bordering mountains: the Cascades on the east and the Olympics on the west. At the same time the bordering mountains were being glaciated by relatively small alpine glaciers which flowed down to join the lobe of Cordilleran ice in the Puget Sound Basin.

During retreat of the Admiralty ice, meltwaters built up a plain of glaciofluvial materials, called Admiralty sediments, which filled all of the Puget Sound Basin.

During the Puyallup interglacial epoch, a lowering of

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1. Bailey Willis, Drift Phenomena of Puget Sound, Geol. Soc. Am. Bull. v. 9 p. 111-162 (1898)
2. J. Harlan Bretz, Glaciation of the Puget Sound Region, Wash. Geol. Survey Bull. 8 (1913)

base level caused the deep dissection of the plain of Admiralty sediments by consequent streams.

By the beginning of the Vashon epoch, the Admiralty drift plain was sub-maturely dissected. A lobe of the Cordilleran Glacier moved southward over the area for the second time. The movement of its lower ice was guided somewhat by pre-existing valleys and the valleys were thereby deepened by gouging. The "deeps" of Puget Sound were formed at this time under special conditions of a bedrock constriction in a valley or the junction of two southward-trending valleys which crowded together the basal ice from two troughs into one. (3) Bretz (4) and others (5) have presented evidence that ice of the Vashon Puget lobe was actually thrust up into some of the mountain valleys of the Cascades and Olympics in the face of their descending glaciers.

During the waning of the Vashon glaciation, alpine glaciers in the bordering mountains melted back in general more rapidly than the lobe which lay in the Puget Sound Basin. This resulted in many ice-free mountain valleys dammed at their mouths by the ice still remaining in the Puget Sound Basin. Lakes, whose existance is indicated today by lake clays in the mountain valleys, (5) occupied the valleys for

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3. Bretz, op. cit., p. 219
4. Bretz, op. cit., p. 33
5. Allen S. Cary and Charles W. Carlston, Notes on Vashon Stage Glaciation of the South Fork of the Skykomish River Valley, Washington, Northwest Science, v. 11 p. 61-62 (1937)
J. Hoover Mackin, forthcoming publication

a time, until the lobe in the Puget Sound Basin had lowered sufficiently by melting to open the mouths of the mountain valleys.

During a still later stage of retreat there were formed short-lived lakes in the Puget Sound Basin, held up between the divide into Chehalis River drainage to the south, and the ice to the north, and intermittently lowered by northward retreat, until the ice had withdrawn far enough to open the northern passage into the Strait of Juan de Fuca. These lakes are evidenced by outlet channels and many deltas which were built into them at successive levels, and were the last glacial features in the Puget Sound Basin.

ON GLACIAL RELATIONS ALONG OLYMPIC BORDER

Bretz has not specifically treated the Hamma Hamma valley but he has described in some detail the history of the western border of the Puget Sound Basin, adjacent to the Olympic Mountains, which has a bearing on the glacial history of the Hamma Hamma River.

One of the hypothetical consequent streams which dissected the plain of Admiralty sediments during the interglacial epoch was named the Matlock Pathway River. (6) This river flowed southward along the present course of Hood Canal, taking the drainage of the western part of the Puget Sound Basin and the eastern slope of the Olympic Mountains south through the

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6. Bretz, op. cit., p. 210-212

Matlock Pathway to the Chehalis River.

Bretz has presented evidence, to be discussed in a later section, tending to prove that at the beginning of the Vashon epoch alpine glaciers from several Olympic valleys moved out beyond the mountain front and coalesced to form a piedmont lobe of Olympic ice, which was destroyed by the advance of the much greater lobe of Cordilleran ice into the Puget Sound Basin. This foreign ice dammed or pushed up into the valleys of the Olympics. Bretz described (7) the relations between Olympic and Puget ice in the Skokomish valley, about twelve miles south of the Hamma Hamma valley, showing that Vashon Puget ice held back the Skokomish valley glacier. Foreign granite pebbles were reported (8) four miles up the valley of the Dosewallips River, about ten miles north of the Hamma Hamma.

During the retreat of Vashon ice, lakes existed at three well recorded levels in the Hood Canal trough. The earliest, highest lake, occupying only about ten miles of the head and eastern and western arms of Hood Canal, was named Lake Skokomish. (9) Lake Skokomish, at 350 feet elevation, outletted to the south over the Shelton Delta into the much larger Lake Russell which occupied the rest of the Puget Sound Basin which was then uncovered by the ice. As soon as farther retreat of the ice front opened a lower outlet to Lake Russell via the east end of the eastern arm of Hood Canal, a second, lower

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7. Op. cit., p. 32-33
8. Op. cit., p. 33
9. Op. cit., p. 145

stage, called Lake Hood was inaugurated. (10) Lake Hood, at 220 feet elevation, existed until after 26 miles more of northward retreat had uncovered the Poulsbo Channel which permitted Lake Hood to lower 100 feet and become an arm of Lake Russel at 120 feet elevation. (11) Finally with farther northward retreat of the ice front the waters in Hood Canal were lowered gradually to sea level with building of deltas at various levels.

STATEMENT OF PROBLEM

The purpose of the present paper is to describe the glacial history of one of the Olympic valleys, the Hamma Hamma. In such a study it is necessary, first, to distinguish between Puget drift and Olympic drift, second, to distinguish between Admiralty drift and Vashon drift whether of Puget of Olympic origin, and third, to determine height of ice along the Olympic mountain front during the Admiralty and Vashon epochs.

The general plan of presentation will be first: discussion of criteria for distinguishing Olympic from Puget till, and Admiralty from Vashon till, and for determining height of Puget ice along the Olympic mountain front; second: description of features of Vashon glaciation at the mountain front and within the mountain valley; third: description of features of Admiralty glaciation at the mountain front and within the mountain valley; and finally: discussion of post-glacial features.

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10. Op. cit., p. 146
11. Op. cit., p. 148

CRITERIA FOR DISTINGUISHING OLYMPIC DRIFT FROM PUGET DRIFT

The absence of granitic rocks in the Olympic Mountains and the presence of granites in Puget tills in general, make it possible to distinguish between tills of Olympic origin and tills of Puget origin, and also to determine the minimum height of Puget ice along the border of the Olympic Mountains.

The bedrock over most of the Hamma Hamma area has been mapped (12) as Metchosin formation (volcanics). However, several of the Hamma Hamma tributaries from the north, including Upper Lena Creek, Boulder Creek, and Whitehorse Creek, bring down pre-Metchosin sedimentary rocks into the Hamma Hamma valley. The Olympic till of the Hamma Hamma valley is therefore composed of volcanics and sediments, with volcanics usually greatly predominating. The volcanics are chiefly dense basalt, vesicular and amygdaloidal basalt, greenstone, agglomerate, and diabase. The sediments are coarse grained grey micaceous sandstones frequently containing small fragments of black shale. Occasionally slaty boulders occur in the till.

Lithologic types in Puget till are much more varied. Its lithologic composition varies markedly in different locations due to contamination either by local ice outflowing from an Olympic valley or by erosion of a nearby outcrop. Nevertheless pebbles of lithologic types which are foreign to the Olympic

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12. Charles E. Weaver, Tertiary Stratigraphy of Western Washington and Northwestern Oregon, Univ. of Wash. pub. in geol. v. 4 plate 3 (1937)

Mountains can usually be found constituting from 10% to 15% of the pebbles in Puget till. Some isolated summits along the Olympic mountain front, to be described later, show much higher proportions, up to about 50%, of foreign pebbles. The pebbles contained in an average Puget till along the border of the southeastern Olympic Mountains may be divided into four groups: (1) the varied types of volcanic rocks from the Metchosin formation, (2) the grey micaceous sandstone from the interior of the Olympics, (3) soft, brownish sandstones and shales of the post-Metchosin formations exposed to the north and east in the Puget Sound Basin, and (4) distinctively foreign pebbles: granitic rocks, gneisses, schists, conglomerates, and andesites; of unknown northern origin.

Two complications are encountered in distinguishing Olympic tills from Puget tills on the basis of rock types. First, Puget ice moving southward along the Olympic mountain front might well have become so cluttered with local material that the till would not reflect the foreign origin of the ice. Therefore it is necessary to note that lack of foreign boulders in a till does not necessarily indicate that the till is of Olympic origin. Second, since early Puget ice may have pushed up into the Olympic valleys, leaving a granite-rich till, later Olympic ice might, by reworking earlier moraines, bring granite boulders out of the Olympics. Thus a till of Olympic origin might be granite-bearing. In this connection the relative abundance of granites in a till is significant.

CRITERIA FOR DETERMINING HEIGHT OF PUGET ICE AND DISTINGUISHING BETWEEN VASHON AND ADMIRALTY TILL

Two criteria are employed in determining height of foreign ice along the mountain front: (1) elevation at which foreign boulders are found and (2) elevation of ice-marginal features. In addition, it must be noted that actual ice height was somewhat greater than the present elevation of any physical evidence, due either to deposition or erosion. For morainal ridges along mountain slopes would be dropped down during melting, and ice-marginal channels were cut below the level of the ice.

Bretz presents no evidence bearing on the relative heights of Vashon and Admiralty ice in the Puget Sound Basin. In this connection he states only that Vashon ice at the terminal moraine slightly exceeded the limits reached by Admiralty ice. (13) Dawson, Clapp, and James (14) state that evidence in British Columbia indicates that the Admiralty glacier exceeded the Vashon in maximum height. Mackin (15) has determined that along the west front of the Cascades in the latitude of Seattle the Admiralty ice reached several hundred feet higher than the Vashon. Thus two periods of glaciation complicate the deter-

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13. Op. cit., p. 36-37
14. George M. Dawson, On the later Physiographical Geology of the Rocky Mountain Region in Canada, with special reference to Changes in Elevation and to the History of the Glacial Period, Roy. Soc. Canada v. 8 sec. 4 p. 43-45 (1890)
Charles H. Clapp, Sooke and Duncan Map-Area, Vancouver Island, Canada Geol. Survey Mem. 96 p. 352 (1917)
H. T. James, Britannia Beach Map-Area, B. C., Canada Geol. Survey Mem. 158 p. 64-65 (1929)
15. Mackin, forthcoming publication

mination of ice height by making it necessary first to distinguish between deposits and features of Admiralty and Vashon ages.

Degree of weathering of the boulders is found to be inadequate in distinguishing relative age of drifts. Weathering is affected too much by situation of the drift, whether well exposed since ice retreat, or deeply buried and only recently exposed artificially, or in sea-cliffs, river banks, or landslides. On steep slopes and summits of small area, degree of weathering is difficult to apply as a criterion because erosion removes decayed material so rapidly that all rock is fresh, even the bedrock underlying till.

It seems that the best distinction between Admiralty and Vashon moraines lies in surface appearance and topographic form. The younger, Vashon, moraines have irregular or ridged, frequently bouldery, surfaces on which foreign boulders are commonly seen projecting above the soil. The older, Admiralty, moraines are smoother with gentler slopes. Usually boulders are not visible on their surfaces.

THE VASHON GLACIAL EPOCH

PUGET DRIFT AND ICE AT THE OLYMPIC MOUNTAIN FRONT

DISTRIBUTION AND HEIGHT OF ICE

Vashon ground moraine covers the surface of the 500-to-700-foot flat which flanks the Olympic Mountains. On the flat there are numerous kettle lakes and depressions such as, in the northern part, Lake Armstrong, and, in the southern part, Tenas Lake and nearby ponds. The surface of the flat is irregular and everywhere studded with foreign boulders.

Vashon drift, recognized by the fresh foreign boulders on its surface, occurs well up on the slopes of the mountain front. About four miles southwest of the mouth of the Hamma Hamma River there is an unnamed hill at 1608 feet elevation, a part of the mountain mass but separated from it by a channel 600 to 700 feet deep. Vashon Puget drift covers the summit and western, or inner, slope of this hill. The next adjacent spur to the north exposes granite boulders up to at least 1700 feet, beyond where there are no more fresh cuts. North of the Hamma Hamma River Vashon Puget drift occurs on both the outer and inner slopes of the ridge extending south from Webb Lookout, and on the western slope of the Waketickeh valley, thus indicating that the Waketickeh valley was filled by Vashon Puget ice. (See Fig. 7)

The most satisfactory evidence on the height of Vashon Puget ice is found north of the Hamma Hamma River, on the western side of the Waketickeh valley. Here, road cuts up to 1700 feet show till with abundant granites. Above this ele-

vation granites are occasionally found on the surface up as high as 1900 feet. At about 1900 feet there occurs a noticable break in slope, steepening upward. On the steep slope ledges of bedrock are common, while they are absent below, except in stream valleys. The 1900-foot break in slope is believed to represent the highest level of deposition of Vashon Puget till. The actual ice height at this location may have been considerably higher as noted in an earlier section. Immediately to the south a long narrow spur, at 2100 feet, extends southward. (See Fig. 3) At the northern, inner, edge of the spur there is a notch about 50 feet deep and 200 feet wide suggesting an ice-marginal channel cut when ice lay just over the long 2100-foot spur. This high ice-marginal drainage channel with the foreign boulders of Vashon drift close below it suggest that the Vashon Puget ice stood at about 2100 feet elevation at the north side of the mouth of the mountain valley of the Hamma Hamma River.

ICE-MARGINAL DRAINAGE CHANNELS

There are several other ice-marginal drainage channels besides the one described above.

The previously mentioned channel behind the 1608-foot hill is 600 to 700 feet deep and a mile and a half long. It was undoubtedly occupied by southward-moving ice and southward-flowing water at different stages. It is now occupied by upper Jorsted Creek flowing northward. Drainage changes through this channel will be discussed later.

There is another channel parallel with the mountain front located on the next adjacent spur to the north. This small

narrow channel at about 1100 feet drains southward but is not occupied by any stream. The slopes of its sides, unlike those of the large channel occupied by Jorsted Creek, are mostly bare rock or talus, unmantled by till, although smooth slopes covered by Puget till occur close by on both sides of the channel. Crumbling pillow lavas occur in the bedrock along the channel, suggesting that it was cut out rapidly along a weak zone while meltwaters flowed southward at the 1100-foot level.

Elsewhere along the mountain front north to the Hamma Hamma valley there are other similar and smaller channels and notches suggesting ice-marginal drainage channels at various lower levels used during retreat.

HAMMA HAMMA DRIFT AND ICE WITHIN THE MOUNTAIN VALLEY

Evidence bearing on the extent and results of Olympic Vashon ice in the Hamma Hamma valley and tributaries may be presented topically as follows: (1) occurrences of till, (2) evidences of glacial erosion, (3) lakes in tributary valleys, (4) terminal moraine of valley ice with associated outwash materials, and (5) aggradation by tributary streams.

OCCURRENCES OF TILL

Small exposures of till in road and trail cuts are found frequently along the slopes of the middle section of the Hamma Hamma River; that is, from the junction of Phantom Creek upstream about five miles to where the Hamma Hamma is in a gorge. The exposures usually reveal the bedrock overlain by a thin till cover. No thickness greater than five or six feet was observed. The till is earthy with a few large boulders, occasionally striated. The boulders are fresh but the matrix is usually stained orange throughout its entire thickness. This deep oxidation may be due to the slight degree of compaction of the till. Its rock composition is of various volcanic types of the Metchosin formation and of grey micaceous sandstone.

In the upper section of the Hamma Hamma River no till is to be found along the valley floor, probably because it was buried by the aggradation of Boulder Creek and Whitehorse Creek where they come out onto the Hamma Hamma valley floor. The lack of Hamma Hamma till in the lower section of the mountain valley is due in part to burial under later outwash

materials and in part to the presence of Puget till brought into the valley mouth, as described later.

EVIDENCES OF GLACIAL EROSION

There are three types of evidences of glacial erosion in the Hamma Hamma valley: (1) roche moutonnées, (2) knobs on the valley bottom, and (3) cirques and hanging valleys.

Roche Moutonnées: Roche moutonnées occur on the slopes of the valley sides in several places. They are best developed on the steep slopes along the north side of the Hamma Hamma between Watson Creek and Lena Creek. Most of the summit areas here as well as elsewhere along the Hamma Hamma valley are, in part at least, bare rock. Such outcrops, also present on the steepest slopes, resemble roche moutonnées in appearance, only differing from them in the lack of glacier-smoothed surfaces. The jaggedness of the high areas and steep slopes make it impossible to determine height of valley ice from the roche moutonnées.

Knobs on the Valley Bottom: There are three small but conspicuous hills in the middle section of the Hamma Hamma valley probably genetically connected with Vashon glacial erosion. Two of them are bedrock knobs. The other is composed of an indurated till, to be described later as Admiralty Olympic till.

The two rock hills (Fig. 4) are situated on the south side of the river opposite the mouth of the unnamed creek between Delta Creek and Maple Creek. There is a pond, outletting down valley by a small waterfall, between the two knobs. On

Figure 4. ROCK KNOBS ON THE VALLEY BOTTOM
(looking southwest)

the upstream slope of one knob there is a small patch of Vashon Olympic till.

Two possible modes of origin are suggested for the hills: They may be blocks slidden down from high on the valley side at some time after the last ice had melted. Or they may be resistant parts of bedrock which have withstood glacial erosion and have been made to stand out even more sharply by glacial action removing the adjacent weaker bedrock. The Hamma Hamma River may have sharpened the notch between the two knobs by flowing there temporarily while ice or till occupied the lower part of the valley. The latter possibility seems more likely because of the absence of other smaller rock fragments which should have accompanied a landslide.

The hill composed of Admiralty till is near the mouth of Lena Creek. It is elongate in an east-west direction, extending parallel with the valley wall. It rises about 60 feet above the valley floor and is connected at its western end to the valley side by a low curving ridge. (See map Fig. 10) The topographic form suggests a lateral moraine of a glacier in Lena valley. But the extreme induration of the till suggests that it is a remnant of a much larger mass of till, as described later. If this is true, then the hill has been carved out by the combined action of ice and water, possibly in the following manner.

The Vashon glacier, flowing down over the Admiralty till in the Hamma Hamma valley, left some of the hard till remaining between the sides of its valley cut in till, and the bedrock

walls of the valley. Then after the Lena glacier had melted back up into its valley, Lena Creek flowed down into the Hamma Hamma valley and, finding the lowest place in the valley to be along the valley side, eroded the valley there which now separates the elongate hill from the valley wall. When the Hamma Hamma glacier had retreated upstream beyond the present junction of Lena Creek with the Hamma Hamma, Lena Creek took its more direct present course to the Hamma Hamma River.

Cirques and Hanging Valleys: All of the streams tributary to the upper section of the Hamma Hamma River drain cirques or cirque lakes. One of these streams, the one extending southwest from the end of the road, drops down from a well developed hanging valley at 2500 feet into the Hamma Hamma at 1680 feet. There are other hanging valleys at higher elevations. Only two of the streams tributary to the middle and lower sections of the Hamma Hamma valley come from valleys showing clear evidences of glaciation. These two, Lena Creek and Jefferson Creek, will be discussed in the following section.

LAKES IN TRIBUTARY VALLEYS

Two of the creeks tributary to the Hamma Hamma River drain lakes: Lena Creek draining Lena Lake at 1774 feet; and Jefferson Creek draining Elk Lake at 1046 feet. The situation of these lakes has a bearing on the Vashon glacial history of the Hamma Hamma valley.

In both cases the creeks are only intermittently connected with their lakes. In both cases the lakes are retained behind a jumble of angular blocks of rock eight to ten feet in diameter

or larger, scattered over a bumpy surface. In both cases the lithology of the rocks shows nothing foreign to the Olympics.

Elk Lake: The flat basin of Elk Lake is believed to have been formed by the filling in behind a terminal moraine of an ice tongue moving down from Jefferson Creek valley.

The 1300-foot hill separating the Elk Lake basin from the small unnamed lake to the south shows no outcrops of bedrock as are usually seen on comparable slopes elsewhere. There are only a few rounded boulders of various Olympic types scattered on the surface. In one small trail cut, the best exposure, was found a block of Admiralty till. On these evidences it is believed that the 1300-foot hill is a Vashon moraine composed mainly of material brought down by a tongue of ice in Washington Creek valley which was dammed at its mouth by the larger Jefferson Creek glacier.

Lena Lake: The dam of Lena Lake resembles that of Elk Lake in surface appearance but it differs in that the outlet of the lake during high water flows between the dam and the west wall of the valley, not over the dam in the central part. The Lena Lake dam grades up onto the east side of the valley wall, but not perfectly smoothly. There is a break in slope at 1920 feet marking the top of the dam. (See map Fig. 10)

The Lena Lake dam may be, like the Elk Lake dam, a terminal moraine, or it may be a landslide from the steep eastern valley wall. Whichever it is, it came after an earlier period of ice advance when ice flowed down the lower Lena Creek valley to join the ice in the Hamma Hamma valley because till is

found below the dam along the east side of Lena Creek valley.

These two lakes dammed in tributary valleys indicate that there was a late stage during the Vashon epoch when two small glaciers stood in the Jefferson and Lena valleys long enough to build moraines. It may have been during this time that the large deposit of Jefferson Creek, described in a following section, was built out into the Hamma Hamma valley.

TERMINAL MORAINE OF VALLEY GLACIER AND ASSOCIATED OUTWASH MATERIALS

Glaciofluvial material is found in terraces in the lower Hamma Hamma valley from the junction of Cabin Creek downstream. On the north side of the valley just east of the mouth of Cabin Creek the highway passes along an exposed terrace face showing about 20 feet of silts, fine sands, and gravels. (Fig. 5) In this exposure are seen the finest-grained sediments in the valley. Elsewhere terraces reveal chiefly coarse gravels.

The top of the terrace at the junction of Cabin Creek is at about 620 feet, 70 feet above the Hamma Hamma River. Downstream a terrace appears at Watson Creek at 580 feet, 60 feet above the Hamma Hamma River. About a mile and a half farther downstream on the north side of the valley another terrace stands at 500 feet, 60 feet above the river. These terrace remnants (See Fig. 10) are evidently parts of a former graded surface whose origin will be discussed later.

Looking up-valley from the top of the 620-foot terrace near Cabin Creek, one sees a slight rise, the surface of which differs from the terrace top in that it is scattered over by large angular blocks of rock.

Figure 5. TERRACE OF OUTWASH MATERIALS

(near junction of Cabin Creek and Hamma Hamma River)

Figure 6. SURFACE OF TERMINAL MORAINE
OF HAMMA HAMMA VALLEY GLACIER

(looking toward gorge of Cabin Creek)

The block-covered area (Fig. 6) is a low north-south ridge extending transversely across the Hamma Hamma valley and rising to between 640 and 660 feet, 20 to 40 feet above the valley floor upstream from it and the terrace top downstream from it. (See profile Fig. 10) The surface is highly irregular, containing depressions; and the irregularity is added to by the haphazard arrangement of large blocks, not equally distributed everywhere. In places there are suggestions of channels but without any definite arrangement. The elevation of the top of the block-covered area rises slightly northward, appearing to slope out gradually from the north valley wall just upstream from the Cabin Creek gorge. There is a difference in the surface appearance of the area from the south side of the valley to the north. It becomes less boulder-covered toward the north side; that is, toward where Cabin Creek emerges from its gorge into the Hamma Hamma valley to flow about 60 feet below the Hamma Hamma terrace. Here the area is still bumpy as if boulders had been buried under the debris brought out by Cabin Creek, when Cabin Creek was flowing at the level of the block-covered surface. Toward the south wall of the Hamma Hamma valley the blocks continue across the river. Typical blocks of rock appear some distance up on the south wall of the valley. The river, close against the south valley wall, flows over bedrock with a steepened profile for about half a mile, appearing to have been pushed over against the south wall.

The lithology of the blocks shows a striking lack of variety. All of the large blocks examined were basalt, most

of which contained veins of quartz and epidote. This type of rock, while not rare in the present Hamma Hamma river gravels, in the river terraces, nor in the Olympic tills, nowhere else comprises such a large proportion of the rock types.

The highly irregular block-covered surface is suggestive of either moraine or landslide topography. Either origin is possible. To the south the valley wall is steep and jagged, a favorable place for a landslide to have occurred. Furthermore, the lack of variety of rock types favors the landslide possibility.

There is stronger evidence for morainal origin. The fact that there is no terrace upstream is significant. The low ridge rises about 40 feet directly from the valley floor, while downstream it rises also about 40 feet above a terrace which is itself 70 feet above the river. Such a relation indicates that the terrace is genetically connected to the low ridge, and that the ridge was not subsequent to the formation of the terrace. Furthermore, the large volume of sediments which must have filled the lower Hamma Hamma valley, as indicated by the portions still remaining, seems to require a source, such as a glacier, capable of supplying large amounts of sediments. It is therefore believed that the low block-covered ridge is the terminal moraine of the Hamma Hamma valley glacier at a late stage of the Vashon epoch when the height of the foreign ice in the Puget Sound basin was not great enough to allow it to flow up into the Hamma Hamma valley.

The meltwater stream which issued from the terminus of

the Hamma Hamma glacier either built a valley train down the lower Hamma Hamma valley or immediately dropped its sediments into a lake dammed in the lower valley by the foreign ice standing at its mouth. No foreset beds, nor lake clays, were observed to support the second possibility. A third possibility seems more likely: that the aggrading meltwater stream built its deposits under conditions changing between valley train and narrow, currenty lake as the condition of damming by foreign ice at the mouth of the valley changed.

AGGRADATION BY TRIBUTARY STREAMS

As a result of glaciation many of the tributaries have built fan-shaped accumulations of debris on the slopes or out onto the floor of the Hamma Hamma valley.

The most extensive deposit is that of Jefferson Creek. This deposit extends along the valley side for over one mile. (See map and profile Fig. 10) The surface slopes noticably outward in all directions from the exit of Jefferson Creek from the mountains, and is abundantly scattered over by rounded boulders. Exposures along the two small creeks west of Jefferson Creek show the material to be well-stratified gravels and coarse sands. The present feature is a remnant of a much greater original deposit as shown by numerous terraces along the creeks which are now incised into the fan.

The remnants of accumulations of three other smaller tributaries: Watson Creek, Delta Creek, and Boulder Creek, remain as evidence of a stage of aggradation in the Hamma

Hamma valley. The deposits of Watson Creek and Delta Creek are so high on the valley side as to suggest that they were built when there was still some ice in the Hamma Hamma valley, thus making a high base level for the tributaries. The deposit of Boulder Creek grades out onto the floor of the upper Hamma Hamma although Boulder Creek itself is incised about 30 feet below its fan where it issues from its gorge.

These post-glacial features were probably built during and immediately after the retreat of ice from the Hamma Hamma valley but while there were still small alpine glaciers sending much material out of the various tributary valleys down into the large, newly-uncovered Hamma Hamma valley. Finally, after melting of the last glaciers allowed the streams to go back to their normal conditions, the deposits have been largely removed.

RELATION OF VASHON PUGET TO VASHON OLYMPIC ICE

MAXIMUM STAGE OF VASHON

The establishment of the height of Vashon Puget till at about 2000 feet at the mouth of the Hamma Hamma valley presents the problem of the relation between the Puget ice and the Olympic ice.

Granite-bearing till is not found farther than half a mile into the mountain valley of the Hamma Hamma River. The road along the north side of the Hamma Hamma valley exposes granite-bearing till up as far as beyond the first unnamed creek which joins the Hamma Hamma River from the north. Farther into the valley terrace gravels and sands bury other possible occurrences of till of whatever origin. The road along the south side of the Hamma Hamma valley passes between several low knobs at about 580 feet just east of the most eastern unnamed tributary to the Hamma Hamma River from the south. Some of the knobs are bedrock thinly covered by granite-bearing Puget drift. Foreign boulders occur in the two small creek valleys east of Jefferson Creek, indicating that Puget till was deposited over the area they now drain.

It is quite probable, as previously explained, that Puget ice, contaminated by much local debris, pushed up the Hamma Hamma valley considerably farther than any foreign drift occurs. Thus it appears likely that a tongue of the foreign ice pushed up into the Hamma Hamma valley for a distance of perhaps two miles from the mouth of the valley.

The reason for ice flowing up into the valley was the

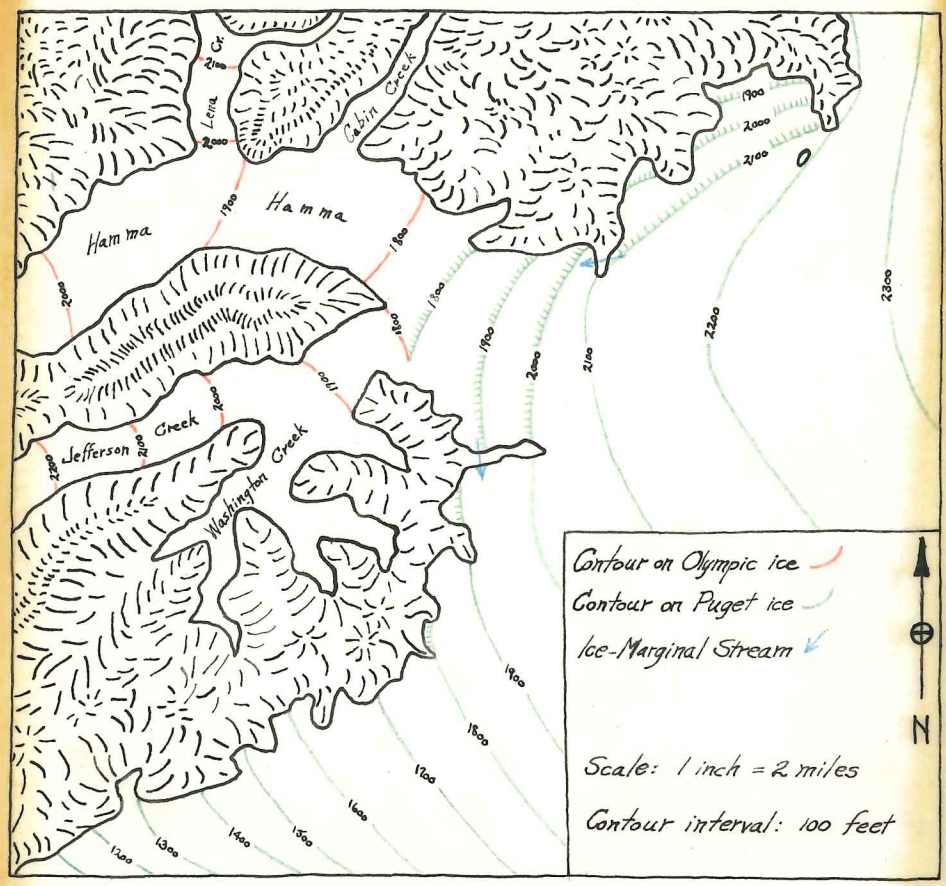

Figure 7. HYPOTHETICAL MAP OF ICE SURFACE DURING MAXIMUM OF VASHON GLACIATION

greater elevation of the ice in the Puget Sound Basin, so that the surface of the glacier sloped downward up-valley, until the Hamma Hamma glacier coalesced with it. This situation is illustrated by a hypothetical contour map. (Fig. 7) If such a sag on the glacier surface existed, a lake might form there with an incoming ice-marginal stream from the north cutting the previously described channel at the inner edge of the 2100-foot spur, and its outlet stream flowing through one of the sags in the spur on the south side of the Hamma Hamma valley.

RETREAT STAGE OF VASHON

Evidence for a stage during the retreat of the Vashon ice when the Hamma Hamma glacier did not extend far enough down its valley to join the foreign ice in the Puget Sound Basin has been presented in a previous section of this paper. No evidence was found bearing on the relations of the Puget ice at this same stage. It is possible that the Puget glacier had by this time melted northward past the mouth of the Hamma Hamma River. But the fact that the gradient maintained by the terrace tops, if extended to the mouth of the Hamma Hamma River, would reach a point about 300 feet above sea level, (See profile Fig. 10) suggests that either ice or a lake in the Hood Canal trough made a high base level at the time of aggradation in the lower Hamma Hamma valley from the valley glacier terminating at Cabin Creek.

THE ADMIRALTY GLACIAL EPOCH

PUGET DRIFT AND ICE AT THE MOUNTAIN FRONT

It is difficult to find evidences of Admiralty Puget glaciation on the Olympic mountain front because of contamination of Puget ice where it bordered against the slopes of the mountains. The most favorable locations for preservation of Admiralty Puget till are summits isolated from the mountain mass in positions where relatively uncontaminated Puget till would be left on them. Three such summits, Walker Mountain, Webb Lookout, and Dow Mountain, are situated about fifteen miles apart along the Olympic mountain front. (Fig. 1)

The most northerly summit is Walker Mountain about twenty miles northeast of the mouth of the Hamma Hamma River. Here on a narrow summit at 3018 feet granitic boulders are fairly abundant in the thin till covering exposed in road cuts but do not occur with the fragments of bedrock scattered over the surface.

About fifteen miles southwest of Walker Mountain, Webb Lookout is situated on a spur near the head of Waketickeh Creek, at about 2780 feet. Here again, as on Walker Mountain, granites are fairly abundant in the till covering exposed in road cuts. The till on these two summits is believed to be Admiralty because of the smoothly sloping surface appearance of the till covering as contrasted with the irregular, boulder-strewn appearance of Vashon tills.

Fifteen miles farther southwest, ten miles southwest of the mouth of the Hamma Hamma River, Dow Mountain stands near

the mouth of the North Fork Skokomish River. On its summit, at about 2600 feet, no granites or other foreign boulders occur. On the slopes of the mountain, road cuts adequately expose the till and underlying bedrock, but nothing foreign was seen anywhere on the mountain side. The till is believed to be Admiralty in age by comparison with the tills on Walker Mountain and Webb Lookout. The till is composed of boulders of volcanics and the characteristic micaceous sandstone which occurs west of the lower contact of the Metchosin formation and is tapped by the North Fork Skokomish River about fifteen miles upstream from Dow Mountain. (16) Because of its situation in the path of ice coming out from the North Fork Skokomish valley it would be expected that Dow Mountain, even though completely isolated from the mountain front, might be covered by till of local origin during Admiralty time if Olympic glaciers were vigorously flowing out into the Puget lobe.

On the three above-described summits are the only occurrences of Admiralty till that were found along the mountain front. No ice-marginal features were observed. There was no suggestion of how much higher than this minimum of about 2700 feet at the Hamma Hamma River, the Admiralty ice reached at its maximum stage.

In spite of the elevation of the foreign Admiralty ice at the mouth of the Hamma Hamma River no foreign Admiralty till is known within the Hamma Hamma valley. The lack of it may be

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16. Weaver, op. cit., plate 3

due to its removal during Vashon glaciation. On the other hand, its absence may be considered to support the idea that the outflowing of Admiralty Olympic ice was great enough to prevent foreign ice from penetrating into the Olympic valleys. This is suggested above by the covering of Dow Mountain, which is completely isolated from the Olympics, by Olympic Admiralty till.

HAMMA HAMMA DRIFT AND ICE WITHIN THE MOUNTAIN VALLEY

The evidence of the Admiralty glaciation of the Hamma Hamma valley consists of the occurrence of a distinctive hard till at several places within the valley.

ADMIRALTY OLYMPIC TILL

The till in question is very hard; so hard that the pebbles must be broken out of it with a hammer. Its color is grey in contrast to the orange color of Vashon tills in the Hamma Hamma valley. Pebbles of the till do not differ in degree of weathering from pebbles of Vashon Olympic till. In this case, as well as in distinguishing between Admiralty and Vashon foreign tills, weathering can not be used as a criterion. No lithologic types foreign to the Hamma Hamma valley were observed in any of the exposures. Abundant pebbles of the micaceous sediments outcropping in the headwaters of the Hamma Hamma River indicate an origin far upstream for the till.

There are two evidences of the Admiralty age of this till: first, its great difference in induration from Vashon till, and second, the occurrence of a block of it in a Vashon Puget till just inside the mouth of the mountain valley of the Hamma Hamma. This block (Fig. 8) was seen in a granite-bearing till in an exposure along the road on the north side of the Hamma Hamma valley in section 8, T24N, R3W. The till block differed from the surrounding orange-colored till in its dark grey color. It had lost some of its hardness but was still harder than the surrounding till.

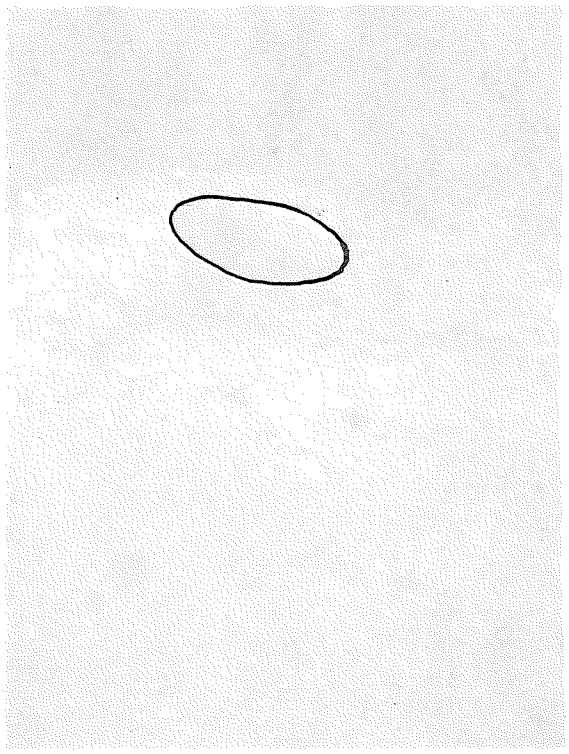
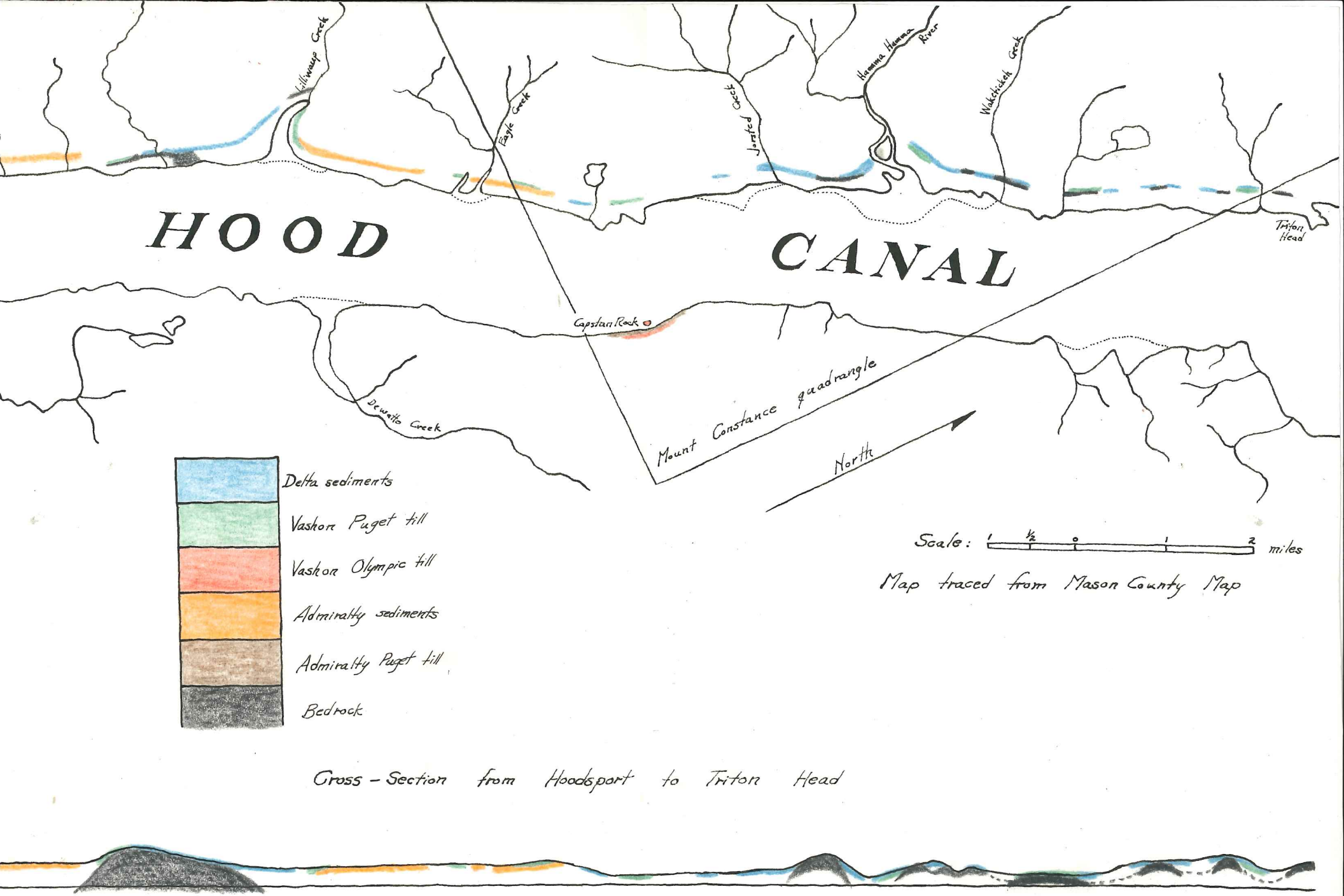


Figure 8. BLOCK OF ADMIRALTY OLYMPIC TILL IN VASHON PUGET TILL

(Note: Color photograph in first copy)



Cross - Section from Hoodsport to Triton Head

DISTRIBUTION OF ADMIRALTY OLYMPIC TILL

The hard grey Admiralty till occurs at widely separated places and at various elevations in the Hamma Hamma valley suggesting its former much greater extent. (See Fig. 3) The largest occurrence of it comprises the previously described 60-foot hill just east of Cabin Creek.

The hard grey till occurs at two localities on the sides of the Hamma Hamma valley: first, at about 900 feet elevation on the spur along the north side of Jefferson Creek; second, at about 1000 feet elevation on the east side of the spur west of Waketickeh valley. This second occurrence is about one mile outside the mountain valley of the Hamma Hamma and may be considered to belong to the Waketickeh valley.

The hard grey till is found in two valleys tributary to the Hamma Hamma. In the Lena valley the till occurs on the east side of the valley in scattered outcrops from 1300 to 1500 feet elevation and on bedrock along the west shore of the lake at about 1300 feet. The till occurs along the east shore of Elk Lake at about 1060 feet, and by indirect evidence described elsewhere, in the valleys tributary to Elk Lake.

INTERPRETATION

From the character and distribution of Admiralty Olympic till it is believed that at the end of Admiralty time the entire Hamma Hamma valley, together with its tributaries, was left with a moraine filling of considerable thickness in places. Then during the interglacial epoch the Admiralty till was indurated so that when the Vashon ice came down the Hamma Hamma valley

the till was resistant enough that it could be broken into blocks which were incorporated as units into the later till. The occurrence of one such block has been described above. The present small scattered remnants of Admiralty till are remnants left after Vashon glacial erosion plus post-glacial river erosion had removed most of the earlier till.

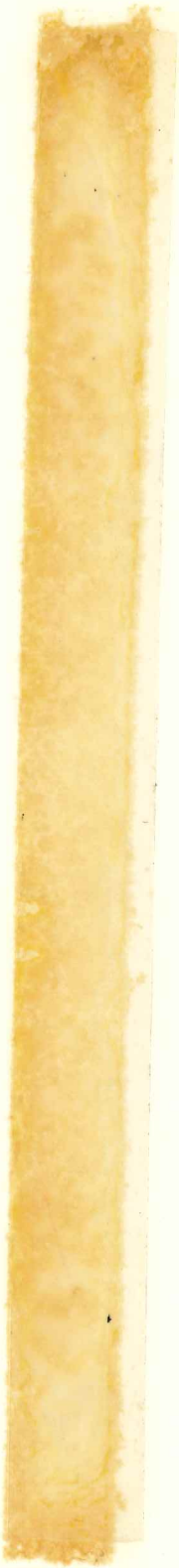


Figure 9. MAP AND CROSS-SECTION OF EXPOSURES ALONG HOOD CANAL

SECTION AT SEA LEVEL ALONG HOOD CANAL

The accompanying map and cross-section (Fig. 9) of exposures along the west side of Hood Canal show the relations between four formations: (1) pre-glacial bedrock, (2) Admiralty sediments, (3) Vashon Puget till, and (4) post-glacial Olympic delta sediments. Along the east shore of Hood Canal there are exposed two additional formations: Admiralty Puget till and early-Vashon Olympic till. These six formations will be discussed in order according to age.

Pre-Glacial Bedrock: The bedrock exposed both north and south of the mouth of the Hamma Hamma River is basalt of the Metchosin formation, locally well polished and grooved by glacial action. Bedrock cliffs south of Lilliwaup Creek are composed of sediments of the Oligocene Blakeley formation. (17) These outcrops also show the effects of glacial erosion.

Admiralty Till: Description will be postponed until the section on early-Vashon Olympic till in order to contrast the two adjacent tills.

Admiralty Sediments: There is a series of sediments exposed along Hood Canal which differs from any occurring in the Hamma Hamma valley or on the flat extending out from the Olympics. The sediments are poorly sorted gravels with some sandy and clayey layers, grading into all clay. They are fairly well compacted, being able to stand in nearly vertical cliffs 30 feet or higher. But the pebbles are not cemented

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17. Weaver, op. cit., plate 7C

together and easily fall out of the cliff leaving their molds in the silty matrix. The color is in general orange. Horizontal orange bands are common, invariably showing sharp top boundaries and gradational lower boundaries, indicating that they are weathering bands. In the most southern occurrence of the formation here mapped the banding is very pronounced, suggesting alternate periods of weathering and deposition. The pebbles are deeply weathered. Some are completely disintegrated. Most of the rock types are from the Olympics but there are enough foreign pebbles to indicate a Puget Sound origin for the sediments.

It is difficult to determine whether the rough stratification is sheeting in till or due to deposition in water. Cross-bedding in local zones indicates water action but the presence of moving ice is indicated by crumpled clay seams. Deposition probably went on under conditions of a retreating ice front.

On the basis of the physical features and degree of weathering the above-described sediments are believed to be Admiralty sediments as defined by Bretz. (18)

Early-Vashon Olympic Till: Bretz has described (19) an occurrence, on the east side of Hood Canal, of an Olympic till overlying weathered Admiralty drift and overlain by Vashon drift. The Olympic till is distinctive in being dark colored, very firm, without granites, composed of subangular instead of

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18. Op. cit., p. 178-194
19. Op. cit., p. 221-222

rounded pebbles, and noticably fresher than the underlying Admiralty till. Bretz stated that the position of the till

> "directly above the old weathered Admiralty drift shows that deployment of Olympic glaciers had filled and crossed the pre-Vashon Hoods Canal trough, before the Cordilleran ice entered the field. The position of this till, in failing to lie opposite a valley from the Olympics, is evidence that a piedmont condition of the deployed Olympic ice was attained, to be later destroyed by the Cordilleran Glacier from the north." '20)

Bretz described a ten-foot sea stack, carved in a block of the Olympic till, which had fallen from an outcrop about 40 feet above tide. The stack is located on the beach in the north part of section 11, T23N, R3W, and is shown on the United States Coast and Geodetic Survey chart #6460 as Capstan Rock.

Only two till sheets are visible from the beach. They differ strikingly in color; the lower being light and the upper, dark. Upon close examination by the present writer the two tills were found to differ in the following qualities:

LOWER TILL, considered Admiralty by Bretz:	UPPER TILL, considered Vashon Olympic by Bretz:
orange matrix (silty)	grey matrix
well rounded pebbles	subangular pebbles
abundant granites	granites rare but not absent
very little compacted	nearly as hand as cement
weathering: white "skins" and "rinds" present	no "skins" or "rinds" seen
wide variety of rock types small proportion of Metchosin types	majority are Metchosin types remainder are sandstones occurring in Olympics

No exposures of this distinctive Vashon Olympic till were found anywhere in the 15 miles mapped along the west shore of Hood Canal.

The induration of the Vashon Olympic till is an interesting but unsolved problem, probably related to the unduration of the Admiralty Olympic till within the Hamma Hamma mountain valley. The fact that no Puget tills of any age show such great induration suggests that there may be something in the composition of Olympic tills which results in their induration. Calcium carbonate cement was looked for but not found.

Vashon Till: A thin cover of Vashon Puget till is found overlying bedrock and Admiralty sediments as shown on the accompanying map and cross-section. Where Vashon till overlies Admiralty clays the effect of the thrust of the moving ice is evident in the crumpled laminations of the clays. Slickensides, upon which there has been subsequent growth of manganese, were also developed in the clays.

Post-Glacial Olympic Deltas: The Hamma Hamma River and adjacent streams flowing into Hood Canal have built deltas into its former higher level as Lake Hood. The deltas of the Olympic streams are not all at a single level. Numerous levels are represented. The delta of Jorsted Creek stands at about 75 feet elevation. The Hamma Hamma delta stands at about 300 feet.

The delta sediments are well rounded, fresh, little compacted gravels and sands, often stained orange from surface weathering. Granites and other foreign rock types are abundant in the delta sediments. Dark, iridescent manganese stains

were seen on some of the delta gravels, especially those of Jorsted Delta where the under sides of all the pebbles were so stained.

There is evidence in the intercalation of till and the presence of disturbed strata in the Jorsted Delta that ice was near during its formation. Elsewhere Olympic gravels overlie Puget till and are the youngest sediments in the region.

Usually only the foreset and topset beds of a delta appear in any exposure, but where silts occur near delta sediments they may be considered bottomset beds of the adjacent deltas, provided there is no overlying exposure of till to prove their interglacial origin.

POST-GLACIAL DRAINAGE CHANGES

The retreat of the Vashon ice left the drainage unadjusted over the 500-to-700-foot flat extending outward from the Olympic Mountains. Parts of the flat still remain in a condition nearly unaltered from the surface of Vashon ground moraine. Some of the Olympic streams have been accidentally superposed on rock in cutting down into their aggraded valleys in post-glacial time. The lower courses of the Hamma Hamma and the Waketickeh are in rock gorges. Lilliwaup Creek, whose mouth is about two miles south of the border of the Mount Constance sheet, flows over bedrock in a waterfall just before entering Hood Canal.

Bedrock obstructions in the lower courses of some of the Olympic streams have placed such streams at a disadvantage and made their headwaters subject to capture by unobstructed streams. One such capture has been committed by Jorsted Creek at the south end of the previously-described channel behind the 1608-foot hill. There Jorsted Creek has captured one of the mountain tributaries of Lilliwaup Creek and diverted it with more than a right angle turn to flow northward behind the 1608-foot hill. The capture of a Lilliwaup tributary was made possible by the holding up of the stream at Lilliwaup Falls.

The contrast in surface appearance between the swampy area drained by Lilliwaup Creek (shown at the southern edge of the Mount Constance sheet) and the well drained area tributary to Jorsted Creek is also due to the obstruction of Lilliwaup Falls.

SUMMARY OF THE GLACIAL HISTORY OF THE HAMMA HAMMA VALLEY

Little is known of the Admiralty glaciation of the Hamma Hamma valley other than that the Puget ice probably did not penetrate into the valley and that a considerable covering of till of local origin was left on the floor and valley sides of the Hamma Hamma and some of its tributaries.

During the retreat of the Admiralty ice, aggrading meltwater streams built up a plain of fluvial sediments in the Puget Sound Basin. Some of these sediments still remain in favorable locations along the west shore of Hood Canal.

During the interglacial epoch the Matlock Pathway River, to which the Hamma Hamma River was tributary, flowed south along the course of Hood Canal.

At the beginning of Vashon time an alpine glacier moved down the Hamma Hamma valley and out beyond the mountain front where it coalesced with other Olympic alpine glaciers to form a small piedmont glacier which extended at least five miles beyond the mountain front. This early piedmont lobe of Olympic ice was obliterated by the greater mass of the Cordilleran lobe from the north.

At the maximum of Vashon glaciation the Puget ice, standing at about 2000 feet at the mouth of the Hamma Hamma valley, had sufficient elevation to push up into the valley a mile or so against the outflowing Hamma Hamma glacier.

During the melting of the Vashon ice there was a stage when the terminus of the Hamma Hamma glacier stood at a position about three miles in from the mouth of the mountain

valley long enough to build a terminal moraine and to form a valley train in the lower Hamma Hamma valley extending down to the Puget ice at some unknown location near the mountain front.

With further melting and retreat of both the Hamma Hamma glacier and the Puget lobe, the Hamma Hamma River cut down through valley train sediments and ground moraine to become superposed, in its lower course, on bedrock of its former valley side. At the same time the Hamma Hamma River was building a delta into the lowering Lake Hood in the Hood Canal trough. When the Vashon ice had melted north far enough to open connection between Hood Canal and the Strait of Juan de Fuca, the present base level was reached at which the Hamma Hamma River has since built a delta extending half way across Hood Canal. The estuary of the Hamma Hamma River was subsequently created by slight submergence of the entire Puget Sound region.

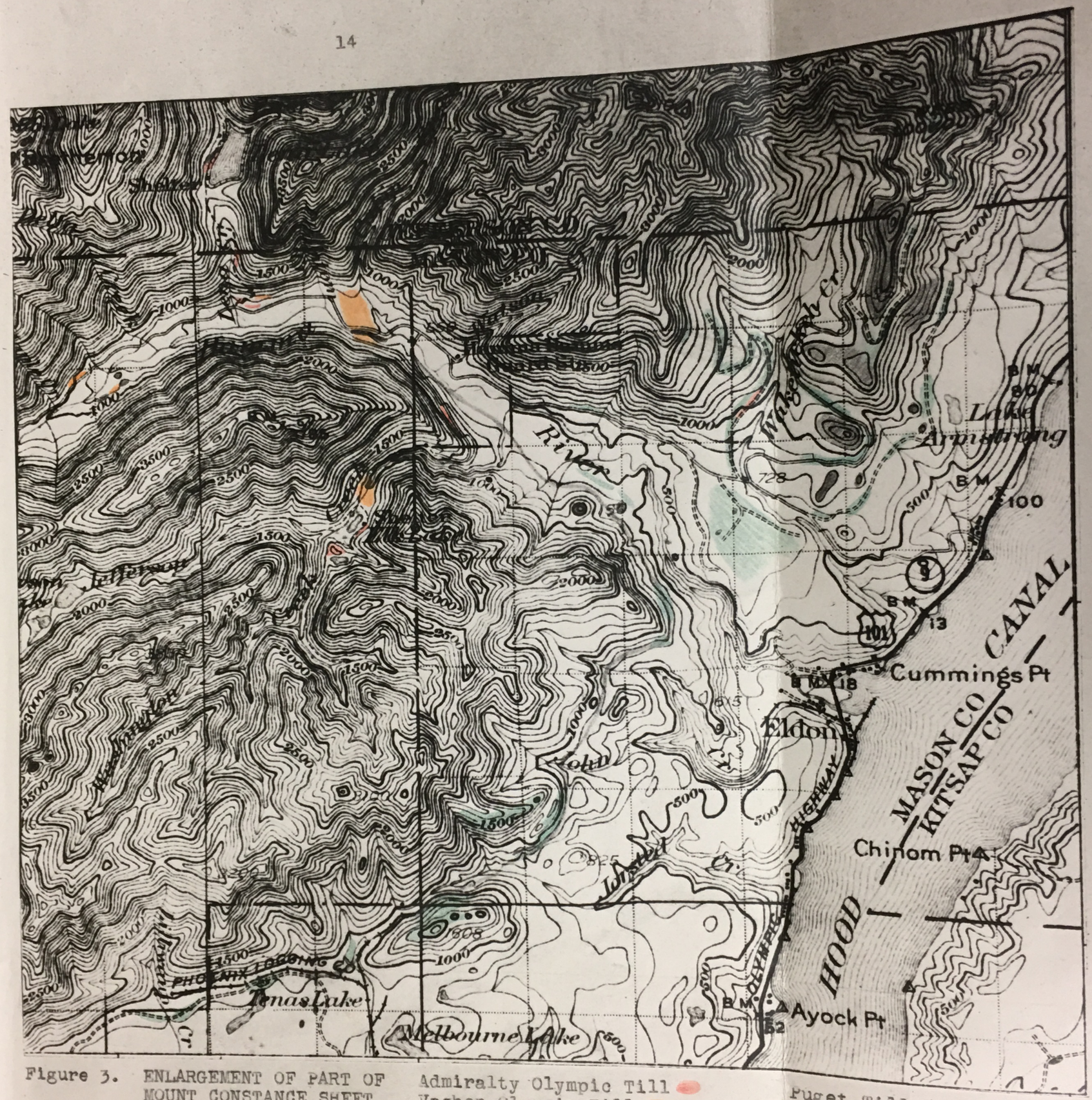


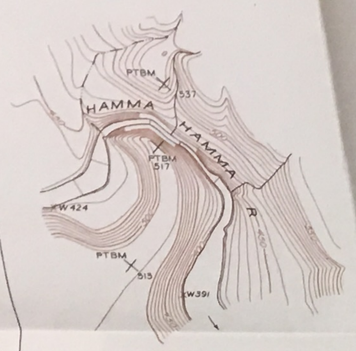
Figure 3. ENLARGEMENT OF PART OF MOUNT CONSTANCE SHEET

Admiralty Olympic Till
Vashon Olympic Till
Puget Till (Ad., Vashon)
Bedrock

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLAN AND PROFILE OF
HAMMA HAMMA RIVER AND TRIBUTARIES, WASHINGTON
DAM SITE

SHEET A

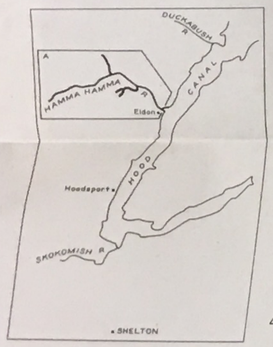


DAM SITE
(3.5 M.)

Scale 1:4800 or 1 inch = 400 feet
400 200 0 400 800 1200 Feet

Contour interval on land 10 feet
Contour interval on river surface 5 feet
Datum is mean sea level
Topography by Arthur Johnson
Surveyed in 1937

TO UPPER LENA LAKE
East Fork
BOY SCOUT CAMP
PTBM 1829
Lena Lake
Lena Lake Shelter
1774
OLYMPIC NATIONAL FOREST
JEFFERSON CO
MASON CO
SIXTH STANDARD PARALLEL
T 25 N
T 24 N
NORTH
JEFFERSON CO
MASON CO
Lena Cr
Phantom Cr
Cabin Cr
Lee Cr
RIVER
Hamma Hamma Guard Sta
PTBM 633
Watson Cr
HAMMA HAMMA
Delta Cr
Skaar Cr
Maple Cr
PTBM 1109
Scotch Pine Cr
PTBM 687
Boulder Cr
Whitehorse Cr
PTBM 1565
PTBM 1978
PTBM 1680
DAM SITE
PTBM 529
Waketickeh Cr
PTBM 722
Jefferson Creek
PTBM 1061
PTBM 1192
Elk Lake
Elk Lake Shelter
Washington Cr
R4W
R3W
John Cr
OLYMPIC HY
TO PORT ANGELES
Cummings Point
Elden
TO SHELTON
HOOD CANAL



KEY MAP OF PLAN SHEETS

PROFILE

Scale: Horiz. 1½" = 1 mile
Vert. 1" = 200 feet

Legend for map and profile:
- Recent alluvium
- Jefferson Creek gravels
- Outwash gravels
- Vashon Olympic moraine
- Puget Till

Topography by W.C.G. Senkpiel and G.W. Crippen
Surveyed in 1932 and 1936

23½°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1936

Scale 1:63,360
2 Miles
8,000 Feet
2 Kilometers

Contour interval 20 feet
Datum is mean sea level

DIAGRAM OF TOWNSHIPS

Subject to adjustment

PTBM — Plane table bench mark

(1 plan sheet, 1 profile sheet)

Printed in 1938

SHEET A