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GEOLOGICAL RECONNAISSANCE OF THE COAST OF THE OLYMPIC PENINSULA, WASHINGTON*

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(*Read before the Cordilleran Section December 30, 1905*)

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Introduction

During the months of June and July, 1904, the writer, under the direction of Dr William H. Dall, made a reconnaissance of the coast of the Olympic peninsula, Washington, from Port Angeles, on the south shore of the strait of Juan de Fuca, to Grays harbor, on the Pacific. Chester W. Washburne, of Eugene, Oregon, and Russell G. Wayland, of Seattle, assisted in the work. The trip was primarily undertaken for the purpose of collecting the fossils and working out the stratigraphy of the Tertiary rocks of the region; in addition to this, however, notes were made on the other important geologic features of the country traversed. This paper embodies an outline of the results of the reconnaissance.

Mr J. S. Diller, of the U. S. Geological Survey, visited the region of Clallam bay in 1892 to investigate the coal deposits there, and Professor Henry Landes and a party consisting of Messrs Charles Landes, Charles A. Ruddy, and S. H. Richardson, made a hurried reconnaissance trip in 1902 over practically the same route as that taken by the writer, but neither Diller nor Landes published any notes on the region. It was through information furnished by Professor Landes that Doctor Dall was induced to send the writer into the country in 1904.

Previous Literature

Probably no other territory of equal extent in the United States has received as little attention from the explorer or geologist as has the Olympic peninsula, and as a result the literature directly concerned with its geology and natural aspects is confined, so far as the writer is aware, to four papers.

Mr S. C. Gilman,* a civil engineer who visited a considerable portion of the region in 1895, has given us a fairly accurate map and a good general description of the peninsula, especially the central mountainous parts.

Dodwell and Rixon,† the forestry experts who examined the Olympic forest reserve, give some notes of interest to the geologist in addition to their technical report on the forest conditions.

Some observations on the geology of the southwestern coast of the peninsula are also included by Mr H. S. Conard in an article on "The Olympic peninsula, Washington." ‡

In addition to the above, the writer has published papers on "Coal in

* S. C. Gilman: The Olympic country. National Geographic Magazine, vol. 7, 1896, pp. 133-140, pl. 16.

† Arthur Dodwell and Theodore F. Rixon: Forest conditions in the Olympic forest reserve, Washington. Professional paper, U. S. Geological Survey, no 7, 110 pages, 20 plates, 1 map, 1902.

‡ Science, N. S., vol 21, no. 532, March 10, 1905, pp. 392-393.

Clallam county, Washington,"* and "Gold placers of the northwestern coast of Washington,"† in the former of which a brief outline of the geology of the region is included. With the exception of the very brief references mentioned, nothing has been written concerning the geology or mineral resources of this extensive and interesting territory.

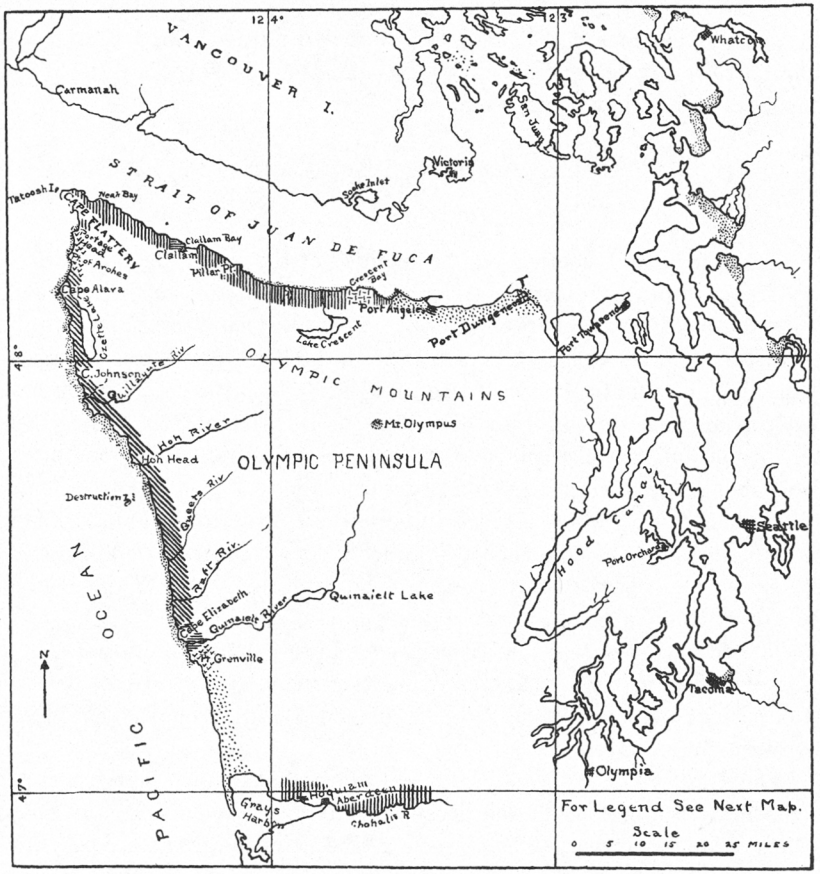

FIGURE 1.—*Sketch Map of Coast of Olympic Peninsula, Washington.*

Showing the principal geologic formations of the northern and western portions. For detail of northern coast and explanatory legend see figure 2. Topography from Coast and Geodetic Survey; Geology by Ralph Arnold, 1904.

LOCATION

The Olympic peninsula occupies an area of about 8,000 square miles, approximately 80 miles east and west by 100 miles north and south, in the

* Contributions to Economic Geology for 1904. Bulletin no. 260, U. S. Geological Survey, 1905, pp. 413-421.

† Ibid., pp. 154-157, fig. 11.

northwestern part of the state of Washington. As implied by the name "peninsula," this body of land is almost completely surrounded by water, the Pacific ocean bounding it on the west, the strait of Juan de Fuca on the north, Admiralty inlet, Hood canal, and other portions of what is popularly known as Puget sound on the east, and Grays harbor and the Chehalis river on the south. It embraces the whole of Clallam and Jefferson and portions of Chehalis and Mason counties. Cape Flattery at the northwestern corner and Port Townsend at the northeastern are its most commonly heard place names.

Topography and physical Features

The Olympic mountains

The natural and commercial development of the peninsula is dominated by the Olympic mountains—a rugged group, occupying with their foothills the greater part of its territory. The higher mountains* are Alpine, with sharp spires and serrate ridges from 6,000 to 8,000 feet high, culminating in mount Olympus, with an altitude of 8,200 feet. They form a circular area 40 miles in diameter in the east central part of the peninsula and are characterized by glacial sculpture, precipitous slopes, and abundance of high barren and prairie land.

West of the region of high mountains the ridges rise to approximately a plane surface that slopes gently seaward from an elevation of about 4,500 or 5,000 feet. This surface truncates the deformed strata of the Solduck region and probably represents a peneplain.

The following paragraph, descriptive of the Olympic mountains, is an abstract of an article by Chester W. Washburne, now in course of preparation, which will appear in a more extended report on the geology of western Washington.

The drainage of the region is radial, the radial pattern being very perfect about the borders of the higher mountains, while within the mountains it is less perfect. The streams of the peninsula are arranged much like the spokes of a wheel, of which the region of high mountains is the hub. This pattern could have one of three possible origins: First, the drainage was initiated on a volcanic accumulation about a center; second, the drainage was initiated on the domed surface of Tertiary strata, which has since been removed by erosion; third, the drainage was initiated on the domed surface of a peneplain. By all of these hypotheses the streams are consequent to some imaginary surface of double curvature. The first

* See topographic map accompanying Professional paper, U. S. Geologic Survey, no. 7, "Forest conditions in the Olympic reserve, Washington," by A. Dodwell and T. F. Rixon.

FIGURE 1.—VIEW LOOKING EAST ALONG STRAIT OF JUAN DE FUCA JUST EAST OF GETTYSBURG

Showing the general shore conditions where no bluffs skirt the coast. Photograph by Chester W. Washburne, 1904

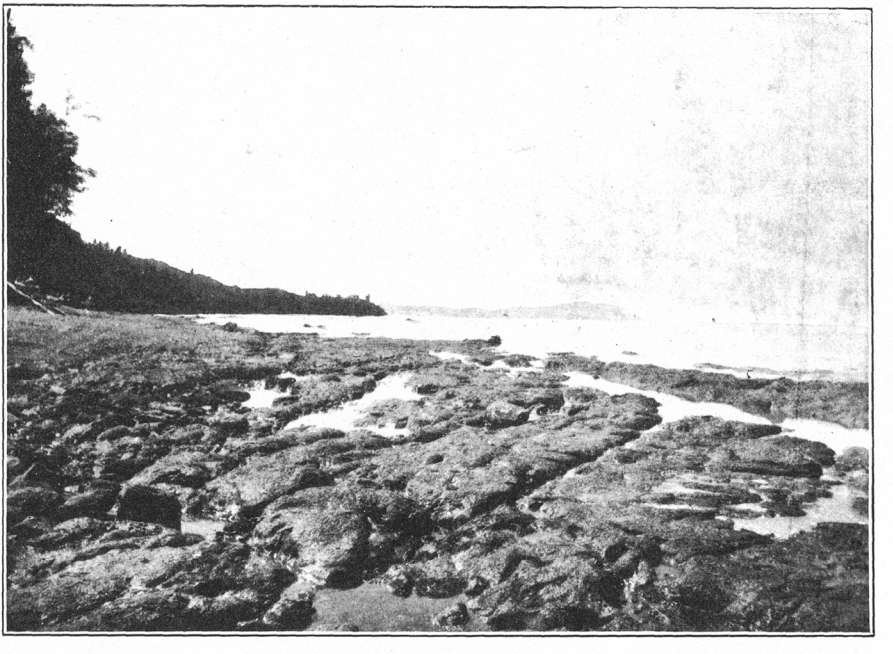

FIGURE 2.—CHARACTERISTIC MOSS-COVERED EXPOSURE OF SOFT OLIGOCENE-MIOCENE SHALE

Locality is between Crescent bay and Gettysburg; Pillar point to the west in the distance. Photograph by Chester W. Washburne, 1904

is disproved by the absence of extensive volcanic material. Choice between the second and third hypotheses is not wise at this time, but there are fewest difficulties in the acceptance of the third hypothesis, that the drainage results from the doming of a peneplain.

THE COASTAL REGION

The coastal region of the peninsula consists essentially of an elevated terrace. Into this the encroaching waters of the ocean and strait have eaten their way, forming precipitous cliffs along the shore. With the exception of low stretches between Tree bluff and Pillar point and in the immediate vicinity of Clallam and Neah bays, the platform varies in elevation from about 50 to 250 or 300 feet. The Terrace is by no means level, being cut by numerous streams and only in a general way conforming to a plane surface. Prominent ridges rise above the general level of the terrace, notable examples being that between Freshwater and Crescent bays and that between the mouths of the Pysht and Clallam rivers. The western border of the peninsula is also a terrace which, in some places, is over 200 feet in altitude. In occasional regions along the ocean, however, lowlands skirt the shore, as, for instance, at the mouth of Queets river. From Point Greenville to Grays harbor the border land is all low.

Figure 1 of plate 55 illustrates the usual conditions where no bluffs skirt the shore. Timber comes down to high-tide level and the beaches are strewn with huge logs which have been undermined and finally washed loose where the sea has cut into the timbered terrace region.

The coast traversed presents an unusual number of interesting physiographic features, mostly those resultant from an encroaching sea. A wave-cut platform skirts nearly the whole shoreline from the vicinity of Freshwater bay to cape Flattery and thence down the coast to point Greenville. Its surface is approximately horizontal and is usually largely exposed at low tide, in some places extending out over half a mile from the shore (see plate 55, figure 2, and plate 58, figure 1).

In certain localities along the strait of Fuca where the terrace truncates, soft shale interbedded by occasional hard thin layers of sandstone, the latter, in fragments varying from cobbles to blocks of considerable size, forms a most effective protecting cover of shingle over large areas of the platform. Even where the rocks of the coast form extremely resistant cliffs, the waves have made their impression, the result often being a narrow terrace with a cave or niche cut into the base of the cliff. An excellent illustration of this latter phenomenon is exhibited at the mouth of the Pysht river and is shown in plate 56, figure 1. At the base of the island in figure 2, plate 56, is another example of a wave-cut niche.

Along the ocean front of the peninsula from cape Flattery south to point Greenville the wave action is more intense and the resultant terrace more pronounced. The terrace is nearly 2 miles wide in the region of the Bodelteh islets, at the mouth of the Ozette river, its surface studded with small islands and sharp rocks, the latter often exposed at low tide but covered when the tide is in. It is this island and rock-studded terrace which has been responsible for so many wrecks and which inspires the navigator with such dread of the western coast of Washington. Islands of all sizes and in all stages of development, from partially isolated promontories (see plate 57, figure 1) to the typical rock-bound forms, are found here. Destruction island is the largest of the true islands along western Washington.

The shoreline conditions along the eastern end of the strait of Fuca are decidedly unlike those of the portion of the coast just described. From the vicinity of Freshwater bay eastward to Port Townsend the coast consists of steep bluffs of more or less incoherent Pleistocene deposits from which two prominent and interesting sand spits extend into the strait. Both spits are long and narrow and bowed, although extending in a general way parallel to that part of the coast on which they are developed. Both protect navigable bays on their inner sides. The spit at New Dungeness is particularly noteworthy because of its form, the main spit having a secondary one developed on its inner side (see figure 2). These spits are due to the strong tidal currents which flow through the adjoining strait, sometimes at the rate of 5 or 6 miles an hour.

Owing to the heavy precipitation on the peninsula (Neah bay, in the northwestern corner, having the maximum mean annual rainfall for the United States), many rivers rise in the central portion of the Olympics and descend through deep, precipitous canyons to the more nearly level border lands, and thence out into Puget sound, Fuca strait, or the Pacific ocean. These rivers are navigable only for canoes, and for these only in the lower channels, but they offer an unlimited field for the development of cheap power.

Flowing northward to the strait are the Dungeness, Elwha, Lyre, East and West Twin, Pysht, Clallam, Hoko, and Sekiu rivers, besides numerous smaller rivers and creeks, while the western portion is drained by the Ozette and Quillayute rivers and the latter's tributaries, the Dickey, Soleduc, Bogachiel, and Calawa. Farther south, and also draining not only the western but the southern flanks of the Olympics, are the Chahlatt, Hoh, Queets, Raft, and Quinaielt rivers. Three important inland bodies of fresh water are found on the flanks of the range adjacent to the

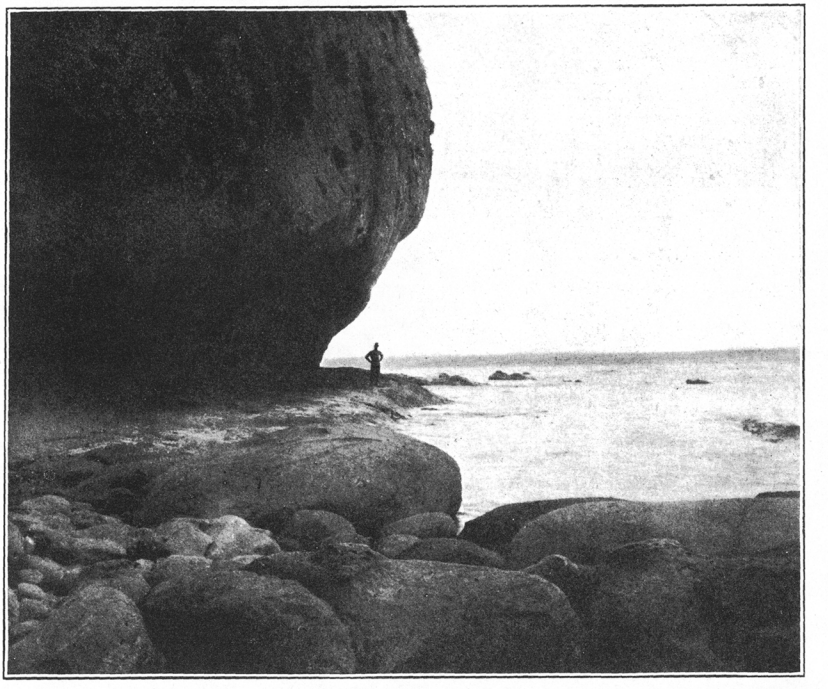

FIGURE 1.—WAVE-CUT NICHE AT BASE OF CLIFF, PILLAR POINT, LOOKING WEST
Photograph by Professor Henry Landes, 1902

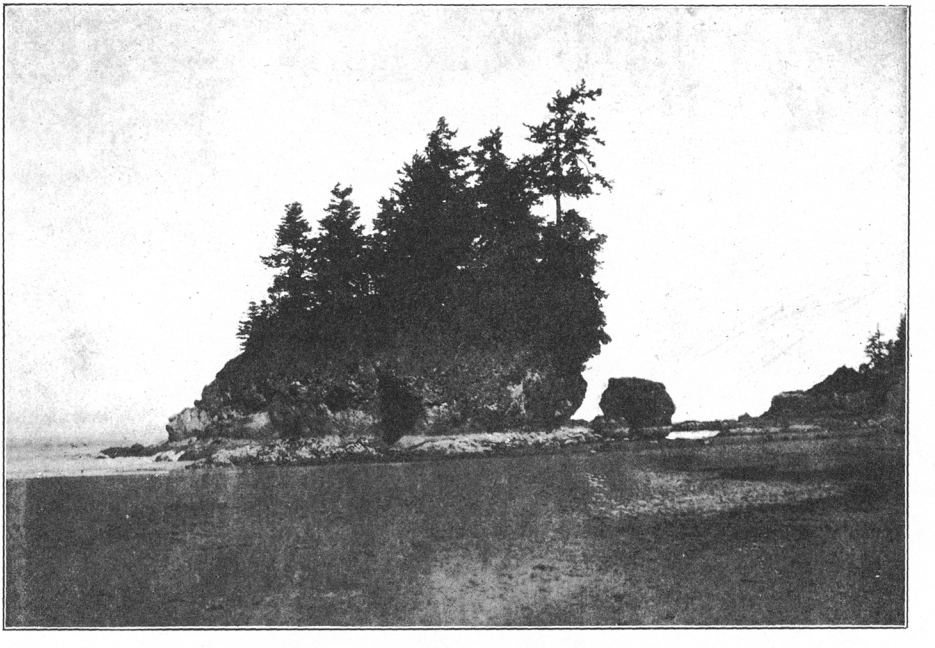

FIGURE 2.—THE BEGINNING OF AN ISLAND
Showing an isolated portion of the old terrace of basalt and basalt tuff, with wave-cut niche at base, eastern end of Crescent bay. Photograph by Professor Henry Landes, 1902

coast covered by the reconaissance. These are lake Crescent, situated at an elevation of 550 feet in the foothills 7 miles inland from Port Crescent; Ozette lake, which lies in the lowlands of the central western portion 2 miles from the coast, and Quinaielt lake, about 20 miles inland from the mouth of the Quinaielt river.

The whole country below timberline, which in this region is at an elevation of approximately 5,500 feet, is heavily timbered with hemlock, cedar, spruce, fir, etc. Between the larger trees is a dense undergrowth of devils club, sallal, brakes, ferns, and vines, which offers an almost impenetrable barrier to ordinary progress.

The country is sparsely settled, the few settlements being located in the lowlands flanking the mountains, and all, with two or three exceptions, being situated on the coast. Excluding several short logging roads, no steam transportation is carried on in the northwestern part of the peninsula, all of the freighting being done either by pack animals, wagons, or the steamers which ply between Seattle and the ports along the strait.

GEOLOGY

THE OLYMPIC MOUNTAINS

Previous knowledge of the region.—Little is known of the geology of the central portion of the Olympics because of the inaccessibility of this inner country. Mr Gilman,* in referring to the Olympic country in general, says:

> "The country rocks of the mountains are syenite, gneiss, quartzite, protogene, crystalline and chlorite schists, slate (hard black flinty to soft green talc), shale, sandstone, trap and basalt."

Dodwell and Rixon,† who examined the Olympic forest reserve, say that "no granite (except a few boulders), slate or porphyry has thus far been discovered on the reserve."

No sign of vulcanism, either in the rocks or in the pebbles of the Quinaielt or Queets rivers, was seen by Mr H. S. Conard, who visited the southwestern portion of the range in 1902.‡

Probable composition.—From evidence obtained by the writer along the western end of the peninsula and by Mr Chester W. Washburne in the Soleduc River canyon south of lake Crescent, it appears probable that at

* National Geographic Magazine, vol. 7, 1896, p. 138.
† Professional paper, U. S. Geological Survey, no 7, 1902, p. 19.
‡ Science, N. S., vol. 21, March 10, 1905, p. 392.

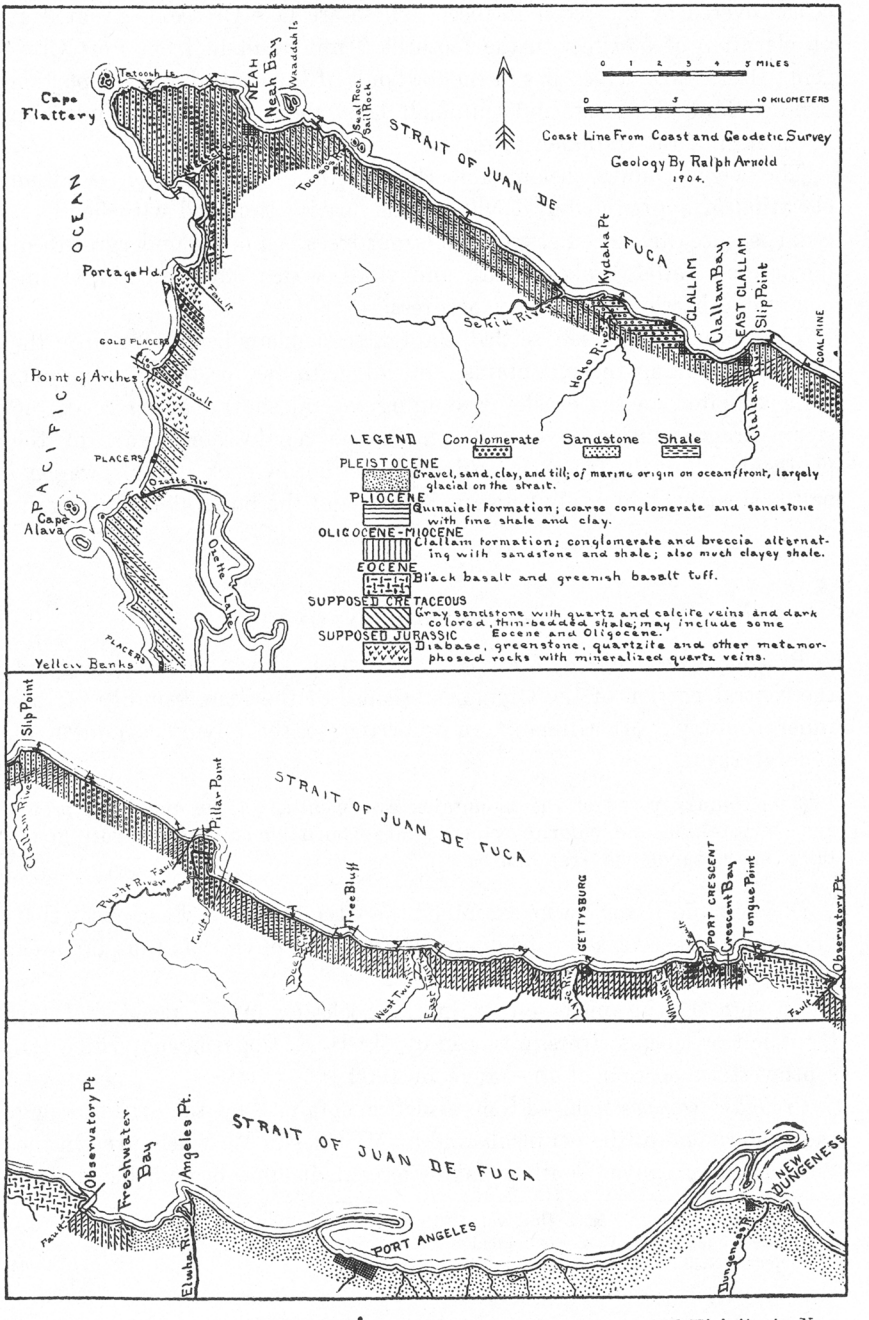

FIGURE 2.—*Detail Map of Geology of Coastline from Cape Flattery and Vicinity to New Dungeness*

least the greater part of the Olympic mountains is composed of a hard gray sandstone, certainly pre-Oligocene and probably Cretaceous in age.

THE COASTAL REGION

Geologic formations.—The formations involved in the geology of the coastal region of the Olympic peninsula include serpentine, old diabase or greenstone, metamorphosed sandstone and quartzite, probably of Jurassic age; 6,000+ feet of gray sandstone with minor quantities of carbonaceous shales, supposed to represent the lower part of the *Puget group* and of Cretaceous age; 1,200+ feet of basalt and basalt tuffs of Eocene age; 15,000 feet of Oligocene-Miocene conglomerate, sandstone, and shale; 2,260 feet of Pliocene conglomerate, sandstone, and shale, and at least 300 feet of Pleistocene till, clay, and gravel. In addition to this, the Oligocene-Miocene breccia contains large quantities of angular fragments of hard black slate, indicating a probable widespread formation of this type of rock somewhere in the general region. Nothing is known of the age of the slate except that it is pre-Oligocene.

Supposed pre-Cretaceous.—The supposed pre-Cretaceous rocks of the territory examined were confined entirely to the coast south of cape Flattery, the most important areas occurring at Portage head, 8 miles south of the cape, Point of the Arches, 3½ miles still farther south, and in the region from Point Greenville south to within a few miles of Grays harbor. The types of rock composing this old series embrace old diabase or greenstone, serpentine, quartzite, conglomerate, etcetera. These are much fractured and faulted and are occasionally cut by quartz veins, some of which, in the Point of the Arches complex, are said to carry small amounts of gold and silver. An interesting fact in relation to the conglomerate and serpentine in this same locality is the occurrence in them of a high grade petroleum. Where freshly exposed, both the conglomerate and serpentine give off a most nauseating odor, like that of benzine or some other allied product. The occurrence of the oil is made the more interesting when it is known that no shales or other possible oil-producing rocks outcrop in the immediate vicinity, although shales of probably Oligocene or Miocene age are found something over a mile south of the serpentine.

Supposed Cretaceous.—The rocks supposed to be Cretaceous in age, the correlation being based on their stratigraphic position and lithologic character, are also confined to the western coast of the peninsula. They extend over most of the territory from 1½ miles south of Point of the Arches to 1 mile north of cape Elizabeth, and 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. 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

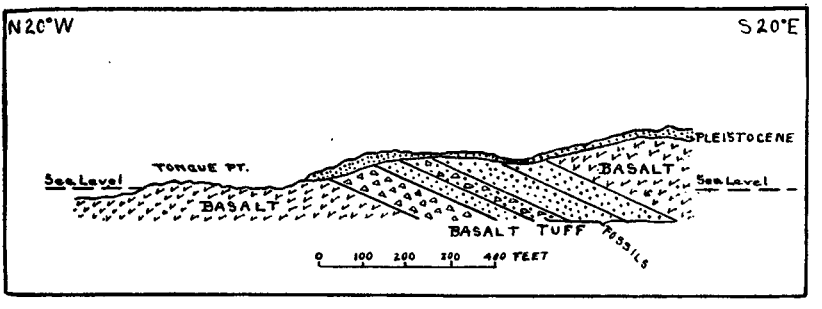

FIGURE 3.—*Section along eastern End of Crescent Bay.*

Showing the relations of the Eocene basalt, fossiliferous Eocene basalt tuff, and the fossiliferous marine Pleistocene.

sandstones and shales south of the mouth of the Quillayute river and at one or two other localities between the Quillayute and cape Elizabeth.

Eocene: Crescent formation.—The oldest formation of definitely known age on the Olympic peninsula is a 1,200-foot series of black basalt and greenish basalt tuffs and tuffaceous sands found in the vicinity of Port Crescent and here designated the Crescent formation. It comprises the region immediately west of Crescent bay and a prominent ridge extending eastward from the latter to Freshwater bay. *Venericardia planicosta* Lamarck, *Turritella uvasana* Conrad, and other characteristic fossils found in the tuff indicate the Eocene age of the series and its general contemporaneity with the Tejon of California.

The basalt occurs in two thick sheets, an upper and a lower, each of which may represent several surface flows. Between the two basalt sheets and intimately associated with the top of the lower is a series of roughly bedded fossiliferous tuffs. Figure 3 illustrates the relations of the differ-

ent beds as they occur at the eastern end of Crescent bay, while figure 2, plate 56, shows a characteristic exposure of the formation at tide level in the same region. In the region of Crescent bay the lower basalt has an exposed thickness of 200 feet, while the tuffs and upper basalt sheet each show approximately the same. The Freshwater Bay section gives basalt and coarse massive basalt tuff 600 feet, thin bedded green tuff 375 feet, and black vesicular basalt 200 feet. The base of the Crescent formation is not exposed, so that the subjacent rocks are unknown. The overlying sediments consist of coarse conglomerates separated from the basalt by an erosion interval. Faults define the contact between the Crescent formation and the Clallam formation (Oligocene-Miocene) adjacent.

These basalts and tuffs are the only rocks of igneous origin found along the whole length of the northern shore of the peninsula. Taking into consideration the volcanic activity which prevailed during the Eocene in the Cascade range, only a comparatively short distance away, this single and rather limited occurrence of eruptives seems rather remarkable. The paucity of igneous rocks, however, may possibly be accounted for, at least along the northern coastal border of the Olympics, by the fact that formations younger than the basalt are the only ones exposed, and it is possible that some of these newer rocks are underlain by the Eocene basalt series.

Oligocene-Miocene: Clallam formation.—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 in the region between Clallam bay and Pillar point, to the east, and for that reason is here named the Clallam formation. According to Doctor Dall, the fossils of the formation indicate that the basal portion of the series is Oligocene in age, while the upper part is certainly Miocene. Since the separation of the two members will necessarily have to be made on paleontologic grounds and will require a more detailed study of the material in hand than time has yet permitted, the term "Oligocene-Miocene series" will be used temporarily to designate the age of the beds. 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.

All of the pre-Pleistocene deposits along Fuca strait from Freshwater bay to cape Flattery, with the exception of the Eocene basalts and tuffs of Crescent bay and the Pliocene conglomerate and sandstone of the Clallam Bay-Hoko River region, belong to the Oligocene-Miocene series, and at least the greater part and possibly the whole of the thick series of

conglomerates, sandstones, and shales exposed in the Cape Flattery promontory, and also the sandstones and shales exposed in the hills south of the Bogochiel river, come under the same head. The thickness of this series as exposed in sections along the strait, which, by the way, virtually parallels the strike of the beds for most of the distance from Freshwater bay to Neah bay, is about 3,650 feet. The Waatch-Neah Bay section, which cuts directly across the strike of the great Cape Flattery monocline, exposes approximately 15,000 feet of conformable strata, most and possibly all of which may be Oligocene-Miocene.

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 zone of conglomerate in the middle of the Cape Flattery section may be the equivalent of the basal conglomerates of the series as developed unconformably above the Eocene around Crescent bay. If so, the sandstones at the base of the Cape Flattery section are older than any of the Oligocene-Miocene beds exposed on the strait. The base of the Cape Flattery section is unknown, as the lowest beds exposed in the section are separated from the subjacent rocks by a fault.

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. They are found at the base and near the top of the Cape Flattery section and below the upper conglomerates east of Clallam bay.

The shale of the Oligocene-Miocene occurs principally in the middle of the formation along the strait. The lower part of the shale is thinly and plainly laminated, but higher up becomes almost massive clay. Figure 2, plate 57, shows a characteristic exposure of the laminated shale. The overthrusting of the beds exhibited at this particular locality is very unusual, as the strata along this portion of the coast ordinarily lie in low simple folds. The shale is gray in fresh exposures, but becomes more or less oxidized upon exposure. Sandstone dikes, probably derived from interbedded sandstones, cut the shales in the region east of the mouth of the Pysht river, and near Gettysburg hydrogen sulphide gas was noticed escaping from cracks in the shale along the beach. Figure 1, plate 58, illustrates the ramification of one of the dikes, while figure 2, plate 55, shows a characteristic beach formed by the truncated beds of the soft clay-shale. Fossils are abundant and beautifully preserved throughout

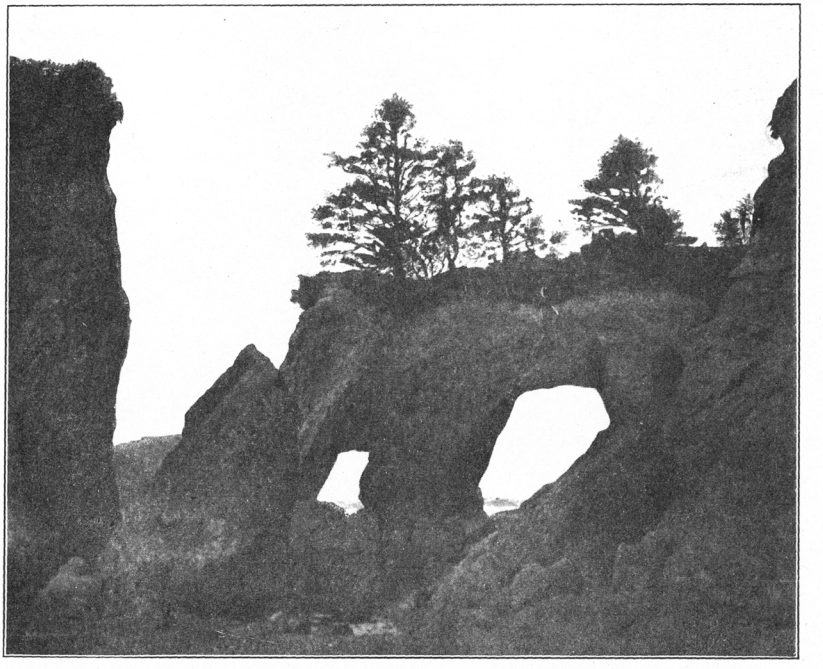

FIGURE 1.—NATURAL ARCHES IN SANDSTONE

At this locality the sea is rapidly encroaching on the cliffs south of the mouth of the Quillayute river. Photograph by Professor Henry Landes, 1902

FIGURE 2.—OVERTHRUST IN OLIGOCENE-MIOCENE SHALE, ¾ MILE WEST OF GETTYSBURG

A characteristic exposure of the shales. Photograph by Chester W. Washburne, 1904

the finer sediments of the series, at least two distinct horizons being recognized.

At least five recognizable faunas have so far been found in the Clallam formation. The oldest comes from the lowest clay-shales of the series and is characterized by such species as the following:

Fossils from the Clallam formation

List of fossils from the lower clay-shale (Oligocene)

Leda sp.
Pecten clallamensis Arnold.
Pecten waylandi Arnold.
Phacoides acutilineatus Conrad.
Nucula sp.
Solemya rubroradiata Conrad.
Tellina sp.
Dentalium substriatum Conrad.
Fusus sp.
Marginella or *Erato* sp.
Natica sp.
Perissolax sp.
Aturia cf. *ziczac* Sowerby.

List of fossils from the second horizon or massive sandstone

Above the clay-shale horizon is a series of medium bedded to fine massive sandstones in which are found fauna apparently transitional from the clay-shales to the coarse sandstones. This sandstone horizon has yielded the following fauna:

Cytherea cf. *vespertina* Conrad.
Leda sp.
Nucula sp.
Phacoides acutilineatus Conrad.
Solemya rubroradiata Conrad.
Tellina (*Angulus*) sp.
Thracia cf. *trapezoides* Conrad.
Cylichna petrosa Conrad.
Dolium petrosum Conrad.
Fusus sp.
Natica sp.
Perissolax (*?*) sp.
Pleurotoma sp.
Scala sp.

List of fossils from the third horizon or Miocene sandstone

Still a third fauna, later than the last, is represented by the following species found immediately east of Clallam bay:

Arca sp.
Chione (aff.) *temblorensis* Anderson.
Cytherea cf. *vespertina* Conrad.
Pecten fucanus Dall.
Pecten propatulus Conrad.
Tellina arctata Conrad.
Fusus oregonensis Conrad.
Natica sp.
Sigaretus scopulosus Conrad.

List of fossils from near the top of the Clallam formation

The fourth fauna is that found in sandstone layers interbedded with conglomerates in the upper part of the formation, and is:

Chione aff. *temblorensis* Anderson.
Mactra sp.
Mytilus aff. *mathewsonii* Gabb.
Panopea generosa Gould.
Pecten fucanus Dall.
Phacoides acutilineatus Conrad.
Tellina sp.
Crepidula præcrupta Conrad.
Dentalium substriatum Conrad.
Fusus sp.
Scala (*Opalia*) sp.

List of fossils from the equivalents of the upper beds of the Cape Flattery section

The fifth fauna of the Oligocene-Miocene is that found at the mouth of the Sekiu river in beds the equivalent of the uppermost strata of the Cape Flattery section. The relation of this fauna to those just given is somewhat problematical, although it appears quite likely that the former is younger than most of the latter.

Cardium aff. *quadrigenarium* Conrad.
Leda sp.
Mactra sp.
Nucula sp.
Tellina aff. *bodegensis* Hinds.
Yoldia sp.
Cancellaria sp.
Cylichna sp.
Dentalium sp.
Fusus sp.
Natica sp.

Correlations.—Correlations between the different fossiliferous localities of the Oligocene-Miocene series over the whole of the Peninsula and Puget Sound region are comparatively easy, as are also correlations with certain of the Oregonian faunas such as those of the Astoria shales and sandstones, but when it comes to making direct correlations with the Californian or Alaskan faunas much difficulty is encountered. One of the greatest surprises the writer had in all of his work along the straits was his inability to find the characteristic upper Miocene fauna of the Sooke beds which are so well developed only 15 miles to the northward on Vancouver island. With an almost unbroken series of Miocene faunas one would certainly expect to find the Sooke species somewhere among the lot, but such was not the case and no plausible explanation of their absence has so far presented itself.

Coal in the Clallam formation.*—Coal occurs in the sandstones east of Callam bay in the upper part of the Oligocene-Miocene series and in the base of the same series in the vicinity of Freshwater bay. Three well

* Bulletin no. 260, U. S. Geological Survey, 1905, pp. 413-421.

defined layers, 12, 22, and 36 inches in thickness, are exposed in the first locality, while in the second 28-inch and 56-inch beds are said to occur. The coal is a hard, glossy black lignite and is, according to Mr Campbell, well adapted for gas-producer engines.

Pliocene—Quinaielt formation.—The Pliocene has a very limited development on the Olympic peninsula, only two areas of importance occurring on its coasts. The more important of these is a great syncline between capes Elizabeth and Greenville through the trough of which the Quinaielt river empties into the sea. The formation in which this syncline is developed is therefore named the Quinaielt. The Quinaielt consists of over 2,200 feet of conglomerates and shales, with minor quantities of sandstone. The conglomerates are developed north of the river, while the shale, with some underlying sandstone, occurs south of it. Owing to the fact that faults limit the syncline on both sides, it was impossible to determine positively which facies of the formation, the conglomerate or the shale, was the older. However, it appears most likely that the latter represents the basal portion of the formation. The beds contain well preserved marine fossils and the conglomerates in particular considerable quantities of almost unaltered wood and bark of trees, often in large fragments.

Fossils from the Quinaielt formation.—The following fossils, which locate the formation in the lower Pliocene and indicate its contemporaneity with the Purisima formation of central California, were obtained at the mouth of Quinaielt river, at various horizons throughout the series.

Terebratalia cf. *occidentalis* Dall.
Leda sp. (short and smooth).
Lima cf. *hamlini* Dall.
Macoma sp.
Mactra sp.
Pecten hastatus var. *hericius* Gould.
Solen sicarius Gould.
Tapes cf. *staleyi* Gabb.
Thracia trapezoides Conrad.
Yoldia cf. *cooperi* Gabb.
Anachis sp.
Chrysodomus aff. *tabulatus* Baird.
Cylichna sp.
Margarita sp.
Natica clausa Broderip and Sowerby.
Opalia cf. *borealis* Gould.
Pleurotoma perversa Gabb.
Priene aff. *oregonensis* Redfield.
Purpura canaliculata Duclos.
Purpura crispata Chemnitz.
Purpura saxicola Valenciennes.
Solariella peramabilis Carpenter.

Beds of concretionary sandstone and gray shale, the equivalent of a portion of the Quinaielt, outcrop to the northward at the mouth of the Raft river. Another area of Pliocene also occupies the territory from Clallam bay westward to the Hoko river. The Pliocene here rests unconformably upon the upturned and eroded Clallam formation (see figure 4) and consists largely of conglomerate. In the cobbles and boulders of the con-

glomerate are numerous well preserved Miocene fossils, similar to those found at the mouth of the Sekiu river (see list). The maximum section exposed in the Clallam Bay-Hoko River Pliocene area is only 240 feet thick, but this probably represents only a part of the formation.

Pleistocene—General character of the deposits.—The Pleistocene deposits of the region under discussion consist of till, clay, sand, and gravel, mostly incoherent but sometimes locally firmly cemented by iron oxide (see plate 58, figure 2). They extend from Port Townsend along the strait to the region about Gettysburg and from Portage head to a short distance south of point Greenville, on the Pacific Ocean side. In the vicinity of Port Angeles and eastward to Port Townsend the Pleistocene is between 200 and 300 feet thick; its lowest member till, the rest of the

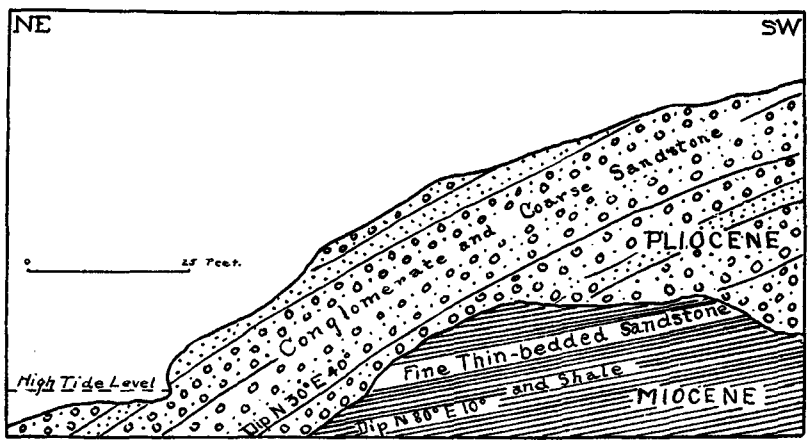

FIGURE 4.—*Section of small Promontory on Coast 2 Miles West of Clallam.* Showing unconformity between the Miocene and Pliocene.

formation roughly stratified sand and gravel. This till is probably the equivalent of Willis's Admiralty till of the Puget Sound country. The top of the till, which is largely a stiff blue clay, is often marked by springs. In the vicinity of Freshwater bay these springs are large and exceedingly numerous, and are said to have been used by the early navigators in stocking their ships with water; hence the name of the bay.

The maximum development of the Pleistocene on the western side of the peninsula is in the region about Yellow banks, 6 miles south of the mouth of the Ozette river, where the deposits of sand and gravel attain a thickness of over 125 feet. The marine origin of at least a part of the Pleistocene deposits along this part of the coast is attested by marine

FIGURE 1.—SANDSTONE DIKE IN SOFT OLIGOCENE-MIOCENE SHALE
Three-fourths of a mile east of East Twin river. Photograph by C. W. Washburne, 1904

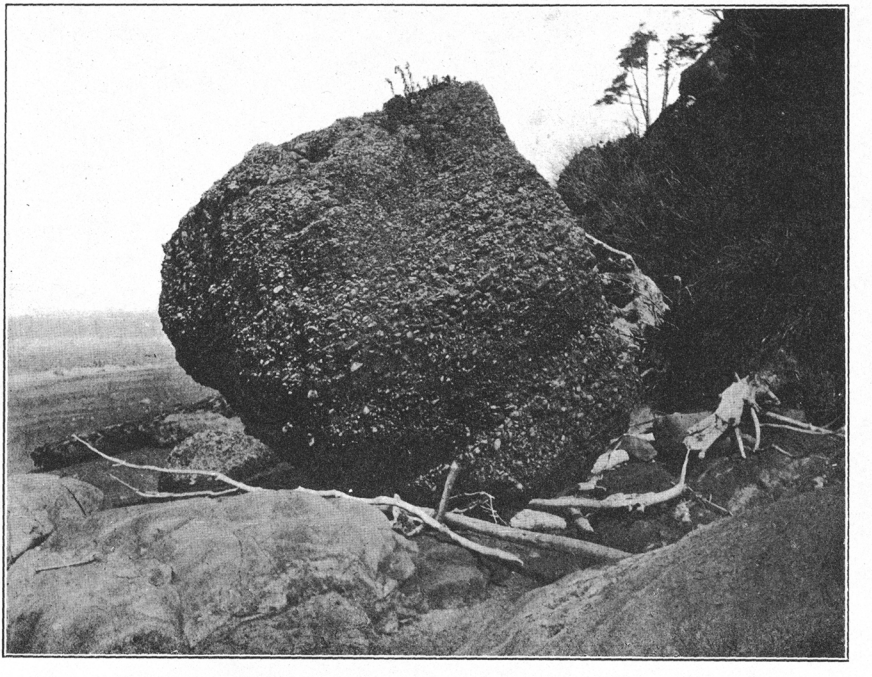

FIGURE 2.—BOULDER OF PLEISTOCENE GRAVEL ON BEACH SOUTH OF MOUTH OF QUEETS RIVER
This gravel is firmly enough cemented by iron oxide to be considered a true conglomerate. Photograph by Professor Henry Landes, 1902

fossils, which are found in fine stratified sands 35 feet above tide level near Point of the Arches.

Gold in the Pleistocene gravels.*—In certain localities the Pleistocene deposits which constitute or cap the bluffs from near Portage head south to Yellow banks carry small amounts of gold, platinum, and iridosmine. By a process of wave action these metals have been concentrated on or near the bedrock at the base of the bluffs, sometimes in quantities of economic importance. The gold and other precious metals in these beach deposits are always associated with magnetite and garnet sand, although the places richest in the "indicators" are often barren of the gold in paying quantities.

Mining has been carried on in the region since 1894, and during this period at least $15,000 has been taken from the Shishi Beach placers between Portage head and Point of the Arches alone. Besides the Shishi Beach workings, there are paying claims being worked intermittently 2 miles north of the mouth of the Ozette river, and at Yellow Banks, 6 miles south of the mouth of the same river. The mining is carried on principally by the sluice-box method, although where the water supply is limited, as at the locality 2 miles north of the Ozette, rockers are used.

GEOLOGIC STRUCTURE IN GENERAL

As indicated by the exposures along the coast, the structural lines in the region from Port Angeles to Gettysburg average approximately parallel to the trend of the Olympics, north 70 degrees west, south 70 degrees east; those in the Gettysburg-Clallam Bay territory almost perpendicular to this, or a little east of north, and those in the Clallam Bay-Cape Flattery stretch north 30 degrees west, south 30 degrees east, or again parallel with the ridges which extend along the coast in this region. A syncline, with its southern limb resting against the sandstones south of lake Crescent and its northern one truncated by the waters of the strait of Fuca, is the major structural feature of the Port Crescent-Gettysburg region. From Gettysburg westward to the mouth of the Pysht river the structural features are not pronounced, the rocks in general, however, having a westward dip. A rather broad syncline, with its axis extending in a northeasterly-southwesterly direction, occupies most of the territory between the Pysht river and Clallam bay. This syncline is complicated in its southeastern portion by sharp local folding and some faulting. The region between Clallam bay and cape Flattery is formed by a great northeast-

* Bulletin no. 260, U. S. Geological Survey, 1905, pp. 154-157.

dipping monocline, the beds of which appear to have a total thickness of over 15,000 feet.

South of the Clallam Bay-Cape Flattery monocline is the western extension of the axis of the Olympic mountains. The structure in the region about this line of disturbance is quite complex, but as one goes away from it toward the south the structure becomes simpler. Several determinable folds with northwest-southeast axes were noted along the coast between the Ozette and Hoh rivers, and in the vicinity of the mouth of the Quinaielt there is a very prominent syncline developed in the Pliocene, with its axis parallel to those just mentioned.

A great uplift in the Olympic Peninsula region appears to have taken place at or near the close of the Miocene epoch, and still another lesser one during the late Pliocene. That orogenic movements are still taking place, or have occurred since the deposition of the Pleistocene, is evidenced by the very gently folded and tilted clays, sands, and gravels in the vicinity of Port Angeles.