

Pleistocene Deformation in the Olympic Coastal Region, Washington

By **SHELDON L. GLOVER***

Recent work for the Washington State Division of Geology on the stratigraphy of the Pacific Coast border of the Olympic Peninsula has shown the existence in some places there, of marked Pleistocene deformation. Evidence of such movement is unusual enough to be of interest wherever it occurs, and this is particularly true of western Washington where, heretofore, folding in Pleistocene strata has not been recognized.

Many writers have touched on Pleistocene events in the western part of this state, but the most detailed accounts are those by Willis¹ and Bretz². Both investigators recognized that the land had been uplifted and depressed during the Glacial epochs, but concluded that folding was not involved in such movements. This may be entirely correct for the areas that received almost exclusive attention; i. e., the region adjacent to Puget Sound. Excellent exposures there that permit detailed examinations to be made in countless places demonstrate the horizontal attitude of the sediments. It must be remembered, however, that these exposures are predominantly of Vashon beds, and that the scarcity of Admiralty sediments (using Willis' delineation of such material) permits only generalizations to be made on the structure of the earlier deposits.

On the coastal area of the Olympic Peninsula, Pleistocene sediments form the surficial deposits and, in some places, erosion has provided excellent exposures. These may be studied in the bluffs fronting the ocean and in banks of many of the larger streams. It is evident that two series are present. One, much older than the other and presumed to be early Pleistocene in age, is here termed the Taholah formation; the younger series, probably of late Pleistocene age, is here termed the Queets beds. From the available evi-

dence, they are thought to correlate with the sediments of Admiralty and Vashon age, respectively, of the Puget Sound region.

The Queets beds, as might be expected, if they are the correlatives of the Vashon sediments, have undergone no known diastrophic disturbance. In some places they have been involved in large-scale block landslides and so give the appearance of local deformation. Also, minute but well-marked faulting and minor warping occur, but such effects have resulted from local adjustments to gravitational sags.

The Taholah formation, too, is mostly horizontal, and throughout great areas shows little, if any, inclination other than that due to primary dip and cross bedding, such as characterize sediments deposited from over-burdened streams. However, there are places where these beds are deformed, and further investigation will doubtless show more evidence of such movement in widely separated regions. One outstanding example is in the Taholah-Moclips vicinity where a sedimentation phase of the Taholah formation occurs that is quite distinct from the usual type. In this particular area the sands, gravels, and occasional clays were deposited in a subsiding basin, presumably an estuary, and so accumulated to a thickness far greater than is known elsewhere on the coast. Detailed sections of as much as 475 feet have been measured, and the persistent structural attitude of scattered exposures indicates that the total thickness of the formation is in excess of 1,500 feet. Individual beds of relatively well-assorted sand may be as much as 75 feet thick, though moderate thicknesses are the rule. The materials are unconsolidated, as contrasted to the Tertiary strata of

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the vicinity, but the sands and gravels are weakly to firmly cemented by iron oxide so that exposures offer sufficient resistance to erosion to attain vertical faces above the cutting agent.

The strata are well exposed in places along the Moclips River and there have been folded into a broad asymmetrical anticline that trends northwesterly. Dips on the west flank are as steep as 42 degrees; on the east flank they are in the amount of 10 to 15 degrees. It is of interest to note that the presence of this structure was doubtless the reason for an oil exploration program conducted by the Standard Oil Company of California in about 1920. Two test wells were drilled in this vicinity and reached a reported depth of approximately 4,000 feet.

Another series of exposures which provides good evidence of Taholah deformation and shows the relationship of that formation to the older Quinault rock and the younger Queets beds is in the vicinity of Wreck Creek. South of the creek a mile or so are occasional poor exposures that indicate the beds there are virtually horizontal. At 2,000 feet south of the creek they have a small but definite easterly dip; this is shown in an old railroad cut that exposes 15 feet of Taholah sand, underlain unconformably by some 30 feet of Quinault sandstone and overlain by 15 feet of horizontal Queets gravels. Exposures north from there to Wreck Creek are fairly continuous and show the strata striking nearly east and steepening to a 45 degree north dip in the bank of the creek. This general trend continues to the axis of the fold, approximately 2,000 feet north of the creek; beyond that the easterly trend is maintained, but the dip is southerly to as much as 22 degrees in the exposure farthest north. The structure here is that of an asymmetrical syncline, plunging easterly at an angle of six degrees or so, and conforms with an axis of anticlinal folding that trends through Point Grenville.

A third, and more spectacular, series of exposures is in the south bank of the Quinault River, southeast of the Indian village of Taholah. Here erosion has cut through the Queets beds in many places, exposing well-stratified thick beds of iron-stained sand and gravel for nearly two miles along the river. One-half mile from the village the series crops out in a high bluff where a stratigraphic thickness of 230 feet of sediments strike N. 5° E., and dip 30° S. E. For 4,000 feet upstream the exposures are poor, but such data as are available indicate a remarkable persistence in attitude to as far as the sharp bend in the river near the center of sec. 6, T. 21 N., R. 12 W. The northerly course of the river in this section appears to have structural control, and massive Taholah gravel is exposed in the left bank. Only Quinault sediments are exposed for the next thousand feet or so upstream from this stretch, and though the juncture of the two formations is concealed, the anomalous relations indicate that the two series are in fault contact.

The small area of older rocks is characterized by extensive landslides, and nothing definite is known of the structure. Profound disturbance, however, is indicated by the sheared and broken condition of shale masses in the nearly black mud that has resulted from their disintegration, and by flexures from 0° to 45° in non-disintegrated masses not over 30 feet across that may or may not be in place.

The Taholah formation is again exposed for 3,000 feet upstream from the east boundary of the area where the older rocks crop out. The contact here is remarkably well exposed and shows that the Quinault formation has been faulted up through the thick early Pleistocene cover. Erosion has stripped the sheared and easily weathered shales from the fault surface and left the Taholah series standing nearly vertically, high above the adjacent shales. This surface trends N. 40° W. and dips 78°

S. W. There are no indications of parallel breaks or of the development of a pronounced fault zone, but patches of mashed shales, a few inches thick, adhere to the fault plane.

The younger sediments, chiefly sands, on the east side of the fault are only weakly cemented by iron oxide, yet they form a cliff nearly 150 feet high. These strata strike N. 60° W. and dip 70° N. E. at the fault; this attitude gradually changes in 100 feet or so to a strike of N. 40° W., 40° N. E., and at the east end of exposures, 3,000 feet beyond the fault, the dip has decreased to 6° and the strike is N. 15° W., conforming rather closely to the regional trend in this general vicinity. Horizontal Queets beds, undisturbed by the movements that affected the earlier formations, overlie this whole area.

The deformation along the Moclips and Quinault rivers was described by Lupton³ in 1914, and two years later Weaver⁴ mentioned the conditions prevailing on the Quinault River. However, both investigators believed the folded early Pleistocene beds to belong to the Quinault formation and variously estimated their age, in consequence, as Miocene to Pliocene. Only the flat-lying surficial gravels (the Queets beds) were accounted as representing Pleistocene sedimentation. Presumably, Lupton thought the up-faulted block of Quinault formation to belong to the "supposed Cretaceous" series of Arnold⁵;

while Weaver definitely places it in that category when he describes it as belonging to the "Hoh formation".

The attitude of the exposures on the Moclips and Quinault rivers indicates an axis of folding roughly parallel to the coast as the major structural control of the Taholah formation in this immediate area. Such deformation is in accord with the dominant folding that affects the older rocks and extends far to the north in the region adjacent to the coast. A transverse fold, the Wreck Creek syncline, has been impressed on the regional structure, and it is reasonable to assume that others exist. If exposures were available, it would probably be found that relics of the folding that produced the Grenville anticline and bordering Quinault syncline also affected the Taholah sediments. This deformation, therefore, appears to be due to recurrent movements along certain lines of weakness that persisted through the early Pleistocene but which have been inoperative since that time.

¹Willis, Bailey, U. S. Geol. Survey Geol. Atlas, Tacoma folio (No. 54), 1899.

²Bretz, J. H., Glaciation of the Puget Sound Region: Washington Geol. Survey Bull. 8, 1913.

³Lupton, C. T., Oil and gas in the western part of the Olympic Peninsula, Washington: U. S. Geol. Survey Bull. 581-B, pp. 51-53, 1914.

⁴Weaver, C. E., The Tertiary formations of western Washington: Washington Geol. Survey Bull. 13, p. 73, 225-226, 283-284, 1916.

⁵Arnold, Ralph, Geological reconnaissance of the coast of the Olympic Peninsula, Washington: Geol. Soc. Am. Bull., vol. 17, pp. 451-468, 1906.

Abstract

Addition of Feldspar to the Kettle Falls Quartzites

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The quartzite formation at Kettle Falls is traversed by a pegmatite sill, but has received little or no feldspar. A few miles to the west, in Hoodoo Canyon, some ten per cent of it has been replaced by rounded orthoclase crystals. These lie along and parallel to small healed fissures cutting across the schis-

tosity of the quartzite at right angles. Still further to the west, all quartzites, whether correlatives of the Kettle Falls quartzite or not, contain substantial proportions of orthoclase and micas, reflecting their nearness to the underlying Colville batholith.

Abstract

A Phosphate Pegmatite From Eastern Latah County, Idaho

By **VERNON E. SCHEID** and **R. M. ALLEN**

A pegmatite dike, containing an assemblage of relatively rare phosphate minerals, has been found in the Mica Mountain region of eastern Latah County, Idaho. The pegmatite occurs in rocks of the pre-Cambrian Belt series that were metamorphosed to schists and gneisses by the intrusion in late Cretaceous time of the granitic Idaho batholith.

Intrusion of the pegmatitic material into the schistose country rock involved both injection and replacement. The pegmatite, which was originally typically graphic granite, has been subjected to periods of intense silicification, al-

bitization, tourmalinization, and finally phosphate mineralization. Until the introduction of the phosphate minerals, the pegmatite was identical with many others in the region.

The minerals of the magmatic stage are quartz, microcline, and muscovite. Through the action of ascending hydrothermal solutions, they were replaced in successive stages by: (1) quartz, which was, however, active throughout the entire intrusive period, (2) albite, (3) muscovite, (4) tourmaline, and lastly the phosphate minerals, (5) strengite, (6) vivianite, (7) triphylite-lithiophilite, and (8) salmonsite(?).

Abstract

Correlation of Some "Latah" Beds of Nezperce County, Idaho

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A fossil flora collected from exposures of "Latah" beds near Juliaetta, Arrow Junction, and Fir Bluff Station, Nezperce County, Idaho, is similar to that found in type Latah beds near Spokane and Republic, Washington, thus strengthening earlier correlations. Most

of the exposures of the sediments, intercalated with the Columbia basalts, are in place and not in landslide blocks. The occurrence of crossbedded sandstones interbedded with the fossiliferous clay layers indicates that the sediments are not wholly lacustrine, but in part fluvial in origin.

Abstract

Pleistocene and Recent Normal Faulting in Southern Colorado

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Several small fault scarps, or scarp-lets, in alluvium have been discovered at and more or less parallel to the west base of the Sangre de Cristo Range in the Southern Rocky Mountains of Colorado and New Mexico. The presence of the scarps not only demonstrates the

existence of recent fault movements in the region, but also supports previous postulates of Pleistocene movement. Thus, the region appears to be related tectonically to the Great Basin and other areas of Pleistocene and Recent normal faulting.