

February, 1878.

(*From the Canadian Naturalist, Vol. VIII. No. 7.*)

TRAVELLING NOTES
ON THE
SURFACE GEOLOGY OF THE PACIFIC SLOPE.

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When on my way to resume my geological duties in British Columbia, in May last, I availed myself of the opportunity to obtain a passing glimpse of Northern California, Oregon, and Washington Territory; leaving the Central Pacific Railway, for that purpose, at Roseville Junction, near Sacramento, and travelling northward, by train and stage coach, to the extremity of Puget Sound, whence a steamer runs to Victoria, Vancouver Island. The region was a very interesting one to me, constituting the southern extension of that which I have been engaged in studying in British Columbia, and characterized in the main by the same great physical features. It is proposed now to give the substance of a few notes taken by the way, on the superficial deposits and general aspect of the country, connecting these with facts already observed in British Columbia, some of which are published in the reports of the Geological Survey, but treated of at greater length in a memoir read before the Geological Society of London, in June last. Dr. A. S. Packard, Jr., of the United States Entomological Commission, passed through the same

region, in August last, and has published some notes on the surface geology in the *American Naturalist* for November, under the title of "Glacial Marks on the Pacific and Atlantic Coasts Compared." To this article I shall again refer.

In descending the western slope of the Sierra Nevada, hard clays, packed with boulders and stones, are seen in some cuttings near Blue Canon Station (elevation, 4,693 feet) and at other places, probably as far down as Dutch Flat Station (3,395 feet). These are doubtless old moraines, due to the former glaciers of the Sierra, which, according to the American geologists who have examined this range, were at one time very extensive.

Leaving the rolling foot-hills, the train glides out on the wide and generally fertile Sacramento Plain, in the midst of which the city of the same name is situated. Near the base of the foot-hills, large areas are covered with the so-called "Hog Wallows," about which some discussion lately occurred in *Nature*, it being suggested by some that they were connected with ancient ice action. Mr. Gabb * is no doubt right, however, in attributing them to the accumulation of drifting sand and soil around clumps of vegetation, which in some cases may have afterwards perished from climatic or other causes, leaving only these peculiar hillocks to mark their former positions. The banking up of sand and soil about patches of cactus and sage is seen frequently in the dry plains east of the Rocky Mountains, as well as in Nevada, to which Mr. Gabb refers.

Leaving the main line of railway at a right angle at Roseville, and turning northward, one continues to travel over the same wide, flat, or gently undulating plain of Central California, bounded to the right by the snowy peaks of the Sierra, to the left by the more rounded summits of the Coast Range. Soon after leaving Maryville—an important town—a rugged and picturesque group of hills, called the Butte Mountains, appear on the left, some miles distant. They owe their outline apparently to prolonged atmospheric waste, and are singularly different from the dome-like summits of a glaciated country. At Reading, about 120 miles north of Roseville, the railway comes to an end, and for 275 miles, the stage coach must carry us through a country remarkably broken and tumultuous. Crossing the Sacramento by a good ferry, soon after leaving Reading, a broad,

* *Nature*, Vol. XVI, p. 183.

broken flat or plateau, with a height, according to the barometer, of 760 feet is reached. Through this little rocky hills project, and its general elevation is probably nearly that of the body of water which must formerly have filled the central "Gulf of California" for a prolonged period. The road continues to follow the Sacramento Valley in a general way for some distance, crossing first a considerable tributary, and then re-crossing the main stream. The upper part of the river is very tortuous, and flows in a deep, steep-sided valley, up which, as the road gains a considerable elevation, distant views of the snow-clad cone of Mount Shasta are, from time to time, obtained.

Leaving the Sacramento where it turns westward, we climb, by a small lateral valley, to the summit of a plateau with an elevation of about 2,300 feet, and at Strawberry Valley find ourselves apparently close to the base of Shasta. A little further on volcanic rocks are seen near the road, piled together in a way suggesting the action of a glacier. Dr. Packard, who stayed here to accomplish the ascent of the mountain, describes three small glaciers which still remain near its summit, the upper four thousand feet of which is covered with snow. These glaciers are still engaged in piling up moraines, and have left others evidencing their former extension. This mountain, at one time, must have been an important centre of local glaciation, though the phenomena of its vicinity are apparently quite distinct from those of the almost universally glaciated north.

Shasta reaches an elevation, according to Prof. Whitney, of 4,442 feet, and, in its grand isolation, and the remarkable symmetry of its conical form, is very impressive.

Leaving Shasta, the road gradually descends into the broad valley of a tributary of the Klamath River, and passing through a wide gap in a range of hills, Yreka—once an important centre of alluvial gold mining—is reached. About fourteen miles from Yreka, a flat resembling a terrace was observed skirting one of the hills, with an estimated elevation of 250 feet above the flat-bottomed valley, or about 2,775 feet above the sea.

Beyond Yreka the Klamath River is crossed, and on the line between California, and Oregon the Siskiyou Range is slowly ascended, the summit on the road being, by my aneroid, 4,500 feet in height, and the actual descent from this place to the stage stable on its western base being nearly 3,000 feet.

After passing Jacksonville, situated on a branch of the Rogue

River, in a small, but fertile and beautiful valley, the main stream of the Rogue River is crossed by a good bridge. Between this river and the South Umpqua, is a rugged and irregular country, in which steep-sided hills are huddled together, but in which also several narrow but fertile valleys are concealed. The Umpqua once reached, is followed to Roseburg, whence a railway stretches to Portland, near the junction of the Columbia and Willamette rivers.

From the Sacramento River to this point all the streams crossed flow westward to the coast, transverse to the proposed Oregon and California Railway, the completion of which will be a very difficult matter. So far no traces of general glaciation, or deposits like the northern drift, have been encountered. The hills appear to have been subjected to prolonged sub-aërial weathering, the rocks, when bared on their slopes, being generally soft and decomposed at the surface. The soil covers the hills almost uniformly from base to summit, except where the slopes are remarkably steep; and is probably in most instances a product of waste of rock nearly in place. The bottoms of the valleys, though occasionally flat, and suggesting the existence of former lakes, or that the sea may at one time have flowed into them, are generally characterized by broad coalescing fan-shaped deltas of the lateral streams. The summits and higher slopes of the hills are generally stony and gravelly, while the valleys have a clayey or loamy soil, which graduates into the former irregularly on the slopes. There is a remarkable absence of any well-marked terraces or benches; though, besides those already mentioned, a probable terrace was observed about thirteen miles above Roseburg, on the Umpqua, with an estimated elevation of 540 feet above the sea. The general impression conveyed by the country is, however, that there are no true terraces, which may arise from the fact that the region has never been flooded, or if flooded, that sufficient available material (detritus) for the formation of distinct terraces has not been at hand, or, lastly, on the supposition that the process of obliteration seen actively in progress in the somewhat similarly circumstanced dry southern interior of British Columbia, has here been so long continued as to remove almost entirely the old water marks. The hills are everywhere seamed with gullies which form the terminations of small valleys, all of which are connected, uniting as they descend toward the main stream. The almost complete absence of lakes or ponds, or

even hollows holding swamps, is very remarkable, and contrasts strongly with the innumerable lake-basins of British Columbia.* The water indeed seems never to rest from its sources in the mountains till it reaches the sea. This is either due to the prolonged action of the streams themselves in completely filling rock-basins, if such there have been, and removing all other impediments to their flow, or is the result of the original absence of those great masses of material accumulated during a stage of the glacial epoch, which in the north (as I hope elsewhere to show) have in many places been mainly concerned, at a later period, in forming lakes by the blocking of old valleys with detritus. The local colouring of the soil, in its close resemblance to that of the decomposed parts of the underlying rocks, indicating the absence of foreign material, appears also to favour the latter conclusion.

North of Roseburg the railway passes for some distance, with heavy grades and sharp curves, through a generally hilly country, crossing several branches of the Umpqua, and then reaching the upper part of the great and fertile Willamette Valley, which runs northward to the Columbia, between the Cascade Mountains with their flanking hills, and the lower ranges of the coast.

Prof. Thomas Condon, of the University of Oregon, has published some account of the state of this country in the later geological times. This I regret not to have had the advantage of reading; but, as the paper is entitled "The Willamette Sound," it would seem to imply his belief in the former submergence of this region. Prof. Le Conte indeed states that Prof. Condon has traced an old sea-margin from the coast up the Columbia River to and beyond the Cascade Range. This he compares with the sheet of nearly land-locked water which must have covered Central California at the same period. †

About two miles south of Creswell station, I noticed what appeared from a distance to be a series of pretty distinct terraces, on a hill-side, at an estimated elevation of from 100 to

* This of course applies to the region traversed, west of the Cascade Mountains. East of that range the Klamath and other extensive lakes appear on the map. These differ singularly in their form from the long river-like lakes of British Columbia, and may possibly be due to mountain elevation taking place more rapidly than the draining streams are able to lower their channels.

† Elements of Geology, 1878, p. 530.

200 feet above the road, which is here about 650 feet above the sea. The valley is wide and flat-bottomed, gradually sloping downward to the north, and quite different from any met with on the line of route since leaving the plain of central California. The soil is usually pale-coloured and often clayey, and north of Eugene, is seen in several places in cuttings to be underlain by beds with large and small rounded stones. Beyond Albany, the country is for some distance more undulating, and in many places more or less perfectly bedded deposits of gravel and sand, with occasional small boulders, occur. These much resemble some varieties of modified drift, and are probably due neither to local glaciers nor to the present or former streams, but to the transport of material by ice during a general submergence. It is here that we first meet with distinct traces of that invasion of the land by the sea during a period of cold, which has been universal further to the north.

The Willamette and Columbia Rivers, immediately below Portland, flow through a flat country, its general aspect, with that of the rivers themselves and the vegetation of their banks, being much like that of the Fraser below New Westminster. The tide affects the Willamette up to Portland. Seven miles below this place, on the left bank, very distinct terraces occur, with elevations estimated by the eye as 100, 180, and 300 feet above the river, the highest being about the general level of the surface of the country here. In several other places more or less perfect terraces appear, at various elevations, less than about 300 feet.

Leaving the banks of the Columbia at Kalama, our route continues northward between the two ranges before referred to. The only portion of the Northern Pacific Railway yet built on the West Coast, connects this place with Tacoma, 105 miles distant, and near the extremity of Puget Sound, which with a ramifying form occupies the northern part of the same great valley. The valley of the Cowlitz river is at first followed up for some distance, several small streams which afterwards unite and flow west through the Coast Range are then crossed, and in a short distance water flowing northward to Puget Sound is reached; no strongly-marked watershed being observed. At Olequa Station, twenty-eight miles from the Columbia, is a well marked terrace or beach with an elevation of about 100 feet,*

* The elevation of places on this part of the route, though taken by barometer, were checked at the sea level at both ends, and are correct within a very few feet.

with a second about 30 feet higher. In following the Cowlitz, banks in cuttings sometimes 50 feet in height, show fine, yellowish horizontally-bedded sands. These are pretty hard, and are interbedded in places with thin and thick layers of gravel, composed of water-rolled stones, some as large as the two fists. The sandy drift exactly resembles that seen in low banks near the water level on the Willamette and Columbia, but as we go northward, and ascend, the gravelly layers continue to increase in importance. Forty miles from the Columbia the railway passes over a distinct and wide bench with an elevation of 337 feet, the general level of the country—which is here nearly flat—being about 380 feet. Gravel beds are abundant at Centreville (54 m.) with a general elevation of about 160 feet. Here the rolled gravel of the subsoil contains some small boulders up to ten inches in diameter. At 65 miles from our initial point, elevation 230 feet, boulders two feet in diameter are first seen, and a few miles further northward gravelly banks are found, of rudely mingled coarse materials, including boulders up to three and four feet in diameter, with overlying or interstratified layers of fine yellowish sand. The country here becomes undulating, with many low ridges and hillocks, and *begins to show small ponds and swamps*. A few miles south of Yelm Prairie (74 m., elevation 295 feet), some ridges, in their composition resemble the closely-packed gravel and boulder deposits of Spring Ridge and Beacon Hill near Victoria. From this point to Tacoma, the county is generally flat or gently undulating, and declines gradually toward the head of the Sound, the superficial deposits being in general not so coarse as those just described.

At Tacoma, the banks along the shore show a great thickness of firm finely-bedded sandy and clayey deposits, which form the substratum of the plateau above, but which I had not time to examine. At Seattle—the centre of the coal mining industry—about 30 miles northward on the east shore of the Sound, the drift consists of sands, gravels and clays, without any apparent regular sequence, but with occasional large and many small boulders scattered through them. The sands are frequently current-bedded, and in one place curiously contorted layers of fine, hard, clayey sand, alternated with others nearly horizontal, as though floating ice had from time to time disturbed the regularity of the deposit. Some beds resemble in all respects true boulder-clays, being thickly packed with large and small stones,

which lie in all positions. These beds, however, seem to form a part of the general series, and do not appertain specially to any particular horizon. No clearly glaciated stones were seen, though from the shape and appearance of many, it is probable that a careful search would bring such to light, as at Victoria. Fine exposures of drift also occur at Port Townsend near the entrance to the Sound, and elsewhere along its banks.

The drift deposits of Puget Sound, as a whole, very much resemble those of the southern part of Vancouver Island and shores of the Strait of Georgia further north, which are described in the paper above referred to. There is good evidence to show that at one time a great glacier-sheet, fed both from the mainland and mountains of Vancouver Island, filled the whole Strait of Georgia, and passing southward, overlapped the low south-eastern corner, at least, of Vancouver Island. It would also appear that when this glacier began to retreat, the sea was at a level considerably higher than at present, and that as soon as the heavily-glaciated rocks of the lowlands were uncovered, the drift deposits—boulder clays, gravels and sands—were laid down on them. These are found in some places near Victoria to include marine shells. From a careful examination of the south-eastern corner of Vancouver Island, my impression is that its glaciation though heavy, was not long continued, and it is probable that in this case the front of the glacier did not at any time reach far southward into the low country of the Sound, or westward along the Strait of Fuca. Be this as it may, however, it is pretty evident that during the submergence above referred to, the great valley, including the Sound, and country to the south, of which the drift deposits have just been described, was a wide strait; along the margins of which local glaciers may have discharged in some places, and in which sea currents, aided by debris-bearing icebergs and coast-ice piled up the deposits now found. It is probable that the same sheet of water passed yet further southward, forming the Willamette Sound, of Condon, with a wide opening to the open ocean by the valley of the Columbia River. If the Strait of Fuca was not at this time encumbered by glacier ice, the high Olympic mountains of the north-western corner of Washington Territory must have formed a snowy sea-washed island.

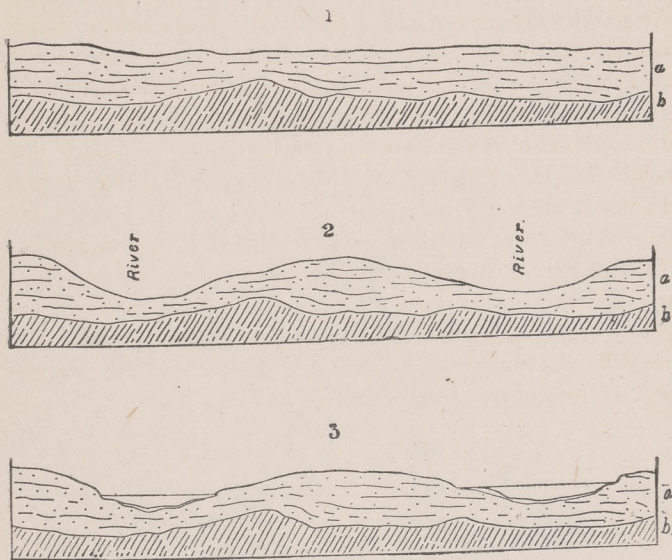
No great mass of glacier ice can have excavated the present channels and water-ways of Puget Sound, as a glance at their

complicated form on any good map will show ; nor do the circumstances allow them to be accounted for by the excavating action of systems of local glaciers. If, however, the Strait of Georgia ice-sheet ever traversed the low country now occupied by the Sound, it may have planed and levelled it to some extent.

Mr. George Gibbs has described the passages and inlets of Puget Sound as excavated in many places in drift deposits, which appear not only to form their present banks, but to underlie their beds. Guided by the general form of the inlets, and this description, I ventured in a note on some of the more recent changes in level of the coast of British Columbia and adjacent regions, printed in the *Canadian Naturalist* for 1877, to suggest that they were cut out by rivers during a post-glacial elevation of the land, and afterwards filled up by sea-water on its depression to the present level.

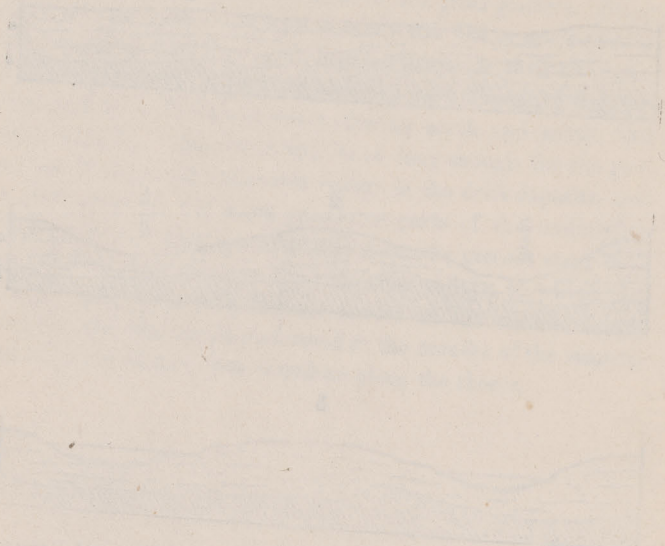
Though aware of the danger of generalising hastily for a region which has not been thoroughly examined, I now venture to again advance this idea with somewhat greater confidence. In their outline on the map, these inlets resemble the fjords with which the whole coast north of the forty-ninth parallel is dissected, but the latter penetrate into the heart of a rugged and mountainous country, and though they may have been cleared of drift material during a post-glacial elevation, have probably been excavated in the hard rocks of the Coast Range of British Columbia during a prolonged period in the later Tertiary, when the land was at a high level. The canals of the Sound are excavated in a low drift-encumbered country, based on soft Tertiary rocks, which, owing to the thickness of later deposits are seldom seen. The average height of the surrounding drift-plateau is from 180 to 200 feet. The channels are deep—often over 100 fathoms—but not uniformly so, as shallower bars cross them in many places which would give rise to a series of great lakes if reelevation should now occur. Here bars, like those so often found near the entrance of the fjords to the north, are generally in observable connection with their cause, in the opposition of tidal currents, the slackening of these currents as they enter wider channels, or other circumstances bringing about the deposition of suspended sediment. They are probably due to the most modern period. In the wide flats surrounding the mouths of streams and rivers, near the present water level, we have evidence of the comparative permanence of the present relations of sea and land.

To recapitulate, a wide hollow deeply scored by rivers, probably extended from the south of Vancouver Island to the Columbia, in later Tertiary times. The northern part of this, now occupied by Puget Sound, may or may not have been planed down by an ice-sheet, but was deeply filled and levelled up with drift during the glacial submergence and retreat of the great glaciers. Being afterwards elevated to a height possibly 600 feet or more greater than the present, streams again began to excavate their channels, guided no doubt in the first instance by such ill-defined longitudinal hollows as the sea-currents, flowing north and south, had before formed. This action continued long enough for the production of deep and wide river valleys in the drift deposits, and in some cases in the more prominent parts of the underlying Tertiary rocks. Lastly, a resubidence to the present stage having occurred, the sea water filled the river valleys, of which the gently-sloping sides soon became eroded at the water-line into sea-cliffs, and tide flats were formed at the mouths of the streams and wherever ditritus was abundant along the shores.



Diagrams illustrating stages in the production of the Inlets and Passages of Puget Sound.

- No. 1. Eroded (perhaps glacier-planed) surface of the Tertiary rocks (*b*) covered uniformly with drift material (*a*) at the close of the glacial epoch.
- No. 2. Wide and deep valleys cut into the drift deposits by streams. Land standing at a greater elevation than at present.
- No. 3. Valleys filled by the sea owing to subsidence. Shore cliffs and recent submarine deposits in course of formation.



The following are the results of the experiments
 conducted on the effect of the various
 factors on the growth of the plant
 under different conditions of light and
 temperature. The results are given in
 the following table.

