by practically every worker in the field. It is clear that later glacial waters, at least, have been operative after the deposition and warping of this formation.

Post-Ringold structural changes clearly involve the uplift of the Frenchman Hills tract and that of the Saddle Mountains, Rattlesnake Hills and Horseheaven Hills probably should be included. In the Saddle Mountains not only has the Ringold participated in the warping, but the extensive faulting of the lavas has affected these sediments also.

Post-Ringold sedimentation history appears simpler, on the whole, than the Ringold history itself. It is largely a record of general erosion with some local continental deposition. Without doubt most of the so-called "Palouse soil" of Whitman County is not only post-Ringold, but derived from that formation in large part. Farther west the surficial sediments are generally more sandy than in the Palouse region as would be expected from the generally coarser character of the Ringold beneath them there.

In a recent article, Professor Beck, of the Ellensburg Normal College has suggested that the calcareous layer at or near the top of some of the Ringold exposures was either "a hardpan subsoil zone" or, as he thought more likely, "the result of leaching from one of the earlier Pleistocene loess mantles."[10] Probably every careful student of this interesting calcareous zone has noted its obvious secondary nature. It is clearly a cementation zone in which lime carbonate has been concentrated. But in the original White Bluffs section, as noted by Merriam and Buwalda, the lime layer lies some 85 feet below the top of the Ringold section. If this be true, it may be necessary to modify the concept set forth by Professor Beck so as to bring out more clearly the relation of the lime zone to the fluctuation of the water table.

It is obvious that the problems of the Ellensburg, the Ringold, and the Palouse are inextricably intermingled. Little progress on any one has been possible without giving a good deal of consideration to the others. For purposes of presentation, however, it has seemed advisable to discuss each formation separately, and in chronologic order. I hope to complete the preliminary paper on the Palouse at an early date, so as to bring out the interesting inter-relations which are indicated.

By way of summary it may be said that the Ringold can be looked upon as extending much more widely than first suggested by Merriam and Buwalda. It appears to have been a rather general filling of the Columbia Basin. Sedimentary materials appear to have come from all sides with the recently uplifted rocks along the west margin furnishing the major portion. The usual continental agencies of erosion and deposition appear to have been operative. The Ringold deposition certainly preceded the uplift of the Frenchman Hills and the Saddle Mountains, but the formation has subsequently been trenched by streams of late glacial time, probably those related by Bretz to his Scabland Flood. Still later, and continuing even today, the original Ringold deposits appear to have been furnishing most of the material making up the substance of the Palouse soil.

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[1] Presented at the annual meeting of the Northwest Scientific Association, Spokane, Washington, December 29-30, 1936.
[2] Merriam, J. C., and Buwalda, J. P., Age of strata referred to the Ellensburg formation in the White Bluffs of the Columbia River: Univ. of California (Geol.), Vol. 10, No. 15, 1917, p. 259.
[3] Ibid., p. 259.
[4] Ibid., p. 259.
[5] Op. cit., p. 263.
[6] Bretz, J. H., Geog. Rev., Vol. XVIII., Pl. V., 1928.
[7] Bretz, J. H., Channeled scablands of the Columbia Plateau: Jour. Geol., Vol. XXI., 1923, p. 625.
[8] Op. cit., p. 265.
[9] Special meeting, Geol. Soc. America, Cordilleran Sec.
[10] Lime-rock zone of Columbia Basin: The Mineralogist, Nov. 1936 (Portland, Ore.).

Notes on Vashon Stage Glaciation of the South Fork of the Skykomish River Valley, Washington[1]

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Two distinct glacial stages[1] have been recognized in the Pleistocene history of the Puget Sound lowland, an earlier Admiralty Stage and a later Vashon Stage. The Vashon glacier, which filled the lowland as far south as the Chehalis River, left on retreat a partly drowned topography of parallel valleys and drumloidal hills composed of Vashon till molded around cores of fluvial and lacustrine sediments which had been deposited in the preceding interglacial stage. The consistent north-south alignment of these features shows clearly that they were formed by a great glacier moving southward from British Columbia. Flanking the lowland are high mountain ranges, the Cascades on the east and the Olympics on the west, which bear evidence of severe local glaciation in their serrated ridges, many cirques and broad, straight, U-shaped valleys. A few small glaciers, probably remnants of the mightier alpine glaciers of the Vashon Stage, still occupy protected cirques in the mountains. The relations of these local glaciers of the Vashon Stage to the main ice sheet in the Puget Sound lowland presents an interesting problem.

Bailey Willis[2] and J. Harlan Bretz,[3] who have made the most important contributions to the glacial history of the Puget Sound region, have expressed somewhat different views on this problem. Willis, whose investigations were confined largely to the region just west of Mt. Rainier, believed that the main sheet of northern ice received considerable contribution from the local Cascade glaciers, while Bretz, whose reconnaisance studies extended all along the mountain front, held that the local glaciers had contributed little or no ice to the main sheet.

The writers have recently studied the glacial deposits in the valley of the South Fork of the Skykomish River, which is located on the west slope of the Cascades about midway between the Canadian boundary and the terminal moraine of the Vashon ice in the Puget Sound lowland. The work was undertaken as part of a general program of research on the Pleistocene glaciation of the Puget Sound region, under the direction of Professor J. Hoover Mackin of the University of Washington. Absence of critical lines of evidence makes a complete statement of the history of the valley impossible but it is felt that certain general conclusions, which bear on the problem outlined above, are worthy of note.

Rising in the high Cascades, the South Fork of the Skykomish River flows through a broad, straight, U-shaped valley before leaving the mountains to flow across the Puget Sound lowland. At the point where the river issues from the mountains its valley is constricted by a high ridge of till and outwash material. On the north side of the stream the ridge has the form of an ice-contact terrace with a pitted ice-contact slope resembling a huge amphitheatre, facing to the west or toward the lowland. The general level of the terrace is about 1850 feet above tide or 1450 feet above the river. Excellent sections in the cut made by the stream across the constricting ridge disclose south-dipping, delta-bedded silt, sand, and gravel, interstratified with lake clay and till sheets. The coarser sediments of the delta grade eastward into warved and laminated lake clays, 600 feet in maximum thickness, which extend several miles up the mountain valley. No glacial till has been found overlying or underlying the up-valley extension of the clays. Farther up-stream, in the main valley and its tributaries, there are glacial moraines of local

origin, but whether these mark the terminus of the local valley glaciers or merely recessional stages cannot be determined with any degree of certainty.

The above described features suggest that during the later part, at least, of the Vashon Glacial Stage, a lake was dammed in the valley of the South Fork of the Skykomish River by the Puget Sound glacier. An ice-marginal stream from the north emptied into the lake, forming the ice-contact delta which grew out chiefly from the north side of the valley during the deposition of warved and laminated clays in quiet water farther up the valley. The highest level at which thees clays have been found is 1100 feet above sea level, but the lake certainly filled the valley to a height of 1800 feet at the stage of maximum delta growth. Interstratification of till sheets in the delta indicate that the Puget Sound ice was by no means stagnant at the time of deposition of the valley filling sequence.

It is clear that the lower part of the mountain valley of the South Fork of the Skykomish River was not occupied by locally derived ice during a late stage of Vashon glaciation when the main ice stood at a level of 2000 feet or more opposite the valley mouth. This relation supports the views of Bretz in regard to the relative strength of local and northern ice. It must be kept in mind, however, that the features described here may be records only of the final stages of the Vashon glaciation, and that the relations of the northern and local ice may have been decidedly different earlier in the Vashon Stage. It must also be remembered that the conclusions of Willis were drawn from field work considerably to the south of the Skykomish and that it is likely that the local glaciers descending from the flanks of Mt. Rainier were larger than those of the Skykomish Valley.

[1] Bailey Willis, Drift Phenomena of Puget Sound, Geol. Soc. Am. Bull., Vol. 9, pp. 111-162, 1898.
[2] Bailey Willis, op. cit.
[3] J. Harlan Bretz, Glaciation of the Puget Sound Region, Wash. Geol. Survey, Bull. No. 8, 1913.

The State Line Earthquake at Milton and Walla Walla[1]

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On two occasions in the writer's experience the senses failed to coordinate. The first time a pilot sent his airship into a tailspin and the passenger seemed to see the earth and the sky roll around over each other. The second time was at 11:05 p. m. on July 15, 1936, when the region around Milton, Oregon, and Walla Walla, Washington, was so shaken in an earthquake that many persons left their beds for the outdoors in haste and perturbation with various styles of deshabile. The writer's house at the north city limits of Walla Walla shook and rattled, and rumbled, and groaned, and squeaked, imitating closely the work of a jazz orchestra, without any permanent damage.

The first and main shock was followed by lesser aftershocks at 11:23, 11:25, 11:30, 11:56, 12:10½, 12:25, 12:27½, 12:38, 1:00, 1:10½, Western Union time, to the minute. Occasional aftershocks have been felt ever since.

Many chimneys were broken, several houses moved an inch or less on their foundations, stacks of boxed and canned goods and shelf wares were scattered over floors with some damage. In one house a half mile west of Ferndale a brick chimney broke at the roof and at the ceiling. The part above the roof was rotated and left standing. The attic portion of the chimney fell to the northward, breaking through the ceiling and strewing

bricks and mortar over the kitchen furniture. A two-story concrete house one mile west of Umapine shed some of the top of the second story wall. The owner has restored this house by moving the second story concrete and lowering the roof to make a one-story house. One fine country residence suffered the complete loss of a large fireplace chimney, and the porch of this house settled two inches, leaving the house roof extension hanging without support. The ornamental railing of cement posts on top of a cement block office building in Freewater was greatly damaged, much of it being thrown southwards to the sidewalk. A brick house at the penitentiary used by the warden has been condemned as unsafe. The writer estimates the loss at $100,000. Repairs on the Milton-Freewater school buildings cost $8500. Many cracked basement and plastered walls may never be repaired, but these are included in the estimate. Many capstones in the cemeteries were rotated, the free corner moving usually less than an inch. About 70 per cent of stones rotated clockwise, viewed from above. Stones in close proximity in some cases rotated in opposite directions.

The quake did some useful work. Several springs are reported to have been revived by the shocks. On the farm of Julius Jensen about four miles south-southwest of Walla Walla is an artesian well 600 feet deep, which, when first drilled, spouted water eight feet above the surface. As other wells were drilled, the flow weakened until a pump was installed to raise the water to the surface. The earthquake revived this well and it now throws a four-inch stream several feet from a horizontal pipe 2½ feet above the surface. This well at present shows no signs of diminishing its flow.

A spur of the Blue Mountains, known locally as the Touchet Ridge, extends from Milton west-northwest, crossing into Washington about five miles east of Wallula. The ridge crossed the Columbia River at one time, damming the water to form a large lake. The north edge of Touchet Ridge in places is very abrupt, the layers of basalt being broken square off at Milton, and marks an old fault line. North of the ridge lies the valley of the Walla Walla River and its tributaries.

Superposed on the old fault is a more recent fault extending from Milton about 20 miles down the valley. The basalt floor underlying the Milton-Walla Walla region has dropped 600 feet below the average gradient of the valley. The south edge of the depression lines up closely with the old fault line, whereas the other sides of the depression slope up gradually to surface exposures of basalt four miles east of Walla Walla, six to eight miles north of Walla Walla, and two miles west of Touchet. No evidence of fracture has been found on the east, north, and west sides.

This local depression has been the site of three successive lakes, as described in a former paper before the Northwest Scientific Association. Alternating layers of lake sediments and river gravels have accumulated to fill this area to meet the common gradient of the valley. A fourth lake in glacial times covered the depressed area with a layer of sediments whose maximum depth is known to exceed 100 feet. Most of these later sediments have been carried away by the Walla Walla River system. Thus, the depressed area has been subjected to varying loads of considerable magnitude.

Between the towns of Milton-Freewater and Umapine are several earthcracks up to three inches in width, some a few feet long, others have been traced 200 yards. The general direction of the cracks is west-northwest, or roughly parallel with the Touchet Ridge fault line. The destructive effects of the earthquake seem to be strongest along the line of these cracks. In a Milton store a small scale pen was jumped out of its socket, showing a vertical life at this point. Three or four miles