

ART. XLIV.—*Notes on the Surface Geology of the country bordering the Northern Pacific Railroad*; by J. S. NEWBERRY.

FROM Chicago through Wisconsin and Minnesota the Northern Pacific Railroad passes over an almost unbroken sheet of drift, which, though of great interest, has been so fully described in the able reports of Messrs. Chamberlin, Winchell and Upham, that nothing further need be said here in regard to it.

Going west from Duluth to Brainerd the line of the road for the most part lies in what is evidently the old deserted bed of a westward extension of Lake Superior. The ground is still low and swampy and much of the surface is formed of what is unmistakably lake sand.

At various points farther west true till is seen with its striated pebbles; and one such exposure at Audubon is within reach of every traveler. Beyond this, bowlders scattered over the surface and pebbles in the ditches continue as evidence of the transport of material from the eastern highlands. About Bismarck the bowlders though fewer are still not rare and are gathered in groups and trails, as elsewhere along the margin of the drift area, suggesting transport by ice floats. The last of these bowlders is seen at Sims, about twenty miles from Bismarck. From this point to the crossing of the Little Missouri one can hardly find a stone to throw at a bird or a shrub big enough for a tooth pick. This is an extension northward of that broad prairie area which I have crossed in many places farther south. Here, between the eastern drift and that from the Rocky Mountains, the soil is formed entirely by the decomposition of the underlying rocks, and wherever these are shales and calcareous sandstones, as they are throughout most of the Cretaceous formation, there are no outcropping ledges of rock; the country is smooth and stones of all kinds are scarce. This belt, which runs from the Mexican to the Canadian line, is prairie because of the dryness of the climate and not on account of the soil or the geological substructure; for between the "Cross timbers" and the Raton Mountains with a considerable variety of geology and topography, there are no trees except along the water courses, which, fed by the melting of the snows on the Rocky Mountains, are perennial and supply constantly the amount of moisture that is a necessity for tree growth.

The peculiar fineness of the soil of the northern portion of this belt has been supposed to have something to do with the prevalence of grass and the absence of trees, since in Illinois and Wisconsin, along the border line between the forest and the prairie, the levels where the soil is fine are grass-covered, while the swells and ridges, rocky or gravelly, carry trees; but as I have shown elsewhere, these local peculiarities of the soil, favoring, the first grass and the second trees, have to some extent caused the observed interlocking of prairie and forest. Farther west, with every kind of soil and geological structure, there are no trees, but everywhere grass, while east of the Mississippi and beyond the battle ground between the two forms of vegetation, all kinds of topography, soil and substructure are covered with forest. No one who has traversed the continent along several parallels of latitude and has studied the relations of vegetation to soil and geological structure will fail to find conclusive evidence that the influence which has determined the kind and quantity of vegetation in the varied topographic and climatic districts of the west is the rainfall.

The valley of the Little Missouri is deeply cut in a table land composed of the Laramie coal-measures, of which 200 or 300 feet with several seams of coal are exposed in the cliffs. Thousands of silicified tree-trunks are scattered over the surface and innumerable stumps are apparently standing where they grew, but no foreign material is anywhere visible. A few miles below the railroad crossing the valley expands and opens into the famous *Mauvaises Terres*, or "Bad lands of the Missouri." The course of that stream being here nearly east and west and the valleys of the tributaries north and south, these coalesce and form in the old lake beds picturesque but dangerous labyrinths.

As soon as one enters the valley of the Yellowstone he finds himself surrounded by transported material. Gravel and bowlders of crystalline, sedimentary and volcanic rocks form the bed and bars of the river, increasing in coarseness and quantity to Livingston, but in all this material I was unable to find anything that was to me even presumably of eastern origin.

Dr. C. A. White (this Journal, vol. xxv, 1883, p. 206) reports finding what he considers eastern glacial drift along the valley of the Missouri and that of the Yellowstone, but my search for such material was vain.*

The geology of the Yellowstone Park has been well described by Dr. Hayden and his assistants, Mr. W. H. Holmes and Mr. A. C. Peale, but I was surprised to find the traces of glacial action so widespread and unmistakable. It is probably not too

* As will be seen farther on, I found in the valley of the Missouri about the falls great quantities of drift with bowlders of fossiliferous limestone, quartzite, gneiss and granite, all remarkably like the eastern drift, but which I subsequently traced to their place of origin in the Belt mountains.

much to say that every valley of the Park was once filled with ice; for moraines, boulders, glacial lakes, and more rarely glacial striæ give testimony on this question that cannot be disputed. Ice-borne blocks are seen on the sides of the Yellowstone valley below the mouth of Gardner's River, and south of Mammoth Hot Springs every depression has once held a glacier. Swan Lake is of glacial origin and is bounded on the south by a terminal moraine, while lateral moraines and striated rock surfaces mark the old ice level high up on the sides of the valley. Near Marshall's the road leads over a succession of great moraines of clay and boulders which continue to and around the Fire Hole basin, and prove that this also was once largely filled with ice. From all I could learn the evidences of glacial action which are found here in the lowest portion of the Park may be traced through all parts of it.

DRIFT OF THE UPPER MISSOURI.

The Missouri River, formed at Gallatin City by the union of the Madison, the Gallatin and the Jefferson, traverses with a northwest and then northerly course the valley between the Rocky and Belt Mountains, and finds its way out to the plains by a long circuit around the northern bases of the Belt and Crazy Mountains, eastern outliers of the Rocky Mountain system. Cutting through barriers formed by interlocking spurs at the "Gate of the Mountains," the river enters an undulating prairie country which extends from the north side of the Belt Mountains to and beyond the Canadian line. All this region is occupied by a sheet of drift that in thickness and extent rivals that of the plains surrounding the Canadian highlands; but, as far as my observation extended, I found this of local origin.

At the Great Falls of the Missouri the underlying rock is exposed, but the drift-sheet comes up to the edge of the gorge and forms the low hills which stretch away to the east and north like the long swells of the ocean. In the valleys of the streams which come down to the Missouri from the Belt Mountains, the rock substratum is generally visible; but the intervening plateaus are covered with a sheet of drift that varies greatly in thickness as it is spread over a rock surface that was once deeply and irregularly eroded. For example, near the Upper Falls of the Missouri, where the banks of the river are solid rock and perhaps a hundred feet high, a tributary coming in from the south cuts across an old valley filled with drift, which extends almost to the present river channel. At its mouth this tributary has high rocky banks, but a few hundred yards above they are altogether composed of drift. This is a true till, thickly set with boulders, some of which are two feet or more in diameter.

The boulders are usually rounded, sometimes subangular, and are composed of gray or red granite, quartzite, Paleozoic limestone and a variety of eruptive rocks. The resemblance to the drift from the Canadian highlands is so great that I was only convinced of its local origin when I found all of its constituents in place in the Belt and Rocky Mountains. The granites were to my eye indistinguishable from those of the eastern Laurentian series. As I subsequently learned, they are of Archæan age, and nothing but careful microscopic examination will show them to be distinguishable, if they are so.

These facts lead me to suspect that the very careful and experienced observers who have reported the finding of eastern Laurentian boulders on the flanks of the Rocky Mountains, 4000 feet above the sea may have been misled by this striking resemblance.

On the undulating surface of the table lands between the tributaries of the Missouri, large boulders are occasionally seen, as in the States bordering the Great Lakes, and we passed one of these somewhat angular in form which had served so long as a rubbing-post for the buffaloes, recently abundant in this region, that its sides are all polished, and a deep furrow is worn around it by their feet.

THE GORGE OF THE COLUMBIA.

The gorge of the Columbia is one of the most impressive and interesting topographical features in all the picturesque West. It is cut with a nearly straight westerly course across the whole breadth of the Cascade Mountains, fifty miles, and its banks rise from 2,000 to 4,000 feet directly from the river side. Most of the material of which the walls are composed is basalt. This can be seen to form distinct layers, the products of different overflows from the great volcanic vents north and south of it. Cape Horn, a bold headland, shows a vertical face of trap nearly 500 feet in height.

No one who examines the gorge of the Columbia will fail to be convinced that it has been cut by the river. The general altitude of the mountains in which there are no other passes lower than about 5,000 feet, as well as the altitude of the lake deposits on the eastern side indicate that the work of cutting this channel began at a height not less than 3,000 feet above the sea. At this time the river must have had a fall of at least this number of feet into the valley of the Willamette; and to realize the conditions then existing, we must picture to ourselves a series of cascades of greater magnitude and more picturesque than any now known. This water-power was, however, busily engaged in cutting down the barrier, and in process of time it was so completely removed that a navigable canal was opened from the Dalles to the ocean. The

Western entrance to the gorge is now at tide-level and the lower part of the river is, like the Hudson, an arm of the sea. It is true that at present the "Cascades of the Columbia," form a serious interruption to the navigation of the river, for they are produced by a dam sixty-three feet high, which fills the channel for three miles. But this dam is of recent date, as we know, and has been caused by an avalanche from the sides of the gorge. Above it the river is simply a long lake, and in low water a series of stumps are seen coming up from below the water-level which belonged to trees that could never have grown in the places they occupy if the barrier of the Cascades had existed.

Steamboats navigate the Columbia from the Dalles down, with a transfer at the Cascades, and this is much the better route to take for those who would get a good view of the gorge with its imposing walls, its hanging forests and its picturesque waterfalls which leap 1,000 feet from the cliffs, to say nothing of the old Indian burial grove, and the multitude of silicified tree trunks at the Cascades.

The railroad is built along the face of the southern cliff, high above the water, and although it gives only a one-sided view of the gorge, it is generally chosen by travelers who prefer rapid transit to beauty of scenery.

ANCIENT GLACIERS OF THE CASCADE MOUNTAINS.

As is well known, the Rocky Mountains from New Mexico to British Columbia abound in evidences of ancient glaciation. The same is true of the Uinta Mountains, the Wasatch, the Sierra Nevada and Cascade Mountains. In the group of five snowy peaks called in Oregon the Three Sisters—because only three are visible from the Willamette valley, miniature glaciers were found by our party in 1855 at the heads of McKenzie's Fork and one of the tributaries of the Des Chutes, and on Mt. Shasta and Mt. Rainier are many true glaciers, of which some are several miles in length. But all the glaciers and snow-fields now existing on the Cascade Mountains are insignificant compared with those of the Glacial period. Then every gorge was filled with snow and ice, the broader and more irregular summits were covered with glaciers and these descended far below the present line of perpetual snow. Now in many localities and over many square miles the rock surfaces are planed smooth or grooved like a plowed field, and every projecting crest of volcanic rock, rough and ragged as it was, is rounded over and worn into a *roche moutonnée*. From the Three Sisters glaciers descend into the valley of the Willamette on the west and that of the Des Chutes on the east, and I traced glacial

markings from the snow line to a point 2,500 feet lower, where they pass under the alluvium of McKenzie's Fork.*

It has been claimed by Lecoq (*Les Glaciers et les Climats*) and following him by Professor Whitney and others (*Later Climatic Changes*), that the great development of glaciers during the Ice Period, such as those of the Canadian highlands, the Rocky Mountains, the Cascades and Sierra Nevada, was not the effect of a cold but a warm period, which increased the precipitation and consequently the snow-fall at all places where the temperature was low enough to cause it to take the form of snow. If this was all, however, the most extensive glaciers should be in the Alpine districts of the tropics or temperate zones wherever the precipitation is most abundant and the temperature low enough to produce perpetual snow. But the great glaciers of the present time are not on the Andes, the Himalayas or the Alps, but on Greenland and the Antarctic Continent where the climate is very cold and the amount of precipitation small.

We also find on the summits of the Cascades a demonstration of the fallacy of this view; since here some of the mountains rise 14,000 feet above the sea and the line of perpetual snow is not over 7,000 feet, while the annual precipitation is greater than in almost any other portion of our country. In fact the snow accumulates in such quantity that even in mid-summer it reaches down to where it is met and opposed by a vigorous forest growth—the product of a high temperature. It is evident that no elevation of temperature, though it should increase the evaporation on the Pacific and the rain-fall on the coast, would cause the renewal of the ancient glaciers; but with a depression of temperature which should continue the present winter conditions through the year, the precipitation remaining the same, the accumulation would soon cover the mountain summits with snow and ice and bring the glaciers down to their old limits.

THE LOWER COLUMBIA.

The country bordering the Lower Columbia is too well known to require description. I am impelled, however, to refer to one or two points in its physical structure which are of special interest when brought into connection with facts of similar import observed in the region about Puget's Sound. I have said that the Lower Columbia is an arm of the sea. It is in fact a deep river valley which has been flooded by an influx of the sea caused by subsidence. This brings tide-water to the foot of the falls of the Willamette at Oregon City, and to the Cascades.

It requires no argument to prove that such a channel could not have been cut unless by a rapid stream flowing into the

* Pacific Railroad Report, vol. vi, Part II, Geology, p. 42.

ocean when it stood at a lower level. Whether the change in the relative level of land and sea here remarked was part of a general movement which produced the influx of the sea into the fiords which fringe the northwest coast; and whether this is not a part of a still grander movement that flooded the old excavated valleys of the James River, the Potomac, the Schuylkill, the Hudson, the St. Lawrence and the Saguenay and at the same time filled the fiords of the northeastern coast, are questions which cannot now be fully answered but are worth considering.

It will be noticed that the general plan of the topography of this part of the coast is altogether similar to that of California; namely, the great wall of the Cascades bordered on the east by the Willamette and Cowlitz valleys, and the Coast Mountains along the sea shore, are reproduced farther south by the Sierra Nevada, the great California valley and the Coast Ranges. And these features are not only physically similar, but geologically identical; the Cascades being the northern continuation of the Sierra Nevada, the more modern Coast Mountains being continuous, the great trough between them essentially one, but filled at its center by a mass of mountains.

SURFACE GEOLOGY OF THE PUGET'S SOUND BASIN.

The name Puget's Sound is made in popular use to cover all the peculiar group of inlets and tideways which lie immediately east of Vancouver's Island,—Puget's Sound proper, Admiralty Inlet, Hood's Canal, etc. These occupy the northern extension of the great Columbian valley, which, like its counterpart in California, lies between the Coast ranges and the Cordilleras. Farther north still this depression is deflected toward the northwest by a change in the trend of the Cascade Mountains and the representatives of the coast ranges on Vancouver's Island.

In Washington Territory the Coast Mountains are higher than in Oregon and have received the local name of the Olympian range, of which the highest summit is called Mt. Olympus. This range terminates somewhat abruptly but is apparently continued in the mountains of Vancouver's Island. Through the gap between these and the Olympian range a deep channel is cut, now an arm of the sea, called the Strait of Juan de Fuca. In former times, when this portion of the continent, and probably the whole northwest coast, stood higher above the sea, this Strait was the valley of a great river which drained most of the western slope of the Cascades in Washington Territory, and had as branches the Skagit, Snoqualme, Dwamish, Puyallup, Nisqually and various minor streams. During the Ice period this hydrographic basin was filled with a great glacier made up of contributions from all the surrounding moun-

tains. It flowed out to sea by the Strait of Fuca, but this channel was far too narrow for it and it spread over all the southern portion of Vancouver's Island, planing off, rounding over or deeply scoring the rocks in its passage. As the glaciers retreated they left behind a sheet of drift several hundred feet in thickness, partly water-worn and stratified, partly unstratified boulder clay with striated pebbles, of which the surface was nearly level. In process of time the draining streams had cut in this plain a series of valleys all tributary to one which led out through the Strait of Fuca to the ocean. After perhaps some thousands of years, during which the excavation of these valleys progressed, a subsidence of the land or rise of the ocean caused the water to flow in and occupy the main valley and all its tributaries up to the base of the mountain slopes.

Such in few words is the history of the formation of this remarkable system of inlets. They are simply the flooded valleys of a great river and of the branches that formerly joined it but now empty into the extremities of the finger-like inlets that have partially replaced them.

There are but few localities in Puget's Sound basin where the rocky substratum rises so as to be visible above the water level. Along the northern and western margin on Vancouver's, Sucia, Orcas and Whidby Islands, and at Chuckanut's and Sohome the rock appears, but at Tacoma, Steilacoom, Seattle, Port Madison, Port Townsend, and it may be said generally about the Sound, the shores are steep bluffs, 100 to 150 feet in height composed of drift alone. From the cliffs at Port Townsend and Tacoma, I took sub-angular scratched and ice-worn pebbles as characteristic and convincing as any to be found in the boulder clays of the eastern States.

The subsidence which caused the sea water to flow into the subaerially excavated valleys of Puget's Sound also filled the channel of the Columbia, the Cascades and the system of fiords, of which these are representatives, that fringe the northwest coast. We have evidence, too, that the area occupied by the sea was at one time much more extensive than now, for all the country immediately about Puget's Sound is marked with a series of marine terraces which Mr. Bailey Willis, who studied them carefully when connected with the Transcontinental Survey under Professor Pumpelly, tells me can be traced to a height of 1600 feet above the present ocean level. These terraces are conspicuous on the low divide which separates the valley of the Cowlitz from the basin of Puget's Sound; and here, as over much of this region, the ground is covered with pebbles and water-worn boulders, the product of the long continued dash of the shore waves on a slope composed of drift materials. In the advance and recession of the shore line, the

finer materials have been mostly washed away, and the stony surface has little agricultural value. Fortunately it is well adapted to the growth of trees, and the splendid forest which covers it is perhaps an equivalent for all it has lost. The facts here given show why the cultivation of the soil in Washington Territory is limited to the narrow belt of modern alluvium along the streams, and indicate that coal mining, the fisheries and the lumber industry must be in the future as they now are, the most important sources of wealth.

MODERN GLACIERS OF THE SIERRA.

From the Willamette Valley and Puget's Sound grand views are obtained of the great snow peaks of the Cascade Mountains; the Three Sisters, Mt. Jefferson, Mt. Hood, Mt. Adams, Mt. St. Helens, Mt. Tacoma and Mt. Baker. Of these, Mt. Hood has an altitude of 11,225 feet, Mt. Adams 12,250, and Mt. Tacoma 14,400. In Colorado and California there are a number of summits of equal absolute altitude, but they have nothing like the relief above their surroundings that these have; carry far less perpetual snow, and in every way are less impressive. In Washington Territory the line of perpetual snow on the west side of the mountains is about 6500 feet; on the east side, several hundred feet higher. Mt. Tacoma carries therefore about 8000 feet of snow. Below this it is covered with a dense forest. As none of its foothills rise to the height of 2000 feet above the sea and are invisible at a distance, from many places about the Sound practically the whole of the mountain is seen at one view; a gigantic cone, 14,000 feet in height, apparently rising directly from the sea level. Mt. Shasta has the same altitude, and as seen from Scott's valley is wonderfully impressive, but it is situated farther inland and farther south, its base is higher and it has less snow, and is therefore somewhat less imposing. It is not too much to say then, that no other mountain on this continent and none in Europe rivals Mt. Tacoma in grandeur and beauty, and it is doubtful whether in the world there is any that produces a profounder impression upon the beholder. Mt. Hood, as seen under favorable circumstances from Fort Vancouver, especially when reflected from the lake-like surface of the Columbia, is as beautiful but far less grand.

Though appearing in the distance so smooth and symmetrical, Mt. Tacoma has been found to be a ragged and compound mass consisting of three conspicuous summits and many subordinate peaks, with precipices 2000 to 3000 feet in height and deep gorges which make the ascent difficult and even dangerous.

It has been ascended, however, several times, and its labyrinths sufficiently explored to prove that it carries from eight to twelve glaciers, some of which are many miles in length and will bear comparison with those of the Alps.

Every traveler who enters Puget's Sound region from the south is sure to be struck by the turbid milky appearance of the water of the Cowlitz River along which the railroad runs for miles. This character it shares with all streams that drain glaciers, and which has caused the Swiss mountaineers to give to the waters of such streams the name of *Gletscher Milch*. Its turbidity is due to the sediment produced by the constant grinding action of these enormous masses of moving ice set with stones upon their beds, and attests the sometimes disputed efficiency of glaciers as eroding agencies. The Puyallup, White River, and other streams, which come down from Mt. Tacoma, are alike milky, and each shows that one or more glaciers are continually grinding away at its head. On the contrary, the streams which do not come from glaciers and are supplied by rain only, and that filter through the decaying vegetation of the dense forests, carry very little sediment and that chiefly carbonaceous matter. These are clear but brown, and the contrast which the water of such streams presents to that of the rivers which drain the glaciers is very striking and justifies the names borne by two such of Black and White Rivers.

It has been contended by some writers, as has been mentioned, that the extension of glaciers in former times was due simply to an increase in the amount of precipitated moisture, but it is easy to see that the heavy rain-fall of Washington Territory might be increased indefinitely with no considerable elongation of the glaciers. But even with the rain-fall remaining as it is, if a depression of temperature should take place carrying the present conditions of winter through the year, the glaciers would soon creep down into their old beds, fill all the valleys of their draining streams and finally coalesce to form one grand glacier which would flow out through the Strait of Fuca to the ocean.

Following the coast northward from Puget's Sound we find the glaciers coming down lower and lower until in Alaska they reach the sea level. No one can claim that this is because the precipitation is greater there, since observations show that it is not, but every candid man will acknowledge that it is because at the north the temperature is lower. He must also accept these facts as a demonstration *that a prime factor in the production of the phenomena of the Ice Period was a secular depression of the temperature.*