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THE LATE PLEISTOCENE SUBMERGENCE IN THE COLUMBIA VALLEY OF OREGON AND WASHINGTON

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This article aims to review previous references to a Champlain submergence in the lower drainage of Columbia River, to eliminate erroneous interpretations and correlate data which belong to this subject, to present more evidence establishing the fact, to define the character and the extent of the submergence, to correlate this with the Pleistocene history of northwestern Washington, and to indicate questions which are still unanswered.

HISTORICAL

So far as known, Thomas Condon published the first note on static water in the Columbia Valley during late Pleistocene time. This was an article entitled "The Willamette Sound" in the *Overland Monthly*, 1871.[1] Condon argued for a submergence of at least 330 feet above present tide, the waters flooding Willamette Valley and backing up through the Gorge of the Columbia across the Cascade Range and submerging portions of the tributary Yakima and Walla Walla valleys. Condon's evidence was the

[1] The article has been reprinted as a chapter in Condon's *The Two Islands* (Portland: J. K. Gill, 1902), and also in his *Oregon Geology* (1910), a revision of *The Two Islands*.

existence of marine Pleistocene deposits along Shoalwater Bay, Washington, 10 to 15 miles north of the mouth of Columbia River, and fossiliferous beds below about 330 feet A.T. at the mouth of Des Chutes River, an Oregon tributary entering the Columbia immediately east of the Cascade Range. If the sediments in these two localities, more than 150 miles distant from each other, were deposited in the same body of water, then Willamette Valley of western Oregon, intermediate in position, must have been largely submerged. To this water body Condon gave the name of Willamette Sound. He correlated it with the Champlain submergence on the Atlantic Coast.

Static waters in the Columbia Valley east of the Cascade Range were postulated by T. W. Symons in a Senate document,[1] published in 1882, dealing chiefly with navigation of the Columbia. Symons saw many rounded bowlders on the basalt plateau along the Columbia in central Washington, he saw considerable tracts of the basalt covered with sedimentary deposits, and he found large, though fragmentary, gravel terraces in the Columbia Valley. All of these he ascribed to a glacial lake which he named Lake Lewis. He thought this lake extended southward as far as Walla Walla and Wallula. He gave no altitudes, cited no evidence for the Champlain age which he assumed for the submergence, and suggested no cause for the ponding.

I. C. Russell made a geological reconnaissance in central Washington in 1892, and in his report[2] revised Symons' data somewhat but adopted his conception of a glacial lake. His revision consisted in eliminating the sedimentary formation exposed in White Bluffs along the Columbia. This he considered to be a portion of the John Day Series of Tertiary age. He also added the valuable item that there were many foreign granite bowlders in the Columbia and Yakima valleys which had been carried in bergs to their present positions. Russell thought that a glacier might have dammed Columbia River at The Dalles, just below the mouth of Des Chutes River, but he admitted the possibility of subsidence

[1] "The Upper Columbia River and the Great Plain of the Columbia," *Senate Document No. 186*, Forty-seventh Congress, 1st sess., Washington, 1882.

[2] "A Geological Reconnaissance in Central Washington," *U.S. Geol. Surv., Bull. 108* (1893).

allowing "the ocean to enter the great central valley between the Cascades and Rocky mountains."

J. S. Diller published his geological reconnaissance of northwestern Oregon[1] two years after the appearance of Russell's report. In it he adopted Condon's notion of a Willamette Sound. Like Russell, he announced the existence of foreign bowlders in the valley and interpreted these as berg-carried in the waters of a Pleistocene submergence.

Russell, in another paper, published in 1898,[2] stated his belief that the Great Terrace in the Columbia Valley, between the junction of the Methow and Chelan valleys, was a delta built in Lake Lewis. He considered that the termination of the Great Terrace, a little below the mouth of Chelan River, was the delta front. Russell noted here that "full and unquestionable evidence of its [the lake's] actual existence cannot be said to have been discovered."

CRITICAL EXAMINATION OF THE DATA PRESENTED BY THE FOREGOING WRITERS

Shoalwater Bay.—These deposits, cited by Condon, are unquestionably part of the coastal phase of the Satsop formation.[3] This formation is largely a river gravel in the Columbia Valley, and only along the coast was it deposited in standing water. In the Shoalwater Bay (Willapa Bay) exposures there is abundant evidence in the presence of gravel strata containing granite, gneiss, and much quartzite that a vigorous current existed throughout the length of the Columbia in Oregon and Washington when these beds were deposited. Though the Satsop is believed from paleontological evidence to be Quaternary in age, it was laid down before the present Cascade Range was folded and therefore long antedates the Champlain epoch. The strata along Shoalwater Bay therefore do not record a Willamette Sound.

[1] "A Geological Reconnaissance in Northwestern Oregon," *U.S. Geol. Surv., 17th Ann. Rept.*, Part I (1895).

[2] "The Great Terrace of the Columbia," *Amer. Geologist*, XXII (1898), 363.

[3] J H. Bretz, "The Satsop Formation of Oregon and Washington," *Jour. Geol.*, XXV (1917), 447.

Des Chutes terrace.—Condon gave no list of fossils from the terrace deposit. He simply said the material was stratified clays, sands, and gravels containing tusks, teeth, and bones "of the land animals of that period, marking at once the height at which these waters stood." No one has since studied the fauna from this locality. There are many Tertiary formations, with vertebrate faunas, in Oregon and Washington in the great lava plain east of the Cascades. The terrace may be the outcropping edge of a formation of this kind, and not a remnant of a post-valley filling. The feature, so far as known, gives no positive evidence for the existence of Willamette Sound.

The Dalles, Oregon.—Condon mentioned sediments deposited in ravines cut in The Dalles beds at this place and ascribed them to Willamette Sound.

Swan Island, Portland.—Quoting Condon: "Currents of such a vast body of water [Willamette Sound] . . . . the agency competent to the heaping up of that long sandy ridge, 100 feet high, through which the river has cut at Swan Island, north of Portland." This ridge is a terrace remnant; left by erosion, not deposition; and is a portion of a great delta of the Columbia built in Willamette Valley. Static waters stood no higher than its surface (300 feet A.T.) when the delta was built. If related to Willamette Sound it is probably a record of the subsiding stages. It will be discussed more fully later in this paper.

White Bluffs (Ringgold formation), Washington.—Merriam and Buwalda recently have shown[1] that the sedimentary formation exposed in White Bluffs is of very late Cenozoic age, probably Pleistocene. They favor the view that it is a flood-plain deposit, and not lacustral. Its summit plane is considerably below the upper limit of drifted erratics, and on this point it cannot be ruled out of the list of phenomena bearing on the Columbia submergence that we are discussing. But it rises 300 feet higher than the broad gravel terraces on the opposite side of the river, and these are very probably deposits of the river immediately following the Champlain submergence. Merriam and Buwalda found no bowlders of any

[1] "Age of Strata Referred to the Ellensburg Formation in the White Bluffs of the Columbia River," *University of California, Dept. Geol. Bull.*, X (1917), 255.

kind in the materials exposed in the 500-foot sections they studied. Absence of anything attributable to floating ice, presence of a fauna of land vertebrates, and the existence of a broad valley cut in the Ringgold formation containing gravel deposited probably during subsiding stages of the submergence seem adequate evidence for ruling the Ringgold formation out of the catalogue of records of Lake Lewis.

"*Sediments north of Saddle Mountains.*"—It is difficult to determine just what Symons meant by this phrase. There are sediments in that region which are warped with the basalt, and there are horizontal sediments, noted as lake beds of Pleistocene age,[1] which lie below the upper limits of this submergence. These are very poorly exposed and best known from well records. There are also fluvioglacial gravels, deposited by the diverted Columbia during subsiding stages of the submergence and correlative with the gravel terraces of the present Columbia Valley.

"*Rounded bowlders and a loose, light, powdery soil.*"—These occur south of Badger Mountain and Crab Creek, surrounding Saddle Mountain, and in the lower portions of the valleys of Yakima River, Walla Walla River, Snake River, and Moses Lake. Symons here grouped a congeries of deposits of varied genesis: fluvial, fluvioglacial, static water, and wind.

Gravel terraces (cited by Symons).—These are fluvial and fluvioglacial deposits and probably only the Great Terrace, above noted, can be correlated with Lake Lewis.

Neither Condon's nor Symons' work was more than hasty reconnaissance. No one then knew that the sediments of many successive Tertiary basins are exposed in the region, and neither observer was carefully discriminative. Neither one noted the existence of *erratics* in the Columbia Valley. Correlation with the Champlain epoch of the eastern states was with both wholly a matter of inference, on the assumption that the Pacific Coast must have been submerged if the Atlantic Coast was.

Russell (1893) was the first to recognize the significance of the erratic bowlders as evidence for the existence and the age of the

[1] A. T. Schwennesen and O. E. Meinzer, "Ground Water in Quincy Valley, Washington," *U.S. Geol. Surv., Water Supply Paper 425-E,* 1918.

ancient water body. He believed that they were derived from the Okanogan Lobe of the Cordilleran ice sheet. He found these stranded erratics from the mouth of Wenatchee Valley to the lower portion of Yakima Valley.

Diller (1895) cited the erratic bowlders of the Willamette Valley as his contribution to the evidences for this Pleistocene submergence. As in Russell's amplification of Symons' idea of a lake, Diller supplied the only trustworthy evidence (and the convincing proof) of the existence of a late Pleistocene water body in the Willamette Valley. Diller, however, thought that the berg-carried bowlders were derived from glaciers descending the western slope of the Cascades. No granite, schist, or quartzite are known to outcrop in this portion of the range, and it is clear that the erratics were carried through the Gorge from regions east of these mountains. If Diller was aware of the publications of Symons and of Russell on Lake Lewis, he did not suggest correlation between this lake and Willamette Sound.

Here, then, is a curious situation with regard to nomenclature. Condon (1871) has priority of publication, but, so far as we can learn, his conclusion cannot stand on his own presented evidence. It is purely a coincidence that there *was* such a submergence as he names. Symons (1882) has a case nearly identical. If Symons had indicated that he found *erratic* or *glaciated* bowlders, his case would have been clear. Russell (1893) did not know of Condon's publication, or he would have mentioned it when he admitted that the cause of the ponding was not known. He preferred the hypothesis of a glacial dam. It seems unlikely that he did not know of Diller's discovery of granite erratics in the Willamette Valley before his own last-published mention of Lake Lewis (1898). Yet he consistently referred to the ponding as Lake Lewis, clearly not correlating the episode in central Washington with that in western Oregon. Russell and Diller independently discovered the evidence which establishes the existence of the water body under discussion. They are to be credited accordingly, though neither saw as broad a vision as did Condon.

There was never a glacial dam across the Columbia in the Gorge. The drifted bowlders in Willamette Valley, derived from the east side of the range, are clear evidence of open waters through the Gorge at the time of the submergence. Further, a study of the various tributary valleys along the Gorge shows that local glaciers, instead of filling it to a depth of more than a thousand feet, probably never reached the Columbia. In Hood River Valley there are moraine deposits apparently recording two different glaciations, during the earlier of which the ice reached within 3 miles of the Columbia, and during the later not nearer than 5 miles. No other local glacier got as near as this to the Columbia. It seems impossible that Hood River Glacier could have filled the Columbia Valley to a depth exceeding a thousand feet and left no trace other than these minor deposits back in the tributary valley. Both Condon[1] and LeConte[2] have referred to glacial deposits near The Dalles, but the writer has never seen anything in this region which could be so interpreted. Topographic situations, altitudes, and the location on the lee side of a mountain range all contribute to weaken the hypothesis of glaciation at or near The Dalles. The Yakima Glacier, on the east slope of the range, 100 miles farther north, did not descend below 2,000 feet A.T., though it was fed from mountains much loftier than those near The Dalles.

NEW EVIDENCE ESTABLISHING THE FACT AND EXTENT OF THE SUBMERGENCE

Foreign bowlders and débris.—This can best take the form of a list of occurrences and altitudes of foreign materials along the Columbia and in some of its tributary valleys.

Kelso, Wash. (5 mi. west of). Granite bowlder, 2½ ft. in maximum diameter. 50 ft. A.T. Has a pegmatite dike in it. Dike projects ½ in. above the pitted surface of the granite.

Manor, Wash. (8 mi. north of Vancouver, Wash.). Granite bowlder in schoolyard; angular, with fresh surface. Altitude close to 300 ft. A.T.

Camas, Wash. Granite bowlder formerly on terrace back of the town, at an altitude of about 175 ft. A.T. Has been broken up and used for foundations. A fragment of it was examined.

Willamette, Ore. (4 mi. southwest of). Several granite and quartzite bowlders lying at the western foot of Pete's Mountain at 300 ft. A.T. Very slightly weathered.

[1] Thomas Condon, *The Two Islands* (Portland, 1902).

[2] Joseph LeConte, "Age of the Cascade Mountains," *Amer. Jour. Sci.*, VII (1874), 167.

Canby, Ore. (4 mi. east of). Several erratic bowlders; granite or granodiorite, porphyritic rhyolite, and quartzite. Altitude 323 ft. A.T. Have been blasted out of the soil in clearing a field. Local authority states that a granite bowlder like those in this group lies on the plateau tract 4 to 5 mi. north of Canby. Its altitude must be about 450 ft. A.T.

Dilley, Amity, and Corvallis, Ore. Diller found foreign bowlders near these places in the Willamette Valley, the highest at 250 ft. A.T. He quotes local authority for their occurrence as high as 1,500 ft. A.T. "near" Oswego, Ore., but there are no elevations of more than 950 ft. A.T. near enough to this place to be referred to its locality.

Granite bowlders are very rare in the Gorge, east of the Willamette broadening. Only one has ever been seen by the writer and none are noted in the literature. The lone bowlder lies in Hood River Valley, Oregon, on the summit of Van Horn Butte, a small cinder cone three-quarters of a mile southeast of Van Horn. It is of granite. Its altitude is between 800 and 900 feet A.T. Immediately east of the Gorge, however, the foreign bowlders are more common than in the Willamette Valley. They occur on the eastern flank of the easternmost anticline of the Cascade Range, about the city of The Dalles, Oregon.

The Dalles, Ore. Granite bowlder on summit of terrace immediately south of the city reservoir.

The Dalles. Valley of Mill Creek, 1½ mi. from town. Large granite bowlder lies in the valley; probably has fallen from the summit of the bluffs, about 500 ft. A.T.

The Dalles (about 6 mi. west of), on old Hood River road. A dozen or more angular fragments of granite, 2–3 ft. in maximum diameter, grouped as though the result of frost action or blasting of an original large bowlder. Altitude about 1,200 ft. A.T.

The Dalles (about 6 mi. west of), north of old Hood River road. Granite bowlder, maximum diameter about 3 ft. 500 ft. A.T.

Arlington, Ore. (1 mi. east of). 30 to 40 angular pieces of granite, from 2 to 6 ft. in maximum diameter, grouped within a radius of 25 ft. Altitude 800 ft.+ A.T. Estimated volume of exposed granite material, 500 cu. ft., equivalent to an original bowlder about $7 \times 7 \times 8$. The granite is light gray in color, composed of quartz, feldspar, mica, and hornblende, and contains lenses and fragments of a dark ferromagnesian phanerite. Portions are a true intrusion breccia. Many of these huge granite bowlders are said to lie on the slopes south of Arlington. Many of them have been broken up for use in cemetery monuments.

Roosevelt, Wash. Slates, diorites, quartzites, and several varieties of granite are all represented in cobbly and bowldery fragments up to 1,000 ft.

A.T. on the slopes of Wood Gulch back of this town. One quartzite, 8 in. in diameter, has glacial striae on one side. These fragments lie below the outcrop of an intra-basalt gravel formation, but quite surely are not derived from it.

Mottinger, Wash. (4 mi. north of). A distinct mound 4 ft. high and 40 ft. in diameter, covered with, and apparently composed of, glacial débris of various kinds, the fragments of various sizes and shapes. It is literally a patch of glacial till deposited on this unglaciated slope. Altitude about 1,100 ft. A.T.

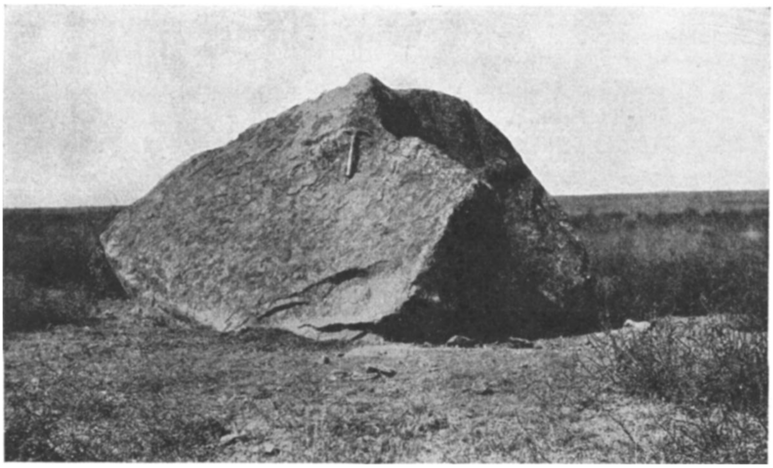

FIG. 1.—Erratic near Prosser, Wash.

Kennewick, Wash. ($3\frac{1}{2}$ mi. south of). Foreign material very abundant on slopes and summit of the ridge. Summit is 900 ft. A.T. Granite, gneiss, quartzite, vein quartz, slate, porphyritic phanerites and a variety of metamorphic rock fragments are present. Striated faces are common. In places here the soil looks like the washed surface of a stony glacial till, though the region is many miles from the nearest glaciated area.

Prosser, Wash. (north of). Slopes below about 1,000 ft. bear many bowlders and fragments of granite and quartzite. The quartzite is prevailingly pinkish to lavender to blue in color, a feature common to most of the angular quartzite in this category. One quartzite is marked with two sets of striae crossing each other. One large granite bowlder, $6\times7\times10$, lies at 840 ft. A.T. along the road. It is almost identical in character with the material at Arlington. Riven fragments lying about the bowlder are equal in volume to half the main bowlder (Fig. 1).

Mabton, Wash. (southwest of). Foreign bowlders and cobbles of granite, quartzite, slate, and basalt in considerable numbers lie scattered over the surface of the fine, light-colored silt which floors this part of the Yakima Valley. Upper limit 1,200 ft. A.T. These erratics occur in groups, several kinds of rock in each group. Both rounded and angular, and both large and small fragments occur in every group.

Snipes Mountain, Wash., between Granger and Sunnyside. Foreign cobbles and bowlders common, scattered over the hillside up to nearly 1,200 ft. A.T. One granite, 2×3×4, at 950 ft. A.T., has a flat, beautifully striated face, 3×4 ft., undoubtedly a glaciated surface.

Toppenish Ridge and Satus Valley, Wash., 5 to 8 mi. south of Toppenish. A striated quartzite bowlder, associated with granite and other foreign material, at about 1,100 ft. A.T. A granite bowlder at 1,100 ft. on the south side of the Satus Valley.

Ahtanum Ridge, Wash. (10 mi. S.S.W. of Yakima). Large numbers of angular granite and quartzite bowlders and cobbles on the southern slopes, below 1,200 ft., and on the floor of the structural valley immediately south. Grouping of angular fragments indicate that some original bowlders were 4 to 5 ft. in diameter. Material fresh, affected only by frost action and temperature changes. One bowlder along road, about midway between Yakima and White Swan, is clearly smoothed and striated on one face.[1]

Dry Creek Valley, Wash. Glacial material plentiful; granite predominant, but quartzite, diorite, slate, etc., present. Observed upper limit about 1,100 ft. A.T. Grouped in the familiar fashion: large and small, rounded and angular, all together except where slope wash has strung them out. Groups separated by intervals of hundreds or thousands of feet where no débris of this sort is to be found. Glaciated surfaces on some bowlders.

Cold Creek Valley, Wash. Situation similar to that in Dry Creek Valley 1,130 ft. maximum altitude observed.

Priest Rapids, Wash. (4 mi. northwest of). Granite bowlders lie on the slopes of the Columbia Valley up to 1,175 ft. A.T. The highest found is 3×4×6 exposed, probably larger. Several nearly as large at 1,150 ft. A.T. on the same hill. Granite is like that in the Arlington bowlder.

Quincy and Burke, Wash. Between these two places 10 or 12 foreign bowlders were seen at altitudes above 1,200 ft. Two are described as follows: (1) six mi. south of Quincy; granite bowlder, 4×5×10 exposed dimensions, of the familiar basic igneous rock in a light-colored granite. (2) five mi. south of Quincy; granite bowlder, largely buried, exposed portion 12 ft. long; the largest and the highest (1,255 ft. A.T.) found by the writer.

Wenatchee Valley at junction with Columbia Valley. Russell reports "great quantities of angular bowlders, some of them of large size, composed principally of quartzite, granite and schists . . . . about Wenatchee and

[1] George Otis Smith, in *Ellensburg Folio No. 86, U.S. Geol. Surv.* (1903), notes the presence of erratic bowlders in Wide Hollow and Wenas Valley, north of Ahtanum Ridge, and says they "must have been dropped from masses of ice floating in the ponded waters of Yakima Valley."

along the river to the south . . . . which were carried to their present positions by ice."[1] He does not say "floating ice" but his own later work showed that no glacial ice ever reached this place, and these bowlders may be listed with the others floated in the Columbia submergence.

Soap Lake and Adrian, Wash. Erratic bowlders very abundant along the Great Northern Railroad in vicinity of these stations. The railroad here crosses the old Grand Coulee channel of the Columbia, occupied while the Okanogan lobe blocked the main valley to the west. Altitude of Soap Lake station is 1,202 ft., of Adrian, 1,234 ft. Whether these bowlders were deposited from bergs in Lake Lewis or were dropped while en route to the lake along the glacial Columbia was not determined. At any rate, they lie close to the entrance of the river into the lake. The Coulee City terminal moraine is distant 20 to 25 mi. by the Grand Coulee route, 15 to 20 mi. in a straight line, and the agency of glacial ice cannot be called upon to explain their presence here.

Ephrata, Wash. "3.7 mi. south of Ephrata, aluminum tablet in large granite bowlder, 1,283.102." Leveled in 1903, by R. A. Farmer and in 1909 by C. H. Semner, of the United States Geological Survey (note taken from *Bull. 674, U.S. Geol. Surv.*)." This is the highest foreign bowlder ever reported from the bed of Lake Lewis, so far as the writer is aware.

Winchester, Wash. "Twenty feet south of track, opposite section house, in top of granite bowlder, aluminum tablet stamped 1277 T. 1277.333" (data from *Bull. 674, U.S. Geol. Surv.*).

The berg-drifted bowlders in the lower Columbia drainage extend almost, if not quite, from the margin of the Okanogan glacial lobe in central Washington to within fifty miles of the Pacific Ocean. This débris did not come from glaciers on the west side of the Cascade Range, for there are no granite outcrops in the drainage of the Willamette Valley. It did not come from glaciers along the east slope of the same range south of Lake Chelan, for none of the valley glaciers here descended below 1,500 feet A.T. and the submergence did not reach much above 1,250 feet A.T. The Chelan Glacier and the Okanogan Lobe appear to have contributed all the bergs which drifted so widely in this inland sea, and débris which they carried was scattered along 350 miles of the lower Columbia Valley.

Most of this débris lies close to the upper limits of the submergence. This is due to two causes: (1) the opportunity for stranding in shallow water along the shores, where the bergs were

[1] "A Geological Reconnaissance in Central Washington," *U.S. Geol. Surv., Bull. 108* (1893).

held until melting, and (2) the subsequent removal or burial of débris dropped in mid-valleys.

Many of the bergs were derived from basal ice in the parent glacier. The amount of fine material associated with the bowlders, and the striated faces of many bowlders, makes this clear.

Practically all of the débris listed in the foregoing catalogue has been derived from rocks of deep-seated origin, indicating the work of glaciers in the heart of an eroded mountain mass.

The upper limit of the submergence, determined from present data on drifted bowlders, is about 1,200 feet through central Washington. The lower altitudes of the known erratics in Willamette Valley may be because the heavy forest above the cleared bottom land conceals higher bowlders. It may also be due to warping in postglacial time along a hinge line approximately coincident with the axis of the Cascade Range.

Off-shore sediments of the submergence.—It is significant that in the lower valley of Yakima River, Dry Creek, and Cold Creek, considerable silt depoists occur below the upper limits of the erratics. Many square miles are covered by these sediments west of Mabton and south of the Yakima flood plain. Here they are dissected to a subdued badland topography and the erratics are scattered widely over the area: on divides, slopes, and valley bottoms. But the material is incoherent and fails to stand in bluffs, so that one cannot be sure that erratics are *inclosed* in the silt deposit. It is probable, however, that these deposits are correlative with those in White Bluffs, now named the Ringgold formation, and older than the glacial submergence.

It is more significant that investigations on water resources in Quincy Valley[1] have shown the presence of "Pleistocene lake beds" below 1,200 feet A.T. Wells nearly 300 feet deep do not penetrate through these beds on Morrison Flat, a few miles west of Moses Lake. These sediments consist of clay, silt, and sand, with a few beds of gravel, and contain bones and shells. "W. H. Dall states that the fossils collected from the lake beds are fresh-water species, all of which are still living and are not older than the Quaternary period. They are of the boreal type and could have lived in the cold water of a glacial lake."[2] Glacial gravels unconformably

[1] Schwennesen and Meinzer, *op. cit.* [2] *Ibid.*, p. 144.

overlie the lake beds, the gravels having been carried down Grand Coulee from the Okanogan Lobe during the subsiding stages of the submergence.

The situation of these deposits near the ice and at the northern extremity of the submergence, and the presence of intercalated gravelly strata make a strong case for their origin in Lake Lewis. If the interbedded gravels were known to contain material of glacial derivation, the case would be clear. Schwennesen and Meinzer think that this lake was local, and that it discharged to the present valley of the Columbia over two abandoned cataracts south and a little west of Quincy. They apparently do not accept the hypothesis of a Lake Lewis as enlarged and set forth by Russell.

Gravel terraces in the Columbia Valley.—Russell and others have noted the presence of several terraces of gravel at different levels in the Columbia Valley from Chelan upstream. The Great Terrace, as Russell called it, appears to be the highest gravel bench in this part of the Columbia Valley. Its altitude near the downstream termination is 600 to 700 feet above the Columbia according to Russell. The Columbia at the mouth of Chelan River is 670 feet A.T., and the surface of the terrace therefore is 1,270 to 1,370 feet A.T. If the Great Terrace is a delta built in Lake Lewis, as Russell thought, and if the present termination is the original delta front, the submergence stood between 1,270 and 1,370 feet in this part of Washington.

The high line of drifted débris is not known to reach above 1,283 feet A.T., though of course the highest bowlders may not have been found. At any rate the close approximation in altitudes strengthens Russell's case for the delta origin in Lake Lewis of the Great Terrace. If top-set beds on fore-set beds are ever found in this terrace their presence will settle the matter affirmatively, and the altitude of their contact will give the precise upper limit of the submergence in this part of the state. If Russell were correct about this, there should also be deltas correlative with the Great Terrace in such tributary valleys as carried glacially fed, and therefore actively aggrading, streams at this time.

The Columbia Valley contains gravel terraces at intervals from the Great Terrace to Portland. Too little is known of these to attempt their interpretation here, but the upper limit of each highest terrace of the localities known is lower with distance downstream. Apparently they form a simple system of river terraces. So far as known their surfaces do not bear the drifted erratics. They are believed to have been formed during and after the subsiding stages of the submergence. One set of these terraces, here named the Portland Delta, is described as follows:

The eastern portion of the city of Portland is built on a series of terraces of river gravel, the highest of which is about 300 feet A.T. The 300-foot portions lie east of Mount Tabor and Rocky Butte and extend eastward up the river to the mouth of the Gorge. Considerable tracts at 300 feet A.T. also lie on the Washington side of the Columbia, east of Vancouver. This 300-foot plain has been dissected by subsequent meanderings and braidings of the Columbia, and a large portion of it has been brought down to about 200 feet A.T. One of these abandoned Columbia channels is traceable from Rocky Butte in the northeast part of Portland westward to the Willamette in the heart of the city. Another is conspicuous immediately east of Vancouver, Washington, across to the 300-foot plain.

The gravel composing the 300-foot plain and 200-foot terraces is fresh material, discolored only slightly by weathering at the surface, and all of its constituent pebbles are hard. This criterion distinguishes it from terraces of the much older Satsop formation on the Washington side, the altitudes of the lower of which are by coincidence almost the same as the highest of this series.

The gravel is almost everywhere disposed in fore-set beds which dip westward and northwestward. Any gravel pit in Portland shows this, and the long cut of the Oregon-Washington Railroad and Navigation Company in the eastern part of Portland shows it most strikingly.

This deposit of fresh, delta-bedded gravel, with summit level of 275–300 feet A.T., does not extend down the Columbia farther than 10 miles north of Vancouver, Washington. Its outline is that of a broad fan or Greek Δ in the Willamette structural valley, with its apex at the mouth of the gorge. It appears clearly to record static water at this level in the Columbia Valley west of the Cascade Mountains. The absence, so far as known, of the drifted bowlders on its surface, the absence of infiltrated clay in it, and the evidence from the distributary channels across it of a lowering water body during its formation all suggest that it was deposited after the maximum of the Pleistocene submergence. This may have been either during a pause in the subsidence of the water, or in a later and lesser submergence. The first interpretation is preferred.

THE SUBMERGENCE ELSEWHERE IN WESTERN WASHINGTON

So great a submergence in late Pleistocene time could not have been limited to the lower Columbia drainage. Its duration was so brief, however, that it is not definitely recorded by shore features or lacustrine plains, and had there been no bergs on it the occurrence perhaps and the extent certainly never would have been known.

There appears scant hope, therefore, of finding records of the submergence elsewhere. The only other region in the Pacific Northwest where a similar episode has been reported is the lowland of Puget Sound. During the latest, or Vashon, glaciation of Puget Sound the sea-level was not more than 75 feet above its present altitude.[1] But after retreat of the ice from the lowland, marine waters submerged the northern part of the region to a depth of at least 290 feet A.T.[2] This is recorded by the presence of marine shells in stratified clay overlying the Vashon till sheet.

Erratic bowlders cannot be used for this study in the Puget Sound Valley or its margining slopes because glacial ice has covered the whole region. South of the terminal moraine of the Puget Sound Glacier, however, they would be as valuable a criterion as in the Columbia Valley. But, so far as known, there are no such bowlders in the unglaciated lowlands of southwestern Washington. This may be charged to lack of intensive search for them, or to absence of bergs in such waters.

GENERAL CONSIDERATIONS

The highest known erratic bowlders in Willamette Valley (323 feet A.T.) and the highest known marine shells in Puget Sound (290 feet A.T.) mark the known upper limit of the submergence

[1] J H. Bretz, "Glaciation of the Puget Sound Region," *Wash. Geol. Surv. Bull. 8* (1913), p. 229.

[2] *Ibid.*, p. 233.

west of the Cascades. The hypothesis that submergence was relatively less on this side of the range may therefore be entertained.

Contemporaneity of submergence and glaciation is clearly recorded east of the mountains. In contrast to this it seems clear that in Puget Sound maximum submergence lagged much behind maximum glaciation, highest water-levels not being reached until the ice front had retreated at least 70 miles and probably more than 100 miles.

Though the tides are felt during lower river stages 150 miles up the Columbia, yet Astoria, a few miles inside the Columbia bar, has a fresh-water harbor. The great volume of the Columbia, then as now, doubtless maintained the fresh-water character of the entire submergence. The downstream journey of hundreds of miles by bergs also indicates a current sufficient to offset the influence of the prevailing westerly winds on these bergs. This fresh-water character of the Columbia submergence explains the absence of marine shells in Willamette Valley such as those deposited in Puget Sound during the same epoch.

From the positive evidence of stranded bowlders the submergence reached a known maximum of 1,283 feet A.T. close to the Okanogan Lobe. Its known maximum at The Dalles was 1,200 feet A.T. The Dalles is 125 miles south of the Okanogan Lobe. On the west side of the Cascades the highest records of the submergence in Puget Sound are 290 feet A.T., and bowlders at 250 feet are reported near Corvallis, Oregon, 160 miles south of the front of the Puget Sound Lobe.

Thus there is no evidence in Oregon and Washington for warping along lines parallel to the general front of the Cordilleran ice sheet, nor in central Washington, for progressive submergence of the glaciated area during retreat of the ice. In fact the entire submergence, save in Puget Sound Valley, was confined to territory beyond the limits of glaciation.

Isostatic depression 125 to 150 miles beyond the extremity of the two most extended lobes, and this without detectible warping, seems an impossibility. Furthermore, the apparent warping along a north-south hinge line in the Cascade Range is wholly out of harmony with isostatic adjustment during deglaciation. The submergence, therefore, is referred to diastrophic movements of greater

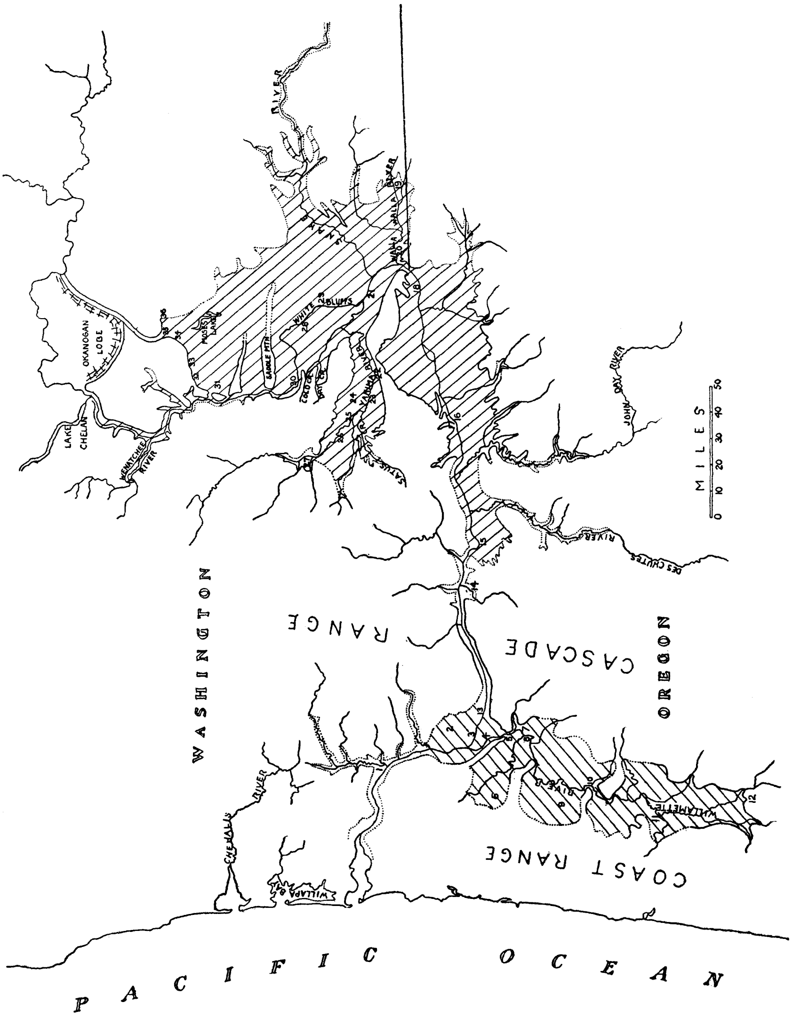

FIG. 2.—The late Pleistocene Columbia submergence

Upper limits of the submergence as shown on this map are 1,250 feet A.T. east of the Cascade Range, 900 feet A.T. in the Columbia Gorge through this range, and 400 feet A.T. west of the range.

N.W.–S.E. diagonal ruling indicates area of Lake Lewis.
N.E.–S.W. diagonal ruling indicates area of Willamette Sound.

1	Kelso, Wash.	13	Camas, Wash.	25	Granger, Wash.
2	Manor, Wash.	14	Van Horn, Ore.	26	Toppenish, Wash.
3	Vancouver, Wash.	15	The Dalles, Ore.	27	Yakima, Wash.
4	Portland, Ore.	16	Arlington, Ore.	28	Hanford, Wash.
5	Oswego, Ore.	17	Roosevelt, Wash.	29	Ringgold, Wash.
6	Dilley, Ore.	18	Mottinger, Wash.	30	Priest Rapids, Wash.
7	Canby, Ore.	19	Walla Walla, Wash.	31	Burke, Wash.
8	Willamette, Ore.	20	Wallula, Wash.	32	Quincy, Wash.
9	Amity, Ore.	21	Kennewick, Wash.	33	Winchester, Wash.
10	Salem, Ore.	22	Prosser, Wash.	34	Ephrata, Wash.
11	Corvallis, Ore.	23	Mabton, Wash.	35	Soap Lake, Wash.
12	Eugene, Ore.	24	Sunnyside, Wash.	36	Adrian, Wash.

extent than, and different genesis from, those resulting from the weight of an ice sheet. In this respect it differs notably from the Champlain submergence of northeastern America.

This hypothesis of a hinge line along the Cascade axis can be most satisfactorily framed in terms of lesser re-elevation west of the range, after the submergence. It is strengthened by the existence of the drowned and alluvium-filled stream valleys of Puget Sound,[1] of the Columbia west of Portland, and of the smaller Chehalis and Willapa valleys. The Columbia east of the Cascades is on a rock floor in many places as far downstream as The Dalles, Oregon.

On the map of the Columbia submergence (Fig. 2) Willamette Sound is assumed to have reached a maximum height of 400 feet. Enough of the valley has been topographically mapped to show that in such a submergence a narrow strait must have existed just south of Portland, and probably another at Salem. Through these straits all the Willamette Valley drainage moved northward.

Diller reports foreign bowlders about Corvallis, south of both straits. It seems impossible that bergs in the Columbia Valley— could have been drifted southward through both straits against the northward flow which must have existed in them. This situation is very strongly suggestive of a submergence in the Willamette Valley even greater than that shown in Figure 2.

When one plots the approximate extent of this submergence in the Columbia Valley on a map, he finds that there were two broadened portions, one on each side of the Cascade Range, connected by a narrow strait in the gorge, and the whole joined to the Pacific by another strait across the Coast Range. If we were dealing with an existing water body of such outline and magnitude we would almost surely find different names applied to such portions. It is therefore proposed to redefine the names "Willamette Sound" and "Lake Lewis," as outlined in this paper, and to continue their use; to recognize the existence of two elongated straits, one across the Cascade Range, the other across the Coast Range; and to consider the whole as "The Columbia Submergence" of the Champlain epoch.

[1] J H. Bretz, "Glaciation of the Puget Sound Region," *Wash. Geol. Surv. Bull. 8* (1913), chap. viii.