II

THE DALLES AND HOOD RIVER FORMATIONS, AND THE COLUMBIA RIVER GORGE

By JOHN P. BUWALDA AND BERNARD N. MOORE

With one text-figure

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THE DALLES AND HOOD RIVER FORMATIONS, AND THE COLUMBIA RIVER GORGE[1]

INTRODUCTION

A definite assignment of geologic dates to the main events of the Cenozoic history of the Columbia Gorge and Columbia plateau—vulcanism, sedimentation, folding, erosion—is manifestly possible only if we know the age of at least some of the formations. Because of their stratigraphic position, the ages of The Dalles beds and of the gravels heretofore known as Satsop lying between the Columbia River lavas and the volcanic Cascades formation in the Gorge have critical value for historical purposes. Some doubt has arisen in recent years regarding the extreme youth heretofore assigned to these sedimentary formations and the consequent recency of the physiographic development of the Columbia River Gorge. The writers and Mr. John H. Maxson devoted about ten days in July 1927 to a study of the region extending from somewhat east of The Dalles to west of Hood River. Efforts were concentrated on securing fossil material from the formations lying on the Columbia lavas and on determining the relations of these formations to each other. A very brief preliminary statement of results has been published.[2]

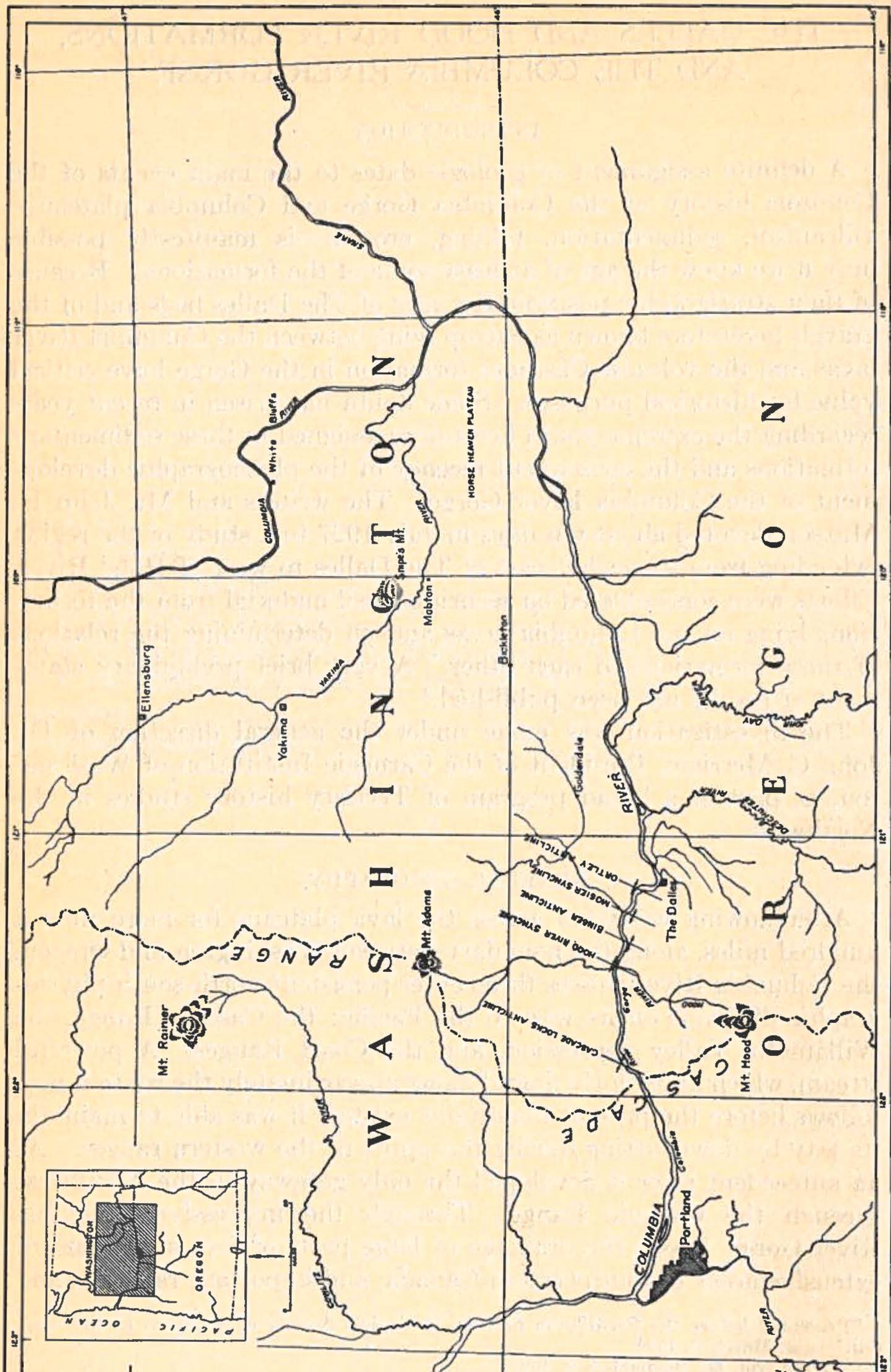
The investigation was made under the general direction of Dr. John C. Merriam, President of the Carnegie Institution of Washington, as part of a broad program of Tertiary history studies in the Northwest.

GENERAL GEOGRAPHY

After flowing westward across the lava plateaus for more than a hundred miles, along the boundary between Washington and Oregon, the Columbia River crosses three other persistent north-south physiographic divisions on its way to the Pacific: the Cascade Range, the Willamette Valley depression, and the Coast Ranges. A powerful stream, which apparently flowed along approximately the route it now follows before the present mountains existed, it was able to maintain its way by downcutting during the uplift of the western ranges. As an antecedent river it developed the only gateway in the Northwest through the Cascade Range. Through the impressive Columbia River Gorge, passes the drainage of large parts of four states and of extensive areas in southwestern Canada, and important railroads and

[1] Presented before the Cordilleran Section, Geological Society of America, at Berkeley, California, March 3, 1928.

[2] Science, vol. 66, September 9, 1927.


WASHINGTON
OREGON
CASCADE RANGE
Mt. Rainier
Mt. Adams
Mt. Hood
Portland
COLUMBIA RIVER
The Dalles
Goldendale
Yakima
Ellensburg
Mabton
Snipe's Mt.
Bickleton
White Bluffs
HORSE HEAVEN PLATEAU
CASCADE LOCKS ANTICLINE
HOOD RIVER SYNCLINE
BINGEN ANTICLINE
MOSIER SYNCLINE
ORTLEY ANTICLINE
SNAKE RIVER
YAKIMA
JOHN DAY RIVER
DESCHUTES RIVER
WILLAMETTE RIVER
PACIFIC OCEAN

highways as well. The city of The Dalles is situated on the south side of the Columbia River near its entrance into the Gorge; Hood River, also on the south bank, lies about twenty miles to the west within the Gorge.

OUTLINE OF THE GEOLOGY

The formations constituting the Cascade Range in the Gorge region and the adjacent parts of the plateau to the east are all of Cenozoic age.

In the core of the range the oldest strata are exposed over a limited area. These belong to the Eagle Creek formation,[1] regarded as of Oligocene or lower Miocene age, and consisting of 2,000 feet or more of andesitic pyroclastics. Its base lies below the level of the Columbia.

Above the Eagle Creek formation lie the Columbia River basaltic lavas, with a thickness ranging from 1,000 to 2,000 feet, and usually consisting of between ten and twenty flows. They are strikingly exposed along the walls of the Gorge and form the plateaus to the east of the Cascade Range. Gravels, sometimes several hundred feet thick and heretofore known as the Satsop, overlie the basalts in the Gorge. Just east of the mouth of the Gorge and south and east of the city of The Dalles a series of basic agglomerates, tuffaceous sandstones and gravels some hundreds of feet in thickness rest upon the basalts, apparently conformably. These strata have been known as The Dalles beds. The Cascades formation, consisting mainly of basic lavas and tuffs, overlies the earlier formations unconformably and forms in many places the upper parts of the walls of the Gorge.

These formations have been moderately folded, as may be clearly observed in the walls of the Gorge. The structure of the Cascade Range in this impressive cross-section consists of three anticlines and the intervening synclines. The axis of the western and broadest of the arches crosses the Columbia near Cascade Locks, and the name Cascade Locks anticline is here proposed for it. East of it lies the syncline in which Hood River is situated; it may well be designated by that name. The two narrower and sharper anticlines to the east, termed the Bingen and Ortley by Williams, are separated by a structural and topographic trough which, because that town is situated in it, may be called the Mosier syncline. The aggregate width of the two synclines and anticlines lying east of the Cascade Locks anticline

[1] R. W. Chaney, *Ecologic Significance of the Eagle Creek Flora of the Columbia River Gorge,* Jour. Geol., vol. 26, 577-598, 1918.

is less than half the width of the Range; these smaller eastern folds are also lower. At the eastern mouth of the Gorge at The Dalles, on the east flank of the Ortley anticline, the Columbia lavas and overlying strata flatten to the relatively gentle dips of the plateau.

Our knowledge of the stratigraphy, structure and history of the Columbia River Gorge has been greatly increased during the last decade by the publication of the results of studies made, in part in collaboration, by J. Harlen Bretz and by Ira A. Williams. While the present authors do not agree with all opinions expressed, these publications are important and very interesting contributions.

AGE OF THE DALLES FORMATION

F. H. Knowlton stated that the age of The Dalles formation is Eocene.[1] R. W. Chaney commented on a collection of leaves from The Dalles beds: "The modern aspect of the leaves of this flora suggests its Pliocene or Pleistocene age." [2]

J. H. Bretz regarded it as probable that The Dalles beds are a local phase of the Satsop formation;[3] the latter he considered Quaternary in age.[4]

The writers were led to search for mammalian fossil remains in The Dalles beds through the report of Thomas Condon[5] that fragmentary bones had been found, and because a few promising badland exposures had been seen during an earlier examination of the region by one of the authors. The fossil material secured in 1927 is unfortunately scanty and fragmentary, but gives valuable information regarding age.

A horse tooth, a proboscidean fragment and a fused artiodactyl metapodial were found in nearly horizontal massive gray tuff estimated to lie about 500 feet above the base of The Dalles beds. The locality is about 2 miles southeast of The Dalles, about 0.25 mile southeast of the Charles Calkins home, on the southwest side of the road and about 75 feet above it. The horse tooth was found in place.

A portion of a proboscidean tusk was found on the north side of the Columbia River. It occurred in place in Satsop gravels lying nearly flat in the Mosier syncline. The locality is about 2 miles west of Lyle, in low bluffs just north of the highway.

[1] *Fossil Flora of the John Day Basin,* U. S. Geol. Surv. Bull. No. 204, 112, 1902.
[2] *Preliminary Notes on Recent Tertiary Collections in the West* (Abstract), Geol. Soc. Am. Bull., vol. 32, No. 1, 137, 1921.
[3] *The Satsop Formation of Oregon and Washington,* Jour. Geol., vol. 25, 454, 1917.
[4] Idem, 466, and Geol. Soc. Am. Bull., vol. 28, No. 1, 170, 1917.
[5] *The Dalles Group,* in *Oregon Geology,* 1910.

Report on Horse Tooth from The Dalles Beds of Oregon, by Chester Stock

The tooth from The Dalles beds is a hypsodont lower cheek-tooth of a horse. While unfortunately the outer side of this specimen is largely destroyed, the metaconid-metastylid column and the entoconid are fairly well preserved.

The tooth appears to have been well cemented. It is comparable in size to $P\bar{4}$ in the type of *Hipparion condoni* from the Ellensburg formation. The size and shape of the metaconid-metastylid column and the type of internal groove between these two cusps as exhibited on the wearing surface remind one rather strongly of *H. condoni.* In *Merychippus* this groove is frequently deep and V-shaped, whereas in The Dalles specimen the groove is broad and open. The entoconid is quadrate in cross-section, in which respect the tooth may again be regarded, perhaps, as slightly more progressive than *Merychippus* and more like *Hipparion.*

Having in mind the fact that the present material is fragmentary, the characters presented by The Dalles tooth would seem to suggest approximately an Upper Miocene or Lower Pliocene stage in the evolution of the Equidæ.

That The Dalles formation is not Eocene, as F. H. Knowlton suggested is moreover quite clear from the fact that it overlies the Columbia River lavas, known to be about middle Miocene in age.

The approximately upper Miocene or lower Pliocene age of The Dalles formation is corroborated by other lines of evidence. The Dalles formation is not definitely known to be conformable on the Columbia lavas, but its strata are at least essentially parallel to the lavas; it has been folded to the same degree. In view of the tectonic activity prevalent throughout the whole west coast region throughout tertiary time, this similarity in the degree of deformation points to probable close relationship in date of deposition; hence approximately upper Miocene. A second line of evidence is the rather remarkable lithologic similarity of The Dalles beds to the Ellensburg of central Washington, now known to be late Miocene or lower Pliocene.[1] Both formations are apparently parallel to the underlying basalts, both are made up in large part of rounded volcanic river gravels and peculiar bluish and gray cross-bedded tuffaceous sandstones and ash beds. The composition of the volcanics in the gravels is somewhat different, but this may indicate merely a somewhat different source. A third indication that The Dalles formation is middle Neocene rather than Quaternary is its induration. A comparison of the induration and resistance to erosion of numerous Neocene and Quaternary formations in the Pacific Coast States, both of marine and continental origin, has led the writers to

[1] Paper by John C. Merriam and John P. Buwalda in course of publication.

the conviction that when extensive exposures can be studied it is usually possible to differentiate in a broad way on the basis of these characteristics between Miocene, Pliocene and Quaternary formations, and certainly between middle Neocene and Quaternary formations. The nature of the materials must naturally be taken into account, as must the loading from overlying formations when the thickness of these can be determined. It is also clear that judgments from limited exposures can not be relied upon, and that the induration of a formation deposited late in one period will often not differ materially from that of strata laid down early in the succeeding period. But with all these reservations, the induration of The Dalles formation is equal to that of other middle Neocene formations of the Columbia plateau region, such as the Ellensburg, Mascall, Payette and Virgin Valley. Its induration is enormously greater than that of Quaternary formations like the Ringold, the Quaternary gravels of the Gorge and the Portland region, and the Quaternary marine formations of the Oregon and California coast. It is on the whole more indurated than the Pliocene Rattlesnake formation of the John Day region.

All the evidence converges to indicate a middle Neocene age for The Dalles formation.

AGE OF THE "SATSOP GRAVELS" OF THE COLUMBIA RIVER GORGE

J. H. Bretz applied the name Satsop formation in 1915 to a deposit of stream gravels in the Chehalis Valley of western Washington.[1] Its age was thought to be Quaternary because of its unconformable relation to Eocene and Miocene sediments, its limitation as a valley filling, and its probable equivalence to Quaternary formations at various localities on the Washington coast. The quartzitic gravels with which we are concerned in this paper, overlying the Columbia basalts in the Gorge, Bretz later correlated with the type Satsop and considered Quaternary in age.[2] The basis for the correlation of the gravels at the two localities, separated about 100 miles, seems to have been mainly lithologic similarity, particularly the presence in greater or less abundance of well-worn quartzitic pebbles of rather unique reddish color. It would seem rather unlikely, however, at the very outset that loose gravels filling a valley in essentially the present topography would be the equivalent, in time of deposition, of indurated conglomer-

[1] *Pleistocene of Western Washington* (abstract), Geol. Soc. Am. Bull., vol. 26, No. 1, 131, 1915.

[2] *The Satsop Formation of Oregon and Washington*, Jour. Geol., vol. 25, No. 5, 446, 452, 1917.

ates buried hundreds or thousands of feet beneath volcanics in a neighboring mountain range which has in post-conglomerate time been folded and trenched some thousands of feet by a stream. I. A. Williams, with whom Bretz had studied the Columbia River Gorge, accepted [1] the very late age determination for the gravels, but seemingly not without some hesitation; this apparently arose from the recognition that a Quaternary age assignment for the gravels necessitated the telescoping of an apparently long history into a surprisingly brief period of time.[2]

Warren D. Smith and Earl L. Packard[3] indicated that wherever they had examined the "Satsop" exposures on the Columbia and Sandy Rivers the formation appears to be an ordinary river gravel plastered against the sides of the valleys. The inference is that the Satsop is Quaternary, although no opinion is stated regarding its age.

While the writers obtained no diagnostic mammalian fossils from the "Satsop" gravels, the age determination of The Dalles formation is also determinative for the "Satsop" because of their stratigraphic relations. (*a*) Bretz considered it probable that The Dalles "is a local phase of the Satsop formation." (*b*) The Dalles beds extend far up the southeast flank of the Ortley anticline west of The Dalles. The writers found the same beds dipping northwestward on the northwest flank of the fold and overlying gravels, certainly assignable to the "Satsop." (*c*) North of the Columbia and one to two miles west of Lyle, Washington, typical quartzitic "Satsop" gravels are likewise overlain by pyroclastics and sediments, without doubt the correlative of The Dalles formation. The gravels are therefore substantially the same age, or older, than The Dalles formation. While they are stratigraphically below the latter beds, the writers did not determine whether they bear conformable or unconformable relations, but regard conformity as probable.

The palæontologic and stratigraphic evidence of the middle Neocene, rather than Quaternary, age of the "Satsop" is corroborated by other considerations.

(1) Bretz and Williams have called attention to the irregular erosion surface on the Columbia lavas, on which the beds were deposited, and the deep weathering beneath that surface. While this would doubtless require hundreds or thousands of years, it does not necessarily indicate the lapse of even a considerable fraction of a geological period. Relief of 25 to 40 feet often develops on the sur-

[1] *The Columbia River Gorge: Its Geologic History interpreted from the Columbia River Highway,* in *Mineral Resources of Oregon,* Oregon Bureau of Mines and Geology, vol. 2, No. 3, 128, 1916.

[2] Idem, page 130.

[3] *Salient Features of the Geology of Oregon,* Jour. Geol., vol. 27, No. 2, 101, 1919.

face of a lava flow when it cools, due to movement after a thick crust has been formed; and this gives the familiar hummocky topography of recent flows. Since hundreds or even thousands of feet of rock, all of which must be weathered before it is susceptible to removal, are often eroded away in part of a geological period, as indicated at many localities in the West, it is clear that a few tens of feet of weathered basalt spell the passage of but a short time in a geologic sense. A more important feature of the basalt-gravels relationship is their approximate parallelism; the dips in the "Satsop" gravels on the flanks of the folds are in general as steep as those in the underlying Columbia basalts. While this does not demonstrate conformity, it indicates probability, in a region which tectonically has been as unstable as the West Coast during the Tertiary, that the hiatus between the two formations does not denote great lapse of time. This is particularly true because the period between the outpouring of the Columbia lavas—approximately middle Miocene—and the Quaternary, the date heretofore postulated for the deposition of the gravels, saw in the John Day region and elsewhere in the Pacific Coast states not merely one but two or more vigorous deformations.

(2) The "Satsop" conglomerate is moreover, as in the case of The Dalles formation, far too highly indurated to be Quaternary in age. In road cuts just east of Hood River this conglomerate breaks into blocks; some of the pebbles are cut through cleanly, as occurs in middle Neocene or older formations, but very seldom in younger beds.

(3) The relation in time of the "Satsop" conglomerate to gravel of true Quaternary age is also well shown at the Hood River locality. Good-sized chunks of the underlying "Satsop" conglomerate, little worn and still very compact, occur in the unconformably overlying Quaternary gravel; the superior induration and an age for the conglomerate greater than Quaternary is there very forcibly demonstrated.

(4) The writers have found the "Satsop," as Bretz reports, at various localities in the Goldendale region north of the Columbia River and across the Horseheaven plateau to the Yakima Valley. But instead of finding it lying unconformable across the edges of the Columbia basalt and the middle Neocene Ellensburg formation, the uniquely colored quartzitic conglomerate dips vertically down the steep north flank of the fold which marks the northern margin of the Horseheaven plateau. At the lower quarry on the switchbacks of the "Mabton Hill," on the Bickleton-Mabton road about ten miles south of the latter town, the conglomerate can be seen standing at

or near the base of the Ellensburg section, near the vertical Columbia basalt contact. Its induration here is like that in the Gorge.

(5) Twenty miles farther north, on Snipes Mountain west of Sunnyside, similar conglomerates are interbedded in a section without doubt referable to the Ellensburg.

Because of the considerations enumerated above the writers are convinced that the "Satsop" gravel of the Cascade Range is not Eocene or Quaternary, but middle Neocene. Since this formation is not the correlative of the Satsop of the Chehalis Valley, a new name—Hood River conglomerate—was applied to it in a preliminary statement of the results of this study. The type section is at the east end of the Columbia River Highway bridge spanning Hood River just east of the town of Hood River, Oregon.

It is quite probable that the Hood River conglomerate is a phase of The Dalles formation, as suggested by Bretz, but the conglomerate appears to be rather distinct from the volcanic series, has been and will doubtless continue to be discussed as a separate entity, is rather unique as a formation, and is believed to constitute a desirable cartographic unit for areal studies; hence the new formation name is proposed.

CORRELATION

Portland Gravels

In a paper published in 1916, Williams recognized two distinct sets of gravels in the lower Williamette Valley around Portland.[1]

Bretz, however, the following year seems to have grouped together as Satsop the unconsolidated Quaternary gravels filling the lower Willamette Valley around Portland and the Neocene indurated and deformed conglomerate, for he speaks of the "Satsop fill," indicates that most of the region is covered by Satsop, mentions that in *some places* the material is indurated to a conglomerate and sandstone, and does not allude to the presence of two sets of gravels.[2] In later papers[3] he differentiates the later gravels as the Quaternary Portland delta gravels, and indicates that they are easily distinguishable from the Satsop through their freshness.

The writers agree with Williams's and with Bretz's more recent view, of the two-fold division of the gravels in the Portland region and of

[1] *The Columbia Gorge: Its Geologic History interpreted from the Columbia River Highway,* in *The Mineral Resources of Oregon,* Ore. Bur. Mines and Geol., vol. 2, No. 3, 15, 1916.

[2] *The Satsop Formation of Oregon and Washington,* Jour. Geol., vol. 25, No. 5, 450, 451, 1917.

[3] *The Late Pleistocene Submergence in the Columbia Valley of Oregon and Washington,* Jour. Geol., vol. 27, No. 7, 501, 502, 1919; *The Spokane Flood beyond the Scablands,* Jour. Geol., vol. 33, No. 3, 252-257, 1925.

the correlation of the older set with the formation which has now been termed the Hood River conglomerate lying on the Columbia basalts in the Gorge. That the Hood River is a valley fill in a relatively recent Willamette Valley is negatived by its Neocene age, its entering into the structure of the Cascades and its clear antecedence to the development of the present physiography of the region. It was deposited before the present Cascades and Willamette Valley existed; it is the Portland delta gravel and related deposits to the north and south which constitute the Quaternary valley fill.

Columbia Gorge Gravels

At Lyle, at the mouth of Hood River, and at other points in the Gorge are bodies of unconsolidated gravels which were deposited by the Columbia River upon substantially the present topography. They are truly Quaternary in age, as Bretz has pointed out. They are entirely distinct from the Hood River conglomerate, bearing strikingly unconformable relations to it. The contrast in physical characters also emphasizes the much greater age of the Hood River.

John Day Region

The Mascall formation lies upon the Columbia lava and almost certainly bears conformable relations to it, but it may not be the exact correlative of the Hood River conglomerate. Its age has been considered to be middle Miocene.

Strong deformative movements had effected the Columbia lava and the Mascall before the lower Pliocene Rattlesnake formation was deposited; such angular unconformities between the Hood River and the Columbia lava are not known to exist, and it is quite certain that the Hood River is therefore older than the Rattlesnake.

Ringold Formation

In the White Bluffs of the Columbia in central Washington 500 feet of light-colored horizontal silt are exposed. The age of these beds, previously considered by several writers to be Neocene because of their supposed equivalence to the Ellensburg formation, was determined to be Pleistocene on the basis of mammalian fossils.[1] The tenor of the age determination is that the beds are older than late Pleistocene.

The Ringold is clearly distinct from, and much younger than, the Hood River conglomerate. It was in all probability laid down during the same episode of deposition which led to the formation of the

[1] John C. Merriam and John P. Buwalda, *Age of Strata referred to the Ellensburg Formation in the White Bluffs of the Columbia River,* Univ. Calif. Publs., Bull. Dept. Geol., vol. 10, No. 15, 257-260, 1917.

unconsolidated silts and gravels near Arlington, The Dalles, and in the Columbia River Gorge, and it probably defines their age. The pre-Quaternary age of the Hood River and The Dalles formation is therewith again indicated in view of the strong unconformity separating the silts and gravels from those formations.

Yakima Region

In discussing the age of the Hood River conglomerate, mention was made of the scattered occurrences of the quartzitic gravel across the Horseheaven plateau and its standing at the base of the vertical Ellensburg section on the Mabton Hill. This stratigraphic relationship and the faunal evidence from the two formations indicate approximate time equivalence.

Bretz stated that the "Satsop" quartzitic gravel lies unconformably across the edges of the Ellensburg and the Yakima (Columbia) basalt in the Yakima country, central Washington.[1] The writers have not examined all the localities cited by Bretz, but they corroborate the observation that a post-Ellensburg quartzite-bearing formation exists in that region.

About one mile east of the Granger brickyards, along the railway on the south slope of Snipes Mountain, horizontal unconsolidated silt and interbedded loose gravel containing the unique red quartzite pebbles lie unconformably upon the Ellensburg beds so excellently exposed in the brickyard pits. The silt and gravel are quite certainly the Yakima valley correlative of the Quaternary Ringold formation and resulted from the same temporary relative rise of base level.

Several miles farther east, due north of the Jackson Ranch, and just west of the highest part of Snipes Mountain, a second red quartzite-bearing conglomerate, highly consolidated, is exposed in a pit on the crest of the ridge. The entire fold making Snipes Mountain is clearly seen in a cross-section of the ridge at this point, and the relations of the quartzite-bearing conglomerate indicate that it is without doubt a part of the Ellensburg section, which here consists of the usual assemblage of tuffaceous sandstone, ash, clay, gravel, and a basalt flow. The quartzite-bearing conglomerate on top of the ridge dips approximately 30° north.

In all probability the red quartzite pebbles in the younger gravel were derived from the nearby exposures of conglomerate on the hill above, for the Yakima River carries no quartzite of this type, and since the landscape on which the practically undeformed silt and gravel were deposited already closely resembled the present topog-

[1] *The Satsop Formation of Oregon and Washington*, Jour. Geol., vol. 25, No. 5, 455, 1917.

raphy it is difficult to see how the Columbia River could have reached this area.

An interesting inference arises from the fact that in central Washington quartzite-bearing conglomerate is interbedded with the andesitic sediments of the Ellensburg. It is that in middle Neocene time, after the close of the eruptions of Columbia basalt and previous to the Pliocene folding, the directions of drainage across the basalt plateau were already much like those of today, for the quartzite quite certainly came from northeastern Washington and adjoining parts of the Rocky Mountains of Idaho and British Columbia, whence the Columbia is bearing it today, while the andesitic detritus was with little doubt derived from the present site of the Cascades. The sources of the Columbia and of its tributaries lie in those same areas at present. The detailed drainage pattern was doubtless quite different, and changed continuously over the aggrading gravel plains of that period.

Methow Peneplain

Bretz states[1] that "* * * little hesitation is felt in correlating the eroded surface named the 'Methow peneplain' with the eroded surface beneath the Satsop formation in the Cascade Range." The Methow peneplain was described by Bailey Willis and George Otis Smith[2] for central Washington; it is reported to bevel both the Columbia lavas and the Ellensburg formation. In view of the apparent similarity in age of the "Satsop" (Hood River) conglomerate and the Ellensburg, it is much more probable that any erosion surface in the Cascade Range, which is the correlative of the Methow peneplain, truncates rather than lies beneath the Hood River conglomerate.

AGE OF THE CASCADE RANGE

Williams[3] and Bretz[4] regarded the Cascade Range in the Columbia Gorge region as Quaternary in age. Williams states that the "Satsop" enters into the deformation of the Cascade Range and that it appears to belong to the Pleistocene. Bretz lists the age determinations of beds at some five Pacific Coast localities with which he correlates the "Satsop" of the Gorge, and then states—"If the foregoing determinations are correct, the Cascade Range, at least in this portion, is of Quaternary age." Even if we consider that the deposition of the hundreds of feet of "Satsop" of the Gorge occurred early in

[1] *The Satsop Formation of Oregon and Washington,* Jour. Geol., vol. 25, No. 5, 456, 1917.
[2] U. S. Geol. Surv. Prof. Paper 19, 1903.
[3] *The Columbia River Gorge: Its Geologic History interpreted from the Columbia River Highway,* in *The Mineral Resources of Oregon,* vol. 2, No. 3, 128-130, 1916.
[4] *The Satsop Formation of Oregon and Washington,* Jour. Geol., vol. 25, No. 5, 458, 1917.

the Quaternary the uplift of the Cascade Range and the cutting of the Gorge could not on this basis of reasoning have begun much before middle Quaternary time.

No reason has arisen to question the essential correctness of the age determinations of the beds at different localities on the Coast with which Bretz correlates the "Satsop" of the Gorge; but the correlation is incorrect. Uplift of the range and cutting of the Gorge commenced earlier than middle Quaternary.

The age of the present range and of the present gorge as distinguished from a possible earlier range and transverse valley, which may have existed in the Gorge region in Hood River time, is rather definitely determined by the facts now available. The uplift and cutting of the present range and gorge occurred after the deposition of the Hood River conglomerate; the writers agree fully with Williams and Bretz that this formation enters into the structure of the range.

On the other hand there is reason to think that the uplift began before the deposition of at least the younger parts of the andesitic lava series known as the Cascades formation which overlies the Hood River and whose exact age is unfortunately not known to the writers. While Williams's cross-section suggests that part of this series may enter into the structure of the range he states "Contemporaneous with its progress [the uplift] the andesitic lavas came in increasing profusion." The Cascades formation is, moreover, not one which would require a long period for its accumulation; if it required part of the Pliocene for its deposition, a considerable part of upper and perhaps middle Pliocene would remain in which the uplift of the range and the cutting of the Gorge could be initiated.

That a fraction of the Pliocene as well as the Quaternary was involved in the uplift and cutting is strongly suggested by certain other evidence. Glacial deposits occupy areas in the Hood River valley, reaching well down to the Columbia River. The topography has been modified in detail since these tills were laid down, but post-uplift erosion had already sculptured the landscape, including the Gorge, to essentially its present form before their deposition. Bretz states that the lowest till is probably not attributable to the last glacial advance.[1] Apparently the task of cutting the Gorge had been essentially completed before late Pleistocene.

This conclusion is also indicated by the relation of the bodies of gravel which lie within the Gorge and which extend out of its western mouth as the Portland delta. Bretz regards these as related to the

[1] *The Late Pleistocene Submergence in the Columbia Valley of Oregon and Washington,* Jour. Geol., vol. 27, No. 7, 495, 1919.

Spokane glaciation, and as pre-Wisconsin;[1] hence at some date before late Pleistocene time the Gorge had already assumed approximately its present form and proportions.

It might nevertheless be held that the duration of the remaining earlier portion of the Quaternary might suffice for the uplift of the Cascade Range and the cutting of the Gorge. But if the fraction of the Quaternary which has elapsed since the earlier till was deposited is roughly a quarter or a sixth of that period, which seems a reasonable estimate, the ratio of the excavation made by the Columbia and its tributaries, in pre-till time is enormously greater than four or six times the amount of post-till dissection. This would point to a requirement of more than merely the pre-till fraction of Quaternary time for the excavation of the Gorge.

The writers are therefore of the opinion that the beginning of the development of the present Cascade Range and the Columbia River Gorge occurred not in the Quaternary but in upper Pliocene time.

[1] *The Spokane Flood beyond the Channeled Scablands,* Jour. Geol. vol. 33, No. 2, 252, 1925.