OIL AND GAS IN THE WESTERN PART OF THE OLYMPIC PENINSULA, WASHINGTON.

By CHARLES T. LUPTON.

INTRODUCTION.

High-grade paraffin oil is reported to have been discovered in the western part of the Olympic Peninsula, Wash., as early as 1881. Since then attempts to obtain oil or gas in commercial quantities by drilling have been made from time to time in different localities in this region, but without success. Within the past few years interest has been aroused in oil seeps near the mouth of Hoh River and in gas vents in other parts of the field to such an extent that many persons have been attracted to this country to search for oil and gas. As a result of this interest and on account of the fact that efforts had been made to lease tracts of land for this purpose in the Queniult Indian Reservation, an examination of this region was made by the United States Geological Survey at the request of the Office of Indian Affairs. The results of the investigation, which are enumerated below and which are discussed in detail throughout this report, suggest that certain parts of the field are worthy of careful consideration by oil operators. The following summary includes the most important facts regarding the area examined:

High-grade paraffin oil issues from two seeps near the mouth of Hoh River, and at other localities oil-saturated sandy clay ("smell mud" of the Indians) is exposed. Natural gas containing about 95 per cent methane escapes from a conical mound just north of the mouth of Queniult River and also from an inverted cone-shaped water-filled depression on Hoh River a short distance west of Spruce post office. Other minor gas vents are also known in this field and are described in detail in this report. Three wells—one in the reservation about 1 mile north and slightly west from Taholah, another near the mouth of Hoh River, and the third about 1 mile south of Forks—are being drilled for oil and gas. So far as drilling has progressed none of these wells have encountered oil in paying quantities, but all of them have struck small amounts of gas. A

study of the structure and stratigraphy in addition to the examination of oil seeps and gas vents reveals the fact that several anticlines, which may serve as reservoirs for oil and gas, exist in the area examined and that they have apparently a close relationship to the oil seeps and occurrences of "smell mud."

FIELD WORK.

The information set forth in this report was collected during an eight weeks' reconnaissance in 1913. Although the field work in this region was done primarily in order that the Queniult Indian Reservation, which includes about one-third of the area shown on the accompanying map (Pl. II, p. 78), could be classified with regard to coal, oil, gas, and other minerals, yet it was necessary to make a careful study of the area surrounding the reservation, because it contains the oil seeps and the localities from which are obtained many of the data that make possible an interpretation of the stratigraphy and structure in the reservation.

Field examination, which was entirely reconnaissance in character, was made on foot and by canoe, as it was impracticable to use horses to much advantage on account of the few and poorly constructed trails and roads and the presence of an almost impenetrable growth of underbrush. The best and most continuous exposures occur along the coast and the larger streams. The coast and the valleys of Humptulips, Moclips, and Hoh rivers were traversed on foot, whereas canoes were used in the reconnaissance of Queniult, Queets, and Clearwater rivers. In attempting to traverse the streams by canoe it is advisable to procure the services of men who are well acquainted with the various streams, as dangerous log jams and "skukemchucks" (bad rapids) are rather numerous. All the streams heading in the Olympic Mountains and flowing into the Pacific are so swift that progress upstream can be made only by poling.

The writer did not visit all the outcrops along the routes traversed in the valleys of Humptulips, Moclips, and Hoh rivers, but examined those exposures most easily reached by short side trips from the trails and roads.

The annual rainfall in the Olympic Peninsula is greater than that in any other section of the United States, and for that reason the forests of spruce, fir, cedar, and hemlock, and the underbrush are dense and jungle-like, so that detailed work on the uplands is rendered very slow and tedious and in many places passageways have to be cut through the exceedingly dense undergrowth. Field work away from streams and the coast is unsatisfactory for the additional reason that the older rocks in the uplands are covered almost entirely with a thick mantle of clay, sand, and gravel of Pleistocene age, and this in turn by soil.

The locations of outcrops and places where the dip of the strata was measured are shown approximately with relation to natural landmarks, such as promontories, bends of rivers, and mouths of streams, on Plate II (p. 78). A Gurley compass with clinometer attachment was used to measure the dip of the strata.

ACKNOWLEDGMENTS.

The writer desires to acknowledge the numerous courtesies extended by officers of the Jefferson Oil Co., Big Creek Timber Co., and the Washington Oil Co. The Jefferson Oil Co., which operates near the mouth of Hoh River, and the Washington Oil Co., which operates near Forks, generously furnished the writer with the logs of their wells and other information of value in this report. Residents of the field and many other persons extended courtesies and furnished information which the writer appreciates and for which he can express his thanks only in this general way.

HISTORY OF DISCOVERY AND DEVELOPMENT.

Oil is reported to have been first discovered about 30 years ago on the beach in the vicinity of Copalis Rock, which is about 3 miles north of Copalis and 6 or 7 miles south of Moclips. Persons traversing the beach noticed at this place an offensive odor similar to that of coal oil, and on investigation found that the bluish sandy clay[1] that outcrops here was impregnated with petroleum gas. At certain times of the year the small streams flowing from this locality are reported to have shown "colors" of the oil.

Early in 1901, twenty years after the discovery, the Olympic Oil Co. was organized and began drilling near Copalis Rock. When the drill reached a depth of 160 feet it encountered a strong flow of gas, which burned with a yellowish-white flame 15 feet high. This occurred about the last of April, 1901, and it is reported that in June of the same year oil was struck in small quantities at a depth of 360 feet. This well was drilled to a depth of 850 feet at a cost of about $10,000, and had to be abandoned on account of a crooked hole. Another well was drilled at Copalis to a depth of 350 feet by the Eldorado Oil Co., in the same year. No oil was obtained, but a flow of excellent artesian water was procured and is still used for domestic supplies at Copalis. It is reported that this well penetrates bluish sandy clay for its entire depth, the proportion of sand increasing with the depth.

It is also reported that in 1901 a drilling outfit was taken to the mouth of Hoh River for the purpose of drilling a well in the vicinity but that after several months of useless effort the plan was abandoned.

[1] Sandy clay with the odor of petroleum is called by the Indians throughout this region "smell mud."

In the meantime the west coast of the Olympic Peninsula north of Grays Harbor had been more thoroughly examined and many outcrops of sandy clay partly saturated with petroleum ("smell mud") had been found.

A well was drilled to a depth of about 550 feet at a point approximately in the NW. ¼ sec. 1, T. 27 N., R. 15 W., 3 miles southeast of La Push, in 1902, by the La Push Oil Co. It is reported that the upper 150 feet of the rocks penetrated by the drill consists of shale and gray sandstone, whereas the lower 400 feet consists of bluish sandy clay. All rocks penetrated in this well are reported to have a strong odor of petroleum. "Rainbow" colors in small quantities were seen on the water taken from the well at various stages in the drilling, but no accumulation of oil was discovered, the colors being as noticeable on the water obtained near the top of the hole as from that taken from the bottom. Reagan,[1] who described this well briefly in his report, states that "the side pressure was so great that it caved in the pipes, and the work had to be abandoned without any oil having been obtained."

No drilling was done in the field from 1902 to 1912. Prospectors, however, during this interval were on the alert, and evidences of oil were discovered at various places along the coast between Cape Flattery and Point Grenville, a few miles north of Moclips. Arnold,[2] who examined a part of this field in 1904, in this description of the "supposed Cretaceous" rocks states:

> Indications of oil are also very noticeable in a soft gray sandstone, which may belong to this series, outcropping in a canyon about a mile north of Point of the Arches. This oil has a similar odor to that found in the serpentine and conglomerate a mile or so to the north and may be derived from the shales associated with the sandstone. Indications of oil are also said to have been discovered in the sandstones and shales south of the mouth of Quillayute River and at one or two other localities between the Quillayute and Cape Elizabeth.

Reagan,[3] who made certain studies in the Olympic Peninsula from 1904 to 1908, and who follows Arnold in his description of the formation in this region, says:

> Indications of oil are very noticeable in the soft gray sandstone of this series ("supposed Cretaceous") about a mile south of the Point of the Arches, and also at several locations on the coast south of the Quillayute River. Oil springs also occur on Hoh Head, a mile north of the mouth of Hoh River. Oil is also said to have been found at several places down the coast south of the Hoh.

Near the end of the report Reagan[4] adds:

> Wherever this Miocene formation is exposed there are oil indications, either in the occurrence of the odor of benzine or an allied product of crude oil, or in seepages. The

[1] Reagan, A. B., Some notes on the Olympic Peninsula, Wash.: Kansas Acad. Sci. Trans., vol. 22, p. 234, 1909.

[2] Arnold, Ralph, Geologic reconnaissance of the coast of the Olympic Peninsula, Wash.: Geol. Soc. America Bull., vol. 17, p. 460, 1906.

[3] Op. cit., p. 162.

[4] Op. cit., p. 234.

latter are most prominently developed along the coast from the mouth of the Hoh River to the mouth of the Quillayute River. On Hoh Head, near the mouth of the former stream, oil forms in pools so that one may dip it up with a cup. This oil is said to be one of the best-grade oils ever found, having a 45 per cent paraffin base.

The presence of oil at Hoh Head, as described above, is reported to have been discovered in the winter of 1906–7 by members of a surveying party. The oil was first seen under the root of a stump near a bear wallow. It was not, however, until December, 1911, that any excavation was made. At that time young men of the neighborhood, in an effort to collect some oil, set off a blast which loosened the adjacent rocks and permitted the oil to flow into a prospect shaft. Previous to this time probably not more than 2 gallons of oil had been collected from this seep, which is now generally known as the Jefferson Oil Co.'s seep, as it is situated near the place where that company is drilling. When the writer visited this locality in August, 1913, a well-cribbed shaft about 18 feet deep, 5 feet long, and 3½ feet wide had been made. A section of rocks exposed in this shaft is given on page 47.

Soon after the discovery of the high-grade oil at Hoh Head several companies were organized for the purpose of drilling for oil and gas on the west slope of the Olympic Peninsula. The first to commence operations was the Washington Oil Co., which located a well on the Anderson farm in the SW. ¼ SE. ¼ sec. 9, T. 28 N., R. 13 W., about 1 mile south of Forks, and began drilling in October, 1912, with an 82-foot standard rig. In March, 1914, this well had been drilled to a depth of more than 1,600 feet.

The first showings of oil occurred at a depth of 950 feet, but gas in small quantities was present in practically all strata below a depth of 120 feet. At a depth of approximately 1,300 feet three hard oil-bearing strata, each about 3 feet thick, were encountered. The drillers reported the gas pressure at this horizon to be sufficiently strong to lift the 1,300-foot column of water and to force it about 15 feet above the top of the casing. When the writer visited this well in August, 1913, the drill had penetrated to a depth of about 1,200 feet. The odor of gas was distinctly noticeable 100 yards from the well, especially when the tools were being withdrawn. The gas, which burns with a bluish-white flame 3 to 5 feet in height, could be ignited directly after the hoisting of the bailer from the well, which at that time contained about 1,100 feet of water. Although some gas issued continuously from the well, yet larger quantities escaped when the water was agitated by the removal of the tools.

An oil seep, locally known as the Lacy seep, situated on the divide between Mosquito Creek and Hoh River at an elevation of about 425 feet above sea level, was discovered in the NW. ¼ sec. 11, T. 26 N., R. 13 W., about 5 miles northeast of the mouth of Hoh River.

The oil at this place was first seen in a bear wallow. The oil mixed with mud probably formed an excellent ointment for keeping disagreeable insects away. In June, 1913, a shaft 16 feet deep, 5 feet long, and 4 feet wide was opened.

Both the Jefferson Oil Co.'s seep and the Lacy seep were discovered by following bear trails to their wallows as above stated. It is quite probable that a number of other seeps may be found by the same means. Owing to the great difficulty in traversing the ridges and streams on account of the dense underbrush, fallen logs, and swamps, a thorough examination of this section has not been made and can not be made without a great deal of labor and expense. Although the Lacy seep is only 5 miles directly east of the Jefferson Oil Co.'s seep, and on the same divide, it is almost impossible to go from one to the other in a direct line. The route traveled is about 6 miles longer than the direct distance.

The Jefferson Oil Co. began drilling with a 72-foot standard rig in the SW. ¼ SE. ¼ sec. 12, T. 26 N., R. 14 W., September 10, 1913. They reached, according to report, a depth of about 870 feet by February 1, 1914. This well is situated about 1,800 feet south and slightly west from the seep first described and on the same anticline, which extends in a northeast-southwest direction. When the writer last visited this well, in the early part of October, 1913, the drill had penetrated to a depth of 445 feet. Gas was escaping from the well in small volume, as shown by the bubbling of the water in the casing. There was also a slight trace of oil in the material brought to the surface by the bailer from the bottom of the hole.

The difficulties of drilling in this region are very much greater than in a locality where roads are numerous and are kept in good repair. In order to bring the machinery and lumber to Hoh Head, it was necessary to transport them by boat to the fairly good harbor for small boats situated just south of Hoh Head. Here the scow on which the machinery and lumber were loaded was brought near shore and a donkey engine—a necessary piece of machinery in these timbered countries—was taken to the top of the terrace, about 300 feet high, over a skid road one-fourth mile in length. All machinery was brought over the skid road to the site of the well by means of the donkey engine and a large sled.

At the time the writer examined the field a well was being drilled by the Indian Oil Co. about a mile northwest of Taholah, approximately in the NW. ¼ sec. 35, T. 22 N., R. 13 W., near the Garfield gas mound hereinafter described. A 64-foot rig and a rotary drill propelled by gasoline power was used. Such an outfit seems fairly well adapted for penetrating the soft sandstones and shales already encountered. Drilling was begun at this place in October, 1913, and, according to report, had reached a depth of a little more than 330 feet in January, 1914.

The well originally was 9½ inches in diameter. In order to set a 10-inch casing and leave sufficient space outside the casing for the free circulation of mud and water, which is necessary when drilling with a rotary outfit, the hole is being enlarged to 14 inches in diameter. It is probable that drilling will be resumed before this report goes to press. This well, which is only 10 miles from the terminus of the railroad at Moclips, is most easily accessible to those interested in the field, and probably will be the first well to prove or disprove the presence of oil in connection with the gas escaping from the Garfield mound, the apex of which is only 125 feet S. 30° W. from the mouth of the well.

Gas is present in small quantities in practically all the wells thus far drilled in the field. In addition it is known to be escaping from several natural vents examined by the writer, and is reported from a number of others not visited. The most prominent of the vents examined is the Garfield gas mound, so named because it is situated on the land of an Indian by that name. This mound is located on a terrace about 250 feet above sea level in the NW. ¼ sec. 35, T. 22 N., R. 13 W., a short distance southwest of the Indian Oil Co.'s well near Taholah. This cone-shaped mound is about 50 feet in height and from 250 to 300 feet in diameter at the base. The gas escapes principally from a small mud-filled crater-like depression, 2 to 3 feet in diameter, situated at the apex. Small quantities of gas escape from other vents near the top of the mound. In September and October, 1913, a barrel had been securely anchored with a gas jet fixed in the top over the principal vent, and the gas which collected in the barrel could be burned. A sample of the gas was collected and has been analyzed by the Bureau of Mines. The analysis and a discussion of the characteristics of the gas are given on page 33. The mound has undoubtedly been built up by the mud, which at all times is carried up by the gas and deposited around the mouth of the crater. The age of the mound is doubtful, but it must be recorded in hundreds of years, because the forest is just as dense on the mound as on the adjacent flat land at its base. A spruce tree 3 feet 6 inches in diameter is growing within 25 feet of the vent and an alder 1 foot 3 inches in diameter within 10 feet of the apex.

Another prominent gas vent, the antithesis of the Garfield mound, locally known as the Devils Mush Pot, is situated in the NE. ¼ sec. 35, T. 27 N., R. 11 W., on the south side of Hoh River, about one-half mile west of Spruce post office. The gas here escapes continuously, and in much larger volume than at the Garfield mound, through water which fills a funnel-shaped depression. The "mush pot" is a little less than 60 feet in diameter and is probably 30 feet deep from the level of the water to the apex of the funnel. Although logs and other débris partly fill the depression, yet a pole 22 feet long pushed

vertically into the water did not touch bottom. The gas from this place is almost odorless, burns with a bluish-white flame, and is believed to be of the same quality as that escaping from the Garfield mound. The water through which the gas escapes has a milky color due to the fine sediment continuously brought up by the gas. This minute but continuous erosion, extending through a long period of time, without doubt has produced the funnel-shaped depression.

Gas escapes in a number of places in sec. 8, T. 23 N., R. 9 W., at the upper end of Queniult Lake, and also near by, just above the mouth of Canoe Creek. Although this gas resembles in odor and character of flame that collected from the Garfield mound at Taholah, yet the fact that it occurs near the mouths of streams which have deposited and buried enormous quantities of vegetation suggests that it may be marsh gas and of recent origin. No analysis of the gas from these localities was made.

A small but interesting occurrence of gas was examined by the writer in the NW. ¼ sec. 27, T. 28 N., R. 14 W., on the south side of Bogachiel River, about 7 miles southwest of Forks. On the south side of the stream there is a small landslide of soft bluish-gray sandy clay impregnated with petroleum gas. The gas about 75 feet above river level is so abundant that if a small stick is pushed a foot or more into the soft "smell mud" and then removed it escapes in such volume that it can be ignited and will burn for a few seconds.

A small volume of gas escapes near the bridge over Big Creek just above the mouth of Camp No. 2 Creek, at the extreme south end of the area shown on Plate II (p. 78), in the SE. ¼ sec. 32, T. 20 N., R. 10 W. Some of this gas was collected, but it could not be ignited; hence it is believed that it is different from the gas in other parts of the field.

Gas was noted escaping through the water on Queniult River, a mile or two above Taholah, and also on Hoh River, near Hough's place, in the southern part of sec. 22, T. 26 N., R. 13 W., about 1½ miles southeast of Hoh post office. The character of the gas escaping at these places was not ascertained.

In addition to these gas vents, which the writer examined, some others briefly described below are reported. Gas, according to Billy Snell, of Taholah, escapes around the edge of a spring near the center of sec. 26, T. 27 N., R. 12 W., on the north side of Hoh River, about 8 miles west of Spruce. He states that the water in the spring is milky and that the gas burns very much like that at the Devils Mush Pot, a few miles farther up the river.

The Indians at Taholah report that there are other small gas mounds similar to the Garfield mound at different places in the reservation on both sides of Queniult River. They were not very sure of their locations, as they had seen them only on hunting trips.

It is significant that practically all the seeps and vents already discovered are near trails and small settlements. The writer firmly believes that many other oil seeps and gas vents exist in the area shown on Plate II, and that they will be discovered as more and more of the region becomes accessible by the construction of trails and roads.

CHARACTER OF THE OIL.

The samples of oil collected from the seeps north of Hoh River show that it is high grade and has a paraffin base. In reflected light it has a light to dark green color, whereas in transmitted light the color is dark cherry-red. The odor of the oil as it comes from the seep is very much like that of kerosene. Two samples were collected from the seeps north of Hoh River and analyzed by David T. Day in the Survey laboratory with the following results:

Analysis of crude petroleum from the Jefferson Oil Co.'s seep, in the SE. ¼ sec. 12, T. 26 N., R. 14 W.

Physical characteristics.

Color	Light green.
Odor	Like Pennsylvania oil.
Specific gravity	0.8679.
Equivalent to	31.5° Baumé.

Distillation.

Begins to boil at	103° C.
100° to 125°	½ per cent gasoline.
125° to 150°	7 per cent gasoline.
	7½ per cent gasoline.
150° to 175°	7 per cent kerosene.
175° to 200°	9 per cent kerosene.
200° to 225°	10 per cent kerosene.
225° to 250°	12 per cent kerosene.
250° to 275°	16 per cent kerosene.
275° to 300°	9 per cent kerosene.
	63 per cent kerosene.

Average specific gravity of kerosene, 0.8545.

Mr. Day states that the oil contains no asphaltum and that the residuum yields a large percentage of paraffin wax.

Analysis of crude petroleum from Lacy seep, in the NW. ¼ sec. 11, T. 26 N., R. 13 W.

Physical characteristics.

Color	Dark green.
Odor	Like Pennsylvania oil.
Specific gravity	0.9365.
Equivalent to	19.5° Baumé.

Distillation.

Begins to boil at	190° C.
Up to 250°	4 per cent kerosene.
250° to 275°	10 per cent kerosene.
275° to 300°	14 per cent kerosene.
	28 per cent kerosene.

Mr. Day in commenting on this sample says:

The specific gravity of the kerosene oil fraction is rather high on account of the initial boiling point of the oil. The quality of the distillate, however, is like that of Pennsylvania oil. The oil contains no asphaltum but considerable paraffin wax. The residuum from the kerosene distillate is well suited for the manufacture of lubricating oil and paraffin wax.

The above analyses show that the oil taken from the Jefferson Oil Co.'s seep on Hoh Head is much lighter than that taken from the Lacy seep 5 miles farther east. This difference in specific gravity is believed to be due partly to the character of the rocks through which the oil filters into the seeps. The oil enters the Jefferson Oil Co.'s seep through soft sandy clay, which has some of the characteristics of fuller's earth, whereas the rock through which the oil enters the Lacy seep is much coarser and consists principally of sand and gravel. The oil issuing through the less porous rock, like that at the Jefferson Oil Co.'s seep, probably more nearly represents the oil under thick cover than does the oil issuing through coarser material like that at the Lacy seep, where the lighter, more volatile fractions, such as gasoline, have escaped into the atmosphere, leaving the heavier portions behind to flow into the seep. Not only the absence of gasoline but also the greater specific gravity of the sample collected at the Lacy seep seems to support the statement made above in explanation of the difference in the specific gravities of the two samples.

The oil from this region is unlike the oil from the California fields, which has an asphalt base but resembles that from the Katalla district of Alaska, according to the statement of Martin,[1] who, in discussing the oil of the Katalla district, says: "The petroleum is clearly a refining oil of the same general nature as the Pennsylvania petroleum. It resembles the latter in having a high proportion of the more volatile compounds and a paraffin base and in containing almost no sulphur."

CHARACTER OF THE GAS.

Gas from the Garfield gas mound was analyzed by George A. Burrell in the laboratory of the Bureau of Mines, with the following results:

Analysis of natural gas from the Garfield gas mound in the NW. ¼ sec. 35, T. 22 N., R. 13 W.

	As received.	Air free.
Carbon dioxide	2.67	2.67
Oxygen	.28	.00
Methane	94.38	95.65
Ethane	1.52	1.54
Nitrogen	1.15	.14
	100.00	100.00

[1] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, p. 124, 1908.

The heating value of this gas at 0° C. and under 760 millimeters pressure is 1,305 British thermal units. Its specific gravity is 0.72 of that of air.

Mr. Day, who also examined this gas, states: "The gas has none of the odor characteristic of marshy emanations and gives evidence of being deep-seated gas, although there is no odor of oil or other indications of its being connected with oil."

As heretofore stated, the gas escaping from the Devils Mush Pot, near Spruce post office, and also that escaping in sec. 8, T. 23 N., R. 9 W., at the upper end of Queniult Lake, are similar, in regard to odor and character of flame, to the gas collected from the Garfield mound, the analysis of which is given above.

GEOGRAPHY.

LOCATION AND ACCESSIBILITY.

The area examined, which is shown on Plate II (p. 78), lies on the west slope of the Olympic Peninsula (see fig. 1) and is bounded by meridians 123° 45′ and 124° 40′ W. and parallels 47° 8′ and 48° N. It is approximately 60 miles long, from north to south, and about 25 miles wide from east to west.

The southern part of the field, extending as far north as the Clearwater River basin, is most easily accessible from the Northern Pacific Railway, which has its western terminus at Moclips, situated on the coast at the mouth of Moclips River and approximately 163 miles by rail from Seattle. Taholah, a small Indian village at the mouth of Queniult River, and other settlements along Queets and Clearwater rivers can be most easily visited by following the beach at low tide to the mouths of these streams. There is a fairly good wagon road from Moclips to Taholah, but northward from this place almost to the northern edge of the area shown on Plate II, in the vicinity of Forks and Quillayute, there are no wagon roads. Persons desiring to enter this country must either travel on foot or horseback along the beach and the very poor trails which lead into the interior. The settlements along the rivers are, however, most easily reached from the mouths of the streams by means of canoes. An automobile stage connects Aberdeen and Hoquiam with Humptulips. Between Humptulips and Queniult Lake there is a poor wagon road, but the State is now constructing a highway, which, it is planned, will be extended northwestward to the vicinity of Clallam Bay and from that locality eastward around the peninsula.

The settlements on Hoh River and also those in the vicinity of Forks and Quillayute are tributary to Seattle by way of Clallam Bay. A daily mail stage connects Mora, a few miles from the coast on Quillayute River, and Forks, in the northern part of T. 28 N., R. 13 W.,

with Clallam Bay, which has daily steamer connections with ports on Puget Sound. Clallam Bay is estimated to be approximately 125 miles by boat from Seattle. It is 31 miles or a day's ride by stage from Clallam Bay to Forks, at the northern extremity of the

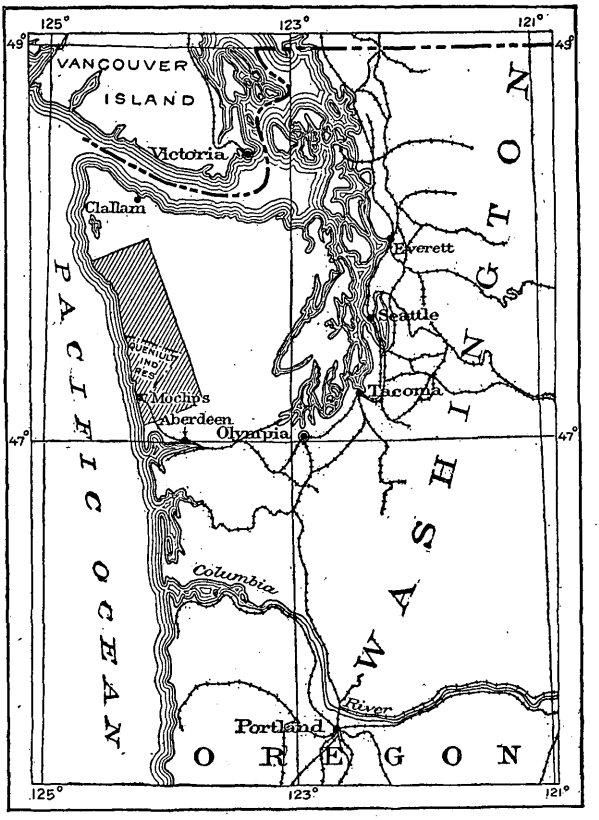


FIGURE 1.—Index map of western Washington, showing location of area examined.

field. The principal trails in the interior of the field are shown on the map (Pl. II, p. 78). Away from these trails traveling is exceedingly difficult and in many places almost impossible on account of the dense growth of timber and underbrush.

WATER RESOURCES AND VEGETATION.

This field is included in one of the areas of greatest rainfall in the United States. At Tatoosh Island, just off Cape Flattery, 25 or 30 miles northwest of this area, the mean annual rainfall for 22 years is about 88 inches. Near the center of this field, at Clearwater post office, the average annual rainfall for 10 years is a little more than 128

inches. The mean annual precipitation at Aberdeen, which is situated about 15 miles south of the field, for a period covering 11 years, is in excess of 86 inches. From these figures it seems safe to assume that the mean annual rainfall in the area shown on Plate II is at least 100 inches. The natural result of this great precipitation, combined with a mean temperature of about 49° F. and extremes of temperature ranging from 11° to 100° F., is that dense forests of spruce, fir, cedar, and hemlock, with an almost impenetrable growth of underbrush, consisting of salal brush, salmon berry, devil's club, and other bushes, cover the greater part of the field, with the exception of a few comparatively small "burns" and "prairies." The latter name is applied to open spaces in the forests where the larger vegetation has not existed recently and where considerable farming is carried on. Good examples of these are the Humptulips and Forks "prairies," situated at the south and north ends of the field, respectively.

The large annual precipitation above mentioned necessarily makes all the streams perennial. Humptulips, Queniult, Queets, Clearwater, Hoh, Quillayute, Bogachiel, Calawa, and Soleduck rivers and many of the larger creeks are navigable for canoes throughout the greater part of their courses in this field, and many of them can be used to good advantage as logging streams. Hoh River, which has the highest gradient and swiftest current, is rather dangerous for canoeing, especially in its upper course. Logging is extensively carried on along Humptulips River. Moclips River, which is a comparatively small stream, flows through an excellent cedar forest and is used to float shingle bolts to the mill which is situated at Moclips, near the mouth of the stream.

Queniult Lake, situated at the east end of the Queniult Indian Reservation, is about 200 feet above sea level and has an area of approximately 6 square miles. It derives its water from the upper part of Queniult River, Canoe Creek, and several smaller streams, and is drained by the lower part of Queniult River.

TOPOGRAPHY.

The topography of the area shown on Plate II (p. 78) ranges from flat lands at many places near the coast to mountains 20 to 30 miles inland. The greater part of the area is included in an uplifted, much eroded, and somewhat terraced coastal plain of Pleistocene age, in which swift mountain streams have entrenched themselves. The larger rivers have not only cut through the Pleistocene deposits, which are 100 to 300 feet thick, but have also eroded their channels in the underlying, more resistant Miocene and older formations, whereas the smaller rivers and creeks have not yet cut through the Pleistocene cover. In places along the coast this old plain has been

raised above sea level as much as 400 feet, but at other localities the uplift is not so great. The valleys of the larger rivers, the Queets and the Hoh, are marked by at least two prominent terraces. Precipitous cliffs, ranging from 50 to 300 feet in height, are numerous along the coast and at many places along the principal streams. In places the watersheds consist of broad, swampy uplands into which the minor streams have not penetrated, thus suggesting that the topography is still comparatively young. The relief ranges from sea level to 1,500 feet or more at the tops of the high ridges in the vicinity of Queniult Lake on the eastern edge of the area. The terraced lowlands slope with slight breaks from the base of the mountains to the coast, whereas the mountains rise almost precipitously from the floor of the old coastal plain.

In the vicinity of Queniult Lake the topography is typical of that of glaciated areas. In fact, the basin of Queniult Lake itself is believed to be due to a glacier, which emerged from the Olympic Mountains through the U-shaped valley of the upper Queniult River, and which deposited the moraine that now forms the dam at the lower end of the lake. The present topography in the northern and northeastern parts of this field is believed to be partly due to glaciation.

STRATIGRAPHY.

CHARACTER AND AGE OF THE ROCKS.

The surface rocks of the greater part of the area represented on Plate II consist of poorly consolidated clay, sand, and gravel of Pleistocene age. Rocks of the older formations are rarely exposed, except along the coast and the larger rivers. The smaller rivers and creeks in but few places have cut through this Pleistocene veneer except near the coast and the mountains, where it is comparatively thin.

The older rocks in the field, which are unconformably overlain by the Pleistocene material, as stated above, are exposed only along the coast and the larger streams. Arnold,[1] who examined the north coast and the greater part of the west coast of the Olympic Peninsula in 1904, classes the rocks outcropping on the west coast between the northern edge of the area shown on Plate II southward to a point about 1 mile north of Cape Elizabeth (location H), as "supposed Cretaceous." He states that they—

> consist almost entirely of a coarse gray sandstone with occasional zones of black shale and rarely a little conglomerate. The thickness of the formation is probably over 5,000 feet, although, owing to its complex structure, this is only a very rough approximation. The series is characterized by calcite veins, which are abundant in nearly all of the exposures. The shales carry some lignite at two or three places, at one locality in particular the coal being used locally for domestic purposes.

[1] Arnold, Ralph, Geological reconnaissance of the coast of the Olympic Peninsula, Wash.: Geol. Soc. America Bull., vol. 17, pp. 459 and 460, 1906.

He then continues with a discussion of evidences of oil in this formation, as quoted on page 26 of this paper.

In this same report Arnold [1] describes three formations—Crescent, Clallam, and Queniult—which lie between the "supposed Cretaceous" below and the unconformable, poorly consolidated Pleistocene beds above. The Crescent formation is assigned to the Eocene series and is described as consisting of "a 1,200-foot series of black basalt and greenish basalt tuffs and tufaceous sands found in the vicinity of Port Crescent" on the north coast.[2] No outcrops of this formation were recognized in the area shown on Plate II (p. 78).

The Clallam formation, which he assigned to the Oligocene and Miocene series, is described as follows:

> Resting unconformably upon the Eocene and older rock of the Olympic Peninsula is a series of conglomerates, sandstones, and shales rich in fossils and extensive in occurrence. The formation is well exposed between Clallam Bay and Pillar Point to the east and for that reason is here named the Clallam formation. * * * A portion of the formation is unquestionably the equivalent of the Astoria sandstones and shales occurring at the mouth of the Columbia River, 130 miles farther south.

The rocks exposed in the hills south of Bogachiel River, according to Arnold, belong to the same formation. He also believes that the thickness of the formation in the vicinity of Cape Flattery is approximately 15,000 feet. Continuing the description of this formation at the type locality, Arnold states:

> The conglomerates of the series are usually quite coarse and hard and consist of pebbles and cobbles of quartzite, jasper, black slate, and occasional granitics. They are found mostly at the base and near the top of the series along the straits and in the middle of the series on the Cape Flattery promontory. * * * The sandstones of the Clallam formation are for the most part thin bedded, hard, and resistant to erosion, and are extremely fossiliferous in certain localities, notably east of Clallam Bay. * * * The shale of the Oligocene-Miocene occurs principally in the middle of the formation along the strait (Juan de Fuca). The lower part of the shale is thinly and plainly laminated, but higher up becomes almost massive clay. * * * The shale is gray in fresh exposures, but becomes more or less oxidized upon exposure. * * * Coal occurs in the sandstones east of Clallam Bay, in the upper part of the Oligocene-Miocene series, and in the base of the same series in the vicinity of Freshwater Bay.

No coal of economic value is known to be present in the area represented on Plate II.

The Queniult formation, which Arnold assigns to the Pliocene,[3] outcrops in—

> a great syncline between Capes Elizabeth and Grenville, through the trough of which Queniult River empties into the sea. The formation in which this syncline is devel-

[1] Arnold, Ralph, op. cit., pp. 460–465.

[2] In a later report by Arnold and Harold Hannibal (The marine Tertiary stratigraphy of the north Pacific coast of America: Am. Philos. Soc. Proc., vol. 52, No. 212, p. 573, and correlation table opposite p. 604, 1913) the Crescent formation is considered to be the stratigraphic equivalent of the Arago formation.

[3] In the report of Arnold and Hannibal, published in 1913 (op. cit., pp. 589, 591, 592, and table opposite p. 604), the Queniult formation is stated to be of Miocene and Pliocene age and to include the stratigraphic equivalents of the Empire and Merced formations.

oped is therefore named the Queniult. The Queniult consists of over 2,200 feet of conglomerates and shale, with minor quantities of sandstone. The conglomerates are developed north of the river, while the shale with some underlying sandstone occurs south of it.

Numerous fossils were collected by Arnold in both the Clallam and Queniult formations.

Unconformably overlying the Tertiary rocks above mentioned are the poorly consolidated beds of clay, sand, and gravel of Pleistocene age, which in places are 300 feet or more in thickness. Beds of very poor peatlike lignite occur in these rocks both along the coast and Queniult River.

Weaver,[1] in a preliminary report on this general region, published a map which shows that in his opinion the rocks outcropping on the west coast are principally "undifferentiated lower Miocene," with a few exposures of "pre-Tertiary metamorphics" and a formation of upper Miocene age which he designates the Montesano formation.

The writer collected but few fossils in the field and so has little information to add to the existing knowledge regarding the paleontology of the region. An attempt is made in the discussion of the various rock outcrops to correlate them with the formations named and described by Arnold, a summary of which is given above.

METHOD OF PRESENTATION OF THE GEOLOGIC DATA.

In the study of the stratigraphy as well as the structure of this field outcrops of rocks along the coast and in the valleys of the principal rivers were carefully examined at places indicated by letters on the map (Pl. II, p. 78). The structure at these places is shown by dip and strike symbols. Wherever anticlines or upfolds are present lines indicating their axes are shown. The anticlinal axes are not extended far from known outcrops.

It seems advisable in a report on this region, where information regarding the character and thickness of the formations is so meager, to describe the outcrops principally by districts rather than by formations and groups. So in the following discussion the writer has described the outcrops of rocks and their structure in regular order along the coast from south to north—from Copalis to a point about a mile north of Hoh Head—and along the streams from their mouths toward their sources. The rocks that outcrop on the coast are described first. Then follows the description of the rocks examined along the rivers and creeks. In describing these outcrops the stream valleys are considered in order from south to north as follows: Humptulips River, including parts of Camp No. 2 and Stevens creeks; Moclips River, Queniult River, Queets River, including parts of Salmon River and Mathney and Sams creeks; Clearwater River as far

[1] Weaver, C. E., A preliminary report on the Tertiary paleontology of western Washington: Washington Geol. Survey Bull. 15, Pl. A, 1912.

east as the west boundary of the Olympic National Forest, Hoh River, and parts of Bogachiel and Calawa rivers at the extreme north.

ROCKS EXPOSED ALONG THE COAST FROM COPALIS TO HOH HEAD.

The rocks exposed along the coast between Copalis and Hoh Head are believed to include the "supposed Cretaceous," the Queniult formation (now regarded by Arnold as of Miocene and Pliocene age), and beds of clay, sand, and gravel of Pleistocene age, in addition to a small upfaulted block of the metamorphic rocks in the vicinity of Point Grenville. Some of the rocks exposed at a few localities are very similar to those described by Arnold as belonging to the Clallam formation, of Oligocene and Miocene age.

From Copalis north to a point a short distance south of location A, near Copalis Rock, the beds exposed along the coast are almost flat-lying, poorly consolidated rocks of Pleistocene and Recent clay, sand, and gravel. The rock exposed at location A, near Copalis Rock, consists of a bluish sandy clay, which in places gives off an odor of petroleum. Large fragments of dark conglomerate, greenstone, gray limestone, and coarse gritty sandstone, all cut by thin irregular veins of quartz and calcite, are intermixed with the bluish sandy clay. These fragments come apparently from the "supposed Cretaceous," the same kind of rock as that which constitutes Copalis Rock, which lies about 1,200 feet from shore. The exposure here may be due to upfaulting of the "supposed Cretaceous" rocks or it may be due to a rough surface of the older rocks not wholly concealed by the Pleistocene cover. Owing to poor exposures it was not possible to measure the dip and strike. A well at this locality was drilled for oil in 1901 to a depth of 850 feet but without success, as stated on page 25.

Pleistocene clay, sand, and gravel, forming cliffs in places as much as 75 feet high, are fairly well exposed along the coast between Copalis Rock (location A) and a point about 1 mile east and slightly south of the extreme end of Point Grenville (location D). For the most part these beds lie flat, but here and there dips are noticeable. At location B soft yellow and gray sandstone that dips 3°–4° SE. and strikes N. 55° E. is exposed. About a mile farther north, at location C, the beds consist of chocolate-colored to yellowish, soft argillaceous and conglomeratic sandstone which dips about 4° NE. and strikes N. 65° W. Just north of the mouth of Moclips River the beds lie practically flat.

In the vicinity of Point Grenville (locations D and E) there are metamorphic rocks which are believed to be in an upfaulted block of the old metamorphic rocks that constitute the core of the Olympic Mountains. These strata which show along the coast from location D to location E are very much broken by faults. A number of large castle-like rocks, situated from a few hundred feet to possibly as much

as a mile offshore, probably belong to the same formation. At location D numerous fragments of metamorphic rocks, some of which seem to be in place, lie along the beach. The beds dip 40° N. and strike N. 65° W. Little more need be said than that these old rocks which form Point Grenville consist partly of conglomerate, sandstone, and slate, much faulted and broken and cut by veins of quartz.

In the southwestern part of sec. 18, T. 21 N., R. 12 W., a few hundred feet west of the road leading from Moclips to Taholah, some very much faulted rocks which are believed to be a part of the Queniult formation are exposed. These rocks are situated about halfway between location D and the southern extremity of Point Grenville. At location E there is evidence of a fault trending approximately N. 40° W., separating the older rocks from the Queniult formation to the north. Directly north of this fault there is a prominent slide due to fractures in the strata adjacent to the fault.

Between locations E and F strata of the Queniult formation are well exposed. For a short distance north of location E the beds consist of yellowish-gray conglomeratic sandstone that lies almost horizontal for about 200 yards; the dip then increases gradually to as much as 25° N. and the strike is N. 85° W. A short distance farther north an overlying soft, friable concretionary yellowish-gray sandstone dips only 21° and strikes practically east. A short distance south of the point where the Taholah-Moclips road descends to the beach the massive conglomeratic sandstone beds of the Queniult formation are terminated abruptly by a small fault. For a short distance north of the fault along the coast they seem to be replaced by soft, sandy clay, gravel, and conglomerate which lie nearly flat. A little farther north the dip of these beds increases from 5° to 25° S., thus forming a small syncline a short distance south of the point where the road leaves the beach between locations E and F. The Queniult formation in this locality is stained a yellowish color by limonite, which has seeped from the overlying Pleistocene beds. Between the point where the Moclips-Taholah road descends from the upland to the beach and location F these strata are very much disturbed, being broken by small faults and folds and in places dipping as much as 62° NE. From point Grenville to location F these rocks are capped by Pleistocene clay, sand, and gravel, in places as much as 100 feet thick. Near the base of this material springs are fairly numerous. Between location F and Taholah the surface rocks along the coast consist of Pleistocene and Recent sand, gravel, and clay. From location G, just north of the mouth of Queniult River, to location H, about a mile north of Cape Elizabeth, the Queniult formation is again well exposed. At location G the formation consists of yellowish-gray sandstone and conglomerate

interbedded. Conglomerate seems to be more abundant in this locality than in the same formation south of the river. A short distance north of location G the beds dip 21° SE. and strike N. 35° E. About one-fourth mile northwest of location G the beds dip about 13° SE. and strike N. 60° E. From this point northwestward the beds dip at slight angles to the south and then gradually flatten and continue nearly horizontal to a point a short distance south of location H, where the dip increases to 10° SE. and the strike is N. 20° E., the bed being approximately the same as that on which the dip and strike were measured at location G. Just south of location H the Queniult formation dips 17° SE. and strikes N. 35° E.

As stated on page 28, the Indian Oil Co. is drilling a well at a point about one-half mile north of location G. The rocks penetrated in the greater part of the well are the same as those exposed on the coast between locations G and H, whereas the black shale at the bottom of the section may be represented at the surface by the dark shale that outcrops in the vicinity of location H. The record of the well given below states the character and thickness of the strata penetrated and also indicates at what depths gas and traces of oil were encountered.

Log of the Indian Oil Co.'s well, in the NW. ¼ sec. 35, T. 22 N., R. 13 W., near Taholah.

[Compiled from the driller's statement.]

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Sand and sandy clay, soft, with soil and poorly consolidated clay, sand, and gravel at top (first gas was encountered at 121 feet and continued to increase to a depth of 295 feet)	155	0	155	0
Sandstone and argillaceous sandstone, alternating with sandy shale; 60 per cent of this material is hard rock	140	0	295	0
Sandstone, brown, very hard	13	7	308	7
Sandstone, soft, very porous (much gas and traces of oil)	13	5	322	0
Sand, very loose	3	0	325	0
Sandstone, coarse	5	0	330	0
Shale, black (contains gas and strong showings of oil)	5	0	335	0

At location H and to the north, for about 1,500 feet along the beach, rocks are exposed which are different from those along the beach between locations G and H. These rocks consist of bluish sandy shale and shaly sandstone interbedded and are somewhat faulted and inclined at different angles. At one place the beds dip 32½° NE. and strike N. 60° W., but in most places it was impossible to obtain good measurements of the dip and strike, owing to slumping and the presence of faults. It is believed that these beds of bluish shale are included in an upfaulted block of the "supposed Cretaceous" of Arnold's classification. The exposures along the coast afford no indication of the inland extent or direction of these faults.

The rocks lying north of the blue shale described above, situated near location H, are in many respects similar to those exposed between

locations E and F, south of the mouth of Queniult River. A few hundred feet south of location I, near the point at which the horse trail descends to the beach, beds of sandstone that dip 31° S. and strike N. 75° E. are exposed. Approximately at location I bluish sandy clay interbedded with yellowish argillaceous sandstone is exposed. These beds dip 19° SE. and strike N. 27° E. A little farther north along the coast soft, friable argillaceous, almost massive sandstone, containing much mica and some concretions, outcrops. It dips 26° SE. and strikes N. 15° E. A short distance north of location I there is an abrupt change in structure, the beds dipping 18° E. and striking N. 5° W. The character of the rocks on which the above measurements were taken is practically the same as that of the rocks at location I.

At location J, in the SW. ¼ sec. 15, T. 22 N., R. 13 W., beds of soft, friable yellowish-gray sandstone are fairly well exposed. They dip 39° SE. and strike N. 50° E. About three-fourths of a mile farther north, at location K, directly north of the mouth of Camp Creek, the formation consists of soft gray sandstone containing concretionary lenses of hard calcareous sandstone. The surface of these beds is stained yellow in many places with limonite. The strata dip 57° SE. and strike N. 27° E. From location K northward along the coast to location L, in the northeastern part of sec. 4, T. 22 N., R. 13 W., the same formation is fairly well exposed. At one place about 1 mile north of location K the beds dip 47° E. and strike N. 10° E. A measurement was made just south of the point where the trail descends to the beach at location L, which shows that the beds dip 10° E. and strike N. 5° E. The rocks consist of friable argillaceous sandstone containing small gray clay balls and a few pebbles of harder material. A short distance, possibly 600 or 800 feet north of location L, the same formation dips 28° SE. and strikes N. 15° E. The rocks at this place more nearly resemble the rocks exposed on the coast near Copalis Rock, location A, a few miles north of Copalis, than do any of the strata exposed between locations A and L. A few hundred feet north of location M, just south of the "Little Hogback," dark sandy clay having an odor of petroleum is exposed. In traversing the coast the writer made a careful examination for this "smell mud," but at no place between locations A and M is any known to be present. The rocks along the sea cliff in this part of the coast have slumped considerably, and in places the unconsolidated Pleistocene materials are intermixed with rocks slumped from the older formations. At some places the strata are very much disturbed by small folds and faults. Just north of the "Little Hogback," at location M, the strata dip 60° SE. and strike N. 35° E. Between location N and the mouth of Raft River the rocks are fairly well exposed. Just south of the

mouth of this stream there is a bold promontory which at high tide is practically an island and in which the water has worn large cavities and tunnels. On this promontory the strata are much contorted, forming, in a distance of 150 yards, two small synclines with an anticline between them. The general dip of the strata at this place is 50° NW. and the strike N. 65° E. Just north of Raft River a massive grayish-blue sandstone is well exposed in a high cliff. It was impossible on account of the massive character of the rock to determine the dip and strike on this outcrop. On one of the small islands near shore, however, the beds dip 53° NW. and strike N. 25° E. About 600 or 800 feet north of the mouth of Raft River a prominent fault trends approximately N. 80° W. and cuts out on the north the massive grayish-blue sandstone described above. The inclination of the fault plane is almost vertical. North of this fault there is a zone about 50 feet wide in which the rocks are very much crushed, so that the dip of the strata could not be determined. These strata in places give off the odor of petroleum. Between locations O and P, a short distance south of the mouth of Kalaloch Creek, the rocks consist of nearly flat-lying beds of clay, sand, and gravel of Pleistocene age, which are stained yellow here and there by limonitic water. A thin bed of very poor lignite is present in these beds about half a mile north of the mouth of Quail Creek.

At location P, just south of the mouth of Kalaloch Creek and about 100 yards from the water's edge at low tide, a massive grayish-brown sandstone, stained yellow in places, is fairly well exposed. It is so massive that it is impossible to determine its dip and strike. The rocks exposed along the coast for about a mile north of the mouth of Kalaloch Creek consist of Pleistocene clay, sand, and gravel, which in places contain some lignite. The best exposure of this material was noted just south of location Q, in the NW. ¼ NE. ¼ sec. 4, T. 24 N., R. 13 W. The greatest thickness of the lignite is 5 feet and it is very impure. It contains many roots, stumps, and branches of trees which have been but slightly altered since their deposition. The cliff at this place is about 60 feet high and is made up of flat-lying strata of Pleistocene age. A short distance north of location Q "supposed Cretaceous" strata are well exposed. They consist of alternating thin beds of dark and light sandy shale and shaly sandstone from 2 to 3 inches in thickness, which dip 50° E. and strike approximately north. For a mile or more to the north along the coast the same formation is well exposed, but at location R these beds abruptly give place to the unconsolidated Pleistocene material for about one-third of a mile. At location R the strata dip 38° SE. and strike N. 12° E. The rocks exposed at location R, just south of the place where the Queets-Hoh trail descends to the beach, consist of

coarse yellowish-brown massive sandstone that contains in places a few pebbles and some hard brown spherical and irregularly shaped concretions, the cementing material of which is iron. At location S, near the center of sec. 28, T. 25 N., R. 13 W., the medium-bedded, yellowish gray "supposed Cretaceous" sandstone, much folded and in places possibly cut by slight faults, is again exposed, dipping in general 55° SE. and striking N. 25° E. At location T, about one-half mile north of location S, the sandstone is yellowish brown, coarse grained, and in places conglomeratic. It dips about 77° SE. and strikes N. 15° E. About one-third of a mile north of location T the beds are also very much disturbed. At one place about 100 yards north of location T the rocks consist of alternating beds of sandstone and shale, which dip 47° SE. and strike N. 18° E. At another place near by hard gray sandstone, locally stained yellow, dips 82° SE. and strikes N. 15° E. At this place all the strata are overlain unconformably by the Pleistocene beds, which in addition to clay, sand, and gravel contain 3 to 4 feet of poor lignite. A short distance farther north the "supposed Cretaceous" beds are vertical and strike N. 70° E. These beds extend along the coast to location U, in the NE. ¼ NW. ¼ sec. 21, T. 25 N., R. 13 W. Northwestward from location U to location V, a short distance north of the mouth of Steamboat Creek, the rocks exposed at the surface consist of clay, sand, and gravel of Pleistocene age. Just north of location V there are exposed thin alternating beds of sandy shale and shaly sandstone of different colors, in appearance resembling somewhat the stripes in a flag. The beds at location V, which are similar to the beds exposed at location Q, dip 60° E. and strike N. 8° E. At various places from location V northward to the mouth of Cedar Creek "supposed Cretaceous" rocks are exposed at low tide. They are quite hard, much jointed, and fractured, so that reliable dip and strike readings are difficult to obtain. At location W, just south of the mouth of Cedar Creek, prominent dark conglomerate in columnar form projects from the sand and gravel along the beach. The pebbles contained in the conglomerate are of different colors, ranging from white through gray and yellow to brown, and the largest are one-third of an inch in diameter. These pebbles resemble in size and appearance the gravel brought up by the bailer from a depth of 450 feet in the Jefferson Oil Co.'s well, a few miles to the northwest. The dip of the strata at location W is approximately 40° NW. and the strike is N. 73° E. This dip and strike measurement was obtained on a prominent mass of rock which extends into the ocean 100 yards north of the mouth of Cedar Creek and which at high tide is an island but at low tide is connected with the mainland. Just north of the mouth of Cedar Creek the soft sandy clay resulting from the weathering of the "supposed Cretaceous" rocks gives off an odor of petroleum and is the characteristic "smell mud" of this general region. Yellowish-gray

sandstone of the same formation as that above described is exposed about one-half mile north of the mouth of Cedar Creek. It dips 33° N. and strikes N. 80° E. For about a mile along the coast northward from this point the surface rocks are of Pleistocene age. They form a cliff 100 to 150 feet in height, from which large slides have occurred in the poorly consolidated sand and gravel. From the north end of this exposure, at location X, to a point about one-fourth of a mile south of the mouth of Hoh River, sandy clay very much disturbed by slumps and slides is exposed. It was impossible to obtain any dip and strike readings on these rocks, but at location Y, just east of the old dance hall at the Hoh Indian village, the strata are well exposed, dipping 29° E. and striking N. 10° W. About one-fourth of a mile south of location Y "smell mud" is plentiful. It is reported that oil seeped from this sandy clay profusely until it was covered by a slide that occurred a few months previous to the time of the writer's visit. Since that time no one has been able to discover any evidence of oil issuing from the sea cliff.

Between the mouth of Hoh River and a point on the beach about 1 mile north of Hoh Head, near the center of sec. 2, T. 26 N., R. 14 W., the "supposed Cretaceous" rocks are well exposed. The most prominent feature is a narrow anticline, the axis of which extends in a northeast-southwest direction through the northern part of sec. 13 and the southern part of sec. 12 of the same township, and presumably through the center of sec. 7, T. 26 N., R. 13 W. At location Z, in the SW. ¼ SW. ¼ sec. 18, T. 26 N., R. 13 W., "smell mud" is very plentiful. At this place the rocks which give off the odor of petroleum consist of alternating "flaglike" beds of yellowish-gray argillaceous sandstone and chocolate-brown soft clay shale. These beds are folded and disturbed, so that a reliable measurement of the dip and strike could not be made. Just northwest of location Z there is a very narrow anticline. The strata near location Z dip about 41° NE. and strike N. 40° W., whereas a little farther north the dip is 54° NE. and the strike N. 50° W. There are so many small folds and faults that no two measurements of the dip and strike agree. Near this locality and about one-third of a mile north of the mouth of Hoh River a dip of 26° N. and strike of N. 80° W. was measured on a bed of greenish-gray sandstone overlain by coarse sandstone and conglomerate, the largest bowlders of which are 18 inches in diameter. A short distance south at low tide it was possible to determine that the beds flatten to a dip of 15° N. and the strike changes from N. 80° W. to N. 80° E. on the same stratum.

At location AA, a few hundred feet northwest of location Z, beds of resistant conglomerate and greenish-gray sandstone are well exposed. The sandstone, in the form of small lenses and beds 40 to 60 feet thick, is interbedded with the conglomerate, which is com-

posed of pebbles and bowlders ranging in size from sand grains to bowlders 3 feet in diameter. The beds are much jointed and folded, and at one point on the south flank of the major anticline on which the Jefferson Oil Co.'s seep is situated they dip about 77° SW. and strike N. 55° W.

The rocks exposed at location BB consist of bluish-gray argillaceous sandstone and interbedded thin sandy shale, which dip 40° SE. and strike N. 35° E. Approximately 75 per cent of the mass is sandstone and the remainder is shale. All these rocks are much jointed and slickensided, showing that they have been subjected to great pressure and movement. Owing to the presence of slides and slumps of "supposed Cretaceous" rocks and also of the overlying Pleistocene material, exposures are poor for about one-third of a mile north of this outcrop and almost an equal distance to the south.

The Jefferson Oil Co. drilled a well to a depth of 868 feet at a point about one-third of a mile north of location BB. The section of strata penetrated by the drill is as follows:

Log of the Jefferson Oil Co.'s well at Hoh Head, in the SW. ¼ SE. ¼ sec. 12, T. 26 N., R. 14 W.

[Drillers' record.]

	Thickness.	Depth.
	Feet.	*Feet.*
Mud	8	8
Sand	5	13
Sand and slate	5	18
Shale	5	23
Do	17	40
Sand	5	45
Sand and slate	5	50
Shale	20	70
Sand	5	75
Shale	5	80
Sand and shale	5	85
Shale	35	120
Sand and shale	5	125
Shale	25	150
Sand	3	153
Shale	37	190
Sand	3	193
Shale	7	200
Sand	4	204
Slate	26	230
Sand	5	235
Slate	20	255
Sand and slate	5	260
Slate	15	275
Sand and slate	20	295
Slate (contained a little gas)	16	311
Sand	3	314
Slate	26	340
Sand (contained gas)	2	342
Slate	38	380
Do	40	420
Sand, coarse with shale[a]	91	511
Sandstone, hard	3	514
Sand, coarse, clayey	88	602
Sandstone, hard	10	612
Sand, coarse, clayey	35	647
Sandstone, rather coarse (big gas showing)	13	660
Sand, coarse; some shale	115	775
Sand, rather coarse (big gas showing and trace of oil)	5	780
Sand, rather coarse, clayey	85	865
Sand, coarse (very strong flow of gas)	3	868

[a] The log below this point is given in much larger units than above.

The section of strata exposed in the shaft at the Jefferson Oil Co.'s seep a few hundred feet north of the well is as follows:

Section of strata in the Jefferson Oil Co.'s shaft in the NW. ¼ SE. ¼ sec. 12, T. 26 N., R. 14 W.

	Ft.	in.
Soil, dark	1	6
Clay, yellowish, sandy	9	0
Shale, bluish, sandy (oil saturated)	7	6
	18	0

The oil seeps from the lower bluish sandy shale and is not present in appreciable quantities in the overlying yellowish clay.

The rocks at location CC, just south of Hoh Head, lie on the north flank of the prominent anticline referred to above. They consist of brownish-gray sandstone interbedded with a small proportion of dark carbonaceous shale. In places the strata are broken by small faults which cut the rocks obliquely to the bedding planes. Lenses of conglomerate, consisting of pebbles and bowlders of bluish-gray sandstone, sandy clay, limestone, and quartzite with much lime and iron in the cement are present in the sandstones. Minute veinlets and stringers of calcite or quartz cut all the strata. A little coal (as much as one-half inch thick in places) also occurs in these beds. The strata on the beach dip about 80° NW. and strike N. 28° E., whereas on the hillside, about 100 feet higher, the beds consist of alternating layers of yellowish-brown and gray sandstone and sandy shale which dip 41° NW. and strike N. 15° E.

On the north side of Hoh Head, a few feet east of the trail and possibly a hundred yards from the ocean, a small landslide has exposed bluish sandy shale which gives off the odor of petroleum. It was not possible to measure the dip and strike of these beds. The rocks exposed on the beach just east of location DD consist of bluish-gray sandstone and sandy shale, which weather into bluish sandy mud and in places give off the odor of petroleum. At location DD, on the north side of Hoh Head, several hundred feet of yellowish-brown, somewhat argillaceous sandstone is exposed, dipping approximately 45° SW. and striking N. 65° W. At location EE, which is almost 1 mile north of Hoh Head, gray carbonaceous and argillaceous sandstone containing thin lenses of coaly material one-half inch in maximum thickness is exposed. The general dip of the strata here is approximately 60° E. and the strike is N. 10° W. Some small faults cut the rocks in this locality.

Location EE is the northernmost point along the coast visited by the writer. The rocks exposed farther along the coast for a mile or more apparently belong to the same formation as do those in the vicinity of Hoh Head.

To summarize, the oldest rocks exposed along the coast between locations A and EE are at Point Grenville. Here the old metamorphic series has been upfaulted and is represented not only by the rocks exposed between locations D and E, but also by those very resistant rocks which form the numerous islands in this locality a mile or more from the coast.

The "supposed Cretaceous" rocks are believed not to outcrop south of location H, about 3 miles northwest of Taholah, except possibly at location A, near Copalis Rock. From present knowledge it seems very probable that practically all the strata, with the exception of the Pleistocene clay, sand, and gravel discussed below, that outcrop along the coast between locations H and EE belong to the "supposed Cretaceous" formation. The only other outcrop of rocks of probably the same age are those exposed in a very small area just east of Copalis Rock at location A.

The Queniult formation outcrops in the vicinity of the mouth of Queniult River, between locations E and H. As stated above, some of the rocks exposed in the vicinity of locations J and K very much resemble the Queniult formation at its type locality.

The Pleistocene beds are exposed almost continuously from Copalis northwestward to location D near Point Grenville, and are again exposed continuously for a number of miles in the vicinity of the mouth of Queets River from location O to location Q, with the exception of a small isolated outcrop of "supposed Cretaceous" rocks just south of the mouth of Kalaloch Creek. Farther north along the coast they are also exposed between locations R and S, in the southern part of sec. 28, T. 25 N., R. 13 W., for about one-half mile, and again for a mile or more directly southeast of the mouth of Steamboat Creek, between locations U and V. From a point about one-half mile north of location W, near the mouth of Cedar Creek, the Pleistocene beds are well exposed northward as far as location X. In addition to the exposures along the coast the Pleistocene caps practically all of the exposures of the Queniult formation and the "supposed Cretaceous" rocks.

ROCKS EXPOSED ALONG HUMPTULIPS RIVER, INCLUDING PARTS OF CAMP NO. 2 AND STEVENS CREEKS.

The rocks exposed along that part of the lower course of Humptulips River shown on Plate II (p. 78) and extending as far northeast as the bridge over the river about a mile above Humptulips post office are believed to consist entirely of poorly consolidated clay, sand, and gravel of Pleistocene age. The writer did not make a thorough examination of the lower course of this river, but at all points where the valley was examined these beds are exposed. A very careful examination of the strata was made along Camp No. 2

Creek for about a mile and a half above its mouth, which is about 2½ miles above the junction of Big Creek with Humptulips River, at the extreme southern edge of the area represented on Plate II. The result of the examination along this creek definitely proves that the rocks are of the same age as those exposed along that part of the lower course of Humptulips River shown Plate II, namely, of Pleistocene age. These rocks on Camp No. 2 Creek consist of yellowish-brown conglomerate, with lenses of soft gray sandy clay alternating, immediately beneath soft bedded sandstone, with yellowish-gray sandy clay. Some of the gray sandy clay includes large numbers of fragments of stems of vegetation similar to grass. At one place a very distinct leaf was found in rather hard, yellowish sandy shale. The conglomerate consists of pebbles, probably derived from the metamorphic rocks and also probably from some of the "supposed Cretaceous" sandstones. This conglomerate is much cross-bedded and in places shows evidence of having been deposited by streams. At one locality a piece of lignite about 6 inches thick was found, but at no place along the stream between locations A and B is any lignite exposed in the walls of the valley. The beds lie practically flat, but at one place, about a mile southeast of location A, they dip 6° N. and strike approximately N. 70° W.

At location C, on Stevens Creek, in the NE. ¼ sec. 7, T. 20 N., R. 10 W., an extensive outcrop of the Pleistocene beds occurs. These strata are about 75 feet thick and consist principally of poorly consolidated gravel and sand.

About 1½ miles east of Humptulips, on the south side of Humptulips River and about one-third of a mile above the wagon bridge, at location D, there are beds of dark bluish-gray shale which contain thin lenses of iron-stained sandy material and numerous iron nodules. The nodules range from one-half to 1 inch in thickness and some of them are 2 feet in length. The outcrop at this place occurs in the edge of the stream and is entirely covered at high water. It is quite probable that these beds, which dip 69° NE. and strike N. 65° W., are of the same age as those along the coast which have been classed as "supposed Cretaceous."

In examining the outcrops along Humptulips River the writer did not follow the stream channel except in places but traversed mainly the wagon road from which he departed here and there to note the character of the rocks in the valley. At location E, at the bridge in the southern part of sec. 9, T. 20 N., R. 10 W., yellowish-brown fine-grained argillaceous sandstone, somewhat massive in character, is exposed. Owing to the absence of definite bedding planes the dip and strike could not be determined. Just below the forks of Humptulips River, at location F, beds of Pleistocene age are well exposed along the north side of the river for several hundred yards. These beds lie practically flat and consist principally of a poorly consoli-

dated conglomerate with some clay and a little lignite, as shown by the following section:

Pleistocene beds exposed at location F, just below the forks of Humptulips River.

	Feet.
Conglomerate, poorly consolidated	40±
Clay, bluish, sandy, soft	10±
Lignite, very impure (little more than peat)	1±
Clay, bluish soft, sandy	4±
	55±

The strata are fairly well exposed at a small falls at location G, in the south half of sec. 6, T. 20 N., R. 9 W., just north of the wagon road and a short distance south of Humptulips River. The rocks here consist of a coarse brownish sandstone which in places contains grains and small pebbles of greenish material one-tenth of an inch in diameter. The rocks exposed below the falls are probably 60 to 80 feet thick and are predominantly sandy but less resistant than the rocks directly overlying them. The strata dip 53° SE. and strike N. 65° E. At location H, just north of the wagon bridge over the east fork of Humptulips River, approximately in the SW. ¼ sec. 5, T. 20 N., R. 9 W., a great thickness of bluish sandy shale with intercalated beds of shaly sandstone of the same color is exposed. Numerous slides and slumps have occurred here, but the loosened material has been carried away and the bedrock exposed by the frequent "splashings" and "sluicings" at the logging camps farther up the river. The beds dip about 55° SE. and strike N. 26° E. These rocks resemble very much the bluish sandy shale exposed on the beach near Copalis Rock (location A). Rocks having the same characteristics are exposed along the south side of the river in the southwestern part of sec. 5, T. 20 N., R. 9 W. At location I, in the NE. ¼ sec. 5 of the same township, about 1½ miles upstream from the wagon bridge, yellowish-gray sandstone and sandy shale that dip about 72° NE. and strike approximately N. 40° W. are exposed for a short distance. The easternmost outcrop of sedimentary rocks along the east fork of Humptulips River is at location J, in the NW. ¼ sec. 35, T. 21 N., R. 9 W. These rocks, which are well exposed for a short distance along the north side of the wagon road, consist of gray sandy shale, dipping about 66° SW. and striking N. 35° W. This exposure is less than 100 feet west of what is believed to be the contact between the sedimentary and the igneous rocks. Northeastward from location J to East Fork dam (location K) the rocks exposed along the river and wagon road are igneous and are presumably older than those exposed farther west.

The oldest rocks examined along Humptulips River lie between locations J and K, in the southeastern part of T. 21 N., R. 9 W., and are believed to be of igneous origin. Along the river, between

locations D and J, all the rocks examined are considered to be the equivalent of or possibly younger than the "supposed Cretaceous" rocks exposed along the coast in the vicinity of the mouth of Hoh River. The rocks exposed along the lower course of Humptulips River and its tributaries and also near the forks of the river consist of Pleistocene clay, sand, and gravel, and, in addition, these same materials cap all the older, more resistant rocks along the river valley. No indications of oil or gas in the form of oil seeps, gas vents, or "smell mud" are known to exist in this valley.

ROCKS EXPOSED ALONG MOCLIPS RIVER.

The rocks exposed along the lower course of Moclips River westward from location A are composed of clay, sand, and gravel of Pleistocene age. At location A, in the NE. ¼ sec. 7, T. 20 N., R. 12 W., the following section of rocks, which are believed to belong to the Queniult formation, are well exposed:

Rocks of the Queniult (?) formation exposed along Moclips River at location A.

	Ft.	in.
Sandstone, yellow, friable	20	0
Sandstone, very argillaceous; contains thin beds of conglomerate, the pebbles of which range from the size of sand grains to as much as 1 inch in diameter	20	0
Conglomerate, yellowish, lower part chocolate-brown to yellow, pebbles and bowlders range in size from sand grains to as much as 10 inches in diameter and consist principally of metamorphic rocks and "supposed Cretaceous" sandstone	25	0
Lignite, very impure, peatlike (dip 39° SW., strike N. 15° W.)	1	8
Clay, bluish gray and yellowish, sandy; sand increases in the lower part	35	0
Shale, containing thin lenses of lignite	1	0
Clay, sandy, carbonaceous, lower part bluish	12	0
Conglomerate, containing bluish pebbles, the largest 6 inches in diameter, belonging principally to the metamorphic series	2	6
Sandstone, yellow, soft, argillaceous	3	0
Conglomerate, yellowish; pebbles range in size from sand grains to 3 inches in diameter; about 60 per cent from the metamorphic rocks and the remainder from "supposed Cretaceous" rocks	18	0
Poorly exposed (probably consists of conglomerate and sandstone)	100±	
Sandstone and sandy clay, yellowish	15	0
Clay, bluish, containing thin beds of lignite, one at the base about 2 feet thick, the other just above the middle (dip 43° SW. and strike N. 20° W.)	50	0
Sandstone, yellow and brown, containing a little conglomerate near the middle (dip 45° SW. and strike N. 25° W. near the middle of these rocks)	120	0
Sandstone, bluish, argillaceous	2	0
Sandstone, yellowish and brown, contains little conglomerate	50	0
	475	2

At location B, about 1 mile upstream from location A, the same formation outcrops on the north side of the river. Here the rocks consist of brownish-gray sandstone from which issue many seeps of limonitic water. At this locality the beds dip 10° NE. and strike N. 20°–30° W., being much more nearly flat-lying than farther downstream. At location C, approximately in the SW. ¼ sec. 3, T. 20 N., R. 12 W., sandstone of the Queniult (?) formation is again exposed. The strata dip 15° NE. and strike N. 35° W. The writer traversed Moclips River as far northeast as M. R. Smith's shingle-bolt camp, situated about a mile farther upstream than location B. All the rocks exposed between location C and the above-mentioned camp are of Pleistocene age. The foreman of this camp, who has traversed the entire length of Moclips River and the adjacent country, reports that all the rocks exposed northeast of the camp are practically the same as the beds exposed near the camp, which are of Pleistocene age.

ROCKS EXPOSED ALONG QUENIULT RIVER AND LAKE.

At location A, on the south side and about 1½ miles from the mouth of Queniult River, 400 to 500 feet of soft yellowish sandstone and conglomerate are exposed. The pebbles in the conglomerate consist of hard material stained brown and the largest are 6 inches in diameter. These beds, which dip 23° E. and strike N. 8° E., are believed to be a part of the Queniult formation, which is well exposed along the coast both north and south of the mouth of Queniult River. The same formation is exposed on the north side of the river at location B, about one-half mile east of location A. At this place a little fine-grained conglomerate, capped with slightly consolidated Pleistocene rocks, outcrops a short distance above water level. The strata dip 17° SE. and strike N. 15° E. Southeast of location B several feet of Pleistocene sand and clay is exposed at location C, on the east side of a small creek emptying into Queniult River from the north. At location D, on the south side of the river, in the SE. ¼ sec. 6, T. 21 N., R. 12 W., very soft, poorly consolidated sand and conglomerate, similar to those beds described at location A, are well exposed for a short distance. At this place there is a fault and an abrupt flexure of the strata. The fault trends N. 30° W. and is nearly vertical. About 20 feet east of the fault the strata dip 70° NE. and strike approximately N. 60° W., but 50 feet farther east the beds flatten to a dip of about 20°. Southwest of the fault, along the south side of the river, there is a very prominent slide 300 or 400 feet in width, composed of soft blue mud, but no indications of petroleum gas were noted. The exposure of soft bluish sandy mud is bounded on the northwest by a conspicuous outcrop of fairly well consolidated sandstone and conglomerate approximately 125 feet thick. It is probable that a fault separates these beds from the slide, although no definite evidence was obtained regarding it. All the beds at location D

are unconformably overlain by beds of Pleistocene sand, clay, and gravel.

For several miles up the river no Tertiary or older rocks are exposed, but at various places described below the beds of Pleistocene age outcrop and in places contain not only the characteristic clay, sand, and gravel but also thin beds of very impure lignite. This material can hardly be considered lignite, but might more properly be classed as peat. However, the term "lignite" has been already used in this report and hereafter wherever it occurs it will be understood as applied to this very poor peatlike material.

At location E, on the north side of the river opposite Billy Snell's place, a cut bank exposes several feet of bluish sandy clay overlain by a little lignite and unaltered wood, which in turn is overlain by about 25 feet of yellowish-gray conglomerate. The pebbles of this conglomerate consist principally of smooth subangular fragments of metamorphic rocks. In places the bowlders reach a maximum size of 18 inches, but for the most part they are less than 6 inches in diameter. At location F, about 1¼ miles upstream from location E, beds of Pleistocene age are exposed on the south side of the river for a short distance, and again at location G in the NE. ¼ sec. 3, T. 21 N., R. 12 W.

Probably the most prominent exposure of the Pleistocene along the whole course of Queniult River is found at location H, northeast of John Chowchow's place. The bluff on the north side of the river at this place is about 300 feet high, and consists of poorly consolidated yellowish sandstone and grayish conglomerate with a little bluish-gray sandy clay. A detailed measurement of these strata was not made, but from the fairly large pieces of lignite found in the talus near the water's edge it is believed that a lignite bed 1 to 2 feet thick is present in the upper part of the bluff. The beds lie practically flat. The ridge into which Queniult River now impinges to form this prominent bluff trends approximately N. 10° E., but it is not present near the stream on the south side of the valley.

At location I, about 1 mile northeast of location H, on the south side of the river and also southwest of the mouth of a small creek, a bed of resistant dark-gray sandstone overlain by sandy shale is exposed a short distance above the water. This exposure is of small extent and is believed to be the easternmost outcrop of the Queniult(?) formation on Queniult River, but it may be part of the "supposed Cretaceous" formation, in which case it is necessary to assume the presence of a fault or a fold lying to the west. The strata here dip approximately 43° NE. and strike N. 70° W. Between location I and Burnt Hill (location R, described below), a distance of about 15 miles by the river, no rocks older than Pleistocene are exposed along the river banks. These exposures are described hereafter, together

with certain indications of the presence of older rocks near the surface.

At location J, on the south side of the river, about one-third mile west of Tommy Ford's place, about 15 feet of bluish sandy clay, overlain by approximately 20 feet of poorly consolidated conglomerate, is exposed for a short distance. At location K there is a large rapids locally known as Bookrock Rapids, in which numerous large bowlders and angular rocks suggest the existence of a ridge or ledge of metamorphic rocks near the surface at this place, unless they have been carried here by the glaciers from Olympic Mountains. A very large erratic at location O, on Queniult River, described below, suggests that these large fragments of rock were brought by ice.

Just upstream from Bookrock Rapids, on the south side of the river, dark-bluish sandy clay about 15 feet thick, overlain by poorly consolidated sand and gravel about 40 feet thick, both of Pleistocene age, is exposed for a short distance. Another very striking exposure of Pleistocene rocks occurs at location L, on the north side of the river, approximately in the NW. ¼ sec. 21, T. 22 N., R. 11 W. The greater part of this consists of almost flat-lying beds of bluish sandy clay, sandstone, and conglomerate, as shown by the following section:

Pleistocene beds exposed at location L, on Queniult River.

	Ft.	in.
Clay, sandstone, and conglomerate; capped with soil, poorly exposed	20±	
Sand and gravel, poorly consolidated	12±	
Lignite, very impure		8
Clay, drab, sandy	4	0
Lignite, brown, very impure (about 200 feet west the lignite bed is replaced by other rocks)	3	0
Conglomerate and sand, interbedded with some blue sandy clay; pebbles of conglomerate range in size from sand grains to 6 inches in diameter, and consist of sandstone and fragments of resistant metamorphic rocks	50±	
Clay, bluish, sandy, to river level	10±	
	99	8

The section above described gives an idea of the thickness of the beds overlying the entire area west of the Olympic Mountains. The bluff in which these strata are exposed is 600 or 700 feet long. At location M, on the south side of the river, about one-half mile west of the mouth of Cook Creek and about 2 miles upstream from location L, there is a bluff 40 to 60 feet high in which bluish clay mixed with sand, gravel, and bowlders, the largest of which are 1 foot in diameter, is exposed in the lower 30 feet of the outcrop. Just above this bluish clay about 10 feet of grayish conglomerate is exposed.

The lower course of Cook Creek was examined as far east as location N, a distance of more than a mile. The rocks outcropping along this

portion of the stream are either of Pleistocene or Recent age and consist of poorly consolidated clay, sand, and conglomerate. The banks of the creek are not more than 15 feet high and are covered to the water's edge with a very dense growth of timber and underbrush.

At location O, on the south side of Queniult River and about three-fourths of a mile from the mouth of Cook Creek, there is a large rock approximately 25 feet long, 15 feet wide, and 15 feet high. This rock is very hard and resistant and is similar to that exposed at Burnt Hill, about 6 miles upstream, hereinafter described. It was impossible to determine whether or not this rock is in place, but as no other rocks of similar composition are exposed near by it seems probable that it is an erratic. Its presence here, together with the large bowlders described in the vicinity of Bookrock Rapids, 5 or 6 miles below, suggest strongly that glaciers from the Olympic Mountains extended to this locality and brought these immense fragments of rock at least from the vicinity of Burnt Hill if not from the main range east of Queniult Lake.

A short distance upstream from location O, and on the north side of the river, a cut bank exposes about 50 feet of poorly consolidated cross-bedded conglomerate of Pleistocene age. At location P, about one-half mile southwest of the mouth of Boulder Creek, approximately in the western part of sec. 14, T. 22 N., R. 11 W., blue clay of Pleistocene age is also exposed. As large quantities of this clay occur at many places along the streams several miles inland it is suggested that it may be valuable for the making of bricks. It has not been tested, but is believed to be worthy of examination by those interested in such materials. Owing to its location it is not of value at the present time, but in the future, when this region may be rather densely settled, it probably will be of considerable importance.

The Pleistocene beds are well exposed at location Q, on the north side of Queniult River, a short distance northeast of the mouth of Boulder Creek. At this place the lower part of the Pleistocene exposure consists of very fine bluish clay and the upper part of a poorly consolidated conglomerate. There is a marked local unconformity separating the two. The upper 4 inches of clay underlying the conglomerate is stained yellowish gray with iron, which is the principal cementing material of the overlying conglomerate.

No extensive exposures were noted between location Q and location R on the north side of Queniult River, approximately in secs. 1 and 12, T. 22 N., R. 11 W. Location R is locally known as Burnt Hill on account of the vegetation having been burned several years ago. The rock, probably greenstone, exposed in Burnt Hill is dark greenish gray and belongs to those rocks of the Olympic Peninsula that have been designated the old metamorphic series. In places the fractures and joints have a purplish color, but where the rock is

much weathered the color is lighter and has somewhat of a greenish tinge. Two sets of joints cut the rock, one trending N. 55° E. and dipping about 77° NW., and the other trending N. 85° E. and dipping about 80° N. The smooth rounded surface of Burnt Hill suggests that it has been glaciated.

At location S, on the north side of the river, in the S. ½ sec. 5, T. 22 N., R. 10 W., Pleistocene conglomerate approximately 100 feet thick is exposed. At location T, in the S. ½ sec. 35, T. 23 N., R. 10 W., about 3½ miles upstream from location S and about one-half mile east of Shortys Rapids, large amounts of bluish sandy clay are exposed on both sides of the river. The clay is very distinctly bedded and quite soft and slippery when wet. At location U, locally known as the Blue Banks, about 1½ miles upstream from location T, 40 to 60 feet of bluish sandy clay containing thin lenses and beds of gravel overlain by yellowish-gray poorly consolidated conglomerate 30 to 40 feet thick is exposed. The conglomerate is well stratified and dips slightly to the west. Farther up the river, at location V, which lies between location U and the west end of Queniult Lake, the beds of Pleistocene sand and gravel dip to the west at angles as high as 30°. As stated under the heading "Topography" (p. 36) it is believed that without question the Pleistocene deposits in the vicinity of Queniult Lake are of glacial origin and that the lake itself is due to the presence of a prominent terminal moraine crossing the valley in a northwest-southeast direction through the southeastern part of T. 23 N., R. 10 W. The glacial deposits are known to surround the western part of Queniult Lake and are believed to extend for several miles both to the northwest and southwest from the lake. At the northeast end of the lake apparently glaciated metamorphic rocks are exposed and they also show at location W, about one-fourth of a mile west of Higley's hotel. The outcrop at this place is known locally as Onion Rock from its very smooth surface, which is probably the result of glaciation. Two other exposures of similar rock were seen on the same side of the lake and about 1 mile west of Higley's hotel. The remainder of the rocks surrounding Queniult Lake, as far as the writer is aware, belong to the poorly consolidated beds of clay, sand, and gravel of Pleistocene age.

The gas which issues from the water near the upper end of the lake and also near the bridge over Canoe Creek at Higley's hotel escapes through beds of Pleistocene and Recent age.

To summarize, metamorphic rocks are exposed along Queniult River and Queniult Lake at two localities—one at Burnt Hill, in secs. 1 and 12, T. 22 N., R. 11 W., and the other on the north side of Queniult Lake in the vicinity of Higley's hotel. One of the most conspicuous of these outcrops on the lake is known as Onion Rock.

The rocks exposed at locations A, B, D, and I are believed to be outcrops of the Queniult formation, although it is possible that the exposure at location I is composed of "supposed Cretaceous" rocks.

All other exposures along Queniult River and Queniult Lake are believed to be of Pleistocene and Recent age.

ROCKS EXPOSED ALONG QUEETS RIVER FROM ITS MOUTH TO THE MOUTH OF SAMS CREEK AND ALONG THE LOWER COURSES OF SALMON RIVER AND MATHENY AND SAMS CREEKS.

QUEETS RIVER.

The rocks exposed at the mouth of Queets River for about a mile from the ocean consist of beds of clay, sand, and gravel of Pleistocene age. At location A, on the south side of the river, near the center of sec. 35, T. 24 N., R. 13 W., dark bluish-gray sandstone, stained yellow in places with limonite, is exposed for a short distance. The strata dip 70° N. and strike N. 15° E. About one-half mile upstream and on the north side of the river, in the vicinity of location B, rocks of the same formation ("supposed Cretaceous") are exposed. They consist of about 200 feet of gray coarse-grained thin to medium bedded sandstone, overlain by approximately 400 feet of dark-bluish sandy shale. The shale is characterized by weathering into small cubes, the joints of which have a conchoidal fracture. The underlying sandstone dips about 38° SE. and strikes N. 32° E. Possibly a thousand feet farther upstream the shale dips 48° SE. and strikes N. 25° E. Both the sandstone and shale in this exposure are broken by faults and are somewhat contorted by small folds. The upper part (stratigraphically) of the shale is more sandy than the lower part and contains "flaglike" beds, which consist of alternating beds of shaly sandstone and darker sandy shale, each bed of which is generally from 2 to 3 inches thick. A few hundred feet farther upstream the "flaglike" beds overlain by bluish sandy shale dip about 24° SE. and strike N. 50° E. At location C, approximately in the SW. ¼ sec. 36, T. 24 N., R. 13 W., and on the west side of Queets River, yellowish-gray slightly argillaceous "supposed Cretaceous" sandstone, which dips 29° SE. and strikes N. 20° E., is well exposed for a few hundred feet. The shaly "flaglike" beds of this formation are exposed at location D, just above Moses Bend. The strata are so much folded and broken by small faults that dip and strike readings have little value and hence none were made. At location E, on the south side of the river about half a mile farther upstream, a very argillaceous sandstone, which dips 43° NE. and strikes N. 66° W., is exposed. About half a mile farther upstream, at location F, in the NW. ¼ sec. 31, T. 24 N., R. 12 W., just west of the mouth of Elk Creek, a very massive, much jointed, and fractured dark-gray sandstone outcrops for a short distance along the river bank. The beds dip 58° NE. and strike N. 30° W. The "supposed Cretaceous"

rocks are well exposed for several hundred yards along the south bank of the river at location G, near Frank Harlow's place, at the mouth of Clearwater River. The westernmost exposure in this locality consists of the "flaglike" beds of sandstone and shale, which dip about 32° SW. and strike N. 45° E. A few hundred feet farther northeast, in front of the house, dark-bluish iron-stained sandy shale is exposed for about 125 feet. The shale rests with apparent conformity on the "flaglike" beds just described; it dips about 51° NE. and strikes N. 16° W. The apparent discordance in the strike of the rocks at these two places so near each other is due probably to a minor fold. At location H, on the north side of the river, about one-half mile northeast of Frank Harlow's, there is about 40 feet of dark-gray fine-grained argillaceous sandstone that dips 36° NW. and strikes N. 30° E. At location I, in the NE. ¼ sec. 28, T. 24 N., R. 12 W., 75 to 100 feet of almost flat-lying beds of Pleistocene conglomerate and sandy clay is exposed.

In the vicinity of the mouth of Salmon River there are broad bottom lands to the south and west of both Salmon and Queets rivers. On the north side of Queets River in this locality and within possibly one-fourth to one-third of a mile of the stream there are terraces 50 to 75 feet above the level of the river flood plain. These terraces consist of practically the same material as that exposed at location I except that it has been worked over by the present stream since Pleistocene time.

At location J, on the north side of Queets River, in the NW. ¼ sec. 26, T. 24 N., R. 12 W., 600 to 800 feet of thin-bedded gray "supposed Cretaceous" sandstone is exposed at low water. The bed dips 42° E. and strikes north at the west end of the exposure, whereas it dips 48° SE. and strikes N. 25° E. at the east end. At location K, on Hartzel Creek near its mouth, in the SE. ¼ sec. 26, T. 24 N., R. 12 W., a very hard yellowish-brown sandstone, which dips 31° E. and strikes north, is exposed a short distance southeast of the cabin on the Bill Donaldson homestead. On the same side of the river, and about 300 yards upstream from the Donaldson house, hard gray fine-grained sandstone, which dips 47° SE. and strikes from N. 25° E. to N. 65° E., is exposed for a few hundred feet. The strata are also fairly well exposed for about one-half mile at location L, on the south side of the river, in the vicinity of the mouth of Mud Creek. The rocks at the western end of this outcrop, which is about one-third of a mile east of the Steeple place, consist of hard massive quartzitic sandstone overlain by medium-bedded, very dark gray, somewhat argillaceous sandstone. At one place near the west end of the exposures the quartzitic sandstone shows in the river bed at a low stage of water in the form of a half dome. The sandstone is about 20 feet thick and is overlain by more than 300 feet of dark gray argillaceous

sandstone. These strata are affected by small faults and folds. At one place near this dome the beds dip 15° SE. and strike approximately N. 30° E. A few feet west of the point where the last-mentioned dip was measured, and on the east side of a very distinct fault, the beds dip about 10° S. and strike approximately east. A little farther upstream soft argillaceous thin-bedded sandstone overlies the hard sandstone mentioned above, dipping about 51° E. and striking north. About 500 feet farther east "flaglike" beds of the same formation are exposed. They dip approximately 80° NE. and strike N. 40° W. About 800 to 1,000 feet of the "flaglike" beds are exposed in the eastern part of the rather extensive exposures in the vicinity of the mouth of Mud Creek. Near the east end of this outcrop grayish-blue to brown shaly sandstone, which dips 70° SW. and strikes N. 15° W., is exposed. The exposed rocks are much broken by joints cut by veins of quartz and possibly by some calcite, so that reliable dip and strike measurements could not be made. It is believed, however, that this sandstone, 400 feet or more thick, is very similar to the beds exposed at location B, a mile or two above the mouth of the river.

At location M, which is on the south side of the river, about three-fourths of a mile east of the old Evergreen post office and in the northern part of sec. 21, T. 24 N., R. 11 W., blue sandy clay with yellowish and bluish gravel of Pleistocene age outcrops for a short distance. These beds have been disturbed by slumping, so that they now dip about 27° SE. and strike N. 50° E. At a few places along the river beds of Pleistocene clay, sand, and gravel have been disturbed by slumping, so that they now lie in positions much different from those in which they were originally deposited. An example of the disturbance created by one of these slides is well illustrated by a landslide that began about 10 years ago at location N, on the south side of Queets River, just west of the mouth of Matheny Creek and about one-half mile east of location M. At the time this slide began to move the bed of the river seemed to rise and form a dam, so that for a few days the water was ponded and flowed over the broad bottom lands south of the Streater place. A flood that occurred a little later cut a channel through this obstruction in the river bed, so that the principal channel was left in almost the same position as it had been formerly. This phenomenon was believed by some of the settlers to be caused by the expansion of a large quantity of gas underlying the river. Others, however, believed it to be simply a landslide, in which the pressure from the side of the river caused the river bed to buckle, thus forming the dam. The latter explanation is undoubtedly correct, as indications of an immense landslide extending for at least one-fourth of a mile south from the river are very noticeable. It is believed by the writer that additional deformation of the

Pleistocene beds will occur from time to time at this place. The buckling, as one would naturally expect, has left the beds of poorly consolidated clay and sand inclined at various angles, hence wherever marked dips are found it may be assumed that they are due to slumping.

All the rocks exposed along Queets River, from location M, about 1 mile west of the mouth of Matheny Creek, to a point 2 miles up Sams Creek, consist entirely of clay, sand, and slightly consolidated conglomerate of Pleistocene age. Generally the beds are horizontal, but in places they are very much inclined through slumping, as explained above. It is reported that these beds are exposed some distance up Queets River above the mouth of Sams Creek, but as the writer did not traverse that part of the river a confirmation of the report was not made.

Horizontal bluish sandy clay, overlain by conglomerate and soil, is exposed on the east side of Queets River, about one-half mile north of the mouth of Matheny Creek. At location O, in the SW. ¼ sec. 10, T. 24 N., R. 11 W., on the north side of the river, the same formation as that outcropping at the mouth of Matheny Creek is exposed for a short distance. The bluish sandy clay, which everywhere weathers into a soft sticky mud, contains at this locality irregular sandy concretions, some of which are in the shape of disks and others are very much elongated, but all of them are flat. At location P, also on the north side of the river, and about a mile farther northeast, the same beds are exposed. They dip 39° W. and strike practically north. The finest clay from this place, after being thoroughly mixed with a certain proportion of milk, has been used by some of the settlers as paint, which is reported to be very durable.

At location Q, on the north side of the river, approximately in the SW. ¼ sec. 1, T. 24 N., R. 11 W., and just above the Aker place, flat-lying bluish sandy clay of the Pleistocene formation is exposed for a short distance. At location R, about one-half mile farther upstream, similar bluish sandy clay is exposed, dipping about 36° NW. and striking N. 60° E. The older rocks are not known to be exposed between location R and the Billy Howard place, in the NW. ¼ sec. 1, T. 24 N., R. 10½ W., but it is possible that they are present in high tree-covered ridges situated from one-third to three-fourths of a mile back from the river. As these ridges were not visited and no information was obtained regarding them it is impossible to determine the point.

SAMS CREEK.

At location A, at the mouth of Sams Creek, and for a short distance up Queets River on the south side, flat-lying beds of bluish sandy clay were observed. Gas is reported just above the mouth of Sams

Creek, but no evidence of its escape was seen by the writer when the locality was visited in September, 1913. All the rocks outcropping along Sams Creek between location A and location C, in the SE. ¼ sec. 34, T. 25 N., R. 10 W., consist of beds of clay, sand, and gravel of Pleistocene age and soil, gravel, and hill wash derived principally from the erosion of these beds.

At location B, approximately in the N. ½ sec. 5, T. 24 N., R. 10 W., the bluish sandy clay, so common along Queets River above Matheny Creek, is exposed for a short distance. This material contains flat sandy concretions similar to those noted at location P, on Queets River. The beds dip about 40° NW. and strike N. 80° E. At location C, which is about a mile downstream from the west end of Sams Creek canyon, hard resistant grayish-brown quartzitic sandstone is exposed for about one-fourth of a mile along the south side of the creek. It was not possible to obtain an accurate measurement of the dip and strike at this place. At location D, on the north side of the creek and a little farther east than location C, Pleistocene bluish sandy clay that dips about 40° NW. and strikes N. 70° E. is exposed for a short distance. At location E, on the south side of the creek and about one-half mile east of location D, quartzitic sandstone similar to that exposed at location C on this creek outcrops for a distance of 600 feet. These beds, which include some interbedded shaly sandstone, dip about 85° NE. and strike N. 50° W. Approximately 500 feet farther upstream the beds flatten so that they dip only 65° NE. and strike the same as at location E. At location F, on the south side of the creek, in the northeastern part of sec. 4, T. 24 N., R. 10 W., about one-half mile southeast of the mouth of the canyon, beds of sandstone and sandy shale, which are slickensided in places and somewhat broken by small faults, are exposed. It is believed that the shale constitutes less than 5 per cent of the rocks exposed. The general dip seems to be 76° E. and the general strike north. At location G beds of sandstone and shale that dip 72° E. and strike N. 55° W. are exposed. At location H, which is about a mile from Queets River and the easternmost point reached on Sams Creek, a bed of shale that dips 69° SE. and strikes N. 50° E. is exposed for a short distance.

Along Sams Creek pebbles of the metamorphic rocks and also the softer and lighter-colored "supposed Cretaceous" sandstones are numerous.

MATHENY CREEK.

The strata exposed along Matheny Creek from its mouth to location A, a distance of about 3 miles, consist entirely of bluish sandy clay and yellowish-brown sandy gravel. The gravel seems to lie unconformably on the clay, which contains the sandy disks and irregular flat concretions noted at location P, a few miles up Queets River

above the mouth of this creek. The Matheny Creek canyon begins at location A and extends for 2 miles or more to the east. The rocks exposed at the mouth of the canyon are principally sandstone with a little sandy shale interbedded, but it is believed that the shale constitutes not more than 2 per cent of the entire thickness of rock exposed. At a point about one-third of a mile up the canyon the beds dip approximately 47° E. and strike N. 3° E. The rocks in general at this place are very much jointed and broken by small faults. About one-half mile above the mouth of Matheny Creek canyon the rocks are the same as those at location A, between which point and the lower end of the canyon fully 800 feet of strata are exposed. At another point in this part of the canyon, a few hundred feet farther upstream from the point at which the dip and strike readings given above were taken, the strata dip 59° E. and strike approximately north.

SALMON RIVER.

The rocks exposed along Salmon River from its mouth to location A, a distance of about 2 miles, consist of sand, clay, and gravel of Recent age, and possibly here and there an outcrop of the underlying Pleistocene beds, but above location A, as far as the writer examined the section, the rocks exposed belong to the "supposed Cretaceous" formation. At location A, on the south side of the river, the rocks consist of grayish-brown soft sandstone and sandy shale. These strata dip 27° SE. and strike N. 33° E. About 75 feet farther upstream on the same side of the river the rocks dip 48° W. and strike N. 5°–10° E. On account of the discordance in dip and strike it is believed that a fault lies between the two points at which these dip and strike readings were measured. About 150 feet upstream from location A the rocks dip 41° NW. and strike N. 65° E. At location B, about 450 feet upstream from location A, the beds dip 65° NE. and strike N. 55° W. At location C, approximately three-fourths of a mile up the canyon, the same rocks dip 30° SE. and strike N. 25° E. The beds are very much contorted between locations B and C, dipping at many angles and striking in practically all directions. This condition is due not only to small faults but also to numerous small folds. At location D, about a mile up the canyon and near the reservation line, the beds dip 25° E. and strike practically north. At location E, about 1½ miles up the canyon, the strata dip 20° NE. and strike N. 15° W. Location E was the southeasternmost point reached in the examination of the lower course of Salmon River. It is reported that the river flows through two main canyons. The westernmost canyon is said to extend probably not more than a mile east of location E, and the second canyon is reported to lie east of the trail which crosses the river near the Salmon ranger station in sec. 5, T. 23 N., R. 11 W.

SUMMARY.

To judge from the general eastward dip of the older strata along the Queets and Salmon rivers and Sams and Matheny creeks, it seems logical to assume without conclusive paleontologic evidence that the older rocks of the section lie farthest to the west and the younger formations to the east. The rocks exposed farther east along these streams are harder and more resistant than those that outcrop near the coast, but this condition is probably due to the greater metamorphism of these supposedly younger strata lying near the mountains in the eastern part of the section traversed.

The rocks exposed along Queets River from its mouth to the vicinity of location H, a mile or more above the mouth of Clearwater River, are undoubtedly the same beds as those that outcrop along the coast, which in this report have been classed as "supposed Cretaceous." The hard resistant sandstones outcropping on Queets River and along the lower course of Salmon River may belong to the "supposed Cretaceous" formation, but they are undoubtedly younger and lie stratigraphically above the rocks exposed near the mouth of Clearwater and Queets rivers. The beds outcropping in the canyons of Matheny and Sams creeks are probably still younger than the rocks farther west.

The beds of bluish sandy clay and gray to yellowish, poorly consolidated gravel outcropping at different places along Queets and Salmon rivers and Matheny and Sams creeks are, with but little question, of Pleistocene age. The terrace gravel, soil, hill wash, and talus at different places along these streams are entirely of Recent age.

ROCKS EXPOSED ALONG CLEARWATER RIVER WEST OF THE OLYMPIC NATIONAL FOREST.

The strata exposed along Clearwater River west of the Olympic National Forest probably all belong to the "supposed Cretaceous" formation and are better and more continuously exposed than the rocks of any other part of the area examined. (See Pl. II, p. 78.) Although these beds are well exposed, yet the unusual number of folds and small faults makes the interpretation of the structure very difficult. The Pleistocene beds of clay, sand, and conglomerate are exposed at only a few places. In fact Clearwater River runs from the western boundary of the Olympic National Forest to a point about one-fourth of a mile north of Clearwater post office, through a comparatively narrow canyon of the older rocks, whose walls attain a maximum height of 200 feet.

At location A, about one-half mile above the mouth of Clearwater River, on the east side of the stream, there is an exposure of yellowish-brown sandstone and yellowish gravel very poorly consolidated.

These beds lie practically flat and unquestionably can be correlated with the beds of Pleistocene age in other parts of the field. Soft, yellowish-brown sandstone is exposed at location B in the northern part of sec. 30, T. 24 N., R. 12 W., on the west side of the river. The beds here are medium bedded, dip 37° NE., and strike N 30° W. At location C, about one-fourth of a mile farther north, the "flaglike" beds, consisting of thin-bedded sandstone alternating with sandy shale, outcrop on the west side of the river. They dip 73° NW. and strike N. 40° E. The total thickness of the beds exposed here is approximately 800 feet. At the north end of this exposure the strata dip 71° NW. and strike N. 35°–40° E. The "flaglike" beds of alternating sandstone and sandy shale are exposed at location D, just below the mouth of Hurst Creek, and also for 300 or 400 feet up that stream, where the strata dip 74° E. and strike N. 5°–10° E. At location E, on the west side of Clearwater River, about one-half mile upstream from the mouth of Hurst Creek, beds of hard dark-gray resistant sandstone about 500 feet thick are exposed. The upper part (stratigraphically) of this exposure is not distinctly bedded, so that dip and strike readings are not reliable. The lower portion of the beds dips 68° W. and strikes N. 5°–10° E. At location F, on the east side of the river, about 100 feet of "supposed Cretaceous" sandstone dips 49° NW. and strikes N. 55° E. At location G, at the west end of the big bend in the river in the SE. ¼ sec. 12, T. 24 N., R. 13 W., the "flaglike" beds, which dip 60° E. and strike N. 5° W., are also exposed. The strata exposed at location H, on the east side of Clearwater River, about three-fourths of a mile east of location G, consist of about 250 feet of the "flaglike" beds, which are overlain unconformably by fairly well consolidated Pleistocene conglomerate at least 100 feet thick. The "flaglike" beds are inclined 30° NE. and strike N. 45° W. The striking differences noted here in angle of dip and in direction of strike are due to abrupt flexures and in places possibly to small faults. At one locality a short distance upstream from location H the beds dip 29° NW. and strike 18° E. The same beds 150 feet farther upstream dip 39° SE. and strike N. 30° E. and at location I, 200 feet farther upstream, the dip is 36° SE. and the strike is N. 65° E. The "flaglike" beds at this place consist of about 60 per cent of sandstone and 40 per cent of shale in beds 2 or 3 inches in greatest thickness. About 300 feet farther upstream from location I the same beds stand vertical and strike N. 55° E.

At location J, on the east side of Clearwater River and about one-third of a mile north of location I, beds of sandy shale dip about 66° NE. and strike N. 25° W. At location K, at the west end of a prominent bend, approximately in the SE. ¼ sec. 1, T. 24 N., R. 13 W., the sandstone and shale beds of the same formation as that described above, as far as can be ascertained, dip 55° NE. and strike N. 60° W.

The strata are much disturbed by folds and small faults, as the following dip and strike readings show. At a point 25 feet downstream from location K the beds dip 60° SW. and strike N. 20° W. The fault line separating the points where these two last-mentioned dip and strike readings were taken is very distinct. About 1,000 feet farther downstream the "flaglike" "supposed Cretaceous" beds stand vertical and strike N. 20° W. A few hundred feet farther downstream and on the opposite side of the river beds of massive, much broken sandy shale are exposed, but it was not possible to measure dip and strike readings on these beds. At location L, about 1 mile upstream from location K, the "flaglike" beds dip 87° S. and strike N. 85° W. A short distance downstream from this place the same beds dip 58° SE. and strike N. 30° E. At location M, on the south side of the river, in the northeastern part of sec. 6, T. 24 N., R. 12 W., and 600 or 800 feet northeast of location L, the "flaglike" beds dip 67° SE. and strike N. 70° E. At location N, on the east side of the river and about one-half mile farther north, beds of gray sandstone, which alternate with thin beds of shale, are exposed for a short distance. The dip is 67° E. and the strike N. 10° W.

Exposures are fairly good on the east side of the river from location N southward for one-fourth to one-half mile. Several hundred feet of strata are well exposed in the vicinity of location O, in the northern part of sec. 32, T. 25 N., R. 12 W. At the western end of this exposure the beds, which dip 56° NW. and strike N. 30° E., consist of dark-bluish sandy shale and several hundred feet of "flaglike" beds of alternating sandstone and shale. Many of the joints of these strata are filled with iron-stained calcite. A short distance east of location O beds of gray sandstone, overlain by a few hundred feet of dark-bluish sandy shale, dip 65° W. and strike north. The beds upstream from location O have a brownish tinge, whereas those downstream are bluish black. From the mouth of Elkhorn Creek, which joins Clearwater River in the NE. ¼ sec. 32, to location O the river flows through a narrow canyon in the walls of which the "flaglike" beds, together with some dark shale, are well exposed. On the south side of the river in this canyon the beds in places stand almost vertical. At location P, just above the mouth of Elkhorn Creek, strata of similar character that dip 42° NE. and strike N. 20° W. are well exposed for a short distance. A little farther upstream, at location Q, approximately in the SE. ¼ sec. 29, T. 25 N., R. 12 W., sandstone beds dip 51° SE. and strike N. 20° E. At location R, on the west side of Clearwater River, about one-half mile northeast of location O, beds of sandy shale that dip 40° SE. and strike N. 25° E. are exposed for 300 or 400 yards. A few hundred feet southwest of location R the strata dip 45° NE. and strike N. 30° W. This dip and strike reading is not so reliable as the readings taken at locations Q

and R. At the mouth of Shale Creek (location S) about 6 feet of sandstone containing calcite in the joints, overlain by bluish-black shale containing hard calcareous nodules, is exposed. The beds at this place dip 63° SE. and strike N. 55° E. About 500 or 600 feet north of the mouth of Shale Creek gray hard fine-grained shaly sandstone is exposed on the east side of Clearwater River. The strata both overlying and underlying this sandstone are poorly exposed, but seemingly consist of dark-bluish sandy shale interbedded with shaly sandstone. They dip 53° NE. and strike N. 45° W.

An unusually long and steep rapid, known locally as the "Skukemchuck," is situated a few hundred feet upstream from the mouth of Shale Creek. At location T, on the west side of the river, one-third of a mile upstream from location S, about 300 feet of yellowish-gray sandstone and bluish-yellow sandy shale are exposed. In both directions from location T, for at least one-fourth of a mile, dark-bluish sandy shale is exposed in the river banks. These beds are cut by joints and fracture planes which in many places are filled with calcite. The rocks are so much broken by small faults that within a distance of 200 feet beds may be found flat-lying, almost vertical, and dipping 45°, all striking in different directions. At location U, on the east side of Clearwater River and just below the mouth of Miller Creek, there is an outcrop of dark-brown to black clay shale, in which the surfaces of joints and fractures show slickensides. At the mouth of Miller Creek on the north side of the river there is a fairly good outcrop of yellowish-gray sandstone. These beds are so deformed that reliable readings of dip and strike could not be made. At location V, on the south side of the river and about one-half mile farther upstream, the "flaglike" beds consist of soft, dark thin-bedded sandy shale and sandstone, which dip 72° SE. and strike N. 60° E. At the upper end of the outcrop near the bend of the river the beds seem to be overturned. The dip is 89° NW. and the strike N. 65° E. Approximately 300 feet of shale and shaly sandstone outcrop at this easternmost exposure.

On the west side of Clearwater River, beginning a short distance north of Giberson's house, situated in the NE. ¼ sec. 27, T. 25 N., R. 12 W., sandstone and sandy shale are exposed almost continuously upstream to the mouth of Christmas Creek. At location W, which is on the west side of the river and about 100 yards below the mouth of Christmas Creek, beds of bluish sandy clay, which dip 33° N. and strike N. 80° W., are exposed. Many small faults and folds were observed here. At location X, about one-half mile south, slightly east of location W, beds of dark sandy shale are exposed on the south side of the river. These beds dip 59° E. and strike N. 10° E. About 100 feet upstream from location X the rocks are cut

by a small fault and about 300 feet farther up the river the same beds dip 48° E. and strike N. 10°–15° E. Between the fault and the point where the last dip and strike readings were measured, the strata are much contorted and strike more nearly east. At location Y, on the south side of Clearwater River, approximately in the NE. ¼ NW. ¼ sec. 26, T. 25 N., R. 12 W., beds of sandstone and sandy shale that dip 15°–20° E. and strike N. 10°–15° E. are fairly well exposed for a short distance. Some of these beds are "flaglike" in appearance and are similar to those mentioned as occurring at other places along this river. About 500 feet farther up the river "flaglike" beds that dip 24° SE. and strike N. 25° E. are well exposed and are overlain unconformably by poorly consolidated conglomerate of Pleistocene age. At location Z, situated near a bend in Clearwater River, about 1¼ miles directly west of the Olympic National Forest boundary, beds of bluish sandy clay and slightly consolidated conglomerate of Pleistocene age are exposed, but the bedding is so indistinct that dip and strike readings could not be obtained. At location AA, on the south side of Clearwater River, in the NE. ¼ sec. 26, T. 25 N., R. 12 W., beds of dark-bluish sandy shale, alternating with yellowish-gray medium to thin bedded sandstone, are exposed. The dip at this place is 67° S. and the strike is approximately east. At location BB, in the northern part of sec. 25, T. 25 N., R. 12 W., similar beds of sandstone and sandy shale, containing probably a little more shale than the beds at location AA, dip 85° SE. and strike N. 40° E. At location CC, on the north side of the river a short distance west of the forest reserve line, the same beds, dipping 63° NW. and striking N. 45° E., are also exposed. The "flaglike" beds are exposed fairly well at location DD, on the north side of the river, presumably just west of the boundary of the Olympic National Forest. Dip readings on these beds range from 40° NW. to vertical and the strike is N. 65° E. At location EE, at the bend of the river a short distance above the mouth of Deception Creek, which is the easternmost point visited by the writer during the traverse of this river, beds of sandstone with a little intercalated shale are exposed on the south and east sides of the river. The beds stand almost vertical and strike N. 65° E.

Practically all the rocks exposed along Clearwater River, with the exception of those outcropping at locations A and Z, are believed to belong to the "supposed Cretaceous" formation.

The beds of bluish sandy clay and poorly consolidated sand and conglomerate exposed at locations A and Z and overlying the "supposed Cretaceous" at locations H and Y are of Pleistocene age. The rocks on the uplands are concealed by a thick mantle of soil, hill wash, and talus.

ROCKS EXPOSED ALONG HOH RIVER.

Before the description of the rocks noted along Hoh River is given it seems proper to state that the writer did not visit all the exposures along this stream but only the more prominent ones that could be easily examined when traveling along the principal trail on the north side of the river valley. The stratigraphy and structure along this stream can best be studied from a canoe, but it was impossible, on account of the short time spent in this portion of the field, to make a careful study of the beds exposed in the river banks.

At location A, on the north side of Hoh River, about one-half mile from the ocean, beds of gray sandstone and sandy shale about 75 feet thick are exposed. These beds are much broken by joints and fractures and on account of the presence of many small faults dip at different angles and strike in different directions. They dip approximately 31° SW. and strike N. 55° W. At location B, on the south side of the river, in the SE. ¼ sec. 21, T. 26 N., R. 13 W., there is an exposure 100 to 200 feet in length of yellowish-gray thin-bedded, somewhat micaceous sandstone, which dips 75° NW. and strikes about N. 25° E. At location C, on the south side of the river, about one-third of a mile southeast of location B, almost flat-lying beds of bluish sandy clay of Pleistocene age are exposed. At location D, just east of W. D. Hough's house on the south side of the river, a grayish-blue sandstone, which weathers yellow and which is soft when wet, dips 45° SW. and strikes N. 15° W. Another reading taken near by shows that the same bed dips 46° SW. and strikes N. 33° W. About 200 yards downstream from this locality, near an old log jam, bubbles continually rise to the surface of the water. It is possible that these bubbles are formed by escaping natural gas, but more probably they are due to air that has been carried into the water or to marsh gas. Some of the gas was collected, but an attempt to ignite it was unsuccessful. At location E, on the north side of the trail, about 2 miles east of Hoh post office, approximately in the SE. ¼ sec. 15, T. 26 N., R. 13 W., 150 feet or more of poorly consolidated conglomerate is exposed. This conglomerate probably corresponds in age to the beds of similar clay and conglomerate of Pleistocene age noted in other parts of the area.

The rocks exposed in the shaft of the Lacy oil seep, situated about 2½ miles northeast of Hoh post office, are reported to consist of soil, sandy clay, sand, gravel, and bowlders of Pleistocene and Recent ages. The larger pebbles and bowlders are a foot or more in diameter and increase in size with the depth of the shaft. Most of them are subangular or flat sided, suggesting glacial scouring. W. H. Abbott, who assisted in opening the shaft, stated that it was his opinion that when the water is removed from the shaft the maximum flow of oil is about 2 barrels a day. At the time this place was visited by the writer, in

August, 1913, the shaft was full of water. A small amount of oil floating on the water was collected and sent to the laboratory of the Geological Survey, where it was analyzed. A discussion of the results of this analysis is given on pages 31, 32. Gas escaping from the shaft disturbed the water somewhat from time to time. The small amount of oil on top of the water in the shaft is explained by the theory that the weight of the water prevents the oil from flowing into the shaft.

Beds of yellowish-gray sandstone are poorly exposed for a short distance along the side of the trail at location F, near Anderson Creek, about 1 mile west of W. P. Elliott's house (formerly Pins post office). A fairly good reading obtained on this sandstone shows that it dips 70° N. and strikes N. 76° W. At location G, on the north side of the river and about 300 yards upstream from Elliott's house, gray sandstone and bluish-gray shale interbedded is exposed for 200 or 300 feet. About 200 yards east of Elliott's house there is a rather massive sandstone bed which contains some shale and is reported to contain coal in very thin lenses. The beds here dip at different angles, but the prevailing dip is about 86° W. and the strike N. 6° W. Farther east, at location H, on the same side of the river and one-half mile east of Elliott's house, beds of gray to chocolate sandstone and sandy shale are exposed. They dip 52° NE. and strike N. 50° W. These beds are somewhat broken by faults, and there is also evidence of the presence of small folds.

In secs. 27 and 28, T. 27 N., R. 12 W., Hoh River flows through a canyon 100 feet deep and 2 miles or more in length. At the eastern end the walls of the canyon are composed of yellowish-gray to bluish-gray sandstone, shale, and shaly sandstone. These rocks occur in about the proportion of 1 part of shale to 10 parts of sandstone. At location I, at the east end of the canyon, on the north side of the river, in the SW. ¼ sec. 27, the beds of sandstone and shale were examined for one-third to one-half mile. They dip 56° N., strike N. 80° E., and consist of the same kind of rocks and same proportion as described above. About 1,000 feet downstream from the upper end of the canyon the rocks consist of yellowish to chocolate-brown, very thin bedded sandstone and a little sandy shale. In the bed of a small brook about 200 feet north of the river the strata dip 32° NW. and strike N. 30° E. On the river's edge at the mouth of the same brook the beds consist of gray medium-bedded fine-grained, rather resistant sandstone, which dips 55° NE. and strikes N. 45° W. A small fault was observed between these two places. Possibly 50 to 100 feet downstream from the mouth of the brook the beds dip 55° NE. and strike N. 70° W. Between this locality and the mouth of the brook the strata are very much disturbed by small faults. About 100 feet farther downstream interbedded sandstone and carbonaceous shale, which dips 58° NW. and strikes N. 30° E. is exposed.

The same distance farther downstream medium-bedded gray sandstone, dipping 63° NE. and striking N. 57° W., is exposed. Two hundred feet farther down the river sandstone similar in appearance to that last described dips 52° NE. and strikes N. 55° W. The last two dip and strike readings are very much alike and indicate that probably both were measured on the same fault block. At location J, on the north side of the river, near the mouth of a small creek near the center of sec. 26, T. 27 N., R. 12 W., gas is reported by the owner to be escaping from the edge of a circular spring of water. The water in this spring is said to have a milky-white color, like that at the Devils Mush Pot, a few miles farther up Hoh River, which is due to the action of gas in loosening and carrying up very fine sediment from the bottom of the inverted funnel-shaped hole.

At location K, about 1½ miles farther upstream, on the south side of the river, near T. H. R. Schmidt's place, beds of massive sandstone and brownish chocolate-colored sandy shale, dipping 31° E. and striking N. 39° W., are exposed just below the mouth of a small stream that joins Hoh River from the south. This exposure, which consists of about 5 per cent shale and the remainder sandstone and sandy shale, is the only one along the river for a mile or more both up and down stream. Very small lenses of coal, which attain a maximum thickness of 2 inches and a maximum length of 6 inches, are included in a sandstone stratum about 4 feet in thickness. The coal, which has a bright luster, burns with a bituminous odor and yellow flame. A small, almost vertical fault, trending N. 65° E., cuts these rocks. The section measured at this place is as follows:

Section of rocks exposed at location K, near the center of sec. 25, T. 27 N., R. 12 W.

	Feet.
Sandstone, gray, massive, coarse	40+
Sandstone, brownish gray; contains a little coal	4
Sandstone, bluish gray and rusty in places, argillaceous	15
Sandstone, gray, massive, with thin beds of shaly sandstone which contains a little coal in small lenses at base [1]	45
Sandstone, grayish brown, thin bedded at base; contains thin lenses of conglomerate	75
Sandstone, gray, thin bedded, with a little sandy shale	40
Sandstone, gray, massive; contains thin lenses of coal at the top	50
	269+

Rocks that may be exposed along Hoh River, between location K, near Schmidt's place, and location L, about 1¼ miles southwest from Spruce post office, on the south side of the river, were not examined, because on traversing the valley the trail which lies on the north side of the river and some distance from it was followed. The rocks over which the trail passes consist principally of clay, sand, and gravel,

[1] The lower part of this section is slightly faulted.

partly consolidated and partly loose, of Pleistocene and Recent ages. Along the trail from Schmidt's place to Spruce post office none of the older formations are exposed.

At location L, referred to above, a hard dark fine-grained medium-bedded sandstone, containing here and there near the top thin lenses of limestone, is exposed. Above the limestone the rocks consist of dark chocolate-brown iron-stained argillaceous sandstone, which has apparently been subjected to crushing forces, as it is now quite brittle and crumbles easily. The beds dip approximately 50° SE. and strike N. 40° E. At location M, about one-half mile farther east, in the vicinity of the mouth of Owl Creek, very hard dark fine-grained medium-bedded sandstone, with some dark hard fine-grained sandy shale in the western part of the outcrop, is exposed. It is rather difficult to obtain a reliable dip and strike reading at this place on account of the massiveness of the strata. However, the prevailing dip is about 75° NE. and the strike is N. 40° W. The Devils Mush Pot, described in detail on pages 29–30, and referred to in other parts of this paper, is situated at location N, about one-fourth of a mile farther northeast. It may be added here that the rocks surrounding the gas vent consist of gravel, sand, and clay of Recent age. As the "mush pot" is situated near the outcrop of the older rocks, at location M, and as this same formation outcrops to the east of this locality, it is reasonable to assume that the gas which escapes from this vent originates probably deep in the older rocks instead of those at the surface. In traversing the upper part of Hoh River above Spruce post office a recently completed trail, which lies on the north side of the river and in most places one-fourth to three-fourths of a mile from it, was followed, and hence no exposures were seen by the writer in this stream valley farther north than those just described in the vicinity of Spruce post office. It is reported that gas is escaping in small quantities at location O, which is a few hundred feet north of Hoh River and on the eastern edge of the area represented on Plate II (p. 78). This point, which is about 5 miles east of Spruce in the NE. ¼ NE. ¼ sec. 22, T. 27 N., R. 11 W., was visited by the writer, but no evidences of gas were noted.

It is believed, as has been stated in the beginning of the description of the rocks exposed along Hoh River, that many outcrops of rock in addition to those noted above can be seen along this stream, and that whenever more detailed work is to be done in this region it will be necessary for the geologist to traverse the river by means of a canoe and examine carefully every exposure, however small, as was done by the writer along the lower courses of Moclips, Queniult, Queets, and Clearwater rivers.

The strata exposed along the lower course of Hoh River between locations A and H are, with but little question, representative of the

"supposed Cretaceous" rocks, whereas those beds exposed in the prominent canyon of the Hoh River in secs. 27 and 28, T. 27 N., R. 12 W., and from this locality east to location M, near Spruce, probably belong to the Clallam formation, of Oligocene and Miocene age, described by Arnold.[1] It is possible that those beds exposed at locations F, G, and H in the vicinity of Elliott's place (formerly Pins post office) may belong to the same formation. As stated previously, it was Arnold's opinion that the rocks exposed in the hills south of Bogachiel River belong to the Clallam formation. The hills referred to constitute the divide separating the drainage of the Bogachiel from that of Hoh River, and at no place east of range 13 are they more than 4 miles from the Hoh.

Beds of Pleistocene age overlie the older formations unconformably and at one place along Hoh River (location C) bluish sandy clay, presumably of the same age, outcrops along the river bank. At no place along Hoh River did the writer note any evidence of "smell mud" and at but one locality (the Devils Mush Pot) is there any evidence of natural gas, except that reported at location J, on Billy Snell's land.

ROCKS EXPOSED ALONG BOGACHIEL RIVER.

The rocks along Bogachiel River were examined at only five localities. The river was not traversed and the points visited are places where rock outcrop or indications of oil or gas were reported.

At location A, on the south side of the river, in the NW. ¼ NW. ¼ sec. 27, T. 28 N., R. 14 W., about a mile southwest of the Wilson place, which is described in detail on page 30, "smell mud" is very plentiful in a comparatively recent landslide 75 to 100 feet above the river level. At a point about one-fourth of a mile upstream from location A 6 feet of gray sandstone, which contains some carbonaceous material underlain by sandy shale, is exposed. These beds dip 37° SE., strike N. 34° E., and constitute the only known exposure of the "supposed Cretaceous" rocks for a mile or more both up and down stream. At location B, on the opposite side of the river, nearly flat-lying beds of poorly consolidated sand, clay, and gravel, which are believed to be of Pleistocene age, are exposed for several hundred feet. At location C, near the center of sec. 35, T. 28 N., R. 13 W., just north of the place where the trail from Forks to Bogachiel crosses Bear Creek, a very poor exposure of yellowish-gray argillaceous sandstone overlain by yellow clay shows that the strata dip about 36° SE. and strike N. 30° E. Beds of sandstone are exposed at location D, at the point where the trail referred to above crosses Coon Creek, in the NW. ¼ sec. 26, T. 28 N., R. 13 W.

[1] Arnold, Ralph, Geological reconnaissance of the coast of the Olympic Peninsula, Wash.: Geol. Soc. America Bull., vol. 17, pp. 461–462, 1906.

At this locality beds of dark, resistant sandstone are exposed, but it was difficult to measure the dip and strike on account of the massive character of the rock. Apparently the rocks have a southeastward dip and seem to strike in the same general direction as the beds at location C, described above. Another exposure of rock was examined about one-half mile west of Morgan ranger station, at location E, in the NW. ¼ sec. 5, T. 27 N., R. 12 W. The rocks here consist principally of gray sandstone overlain by blue shale which have a general dip of about 39° E. and strike N. 5° W. Joints and fractures which have been filled with quartz or calcite are numerous in the sandstone.

The rocks exposed at location A, 2 or 3 miles above the mouth of Bogachiel River, probably belong to the "supposed Cretaceous" formation so well exposed along the coast south of Hoh Head.

The strata exposed at locations C, D, and E, in the vicinity of the Bogachiel post office, probably are of Oligocene and Miocene age and belong to the Clallam formation, as suggested by Arnold.

Beds of Pleistocene clay, sand, and gravel unconformably overlie the older rocks throughout the greater part of this region. They outcrop extensively along Bogachiel River at location B, near Wilson's place, 6 or 7 miles southwest of Forks.

ROCKS EXPOSED ALONG CALAWA RIVER.

The rocks on Calawa River were examined only at location A, on the south side of the river, in the southern part of sec. 35, T. 29 N., R. 13 W., about 3 miles northeast of Forks. At this place 300 to 400 feet of gray and brown sandstone, much broken by faults, is exposed. The rocks are principally massive, and on account of faulting the joints and bedding planes are so nearly alike that it was difficult to distinguish one from the other and to measure the true dip and strike. The prevailing dip seems to be 62° NE. and the strike N. 45° W. These rocks probably belong to the same formation as do those in the vicinity of Bogachiel to the south, namely, the Clallam formation, of Oligocene and Miocene age.

The Washington Oil Co. is drilling a well on the Anderson farm in the SW. ¼ SE. ¼ sec. 9, T. 28 N., R. 13 W., about a mile south of Forks. In the latter part of March, 1914, the drill had penetrated to a depth of more than 1,600 feet. A general section is given below:

Driller's record of the Washington Oil Co.'s well on the Anderson farm near Forks.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, black	4	4
Sand, unconsolidated (much water)	116	120
Shale, light	380	500
Shale, blue (showing of oil at base)	450	950
Shale, brown	600+	1,550+

STRUCTURE.

GENERAL FEATURES.

The structure of the area represented on Plate II (p. 78) is characterized by a prominent anticline or possibly a monocline, the axis of which is situated some distance out in the ocean, extending in a general north-south direction in places, turning slightly to the northwest. The east flank of this anticline, which underlies the area under consideration, is crossed almost at right angles to its strike by several smaller anticlines and synclines. The general structure is indicated on the accompanying map (Pl. II) by dip and strike symbols, which almost invariably show that the rocks dip in general toward the east and strike in a north or northwest direction. The minor anticlines and domelike structures are also shown by dip symbols.

One of the most prominent of these minor anticlines crosses Queets River about 2½ miles from the coast, extending northeast and southwest through the eastern part of sec. 35 and the northwestern part of sec. 36, T. 24 N., R. 13 W. The dips of the rocks on Clearwater River, a mile or more north of the present site of Clearwater post office, indicate that the same anticline that crosses Queets River near its mouth extends to that locality, but there it seems to be somewhat narrower than it is near the mouth of Queets River. A study of the dips and strikes farther up Clearwater River does not indicate that it continues for a great distance north of sec. 18, T. 24 N., R. 12 W. The writer is unaware of any gas or oil vents along this anticline.

There is evidence of another prominent, although narrow, anticline extending in the same general direction on the coast at the mouth of Cedar Creek, about 3½ miles southeast of the mouth of Hoh River. This anticline seems to cross Hoh River a short distance east of Hoh post office. It is interesting to note that the Lacy seep, situated in the NW. ¼ sec. 11, T. 26 N., R. 13 W., is nearly on the projected axis of this anticline. "Smell mud" is plentiful on the coast near the mouth of Cedar Creek.

Another prominent anticline in "supposed Cretaceous" rocks cuts the coast just south of Hoh Head and like the two anticlines just discussed extends in a northeast direction. No evidence is at hand regarding its extent inland. The Jefferson Oil Co.'s seep and well are situated near the crest of this anticline. Oil-saturated rock is not known to exist along the coast on the upfold, but a little farther south, near location Z, it is plentiful.

As was pointed out by Arnold, the Queniult formation, which outcrops on both sides of the mouth of Queniult River along the coast for 2 miles, occupies a broad syncline. This syncline, to judge from dips and strikes along the coast and about 2 miles above the mouth of Queniult River, also trends in a northeast-southwest direction.

The structure of the beds of Pleistocene age is very simple. In most places they lie practically horizontal. At those localities in which these strata are somewhat inclined their disturbance is undoubtedly of recent date and is due probably to landslides and slumps, which in some places have produced buckling.

Evidences of other small anticlines are pointed out below in the description of the structure by districts. The description of the Pleistocene beds will be omitted in these detailed descriptions, as their structure has nothing to do with the accumulation of oil and gas.

COAST DISTRICT.

Between locations A and B there are no exposures of the older rocks except in the vicinity of location A, near Copalis Rock, where, as has been stated above, reliable dip and strike readings could not be obtained. Between locations D and E, in the vicinity of Point Grenville, much faulting has taken place in what is believed to be the old metamorphic rocks. Dip and strike readings and measurements of the inclination and direction of fault planes differ so widely that the more prominent features of the structure in this locality can not be shown on a map of the scale of Plate II. The principal fact of interest is, however, that between locations D and E lies an upfaulted block of metamorphic rocks, which is very much faulted and folded within itself.

The Queniult formation exposed between locations E and H, in the vicinity of the mouth of Queniult River, is in general a broad syncline, the axis of which extends in a northeast direction and which cuts the coast a short distance south of the mouth of Queniult River. It is doubtful if this formation has any important relation to oil or gas that may underlie these strata in the "supposed Cretaceous" beds. Between locations H and I, along the coast, there is evidence again of a comparatively narrow upfaulted block of "supposed Cretaceous" rocks. Northward from location I to the mouth of Raft River the "supposed Cretaceous" rocks strike in general north slightly east and dip east in almost every locality. At the mouth of Raft River a fairly reliable measurement shows that the beds dip about 53° NW. and strike N. 25° E. for a short distance. This narrow anticline is associated with "smell mud" along the coast, as is shown on Plate II (p. 78).

Flat-lying beds of Pleistocene age occupy the coast from location O to location Q with the exception of a very small area at the mouth of Kalaloch Creek. Northward from location Q to a point a short distance south of the mouth of Cedar Creek the general strike of the strata ranges from north to N. 18° E., the dip being generally eastward. A small anticline, described above, breaks the monotony of the gen-

eral eastward dip for about one-half mile north of the mouth of Cedar Creek, north of which point the older strata are entirely covered for some distance by flat-lying Pleistocene beds. In the vicinity of the mouth of Hoh River and to the northwest as far as location EE, about 1 mile north of Hoh Head, the strata are much disturbed by northeast-southwest anticlines and some still smaller folds and faults. Near the mouth of Hoh River there is evidence of an elongated dome extending in general east and west. Faulting has disturbed this structure at location A, on Hoh River. A mile or more northwest of location Z, on the coast, the prominent northeast-southwest anticline on which the Jefferson Oil Co.'s seep and well are situated dominates the structure. North of Hoh Head there are also indications of a minor anticline extending in a northwest direction, as suggested by a dip of 45° SW. and a strike of N. 65° W. at location DD, whereas there is a dip of 60° E. and a strike of N. 10° W. at location EE.

HUMPTULIPS RIVER BASIN.

The general dip of the strata along Humptulips River and the east fork of the same river between the village of Humptulips and location I, about 4 miles southeast of East Fork dam, is to the east. Beds exposed at location J, a short distance west of the contact between the sedimentary and igneous rocks, have a steep dip to the west. The dip and strike symbols on Plate II show the details of structure along Humptulips River better than any written description. The structure of the almost flat-lying beds of Pleistocene age on Camp No. 2 and Stevens creeks needs no further explanation than that shown on the map (Pl. II, p. 78) in addition to what has already been stated under the heading "General features" (p. 74).

MOCLIPS RIVER.

The beds exposed along the lower course of Moclips River outcrop in an anticline which trends in a northwest-southeast direction. The extent of this anticline in either direction is not known on account of the thick cover of Pleistocene beds, and for that reason the position and direction of the axis are shown only near the stream.

QUENIULT RIVER BASIN.

The description of the structure of the rocks exposed along Queniult River and Queniult Lake will necessarily be brief because the beds exposed in this part of the field are principally of Pleistocene age and in general are flat-lying. The rocks in the vicinity of Higley's hotel, in sec. 8, T. 23 N., R. 9 W., at Onion Rock, and the two exposures farther west presumably belong to the "old metamorphic series," as do also the rocks exposed at Burnt Hill in secs. 1 and 12, T. 22 N., R. 11 W. As stated before in this report, it is believed

that the rocks exposed at Burnt Hill are greenstone, whereas those in the vicinity of Higley's hotel on the north side of the lake, which in places seem to stand almost vertical, are believed to be in part sedimentary.

The strata outcropping at locations A, B, and D, near the mouth of Queniult River, and at location I, about 10 miles from the coast, dip in general to the east. They are broken in places, as has been stated before in the detailed description of location D, on page 30. Without doubt the beds at locations A, B, and D belong to the Queniult formation and possibly those outcropping at location I also. There is a probability, however, that the rocks at location I may be "supposed Cretaceous," in which case a fault or fold must exist to the southwest and west of this exposure. If it is an upfold the axis of the anticline or monocline, on the north flank of which this outcrop is situated, must necessarily lie to the south of this locality, but no information is at hand regarding its exact position.

QUEETS RIVER BASIN.

The outcrops of rock on which dip and strike readings were measured along Queets and Clearwater rivers and the lower courses of Salmon River and Matheny and Sams creeks are much more numerous than are the exposures in any of the other regions examined. The prevailing dip of the rocks, as a glance at the dip and strike symbols on Plate II indicates, is in general to the east. However, at localities where faulting and folding have disturbed the strata, the strike of the beds as well as the direction of dip differs considerably. As stated on page 74, the principal anticline in this basin seems to cross Queets River about 2½ miles above its mouth. The evidence of an anticline on Clearwater River in the vicinity of locations D and E is fairly conclusive, but it is questionable if the anticline noted near the mouth of Queets River and the one on Clearwater River in the vicinity of locations D and E are the same, and it would be unwise to definitely correlate them. A correlation, however, is suggested on account of the relative positions of these two sections of anticlines, as the strike of the rocks near the mouth of Queets River at locations A, B, and C shows that it would cross Clearwater River, if continued in the same direction, at approximately the position where the anticline on Clearwater River exists. More detailed work along Elk Creek and tributaries of Elk Creek in secs. 24 and 25, T. 24 N., R. 13 W., would undoubtedly furnish conclusive evidence regarding this point if these streams have eroded through the Pleistocene cover. Between location L on Queets River and location D on Sams Creek, a distance of about 14 miles as the river runs, no outcrops of the "supposed Cretaceous" or Tertiary formations are exposed. This distance is sufficient for several small narrow anti-

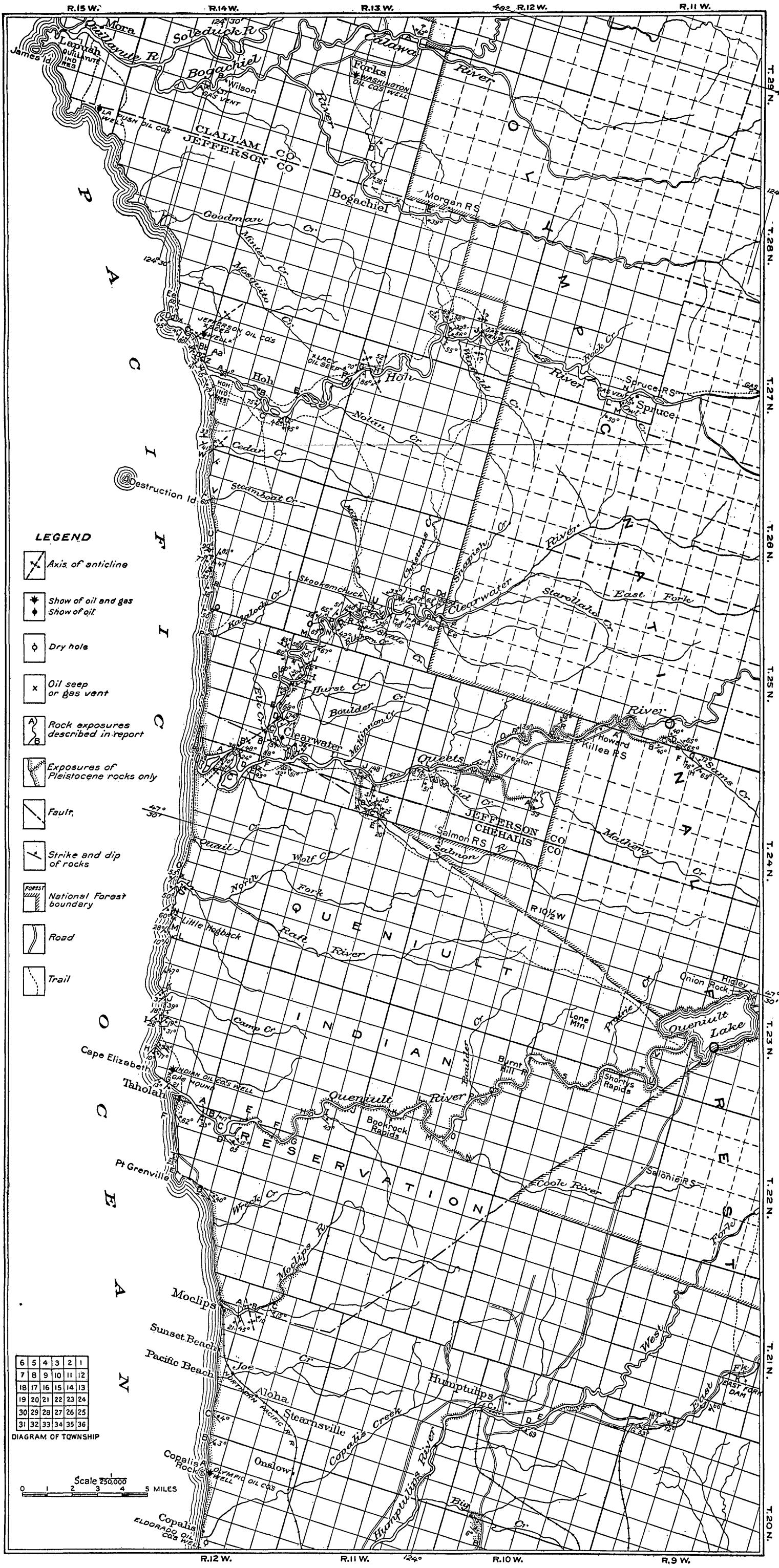
clines, but no evidence is at hand, even taking into consideration the beds exposed in the canyon of Matheny Creek, that there are any such favorable structures for the accumulation of oil or gas. As noted on page 63, the prevailing dip of the rocks in Matheny Creek canyon is to the east, which corresponds exactly with the prevailing eastward dip of the rocks along all the principal streams in the area represented by Plate II.

Dip and strike measurements taken in Salmon River canyon between locations A and E suggest the existence of an elongated dome or anticline, which are favorable structures for the accumulation of oil and gas. As the strata here are broken by minor faults, and as the same beds on Queets River about a mile to the north have persistent eastward dips, it is very questionable if the structure here is really favorable.

Although the dip and strike of the rocks along Clearwater River indicate that the structure is very complex, yet the more reliable measurements show that the rocks have a general eastward dip and that prominent anticlines are absent. Wherever westward dips occur they are usually due to the presence of faults and folds which undoubtedly do not extend to a great depth below the surface and hence would have but little effect in constituting reservoirs for the accumulation of oil and gas.

HOH RIVER BASIN.

Dip and strike readings measured at the mouth of Hoh River, although very meager, suggest that a narrow anticline or possibly a small dome is situated here. This structure apparently does not extend far inland or far north or south from the mouth of Hoh River. About one-half mile southeast of Hoh post office "supposed Cretaceous" beds strike approximately N. 25° E. and dip about 75° NW. At the mouth of Cedar Creek there is evidence of a comparatively narrow anticline which has the same general trend. The axis of this anticline projected inland from the coast would cross the river near the point where the strata were measured in sec. 21, T. 26 N., R. 13 W., and if projected still farther north would lie near the Lacy seep. The position of the axis of the anticline north of Hoh River as above indicated is only approximate, but it seems that this assumption is fairly reasonable. Just east of Elliott's ranch the dip and strike readings indicate the existence of a small anticline which trends in a general northwest-southeast direction. The rocks are faulted slightly and the apparent anticline may not constitute a favorable structure. The rocks farther up Hoh River dip in general to the east, as they do along Queets and Clearwater rivers. The structure of the rocks exposed at the conspicuous canyon on Hoh River, at location I and to the west, and those



RECONNAISSANCE MAP OF AN AREA EXAMINED FOR OIL AND GAS ON THE WEST SLOPE OF THE OLYMPIC PENINSULA, WASHINGTON.

outcropping at location K, southeast of Schmidt's house, on the south side of Hoh River, suggest that a northwest-southeast anticline may extend through this general region, the axis of which may cross the river in the vicinity of the gas vent reported by Billy Snell at location J, on the north side of Hoh River, approximately in the center of sec. 26, T. 27 N., R. 12 W. The rocks exposed at locations L and M, about a mile west of the Devils Mush Pot, near Spruce post office, have a general eastward dip, which suggests that this gas, if it is related structurally to the rocks exposed at locations L and M, must be escaping at some distance down the east flank of an anticline, the main axis of which may cross the river in the vicinity of location J, at the point where gas is escaping near Billy Snell's place.

QUILLAYUTE RIVER BASIN.

Very little information regarding structure was obtained in this locality. As noted by the dip and strike symbols at locations A B, C, D, and E, on and near Bogachiel River, and location A on Calawa River, about 2½ miles northeast of Forks, the prevailing dip of the rocks is to the east, as at nearly all other localities in this field. Most of the points where the readings were taken are so widely separated that there is room for one or more small anticlines to be present in the intervening space, but the writer has no evidence of their existence. Further detailed work along these streams and the streams to the north will undoubtedly yield valuable information regarding the position of any anticlines that may be present.

RELATION OF STRUCTURE TO ACCUMULATIONS OF OIL AND GAS.

In regions where the strata are saturated with water ("wet"), as is the case in this field, oil and gas collect usually under anticlines or domes that are capped by some impervious stratum. On the other hand, in regions where the strata are comparatively "dry" the oil tends to collect in synclines or basins. The principle on which this action takes place is quite simple. Wherever open porous rocks contain water and oil disseminated through the mass there is a tendency for the water, being the heavier, to collect below and thus force the oil to occupy a position above it. If, however, the rocks are thoroughly saturated, there will be a general migration of the globules of oil upward through the strata until they reach the surface of the earth or until their progress is stopped by the presence of rocks like clay, shale, and dense sandstone, which are almost impervious to oil. If the porous stratum and the impervious cover are flat-lying probably there will be no large accumulation of oil, but if they are inclined slightly the oil will continue to migrate up the rise at or near the base of the impervious stratum until it reaches

the upper limit of water saturation, or the surface of the earth and escapes in an oil spring or seep. If the structure is that of a dome or anticline the oil will collect in the porous rock directly underlying the impervious cap in the top of the anticline (except where gas is associated with the oil, in which case the gas will occupy the highest position) and remain there until it can escape to the surface through natural vents, such as seeps and fault planes, or artificial openings (drill holes). It is also true that if oil and gas are associated in the same rocks, as is usually the case, the gas, being lighter than the oil, will naturally occupy the crest of the anticline or apex of the dome underlying the impervious stratum. If the rocks are "dry" the disseminated oil particles acted upon by the force of gravity tend to migrate downward. If the structure is that of a syncline or basin underlain by an impervious stratum the oil will collect in the depression.

In this discussion the simplest condition, that in which the rock containing the oil is a homogeneous mass overlain or underlain by a stratum impervious to oil, is assumed. It is believed that where the conditions are more complex, as where the oil is included in a shale or compact thin sandstone containing lenses of coarser sandy material and the rocks are fairly saturated with water, the oil will be forced into the rock whose pore spaces are larger, owing to the differential capillary attraction of water and oil.

CONCLUSIONS.

The writer does not predict that oil will be found in commercial quantities in this field, but he firmly believes that it is a region worthy of the attention of oil operators.

The report does not attempt to describe the stratigraphy and structure of all the rocks exposed in the area represented by Plate II, but it does set forth all data collected in this field during the two months' reconnaissance.

It is significant that all places where oil is escaping from the surface of the earth, either in seeps or in oil-saturated sandy clay, and the principal places where gas is escaping are situated in that part of the field where the older "supposed Cretaceous" and Tertiary rocks are exposed. It is believed that the source of the gas at the Garfield gas mound is not in the Queniult formation, through which it issues to the surface, but in the underlying "supposed Cretaceous" formation. The gas escaping in Queniult Lake issues from a place where marsh gas is naturally expected to occur, namely, at the mouths of streams which have carried and buried and are continuing to carry and bury large quantities of vegetation, the decomposition of which could easily explain the large quantities of escaping gas. As this gas

was not analyzed, it is impossible to state definitely whether it is natural gas or marsh gas. The location of the vents suggests marsh gas.

In this field, as has already been pointed out, the oil seeps and occurrences of "smell mud" are firmly believed to be situated near the crests of anticlines. The gas vents are not similarly located because, as has been shown, the gas escaping at the Devils Mush Pot, near Spruce post office, on Hoh River, is certainly not associated with the crest of an anticline of the rocks which outcrop just to the west. It is also true that the gas escaping at the Garfield gas mound is not situated near the crest of any known anticline. However, it may be situated near the crest of an anticline of the underlying "supposed Cretaceous" rocks, which are believed to be unconformably overlain by the Queniult and younger formations. As the rocks of this field, which lies in that part of the United States where the annual rainfall is greatest, are undoubtedly well saturated with water, and as the principal oil seeps are situated near the crests of anticlines, it seems advisable for those desiring to exploit the oil and gas resources of the region to drill in the vicinity of the crests of an anticline rather than in a syncline or where monoclinal dips prevail.

The structure of rocks along the various river basins have been considered by districts. That discussion, together with dip and strike symbols and the lines representing axes of anticlines shown on the map (Pl. II), should be a guide in a very general way to those contemplating drilling. It should be kept in mind, however, that the presence of favorable structures, such as anticlines and domes, is not absolute proof that oil will be found. It is fairly safe to assume that if the oil is not discovered where the structure is favorable the chances are very remote that it will be discovered where the structure is positively unfavorable.

The discovery in this region and in commercial quantities of oil similar to that issuing from the seeps near Hoh Head would undoubtedly prove to be a great boon to the Olympic Peninsula in that it would be a means of opening this comparatively unknown region to settlement. From the rainfall, the character of the soil, the numerous water-power sites, and other natural advantages, it seems quite probable that this region may in time furnish homes for thousands.