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I

A NEOCENE EROSION SURFACE IN CENTRAL OREGON

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With one plate and one text-figure

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CONTENTS

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ABSTRACT

A landscape, in the old age stage, termed the Ochoco Erosion Surface, bevels the Columbia lavas and Mascall formation of middle Miocene age at a large angle, and the Rattlesnake lower or middle Pliocene at a small angle, in parts of the Ochoco Range and the John Day country of central Oregon. North of the John Day country the Condon Erosion Surface, locally at least a peneplane, probably but at present not demonstrably the correlative of the Ochoco, truncates the Columbia lavas and perhaps The Dalles formation. A pause in the eventful diastrophic history of this part of the Northwest is apparently indicated by these features. Subsequently, during the present or Dayville cycle, the great gorges and valleys have been excavated.

INTRODUCTION

The observations discussed in this paper were made in the course of the geologic mapping of the Mitchell Quadrangle and the Picture Gorge Special Quadrangle in central Oregon and the incidental study of adjacent areas. The investigations are part of a program of Tertiary history studies being prosecuted under the general direction of Dr. John C. Merriam of the Carnegie Institution of Washington.

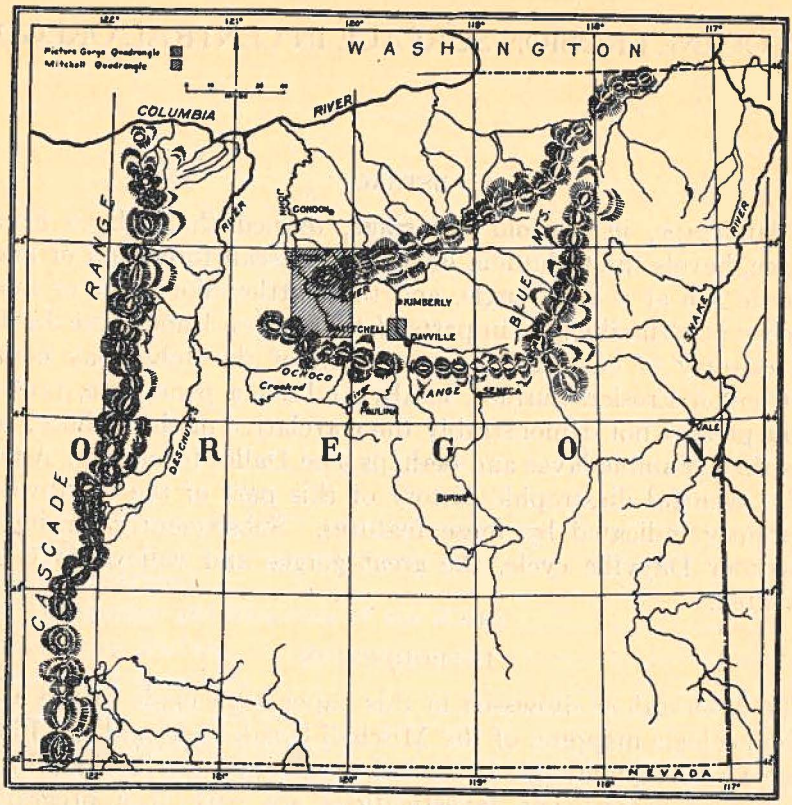
Able assistance has been rendered during much of the field work by Mr. Bernard N. Moore.

GEOGRAPHIC FEATURES

A broad basin, largely structural in origin, occupies a large part of central Oregon. Its middle portion is called the Harney Valley. Lying at about 4,000 feet altitude, it is part of the plateau of eastern and central Oregon. Its profiles are gentle.

Immediately north of this broad basin an east-west belt of mountainous country stretches from the higher part of the Blue Mountains of northeastern Oregon westward nearly to the east base of the Cascades. This mountainous zone consists of east-west ridges, and because the valleys between are drained by the branches of the river of that name it is usually known as the John Day country.

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



Plateaus again border this rougher tract on the north, and with declining altitude extend to the brink of the canyon which the Columbia River has incised to varying depth to mark the boundary of Oregon and Washington.

Central and north-central Oregon comprise then these three provinces: two plateau areas with an intervening mountainous belt usually referred to as the John Day region.

AREAL DISTRIBUTION AND STRUCTURE OF THE ROCKS

Physiographic studies can manifestly not be pursued safely without a knowledge of at least the general character and distribution of the rock masses on which the forms under investigation have been developed.

The central Oregon basin, or Harney Valley, is underlain principally by Tertiary lavas, pyroclastics, and continental formations. Of these, the Miocene and earlier formations are folded gently; the Pliocene and Quaternary lavas and sediments are usually only slightly warped.

In the John Day region a greater variety of formations is exposed. The surface rocks of this mountainous tract form three east-west

anticlines, with two intervening synclines. The north flank of the most northerly anticline becomes the plateau which extends northward to the Columbia River, and the south flank of the southerly of the three anticlines forms the expansive north slope of the Harney Valley. Minor features of course complicate this structure considerably.

Nearly the whole John Day region seems to have been covered originally by the Columbia lavas. Areally they are still the most important rocks. The Mascall formation, consisting of some two thousand feet of ashy sediments, conformably overlies the lavas in a few areas where it has been protected by downfolding. The Pliocene Rattlesnake formation overlies unconformably both the Mascall and the Columbia lavas in one or more districts. Beneath the Columbia lavas, exposed by deep dissection in only a few areas, the Oligocene sediments of the John Day formation present their upturned edges. The Clarno, consisting of hundreds of feet of basic lavas and pyroclastics, constitutes the surface formation in extensive tracts in the western part of the John Day region, usually along the central part of anticlines from which the cover of later formations has been removed. Chico Cretaceous strata are exposed in small patches in certain localities. Along the gentle south slope of the Ochoco Range, the southern anticline of the John Day region, earlier Mesozoic and Paleozoic strata form the land surface in east-west strips of considerable size. The Chico, John Day, Mascall, and Rattlesnake formations, of sedimentary origin, are of course the weak rocks, and form the lowlands; the pre-Cretaceous, the Clarno, and the Columbia lavas are resistant and commonly constitute the higher parts of the ranges, the plateaus, and the mesas.

North of the John Day region the broad plateau which slopes away gently to the Columbia River is underlain almost entirely by Columbia lavas.

OCHOCO EROSION SURFACE

Distribution of Remnants

Of the three provinces mentioned as constituting central and north-central Oregon, the middle one—the elevated and folded John Day country—has been deeply dissected, approximately to the stage of early maturity in the erosion cycle. The stream valleys are still gorges or canyons in the more resistant rocks, but have been widened to narrow valleys in the John Day and Mascall formations (Plate I, fig. *A*). The valley bottoms are sometimes flat alluviated floors, in other cases they are rolling or hilly up to the contact with the more resistant formation which makes the adjoining hill or mountain.

The dissection of the John Day region is due not alone to its higher elevation and the consequently greater precipitation upon it. To the east of the region the Elk Range, highest part of the Blue Mountains, receives still greater rainfall, and the forks of the John Day, receiving a considerable part of this, have therewith developed enlarged excavating powers.

The main branches of the John Day River have been cut to levels considerably below the nearby margins of the plateaus which lie to the north and south of the dissected John Day region. The sloping plateau on the south which rises gradually from the floor of Harney Valley northward attains general elevations, in the crest of the Ochoco Range, of 2,000 to 2,500 feet above Bridge Creek and the main John Day. As a consequence tributaries of these streams are reaching vigorously back into the plateau by headward erosion. The heads of these tributaries have advanced southward, in many cases far beyond the line of maximum heights of the Ochoco Range.

Strong contrast marks the topography north and south of the sinuous drainage divide. To the north, as indicated earlier, the land forms are those of early maturity: steep slopes, divides often sharp, general ruggedness. Southward from the drainage divide of the Ochoco Range the surface is one of gentle slopes, broad divides, and low relief. The southward drainage is of rather low gradient. Broad valleys occur, and meadows, such as Big Summit Prairie in the summit region south of Mitchell (Plate I, fig. *B*).

Some of the flat and gently sloping surfaces on this subdued upland are unquestionably structural in origin. The Columbia lava particularly gives rise to strikingly smooth dip slopes because of its peculiar habit of degradation through complete removal of successive sheets, flow by flow, over large areas. But the surface of relatively low relief here under discussion extends over areas not underlain by the Columbia lavas. To the west and southwest of the summit crossing of the Prineville-Mitchell road the Clarno formation underlies the surface; its detail of form is quite different, but the more subdued character of the upland surface still contrasts strongly with the rugged and dissected topography cut on the same formation north of the divide by the tributaries of the John Day.

The old erosion surface extends along the south slopes of the Ochoco Range from the Big Summit Prairie region south of the Mitchell Quadrangle eastward through the Paulina, Izee, and Seneca regions, where Dr. Packard and Mr. Lupher have been studying Cretaceous and pre-Cretaceous formations, for an unknown distance toward the Snake River region. Several years ago the writer observed

what appeared to be an old surface ascribable to a former erosion cycle on the south slopes of the Blue Mountains, perhaps midway between Burns and Vale.

When traced down the south slopes of the Ochoco Range south of the Mitchell Quadrangle the old surface becomes progressively more dissected, due to invasion headward by the tributaries of the rejuvenated Crooked River. This stream and the Deschutes, which it joins, have cut deep trenches during the present cycle, below remnants of the old erosion surface.

Within the John Day region, in which the topography has advanced in the present cycle to early maturity, but few residual areas of the old surface have been recognized. The Rattlesnake formation, of middle Pliocene age, was deposited in a shallow valley, the floor of which was part of the old erosion surface. North of the areas where the old surface is covered by these sediments, between Picture Gorge and Kimberly, remnants of what is believed to be the same surface truncate the Columbia lavas and stretch eastward and westward from the rims of the 2,500 foot canyon through which the John Day flows at this point.

The plateau north of the John Day country has the physiographic characteristics of youth. High grade canyons lead to the Columbia and the John Day Rivers. They often end headward in the midst of a large expanse of undissected country. The undissected interstream areas are very extensive; well-defined drainage has developed on only a fraction of the whole territory. The critical question, however, is whether the extensive flat surfaces actually truncate the structure in the underlying Columbia lavas. Loess and soil commonly obscure the relation. At many localities structure and surface are parallel, as nearly as can be determined. It is almost inconceivable, however, that this broad expanse of flat country was moulded in the present cycle of erosion, for only part of it has well-defined drainage at the present time, and that drainage certainly appears to be destroying the flat surface, not forming it.

The surface is believed to bevel the lavas but at a small angle, but with the loess cover it has not been possible thus far to find a clearly demonstrable case.

It has sometimes been assumed that flat plateaus in the Columbia lava region are simply the original upper surface of lava accumulation, but it is of course unreasonable to suppose that such a land surface would lie exactly at base level during the whole long interval since middle Miocene time. It would either long since have been degraded, if it lay above base level, or have been buried by sediments if below. It might be supposed that it was buried by sediments and

only recently exhumed; but in that case sizable remnants of the sediments should be found on some of the flat interstream areas, which are often miles wide.

DESIGNATION AND TYPE AREAS

Since the old surfaces here described are extensive for tens or scores of miles and represent a significant chapter in the physical history of central and north-central Oregon, it seems advisable to name and define them.

The old surface on the south slope of the Ochoco Range is properly designated the Ochoco Erosion Surface. The type area is the Big Summit Prairie district, south of Pisgah Peak, and south of the southern part of the Mitchell Quadrangle.

The surface north of the John Day country, sloping down to the brink of the Canyon of the Columbia River may be the correlative of the Ochoco, but this can not at present be demonstrated, and in view of the uncertainty the name Condon Erosion Surface is proposed for it, from the town of Condon which is situated on it. The type area may be taken at that locality.

The present difficulty in correlation of the Condon surface with the Ochoco arises from the absence of known Mascall and Rattlesnake deposits from the Condon region, so that the age of the surface can not be so precisely determined. The Condon surface has not been traced into the areas of Ochoco surface, and it may not be possible to do so.

State of Development Reached

The Ochoco erosion surface was, before its deformation and partial destruction, by no means a peneplane. Certain parts of it may have approached that condition, but in the type area the relief over distances of several miles was several hundred feet. Broad valleys formed part of its surface, and hills and ridges rose above the general level. Now that parts of the surface have been uplifted to 5,000 or 6,000 feet, these hills have become the high points of the country and as peaks have been given specific names. They stand, as does Mount Whitney, above the uplifted old surfaces of the upper Kern in the southern Sierra Nevada. If the Ochoco region were unwarped, however, it would merely be considered hilly in parts and it would have the aspect of an old age surface.

The Condon surface, if restored by filling in the canyons which have begun to trench it, would have less relief than the Ochoco. It was in late old age when uplifted; it approached the peneplane stage over considerable areas.

AGE

Since the Ochoco Erosion Surface bevels the Columbia lavas and Mascall formation, as well as all earlier formations, it is of course post-Mascall, and hence post Middle Miocene in age. More precise determination of its age rests, however, upon its relations to the lower or middle Pliocene Rattlesnake formation. Unfortunately these strata are not present in the areas where the erosion surface is best represented. East of Picture Gorge, however, the Rattlesnake has been faulted down into the Columbia lavas and the erosion surface has quite certainly beveled the lavas subsequently, leaving protected strips of the sediments. Southeast of Mitchell, near the summit of the Ochoco Range, rhyolites, presumably the correlative of the Rattlesnake rhyolites lying along the Mitchell-Dayville road a few miles to the north, are cut by the Ochoco Erosion Surface. While the evidence is not entirely conclusive it seems to indicate that the erosion surface was finished in middle or upper Pliocene time.

While in geomorphic usage erosion surfaces are often designated by the geologic date of completion, it should be pointed out that, when the Ochoco surface is called a middle or an upper Pliocene erosion surface because it bevels lower or middle Pliocene rocks, this does not necessarily mean that it was developed entirely during this brief fraction of a period. The folding of the region which occurred in post-Mascall pre-Rattlesnake time was far more intense, if we compare the dips of the Mascall and the Rattlesnake, than any post-Rattlesnake pre-Erosion Surface deformation. The Rattlesnake formation, while it consists in part of lavas poured out over the pre-Rattlesnake landscape, was largely a valley filling; it thins for instance along the sides of the John Day Valley, and its upper members extend out over the older formations much farther than the lower beds. While its rather coarse nature indicates that considerable relief still existed in some parts of the region it is clear from the above relations that the larger part of the geologic labor involved in truncating the large pre-Rattlesnake folds had been performed previous to Rattlesnake time and that during and after the deposition of the Rattlesnake the erosional activity was mainly one of completing and perfecting the surface.

Since the Rattlesnake formation is not known to occur north of the John Day country it has not been possible to determine the age of the Condon Erosion Surface, the probable correlative of the Ochoco, much more precisely than that it is post-Columbia lava in age. It is highly probable, however, that it bevels The Dalles formation, which has recently been shown to be middle Neocene in age.[1]

[1] J. P. Buwalda and B. N. Moore, *Age of the "Satsop" and The Dalles Formations of Oregon and Washington,* Science, vol. 66, Sept. 9, 1927.

The upper limit for the age of the Ochoco surface is set as middle or upper Pliocene, primarily because of the extent of the excavation and dissection accomplished subsequently. Enormous gorges and quite broad and deep valleys have been developed in the John Day country and the Ochoco Range. The Condon surface has been similarly modified.

Subsequent Modification

As in most other elevated parts of the western United States which have external drainage, the dominant erosional process in the John Day region is vigorous dissection and degradation. In this present cycle, termed the Dayville cycle, land surfaces produced earlier are being rapidly destroyed. This is of course primarily due to uplift in the course of the late Cenozoic topographic revolution which has been and is affecting the whole of western North and South America. The tributaries of the Columbia have been attacking the region from the north, those of the John Day from the west, and the branches of the Deschutes from the south and southwest. While the John Day, due to several favoring conditions, has carried the task to early maturity in the John Day region itself, the destruction of the surface has been only well begun in the Ochoco region to the south and the Condon country to the north.

A second modification of the old erosion surfaces, presumably concurrent with the uplift, has been the post-Rattlesnake folding along east-west axes. This was much less intense than the pre-erosion-surface folding of the Neocene, for the dips in the Rattlesnake seldom exceed a few degrees, while the Mascall and Columbia lava dips are sometimes above 30 degrees. The post-Rattlesnake folding is, however, responsible for the main features of the present relief—the anticlinal ridges like the Ochoco range, and the synclinal valleys like the John Day. Low broad swells on both the Ochoco and the Condon surfaces are quite certainly due to this late Tertiary and Quaternary deformation. Faults cut the Rattlesnake formation and have quite certainly dislocated the Ochoco Erosion Surface also in areas where no Rattlesnake is present.

Slight modification by loess accumulation on the Condon surface has occurred, and post-erosion-surface lavas have accumulated to some extent on parts of the Ochoco surface, but these have affected the form of the land to only a trivial degree.

A—Looking down Rock Creek (middle foreground) and valley of John Day River (in distance) below Picture Gorge. Mature topography; 2,000 feet relief. Ochoco Erosion Surface largely destroyed; probable remnants on skyline in center.

B—Big Summit Prairie, on the gentle south slope of the Ochoco Range, 15 miles south of Mitchell, Oregon. Looking northeast. Tributaries of the John Day River are invading this old-age surface vigorously from the north. This region is the type area of the Ochoco Erosion Surface.