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AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 53

GEOLOGY AND WATER RESOURCES OF NEZ PERCE COUNTY, IDAHO, PART I.—Russell

WASHINGTON
GOVERNMENT PRINTING OFFICE
1901

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES OF NEZ PERCE COUNTY, IDAHO

PART I

By ISRAEL COOK RUSSELL

WASHINGTON

GOVERNMENT PRINTING OFFICE

1901

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., April 12, 1901.

SIR: I have the honor to transmit herewith a manuscript by Prof. Israel C. Russell, of Ann Arbor, Michigan, relating to the geology and water resources of Nez Perce County, Idaho, for publication in the series of Water-Supply and Irrigation Papers. This is the result of the examination conducted during the field season of 1900. The facts obtained have considerable value, not only in the development of water, but also in obtaining a knowledge of the other resources of this important area. The details and descriptions have increased the length of the manuscript to such an extent that, in order to conform with the terms of the law restricting the pamphlets to 100 pages, it is necessary to divide the material into two portions, the first or preliminary part relating to the geology and physiography of the area, and the second part taking up the water supply and other economic features.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

GEOLOGY AND WATER RESOURCES OF NEZ PERCE COUNTY, IDAHO.

PART I.

By Israel C. Russell.

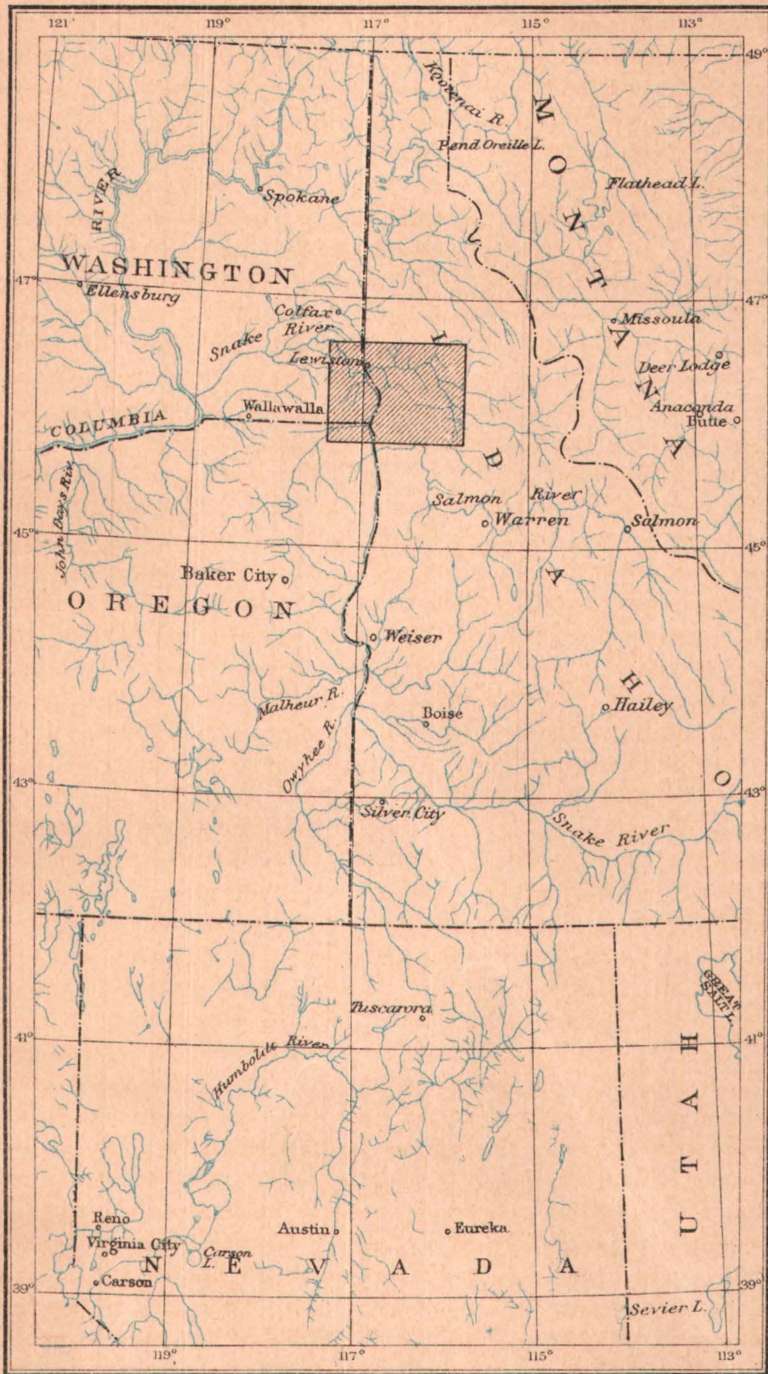
LOCATION AND GENERAL CHARACTER OF REGION.

An investigation of the geology of Nez Perce County, Idaho, was made by the writer during the summer of 1900, with special reference to the possibilities of obtaining artesian water. Field work was carried on from July 4 to September 11, and examination was made of as much of the county and adjacent country as time permitted. In the absence of a satisfactory topographic map, however, only what is understood as reconnaissance work could be done, and without such a map it is also difficult to make a detailed and accurate presentation of the facts observed. For these reasons this paper should be considered as simply a report of progress, and not a complete and detailed geologic survey of the region visited and studied.

Nez Perce County, as is shown on Pl. I, is situated in western Idaho. It is bordered on the west by portions of Washington and Oregon, and the dividing line between these two States if prolonged eastward would cross the county about 10 miles from its southern boundary. As will be seen on the accompanying geologic sketch map (Pl. II), the western border of the county, to within about 4 miles of Lewiston, is marked by the middle line of Snake River. The other portions of the boundary need not be described, as they are indicated on the map referred to, but it will be convenient to bear in mind their relations to certain conspicuous topographic features. A part of the southern boundary is formed by Salmon River, and another part by Lawyers Creek, while the eastern boundary is determined by Clearwater River and the South Fork of the same stream. Each of the streams just mentioned, and also Snake River throughout the portion of its course shown on Pl. II, flows in a canyon 2,000 or more feet deep, so that throughout much of its course the boundary of the county coincides with strongly pronounced features in the relief of the land.

The approximate area of the county is 1,335 square miles—somewhat larger than that of the State of Rhode Island. It is, however, one of the smaller of the twenty-one counties into which Idaho is divided. The main portion of the county lies between latitude 46° and 46° 35′ N., and between longitude 116° and 117° W. The county seat is Lewiston, which has a population of 2,425 and is situated on its western border, at the junction of Clearwater River with Snake River. Lewiston is connected with Clarkston, Washington, on the west side of Snake River, by a fine steel cantilever bridge. These two towns, frequently designated Lewiston-Clarkston, have a joint population of 4,000. There are also many villages and hamlets scattered throughout the county and over the adjacent country, more especially to the east and north, and isolated farmhouses and settlers' cabins are numerous. The population of the county is 13,748. Agriculture is the chief industry.

An examination of any recent map of the New Northwest will show that branches of the Northern Pacific Railroad and of the tracks of the Oregon Railway and Navigation Company extend into Nez Perce County and the country adjacent, and terminate without making through connections. These branches of two great trunk railroad systems suggest at once that the newly settled region which they invade has something that invites capital, and it will be found that the attraction which has drawn the steel bands through profound canyons, across broad plateaus, and over rugged mountains is mainly wheat. No doubt it will be a surprise to many of my readers to learn that the eastern portions of Washington and Oregon, with an adjacent strip of country in Idaho, produce annually from 50,000,000 to 60,000,000 bushels of wheat, as well as considerable quantities of other grain. This great and rapidly growing industry is based on the remarkable fertility of the soil and the favorable climatic conditions. The fine, dark, rich soil, as will be shown later, has resulted from the disintegration and decay of certain widely spread volcanic rocks, and is of almost unrivaled fertility. The climate, although in many respects favorable to agricultural pursuits, is not all that might be desired. The seasons are two in number, winter and summer; or, to use more descriptive terms, a humid season and a dry season. The winters, more particularly in the valleys and canyons and on the lower plateaus, are wet. Snow seldom lies on the ground for more than a few days at a time, but damp, chilly weather is prevalent, and practically all the rain of the year falls during that time. It is stated that the only "zero weather" known at Lewiston within the last ten years or longer occurred in February, 1899, when the temperature during one night fell to 7½° below zero; the next coldest period was in January, 1899, when the thermometer registered 12° above zero. On the higher plateaus and mountains, or, in general, at



MAP SHOWING POSITION OF NEZ PERCE REGION

Scale

100 50 25 0 50 100 200 MILES

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an elevation of 2,000 or more feet above Lewiston, equivalent to an elevation of 3,000 feet above the sea, the climate throughout the year is cooler and more humid than at lower altitudes, and in winter the cold is frequently severe and the snow deep. In the Bitterroot Mountains, to the east of Nez Perce County, the marks made on the trees in winter, known as "snow-shoe blazes," are from 15 to 20 feet above the ground, and show that the snow accumulates to great depths. These mountains are densely forest covered, are uninhabited, and judging from the nature of the vegetation the climate is cold and the precipitation abundant. Between the two extremes in elevation, namely, the canyons and lower plateaus and the truly mountainous portions of the country, there are certain broad plateaus, such as the one to the north of Clearwater River, termed in this paper the Uniontown Plateau, and the Camas and Kamiah prairies, which have surface elevations of about 3,000 feet and are intermediate in climatic conditions between the extremes just referred to. The winters, although colder than at lower elevations, are not severe; snow remains on the ground several weeks, but seldom affords good sleighing, and the rainfall is frequently heavy. During the long, clear summers the days are hot, but the nights are always cool.

The most populous portions of the region are thus without the cold, clear winter weather, with the land snow covered, which forms so characteristic a feature of the States in the same latitude on the eastern side of the continent. On the contrary, the open winters of western Idaho and of adjacent portions of Washington and Oregon are characterized by frequent changes from frost to thaw. The air is frequently damp and chilly, and much of the time the roads are all but impassable, on account of the deep mud. The summers are long, and in the canyons and on the lower plateaus the heat at times is intense, the thermometer frequently registering 100° F. or more in the shade. Owing to the dryness of the air, however, this extreme heat is less oppressive than a much lower temperature would be in more humid lands. During the summer hot winds, the equivalent of the warm chinook winds of winter, also occasionally occur, which, particularly on the lower plateaus, sometimes wither the green grain in a few hours and cause great losses. During the heat of the summer the soil is dry, frequently parched, and the dust on the roads lies several inches deep, being often carried in the air in dense clouds.

The rainfall at Lewiston, situated in the lowest and driest portion of the Nez Perce region, is usually from 14 to 16 inches a year. Of this meager amount the larger portion comes between the first of November and the end of March. With increase in elevation there is an increase in precipitation, but in the absence of definite observations the annual rainfall on the higher plateaus can only be judged from the nature of the vegetation and the success with which various crops are cultivated. On the Uniontown Plateau, where the elevation is about 3,000 feet, the annual precipitation is said to be in the neighborhood of 25 inches. In its original state this broad plateau was without trees, but was covered with a luxuriant growth of grasses and flowering annuals, which made it a beautiful prairie. The broad Camas and Kamiah prairies also were treeless, and may be considered to have about the same rainfall and other climatic features that characterize the Uniontown Plateau. At higher elevations, beginning, in general, at about 3,500 feet, forests appear, and give evidence of more abundant precipitation.

In the lower and drier portions of the county, particularly in the canyons of Snake and Clearwater rivers and on the adjacent plateaus, irrigation is necessary for all forms of agriculture except where the land is so low that it is subirrigated naturally from the streams. On the plateaus, 1,500 or more feet above the sea, wheat, oats, barley, flax, etc., are grown without water other than that absorbed and retained by the fine porous soil, and yield surprisingly abundant returns; but orchards, except under unusually favorable local conditions, require irrigation. On the higher plateaus and in the mountains, although the rainfall is sufficient for growing fruit, the temperature conditions are unfavorable except for berries and, possibly, apples. In the valleys and canyons, particularly those of Snake, Salmon, and Clearwater rivers, where suitable land can be had and where water for irrigation is also available, peaches, pears, plums, prunes, cherries, grapes, berries, and garden vegetables, all of excellent quality, are produced in great abundance.

With reference to native vegetation, the Nez Perce region may be divided into two portions, namely, prairies and forests. Before being plowed, the plateaus at elevations of 3,500 feet or less were clothed with bunch grass and a great variety of flowering annuals. With these natural meadows are to be classed also the precipitous border of most of the canyons, which are, for the most part, still in their natural state, except that they have been utilized for stock ranges and are still clothed with bunch grass. In early spring their rugged slopes are many tints of green, but as the heat of summer increases the grasses wither and become yellow. In late summer the entire landscape, from any commanding eminence rising above the plateaus, is various shades of yellow, for then the grain fields have changed to nearly the same color as the grass-covered canyon walls, the only exception to the prevailing old-gold color being furnished by the rich brown of the crumbling rocks in the canyon walls, the less prevalent black of the but slightly weathered basaltic lava, and rectangular areas of deep black, as it appears by contrast, which mark the locations of fallow lands among the grain fields.

While Nez Perce County and much of the adjacent country is highly favored in many ways by soil and climatic conditions, there is in general a scarcity of water available for town supply, irrigation, and even for household purposes. While the streams are numerous, and several of them are of large size, they are, for the most part, in deep canyons, and are practically unavailable for irrigation or other economic uses. In certain instances, however, the water of streams has been diverted and is being used for irrigation, but the areas thus brought under cultivation are small in comparison with the total extent of rich agricultural land which needs water at certain seasons. The further utilization of the stream is limited by the great cost of constructing storage reservoirs, dams, and ditches, and by the conflicting interests involved. For these reasons attention has been directed to possible subterranean sources of water supply, and a number of wells have been drilled, one of which yields a good surface flow. It was with the hope that if the geologic conditions were understood the present scant water supply might be increased, not only by obtaining artesian water but by increasing the flow of springs, that the studies described in the following pages were undertaken.

GEOLOGY.

The rocks in the Nez Perce region form two sharply defined groups. The older group consists of a large variety of rocks of both igneous and sedimentary origin, and includes also great areas of metamorphic rock the original nature of which has not in all cases been determined. The younger group consists principally of basalt, but includes layers of clay, sand, gravel, volcanic dust, and lapilli interbedded with it. The older group was greatly disturbed by folding and otherwise, and formed a land surface that was deeply denuded before the younger group, which in general has been but moderately deformed, was spread out upon it. Thus, geologically, the two groups are sharply defined. Their differences are also conspicuous from the viewpoint of the economist. The older group contains a variety of excellent building stones, in many places carries gold and ores of various metals, and when decomposed forms usually a light-colored soil, which is not fertile; while the younger group, furnishing only the black basalt and certain soft beds of loosely compacted volcanic dust which can be used for building purposes, is without native metals or ores, but contains lignite which may prove of value, and on decomposing furnishes a deep, rich, dark soil of marvelous fertility.

With reference to the possibilities of obtaining artesian water, only the younger group needs to be considered; and as the principal aim of the reconnaissance was to ascertain to what extent the geologic conditions favor an increase in the underground water supply, but little attention could be given, in the time available, to the study of the rocks of the older group.

PRE-TERTIARY TERRANES.

The older rock group just referred to is considered to be of pre-Tertiary age, partly because of its lithologic similarity to known terranes of older date than the Tertiary, but principally because certain limestones found in it carry obscure fossils which seem to indicate a Mesozoic age, and because the Columbia River lava, which overlies portions of it unconformably, is known, from the fossils contained in the sedimentary beds included in it, to have been outpoured during Tertiary time.

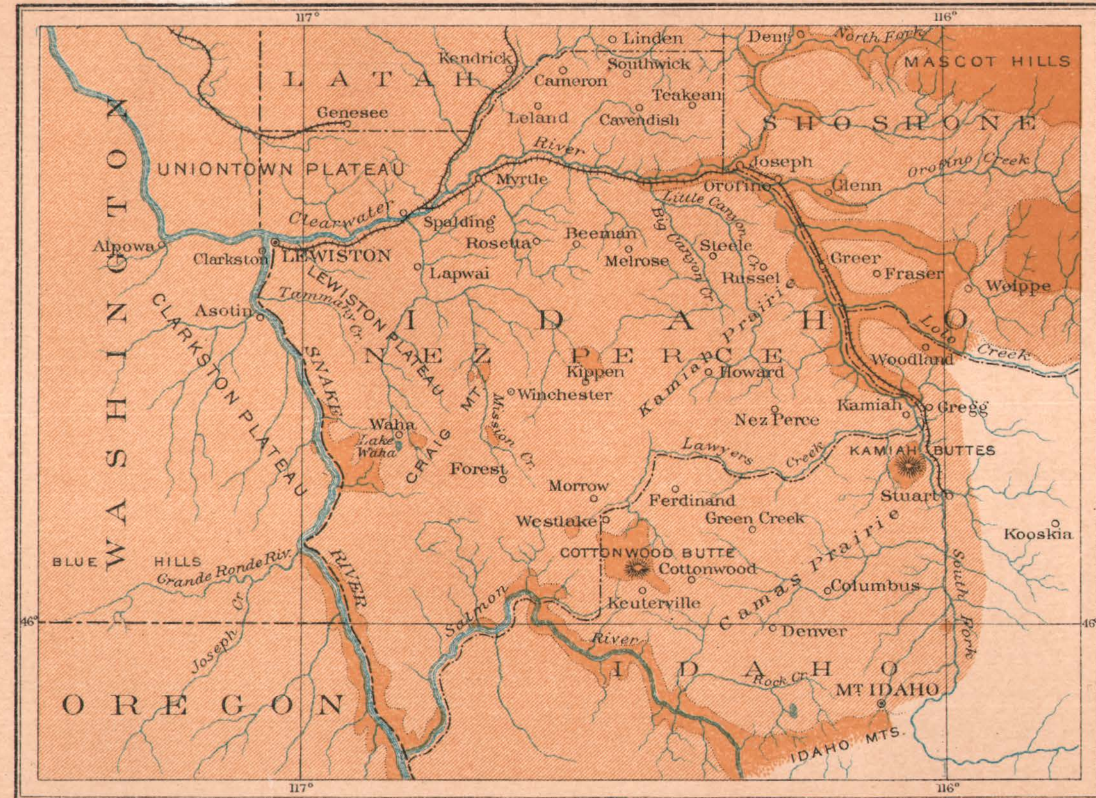
Rocks of older date than the Columbia River lava are now exposed at the surface. In some places these rocks were never covered by the lava, and in other places the lava beneath which they were formerly buried has been cut through or removed by stream erosion. The exposures of the former class, so far as the region shown in Pl. II is concerned, are in the foothills of the Bitterroot Mountains, and where Cottonwood Butte, Kamiah Buttes, and a few other island-like areas rise above the surface of the generally lava-covered country. The exposures of the older formations due to erosion occur where Snake, Salmon, and Clearwater rivers and some of their tributaries have cut through the lava and into the rocks beneath.

BITTERROOT MOUNTAINS.

Comparatively little information is available concerning the Bitterroot Mountains; but it is known that along their western border they are composed principally of gneiss and mica-schist, frequently rich in garnets, diorites, etc., with occasional porphyritic dikes and intrusions of rhyolite. The trend of the structural lines in the gneiss and schist and of the dikes is nearly north and south. About 20 miles east from the generalized western margin, as can be seen along the Lolo trail, a change occurs, and the great central portion of the mountains is seemingly composed throughout of a light-colored granite containing black mica and frequently large crystals of both white and pink feldspar. This granite is the country rock over a great area, extending far to the north of the Middle Fork of Clearwater River, and no doubt is a part of the extensive area of similar rock in the southern portion of the same mountains, mapped by W. Lindgren and shown by him to be intrusive and of post-Paleozoic age.[1] Lindgren makes the statement that this is the largest granite area in the United States, and gives a detailed description of the rock, accompanied by several chemical analyses.

A view of the Bitterroot Mountains from any commanding summit near their western border shows a multitude of peaks and sharp, serrate

[1] The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho, by Waldemar Lindgren: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 79-85.



GEOLOGICAL SKETCH MAP OF NEZ PERCE REGION, IDAHO.

Scale of miles

0 2 4 6 8 10 12 24 36

1901.

Columbia River lava (*Tertiary*)

Terranes older than the Columbia River lava.

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crests rising to a general elevation of about 6,500 feet above the sea. (See Pl. III, *A*.) Between the elevations are deep canyons and valleys with flaring sides. The topography is characteristic of an old land surface, deeply denuded and now drained by a mature and well-developed system of waterways. Every view of the mountains impresses one with the vast amount of erosion that has occurred in the process of shaping the present peaks and removing the solid rocks which once occupied the valleys, and although this herculean task taxes the imagination to picture and understand, it is evidently small in comparison with the total amount of denudation required to lay bare the granite, which at the time of its intrusion must have been covered to a depth of thousands of feet by rocks which were hardened by its heat.

To the south of the Middle Fork of Clearwater River and in the west-central part of the Bitterroot Forest Reserve, is a range of prominent peaks termed The Crags, which rise from 3,000 to 4,000 feet above the general level of the rugged land surrounding them, and have patches of snow in their sheltered recesses late in the summer. Judging from their topography as seen at a distance, the depressions among the prominent peaks appear to have formerly been occupied by alpine glaciers. At least one of the secondary peaks, Rocky Crest, situated about 15 miles west of Bald Mountain and crossed by the Lolo trail, also bears evidence of former glaciation. On its eastern and northeastern sides there are three well-defined amphitheaters in the walls and over the bottoms of which are smoothed rock surfaces such as glaciers leave. These amphitheaters, eroded in the summit of a bold mountain, are about 500 feet deep, and on their lower margins open out into impressive stream-cut valleys. The glaciers which occupied them were in each instance about a mile in length and were isolated from one another. None of the adjacent mountains retain evidences of glaciation, although about 20 miles to the northeast of Rocky Crest there are prominent peaks which are similar in form to that mountain and which very likely once gave origin to small ice streams. This is the only evidence observed of the former presence of glaciers in the region represented on the map forming Pl. II, or over a large area to the east and west of that region. Seven Devils and Powder River mountains, from 40 to 50 miles south of the southern boundary of Nez Perce County, were in plain view from several points visited during the reconnaissance, and, judging from the topography and the fact that late in summer they are whitened with lingering snowbanks, it is to be presumed that they were formerly occupied by glaciers. This meager evidence, taken in connection with observations made by Eldridge[1] and Lindgren[2] in south-central Idaho, shows that throughout central and southern Idaho

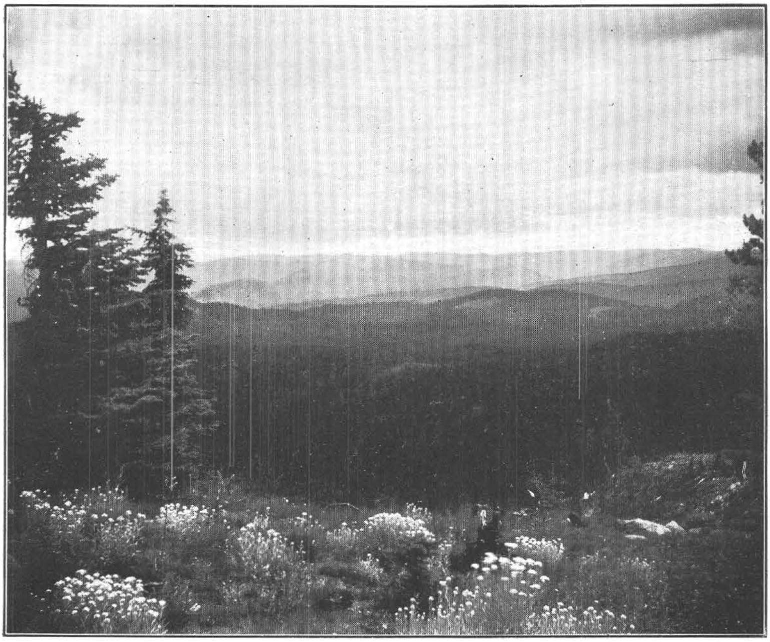
[1] A geological reconnaissance across Idaho, by Geo. H. Eldridge: Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 223-224.

[2] Twentieth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 100-101.

local glaciers only, of the alpine type, existed during the Glacial epoch, and that there was an absence of anything approaching a confluent ice sheet. The most instructive records made in this region during the time referred to are the stream-deposited gravels, some account of which will be given further on.

The Mascot Hills, indicated in part in the northeastern corner of the map forming Pl. II, are a typical portion of the foothills of the Bitterroot Mountains, adjacent to the eastern margin of the Columbia River lava, and may be taken as representative of the conditions that exist for a long distance to both the north and the south of them. These hills rise boldly to a height of about 1,100 feet above the lava plain skirting them on all sides except to the eastward, and form a prominent headland on the margin of the sea of molten rock which, as will be described further on, encroached on the western slope of the Bitterroot Mountains. The rocks forming the Mascot Hills consist, in large part at least, of gneiss and mica-schist traversed by quartz veins. As is an almost invariable rule along the western border of the Bitterroot Mountains, the trend of the rock structure is about north and south, and what appears to be the bedding of the gneiss and the lamination of the schist stands nearly vertical. A marked feature in the topography of the hills is their subdued and generally rounded profiles, indicative of long exposure to the atmosphere. Sustaining this conclusion is the fact that the rocks are deeply disintegrated and decomposed. At the extremity of a tunnel at the Mascot mine, 150 feet from its entrance and about 125 feet below the surface, the rock is so soft and so completely shattered that it can be removed with a pick, and even the quartz can be crumbled between the fingers. Although the rocks are evidently weathered to a great depth, nowhere about the hills is there evidence of the advanced degree of rock decay which gives origin to red soil. The characteristic topography and deep weathering referred to are among the numerous evidences that the older group of rocks under consideration has formed a land surface for a great length of time, and was deeply eroded before the coming to the surface of the younger group of rocks of the region, namely, the Columbia River lava.

From the summit of the Mascot Hills the relation of the Bitterroot Mountains to the vast lava plateau to the northward and westward is plainly revealed in the topography. To the north, and extending well to the northeast, there is a broad, level, densely forest-covered region across which the North Fork of Clearwater River has cut a steep-sided trench. Each branch of the river flows in a canyon, and what in distant views seems to be a level plateau is in reality deeply dissected. The summits of the canyon walls are formed of rim rocks of basalt, and the lower and usually bold slopes reveal the characteristic buttresses or terrace-like shoulders produced by the weathering of the more resistant rocks on which the basalt rests.



A. BITTERROOT MOUNTAINS, SHOWING MATURE TOPOGRAPHY.

B. CAMAS PRAIRIE; KAMIAH BUTTES IN THE DISTANCE.

The same plateau which has been deeply trenched by the North Fork and its numerous tributaries sweeps about the western base of the Mascot Hills and extends eastward up Orofino Creek nearly to Stuart. South of the canyon of Orofino Creek, with its precipitous walls of black basalt, the eye ranges over a long succession of rounded, forest-covered hills which project irregularly into a plateau to the westward, which is without forests and in summer is yellow, as far as the eye can reach, with grain fields. This vast cultivated tract, seemingly as level as a floor, is the Camas and Kamiah prairies. Although the plain is trenched by a number of narrow, steep-sided canyons, they are concealed from view, and the plateau appears as it did when the last of the lava sheets of which it is composed was poured out as molten rock. Rising from the sea-like expanse of the former grass-covered and flower-strewn prairie, and forming conspicuous objects in the far-reaching landscapes, are two elevations, known as Cottonwood Butte and Kamiah Buttes, which are easily recognized, even at a distance of many miles, as mountain peaks which stood as islands when the lava invasion occurred. A view from the summit of the Mascot Hills not only serves to reveal the general relation between the two groups of rocks of which the surrounding region is composed, but brings out the fact that although large portions of the plateau formed by the younger group still retain an essentially horizontal position, other portions have been tilted and otherwise deformed as well as trenched by stream channels. The evidence of extensive movements in the once horizontal lava sheets, however, will be discussed further on.

ISLAND-LIKE AREAS IN A SEA OF LAVA (STEPTOES).

The deep erosion of the pre-Tertiary land over which the Columbia River lava was poured out has already been referred to, but nowhere is it more clearly demonstrated than at Cottonwood Butte, which rises through the lava forming the Camas Prairie and in the adjacent portion of the canyon of Salmon River. This butte, which rises 1,100 or 1,200 feet above the generally level basaltic plateaus surrounding it, is composed of a variety of rocks belonging to the older group referred to. At its summit and on its western side the rocks are compact and massive, and consist largely of old lavas or intrusions which have been altered and somewhat metamorphosed. In its eastern portion reddish slate appears, the cleavage planes of which are nearly vertical, also ancient lavas and lapilli-like deposits that have been consolidated and greatly altered, probably by heated waters and pressure.[1]

[1] Rock samples collected on Cottonwood Butte have been examined by Waldemar Lindgren, who, from their macroscopic characteristics, made the following provisional determinations:

"A sample from west slope of the butte, metaandesite; from the top probably metabasalt or altered volcanic feldspar basalt; east slope, tuff or tuff-breccia, of old effusive rock, greenstone tuff, original character basaltic or andesitic; east end, clay slate (roofing slate), probably containing considerable admixed volcanic tuffaceous material."

These old rocks show that they were deeply eroded before the coming of the Columbia River lava, but were left, by the removal of the material which formerly surrounded them, as isolated mountain peaks. The time required for this topographic transformation was certainly long, although it can not be measured by years, but some idea concerning it may be had by comparing the tasks accomplished by erosion before and after the eruption of the Columbia River lava. The peak has stood fully exposed to storms and sunshine since the lava flowed about it, but evidently it has suffered only a moderate amount of denudation, although the neighboring canyon of Salmon River has been excavated in the lava and the underlying and more resistant rocks to a depth of fully 3,500 feet. The work of the river in shaping its magnificent canyon is small in comparison with the task which was accomplished previous to the coming of the lava in removing the material from about the hard rocks now forming the butte and leaving it a prominent mountain. The peak has suffered but little change during the time the adjacent canyon was being excavated, for the reason that it afforded but a small gathering ground for streams, and also because its slaty layers are on edge and permit the rain water falling on them to percolate through, thus robbing it of the power to corrade. The rocks of Cottonwood Butte are not only resistant to mechanical wear, changes of temperature, etc., but, equally important, they do not yield readily to chemical influences such as the solvent action of percolating water. Even at the surface they are hard, and show visible evidences of weathering to a depth of only a few feet, in some cases only a few inches. The soil on the butte is thin, and the rock exposures are abundant. The weathering which has produced the deep rich soil of the basaltic plateau has made but little progress on the more resistant rocks forming the much more ancient butte. Even when account is taken of the steep slopes of the butte and the fact that rock waste would be removed much more readily there than on the nearly flat prairie surface surrounding it, the evidence still favors the view that the butte has been changed but little in height or contour since the Columbia River lava was poured out. A view of the southern slope of the butte is shown in Pl. V, *A*. It is of interest to note also that the soil on the butte is different from that on the surrounding basaltic plateau, and was derived from the rocks on which it rests. Reference will be made further on to this and other kindred facts which show that the soil of the basaltic plateau was derived from the decay of the basalt itself, and was not brought from a distance through the agency of the wind.

As already stated, the slaty cleavage in the rocks forming Cottonwood Butte is nearly vertical. This has an important influence on the drainage, and accounts for the presence of the numerous springs of clear, cool water which occur there. One of these springs is in the depression between the two summit peaks, and is supplied by the rain falling at higher levels. The northern side of the butte is forest covered, but its southern slope is mostly free from trees, and is clothed with bunch grass down to an horizon about 800 feet below the summit, where a pine forest begins which extends southward over the basaltic plateau.

No more charming camping place and no more attractive location for a summer resort can be found in the Nez Perce region than is afforded by this isolated mountain peak, from the summit of which so much of the earth's history can be read as from a printed page. From the summit of the butte one has not only a magnificent but a most instructive panorama spread out before him. In summer the air is nearly always cool and invigorating, and so clear that the distant mountains as well as the depths of the neighboring canyons seem near at hand, instead of many miles away. The clouds, which frequently form in vast, brilliantly illuminated banks about the higher peaks of the Bitterroot Mountains and drift over the broad wheat fields of the once monotonous prairie, mottling them with slowly moving shadows, serve to enhance the glory of the scene, and perhaps bring refreshing showers; violent storms are unknown in this region. In winter the ancient mountain peak is white with snow, and the cold frequently is intense. Looking southward from the topmost crag of the prominent butte on which the reader is invited to stand, in fancy, one sees at his feet the forest-covered plateau of Columbia River lava. Near at hand, rising from amid the dark pines, is the shining spire of a village church. A few miles beyond the dark plateau breaks off, as if an earthquake had shattered it, and one looks down into the purple depths of the vast chasm which Salmon River has eroded in order to carry its burden of sand and gravel to Snake River and then onward to the sea. The canyon is not a narrow gash in the rocks, with vertical walls, as the term may perhaps be thought to signify, but is a great excavation from 4 or 5 to 10 or more miles wide, with many serrate ridges and buttresses diversifying its precipitous sides. The upper portions of the canyon walls, sculptured into many forms by rain and rills, are of horizontal masses of dark rock (the edges of nearly level lava sheets), below which are more massive slopes showing where the underlying and more resistant rocks have been exposed. The course of the canyon can be traced for 50 or more miles—from far away to the southeast to where it makes a sharp bend, seemingly at one's feet, and thence southwestward to its junction with the larger and still more magnificent excavation of a similar nature in the depths of which Snake River is hidden. To the south of the canyon of Salmon River is a broad forest-clothed remnant of the original plateau, formed of lava, which is bordered on its farther side by the canyon of Snake River, there fully 4,000 feet deep. The upper portion of the vast south wall of Snake River Canyon is in view from the butte, and when brilliantly illuminated by the sun, one can, at a distance of 25 miles, trace the outlines of the castle-like and cathedral-like forms which give diversity to its somber scenery. The brink of the distant canyon is marked by a dark line of pines and firs, and, like the layer of basalt beneath it, is the edge of a widely extended sheet—the great coniferous forest of eastern Oregon. Still farther away, but frequently sharply outlined against the southern sky, rise the angular peaks of the Seven Devils and Powder River mountains, their summits far above timber line and here and there flecked with snow which gleams like burnished silver in the intense light of the unclouded summer sun.

The view to the eastward embraces the broad undulating surface of the Camas and Kamiah prairies, which are checkered with rectangles of yellow grain fields and black fallow lands. The plain, several hundred square miles in area, is everywhere covered with a deep, rich soil, which has resulted from the decay of lava and is of wonderful fertility. Some suggestions are furnished of the deeply sunken stream channels which dissect this young land, but for the most part they are lost to view, and the great expanse, with its mild undulations, recalls the rolling prairie or the great plateaus to the east of the Rocky Mountains. The Camas and Kamiah prairies are bordered on the east by an irregular coast line of hills, beyond which rise the forest-covered peaks and ridges, with flowing outlines, which compose the nearer portion of the Bitterroot Mountains. The view to the westward is less extensive than in other directions, but it presents other instructive features. The generally level surfaces of the Camas and Kamiah prairies rise gently along their western margin and merge by insensible gradations into the long eastern slope of Craig Mountain. With increase in elevation there comes a change in the vegetation, and the open prairie country, with its grain fields, its scattered farmhouses, and its villages, gives place to a dark forest of pines and firs. The rocks which underlie the prairie have been bent upward and form a gently tilted plain, which breaks off abruptly on its farther (western) side, and there possesses some of the features of a mountain.

A few miles to the north and west of Cottonwood Butte there are low hills, composed of rocks which are older than the Columbia River lava, which, like the main butte, are islands in the lava plain. As sheet after sheet of molten rock was poured out and flowed over the land, it rose higher and higher on the sides of the once prominent mountains, but the inundation ceased before they were completely buried. Neighboring peaks of lesser height were no doubt covered, and ages hence will be revealed through the agency of erosion.

Another group of mountain summits left as islands in the lava sea occurs on the west side of the South Fork of Clearwater River, between the towns of Stuart and Kamiah, rising to elevations of 500 or 600 feet above the cooled and hardened surface. The Kamiah

Buttes, as they have been named, are between the canyon of the South Fork, which there is 1,800 feet deep, and the smaller but nearly as deeply cut canyon of Lawyers Creek. The nature of the rock forming the buttes is not definitely known, but what probably are portions of the same mass are exposed in the canyon of the South Fork; they are granite-like in character—more definitely, diorite. The buttes are without timber, and to some extent are now under cultivation. They consist of several rounded summits, and are to be classed with the foothills of the Bitterroot Mountains, now separated from them by about 6 miles of lava. A view of Camas Prairie, showing the Kamiah Buttes in the distance, is shown in Pl. III, *B*.

Another island-like area in the lava bed, of small size and rising only a few hundred feet above its surface, occurs 5 or 6 miles to the south of the Kamiah Buttes, on the brink of the canyon of the South Fork. Still another area, with a similar history, is situated farther north, on the west side of the same canyon, opposite Greer; from Kamiah Prairie it appears as a low hill with an undulating surface. Another and less conspicuous example occurs on the east brink of the canyon of Snake River, near Waha, but in this instance there is some question whether the elevation of old igneous rock now exposed was an island in the lava or was covered by it and has since been exposed by erosion.

Isolated mountain peaks rising through the Columbia River lava, of the general nature of those described, form conspicuous and instructive features in several portions of the vast region occupied by that formation, and are of such importance as to demand a family name by which to designate them. Steptoe Butte, near Garfield, Washington, which has been described in a previous paper,[1] is a typical example of these eminences, and its name may with propriety be adopted as a generic term by which to designate similar topographic forms. A steptoe, then, is an island-like area in a lava flow. Cottonwood Butte and the Kamiah Buttes are the largest steptoes in the Nez Perce region. These are far exceeded, however, by the Eagle Creek Range (known also as the Powder River Mountains) in Oregon, which, as stated by Lindgren,[2] consist of bare, rugged peaks that rise several thousand feet above the basaltic plateau surrounding them on all sides. This, the greatest steptoe known, has a diameter of 24 miles.

FORMATIONS BENEATH THE COLUMBIA RIVER LAVA.

As is indicated on the map forming Pl. II, the older group of rocks in the Nez Perce region is exposed in the deeper portions of several of the larger canyons that have been excavated in the Columbia River lava. The principal outcrops of this nature are along Clearwater

[1] A reconnoissance in southeastern Washington, by I. C. Russell: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4 (1897), pp. 38-40.

[2] Twentieth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 92.

River and several of its tributaries to the east of Peck; along Snake River above the mouth of Grande Ronde River; in the vicinity of Buffalo Rock; and on the sides of the canyon of Salmon River near its junction with Snake River and again at several localities from 20 to 30 miles above its mouth.

Near its mouth the North Fork of Clearwater River has cut through a thousand or more feet of basalt and deep into the underlying diorite and gneiss. The portion of the canyon sunk in these older rocks is steep-sided and all but impassable. Beginning about 6 miles above its mouth, however, the basalt comes down to the stream, and for 4 or 5 miles the canyon broadens so as to leave room for a few small farms on its western side, where it is about 2,000 feet deep. About a mile below the mouth of Elk Creek the older group of rocks appears again in the lower portion of the canyon wall and continues for at least 25 miles upstream, probably to the eastern edge of the basalt. Throughout this distance the rocks beneath the lava are mainly gneiss and mica-schist rich in garnets. In places the older terranes are traversed by light-colored porphyritic dikes, and in a few instances by dikes of dark rock apparently of the same nature as the lava which forms the upper portion of the walls of the canyon. One of the dikes is from 250 to 300 feet wide, nearly vertical, and trends N. 10° W. The structural lines in the gneiss and schist have nearly the same strike, and the apparent bedding and planes of schistosity dip eastward at an angle of from 70 to 80 degrees. At many localities along the river the lower portion of the canyon walls, up to a height of, in general, 800 to 1,200 feet, are composed of the older group of rocks and are bold and precipitous. At the summit of these steep lower slopes there is usually an irregular terrace, due to the more rapid recession of basalt which overlies the more ancient mica-bearing rocks, while the upper portion of the canyon walls, 500 to 1,000 feet in height, according to the irregularities of the subbasaltic floor, is diversified by alternate promontories and recessions. The summit of the canyon walls is frequently marked by a rim rock formed by the edge of the topmost layer of basalt which forms the surface of the bordering uplands. The great forest-covered plateau in which the North Fork has sunk its channel rises, with a gentle gradient, toward the east, and the basalt which underlies it grows gradually thinner when traced in that direction, although there are many important irregularities in thickness, and the influence of the underlying rocks on the topography of the canyon walls becomes more and more marked.

When the region traversed by the North Fork is studied in detail, it will probably be found that there is a progressive change in the rocks beneath the basalt, in reference to metamorphism, from west to east, until the granite, which begins near Rocky Crest and extends at least 20 miles eastward from that peak, is reached. This is seemingly in keeping with the conclusion reached by Lindgren, that the granite of the Bitterroot Mountains is intrusive and has altered the rocks along its contact; but the greater part of the metamorphism observed in the rocks along the North Fork is probably regional and of older date than the granite.

At Orofino, for several miles both up and down each side of Clearwater River, and also along Orofino Creek for a distance of 2 or 3 miles from its mouth, the mica-bearing rocks beneath the basalt are well exposed. In this region the sublava formations are mainly gneiss, mica-schist, crystalline limestone, and quartzite. This association is essentially the same as occurs in Snake River Canyon, where black slate also is found, and it is to be expected that slate is also present in the neighborhood of Orofino. The limestone is in well-defined beds, associated with mica-schist. The beds are nearly vertical and strike N. 15° to 20° W., which is also the general trend of all of the conspicuous division planes in the older group of rocks, and shows the influence of a force acting in an east-west direction. In common with all other portions of the canyon in the Nez Perce region in which the older group of rocks is exposed, the topography of the bluffs in the vicinity of Orofino reveals the junction of the overlying basalt with the rocks on which it rests; but, as is common in other instances also, the precise contact is almost always obscured by landslides and talus slopes.

The rocks exposed beneath the basalt near Orofino can be traced continuously along Clearwater River and its south fork to near Kamiah, and appear again in the west wall of the canyon about a mile above that town. The same group of rocks is also exposed along several of the streams which join Clearwater River from the east, as well as along the main stream above its junction with the South Fork. In the lower portions of the canyon walls in the vicinity of Greer, a light-colored diorite resembling granite is the most important member of the older terrane.

In the first 6 miles of its course below the great bend near Keuterville, Salmon River cuts at least three ridges of hard, resistant rocks belonging to the series which occurs beneath the lava. At each of these localities the stream is narrow, and rushes through the flume-like trenches with a swift, foaming current. The topography of the walls of the canyon permits one to trace in even distant views the outcrops of the rocks beneath the lava, and to distinguish their junction with the black, horizontally bedded basalt resting on them. In this canyon, as in many others in the Nez Perce region, the older rocks, consisting largely of light-colored, acid, igneous rock, are more resistant to atmospheric influences than is the basalt resting on them, and form conspicuous shoulders on the lower portions of the mountain-like spurs which extend into the canyon from either side. Where the basalt descends to the river the trail by which one can traverse the canyon from its mouth to near Keuterville descends also, and follows the bank of the river or runs near it; but where the rocks beneath the basalt are exposed the immediate banks of the river are precipitous, and the trail ascends and crosses the promontory at an elevation of, in general, about 1,000 feet above the bottom of the canyon. Below Deer Creek, which comes from the north and joins Salmon River about 15 miles from its mouth, the river flows over basalt and is bordered by magnificent mountain-like escarpments of the same rock, in which the bedding is essentially horizontal. The basalt continues along the margin of the river to within 4 or 5 miles of its mouth, where, as already stated, it enters a deep, narrow, impassable canyon in quartzite, diorite, and other exceedingly resistant terranes. Some of the finest canyon scenery in Idaho is along this portion of Salmon River and in the still greater excavation made by Snake River near its mouth.

Snake River Canyon between the mouths of Salmon and Grande Ronde rivers presents the most varied and instructive exposures of the sublava formations to be found in the Nez Perce region. Some account of the rocks there laid bare by the excavation of a mighty trench through the lava and deep into the formations on which it rests, as well as of other similar outcrops a few miles below the mouth of Grande Ronde River, in the vicinity of Buffalo Rock, has been given in a previous publication,[1] and although additional facts are here presented much more study must be given to this instructive area before its complete history and the economic importance of its building stone and ores can be presented.

Beginning at the first exposure of the sublava rocks, in ascending Snake River above Lewiston, we find, just west of Waha, on the right or eastern border of the canyon, a bold bluff of ancient porphyry which descends to the river. On the opposite bank there is a small outcrop of the same rock, showing that the river in deepening its canyon in the lava sheets was lowered onto a spur of a buried mountain and cut a channel across it. The precipitous, mountain-like bluff of igneous rock (diorite-porphyry) referred to rises 3,300 feet (aneroid measurement) above the river. From its rounded summit a most instructive view can be had of the deeply dissected lava plateaus about its base. This bluff is at the southwest end of Craig Mountain, and probably formed a small steptoe which rose above the level of the last sheet of Columbia River lava. The basement rocks forming the bluff have been laid bare by the erosion of Captain John and Buffalo Creek canyons, and are well exposed at Buffalo Rock. The walls of Snake River Canyon from above the outcrop of old igneous rocks just mentioned to about 1 mile above the mouth of Grande Ronde River are composed, from base to summit, of horizontally bedded lava,

[1] Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4 (1897), pp. 31–36.

showing that a deep valley in the old land surface was there filled by the lava flows. Upstream from the mouth of Grande Ronde River, as briefly described in the publication just cited, the horizontal lava sheets in the canyon wall abut against cliffs of schist which form the precipitous border of a buried mountain. The side of the old mountain slopes at an angle of about 45 degrees, and is free from débris. Its base is evidently far below the level of Snake River. Each successive layer of basalt extends farther and farther over the metamorphic rock, until, at a height of 2,500 feet, the summit of the old mountain is covered and the horizontal sheets of lava above it have an aggregate thickness of not less than 1,500 feet. The strata beneath the lava are generally inclined northward at an angle of 40 to 45 degrees, but in places are nearly vertical. The upper layer of thin-bedded limestone contains indefinite fossils. Beneath the limestone are schists, and farther upstream an immense mass of compact igneous rock of the nature of greenstone (diorite) is exposed in the cliffs which rise steeply from the river to a height of a thousand or more feet. The same rock may also be studied to advantage in the small tributary canyons which come down, with steep gradients, to the main stream from each side. Farther up Snake River there are associated with the greenstone extensive outcrops of fine, even-grained diorite (granite) suitable in every way for architectural uses. This "granite" has been opened by quarrying on each side of the river near where Corral Creek joins it, as well as at another locality a mile or two below.

The rocks beneath the basalt are exposed in the lower 2,000 feet of the canyon of Snake River all the way upstream from Corral Creek to above the mouth of Salmon River, but they were examined by the writer at only one locality, namely, where Cougar and Cottonwood creeks descend the eastern escarpment. The creeks referred to are small streams, fed principally by springs which come out at the base of the basalt, but they have cut deep canyons in sandstone, shale, limestone, and diabase-porphyry. The stratified rocks are much disturbed, but in general the beds strike about northeast and southwest, or directly across the course of Snake River. The dip of the beds shows great variation, indicating that the beds were disturbed, largely, perhaps, on account of the intrusion of porphyry beneath and among them, forming dikes. The sandstone is coarse, feldspathic, and hard, and contains well-rounded pebbles of dense igneous rock. Certain layers are exceedingly coarse, being in reality conglomerates, containing water-worn pebbles 6 or more inches in diameter. The shale is fine-grained, black, frequently has a glossy surface, and on weathering breaks into sliver-like fragments a few inches long and a fraction of an inch in diameter. Its thickness is evidently great, probably a thousand or more feet, but owing to the disturbances it has suffered it can not easily be measured. It is especially well exposed along Cougar Creek, where it immediately underlies the basalt. Limestone occurs on Cottonwood Creek, and forms well-defined layers which show a diversity of dips. At one locality these strata have a thickness of about 60 feet, but in most places they extend to much greater depths. The limestone is compact, bluish in color, and without recognizable fossils. The variety of rocks at the locality referred to and the abundance of good exposures make it a favorable place for a detailed study of the geology and topography of the old land over which the Columbia River lava was outpoured.

In Snake River Canyon, near the mouth of Salmon River, quartzite and diorite are exposed; and the trenches cut through the basalt and a thousand or more feet into the underlying terranes become narrow, with exceedingly rugged and precipitous walls, where the older rocks are exposed.

The geologic age of the sedimentary beds referred to as occurring in the canyon of Snake River is unknown, but, judging from the few obscure fossils obtained and from the result of Lindgren's studies in what is probably a southern extension of the same terranes in Seven Devils Mountains, they probably belong, in part at least, to the Carboniferous.

COLUMBIA RIVER LAVA.

HISTORY.

On the preceding pages many references have been made to the formation here specially considered, the reason being that it forms so important a feature in both the geology and geography of the Northwest that but little can be written about the natural conditions and economic development of that region without frequent reference to it. The rocks here termed the Columbia River lava[1] are exposed nearly everywhere in the canyon walls of the Nez Perce region to the west of the Bitterroot Mountains, and are familiar to all of its inhabitants. They were poured out in a molten condition, and hence come under the general meaning of the term lava, but more definitely, and from the point of view of the petrologist, they should be designated basalt. Either of these terms may be used in referring to them.

The lava in the region under review is a part of a terrane that is among the most widely distributed of the geologic formations of the continent. Its exact boundaries have not been traced, but enough is known concerning them to determine approximately the area it occupies. It lies almost entirely within the drainage area of Columbia River, for which it is named, forming the surface over nearly the

[1] In previous reports this formation has been termed *Columbia lava;* but to avoid confusion with the *Columbia formation* of the Atlantic States, it has been thought best to change the name to *Columbia River lava.*

whole of Washington and Oregon to the east of the crest of the Cascade Mountains, and extending into Idaho until it meets the older formations, principally mica-bearing metamorphic rocks and old eruptives which form the Cœur d'Alene and Bitterroot mountains. The same great series of lava sheets extends into southern Idaho, where they have been deeply trenched by Snake River. The area of the formation is estimated to be 200,000, possibly 250,000, square miles, and its greatest known thickness more than 4,000 feet.

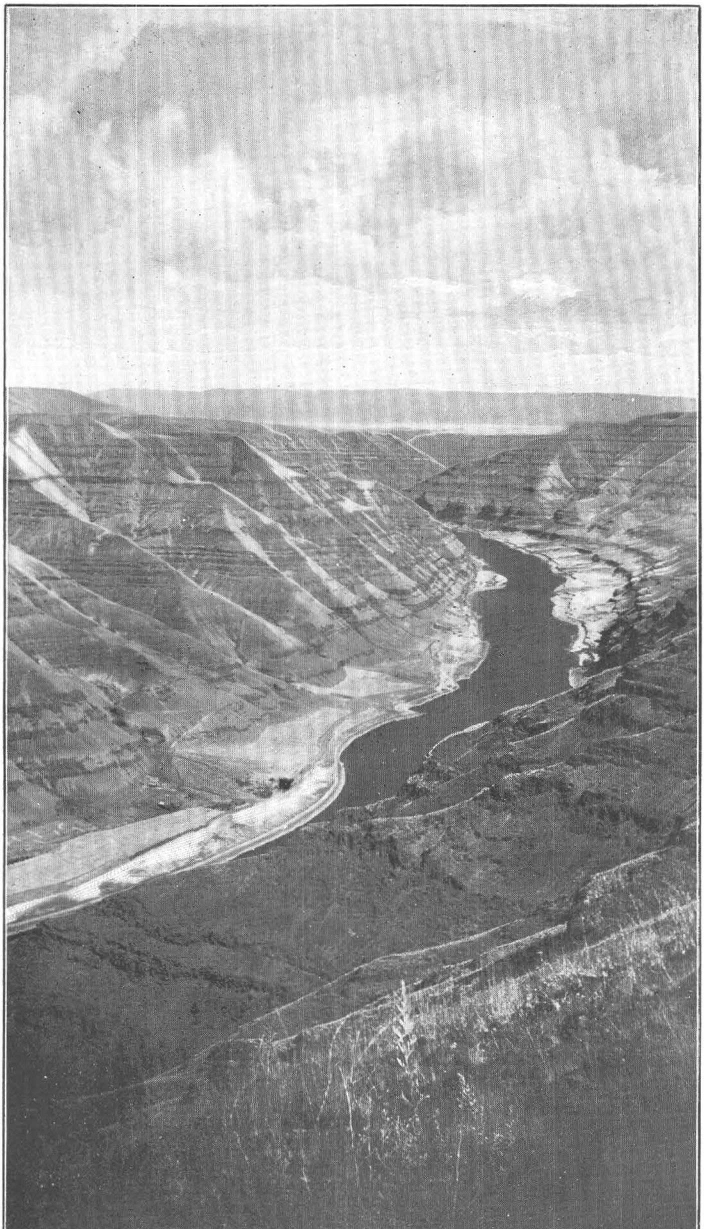
The lava was outpoured at successive intervals embracing a long period of time, as is shown by the occurrence, at several horizons, of layers of sedimentary material, principally clays and sand, between the lava sheets. In places, also, the lava sheets are separated by layers of volcanic dust containing the silicified trunks of trees which grew on a soil formed by the decay of the underlying layer, thus showing that the intervals between the flows were in some cases a century or more in duration. The lava came through fissures in the earth's crust—in what are known as fissure eruptions—and spread widely over the land, from which it is evident that each sheet was spread out horizontally. The movements that have occurred in the layers since they cooled and hardened, and which have caused them to be deformed from their original horizontal position, can be studied in the same way as the structure of sedimentary beds. Although the lava sheets are still essentially horizontal over broad areas, they frequently have gentle dips, and in certain regions are tilted and even sharply folded and faulted. On the eastern slope of the Cascade Mountains the lava sheets occur with a dip to the eastward, for long distances, of 3 or 4 degrees, showing that a large part of that range has been elevated to a height of at least 6,000 feet since the lava was poured out. Similar but less extensive deformations have also occurred on the eastern side of the lava-covered country, as will be described further on. Between these bordering areas is the region of the Great Plains of the Columbia, and southward from it, in Oregon, the lava sheets have, in general, been but little disturbed from their original horizontal position, although a subsidence of three or four thousand feet has probably taken place. Extensive movements in the earth's crust occurred also at certain periods during the time the lava sheets were being formed, as is shown near Clealum, Washington, on the eastern slope of the Cascades, where the upturned and eroded lower portion of the formation is overlain unconformably by later sheets. How widely extended this unconformity may be remains to be determined.

The fact that the Columbia River lava came to the surface through fissures, as molten rock, and that it spread widely over the land, is shown not only by the generally level condition of much of its surface as it exists to-day, and by the absence of volcanic mountains, cinder cones, etc., in connection with it, but is demonstrated in a most instructive manner where denudation has exposed the dikes formed by the cooling of the liquid magma in the fissures through which it was forced to the surface. Over an area of at least 400 square miles on the eastern slope of the Cascade Mountains in Washington, to the south of Mount Stuart, the lava has been eroded away so as to lay bare the rocks on which it formerly rested. In the surface there exposed many hundreds, probably thousands, of dikes are to be seen. These dikes, composed of dense basaltic rock, range in thickness from a few feet to 160 or more feet, but in general they are from 15 to 60 feet across. They stand nearly vertical, usually with a slight inclination to the westward, and in general trend about N. 15° E.[1]

The vast lava flows just considered spread over the land surface like an inundation, covering the broad plains and extending far into the valleys previously eroded in the slopes of the bordering mountains. Although the lava is of volcanic origin, its surface presents marked contrasts to the topographic changes produced by eruptions through definite and circumscribed vents. Volcanoes generally tend to roughen the surface where they occur, and to build up mountains, thus increasing the diversity of the relief. Fissure eruptions, on the other hand, owing to the vast volumes of liquid rock poured out, tend to spread out widely and to obliterate the inequalities of the land over which they flow, and produce horizontal surfaces. For this reason it is safe to assume that the entire region occupied by the Columbia River lava was a monotonous plain nearly as level as the ocean's surface at the time each successive sheet of molten rock was outpoured. The surface was no doubt rough and strewn with broken fragments of the first-formed crust, and, as cooling progressed, it was in places forced up into mounds and low ridges, which were probably cracked open at the top, as is the case to-day on the very fresh lava sheets forming the Snake River plains; but these small features would not detract from the general monotony. Again, some diversity of surface was no doubt produced owing to the unequal extent of the various lava flows. Although individual sheets are known to have a great area—their edges as exposed in canyon walls in many instances being traceable for a score or more of miles without noticeable variations in thickness and without any indications of approaching a limit—it is not to be supposed that each one had precisely the same extent as its predecessor, and differences in elevation from this cause are to be surmised.

Where a lava sheet was thickest a greater amount of vertical shrinkage on cooling would occur than where it was thin, and in such depressions shallow lakes would form. The greatest influence on the streams, however, occurred from the fact that the lava invaded the lowlands and entered the lower portions of the valleys in the mountains, thus

[1] A preliminary paper on the geology of the Cascade Mountains in northern Washington, by I. C. Russell: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 121-122.



CANYON OF SNAKE RIVER NEAR WAHA.

obstructing the drainage and furnishing conditions for the origin of extensive lakes. The truth of this deduction is verified by the presence of lacustral deposits, some of them of great thickness and wide extent, interbedded with the lava sheets.

The age of the lava, as determined principally from the fossil plants contained in the sedimentary layers and beds of volcanic dust interstratified with it, is Tertiary. It seems to have been outpoured mainly during the medial division of the Tertiary, or during the Miocene epoch.[1] The time when the eruptions ceased has not been determined, and if the lava forming the Snake River plains in southeastern Idaho is included in the same formation as that of the central portions of Oregon and Washington, it will probably be found to extend into late Tertiary, or possibly into the Pleistocene division of geologic time.

In the history of the Columbia River lava Nez Perce County and the country adjacent on the east occupy an important place, for there the lava met the mountains which form the eastern border of the region it inundated. Although the western shore of the sea of molten rock in the same latitude is not definitely known, it was to the west of the present crest line of the Cascade Mountains and at least 250 miles distant.

The lava is well exposed in the canyon walls throughout the region under consideration, all through the Palouse country and the Great Plains of the Columbia in Washington, and throughout central and eastern Oregon. In the central portions of each sheet the rock is usually compact and massive, nearly black in color, and is typical basalt. As determined by J. S. Diller,[2] it is composed of plagioclase, augite, olivine, and magnetite, with considerable globulitic base. An exception to the prevailing characteristics of the lava occurs in the rock on the eastern side of Snake River Canyon, at Corral Creek, and again near the junction of Snake and Salmon rivers. At each of these localities, at a depth of about 2,000 feet below the top of the formation, there are exposures of a sheet of black rock, from 90 to 100 feet thick, which contains crystals of labradorite an inch or more across. Below and above this sheet are layers of the normal and in places markedly characteristic Columbia River lava. In the central portions of thick sheets the rock is frequently columnar in structure, illustrated by a conspicuous example at what is known as the Candle Rocks, on the left bank of Snake River about 3 miles below Lewiston. While the central portions of the sheets are hard, compact, without steam holes, and frequently are conspicuously jointed, their upper and lower portions are irregularly and confusedly jointed, and usually are scoriaceous. The scoriaceous layers are likely to be of a reddish color; occasionally they are bright red,

[1] F. H. Knowlton, Bull. U. S. Geol. Survey No. 108, pp. 103–104.
[2] Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4, p. 43.

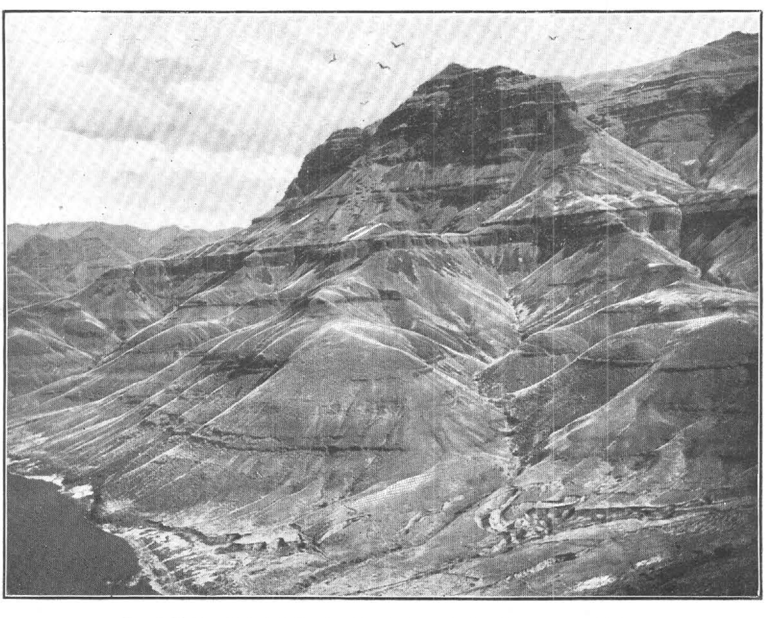
due to the oxidation of the iron which they contain. The number of separate sheets in an exposure, as in the wall of a canyon, for example, is usually difficult to determine, on account of the disintegration that has occurred and because of the prevalence of talus slopes and landslides, but an approximation to the actual number can be made by counting the layers where the rock is sufficiently massive to stand in vertical walls. On the sides of Snake River Canyon between Asotin and the mouth of Grande Ronde River, where the cliffs are about 2,000 feet high, from 12 to 15 sheets of lava are exposed. An estimate made in the same canyon, near Corral Creek, by counting the layers of scoriaceous rock, gave a still larger number. The thickness of the sheets is in general from 50 to 150 feet. The appearance of the edges of the lava sheets exposed in the walls of the numerous canyons excavated in it is well shown in Pls. IV and V, *B*, which also indicate the extent to which they are concealed beneath their own débris. On the surface of the plateaus between the canyons such deep decay has occurred that usually no hard rock is seen. In fact one might travel many miles through the cultivated fields above the lava without finding a fragment of rock of sufficient size to show its common features.

The feature of the lava which is of greatest interest in connection with the possibilities of obtaining artesian water is its texture. Is it sufficiently porous to permit water to percolate through it, or should it be classed as impervious? The compact portions of the rock should no doubt be considered impervious; but it is so generally broken into blocks or columns, by joints, that the ability of even thick sheets to retain water in a lower porous layer under pressure is doubted. The scoriaceous surfaces of the sheets where they come in contact are sufficiently open to permit the ready passage of water through them, and if interbedded with clay or some similar material they would furnish one of the requisite conditions for flowing wells. In this connection the sheets of volcanic dust and the beds of sedimentary material interstratified with the basalt demand careful study.

SHEETS OF VOLCANIC DUST.

Between the sheets of Columbia River lava there are, at several localities, beds of almost pure white, fine-grained volcanic dust, which was blown out of some distant volcano and widely spread over the land through the agency of the wind. Exposures of this material, known locally as magnesia, occur beneath the Candle Rocks, on the left bank of Snake River below Lewiston; near Swallow Rock, between Clarkston and Asotin; on Asotin Creek, about 10 miles from its mouth; on Captain John Creek; at several localities in the canyon of Grande Ronde River; and at a number of places on each side of Potlatch Canyon. The exposures referred to, which occur on the west side of

A. SOUTHERN SLOPE OF COTTONWOOD BUTTE.



B. COLUMBIA RIVER LAVA IN SALMON RIVER CANYON.

Snake River, probably belong to a single sheet, the position of which is about 200 feet below the surface of the topmost layer of lava as it exists to-day; but most of the exposures are in landslides, and the exact position where they occur in place has not been determined. The evidence seems to indicate that in the region under review there are several layers of volcanic dust, some of them mingled with sedimentary material. These deposits are of special interest in connection with the question of obtaining artesian water, as the coarser layers more particularly are sufficiently porous to permit water to percolate through them. This is shown not only by their texture but by the fact that in certain instances, where their edges are exposed, springs come to the surface, the water having a peculiar opalescent or slightly milky appearance, due to the exceedingly fine particles of dust held in suspension. These layers frequently contain fossil leaves, which afford excellent illustrations of the nature of the varied and luxuriant flora which clothed the lava plain at the time the dust showers occurred, and also serve to define the stratification of the lava sheets with which they are associated, and, further, they are of economic importance, as will be shown further on.

Near the heads of many of the small streams, particularly at the lower extremities of small gulches, down which there is only an occasional flow of water, there are, throughout a wide extent of territory in eastern Washington and adjacent portions of Idaho, small surface deposits of fine white material, usually designated by herdsmen and others as alkali. If examined under a microscope, however, this material will be found to be composed of small angular grains and shreds having a glass-like appearance; to be, in fact, volcanic dust, which chemical analyses prove it is. The deposits referred to are usually from a few inches to 6 or 10 feet, possibly more, in thickness. Characteristic examples occur on Cottonwood and Cougar creeks, which flow into Snake River; about the mouth of several of the small gulches opening into the canyon occupied by China Creek, and elsewhere, particularly in the southern portion of Nez Perce County. In all of these instances the dust has accumulated in alluvial cones or flood plains near the mouths of gulches which are usually dry, and has not been noted where the conditions favor rapid transportation. Evidently it was brought down by brooks and rills flowing through the small ravines and gulches at the mouths of which it is now found, and was deposited at a recent date. The probable explanation of these occurrences is that a light shower of volcanic dust occurred over the Northwestern States not many years ago, and that the material has been washed from the steeper slopes and in part accumulated in the flood plains and alluvial cones of small, particularly of intermittent, streams. The larger streams, which must also have received their share of the material, being able to carry it away, evidence of the shower is now to be found in only sheltered situations. That these accumulations of volcanic dust are not due to the washing out and redeposition of the similar material from between the sheets of the Columbia River lava is shown by the fact that characteristic examples of the deposits occur at the mouths of gulches which drain areas of the older group of rocks only, as, for example, on some of the tributaries of Cougar Creek, from which the lava has been removed by erosion and deep trenches excavated in the shale, limestone, etc., beneath.

An analysis of a characteristic sample of the dust from Cottonwood Creek, one of the small tributaries of Snake River, in the southern part of Nez Perce County, is given herewith, which shows that it is richer in silica, potash, and soda than the basalt which forms the Columbia River lava. Evidently the fissure eruptions which furnished the basalt can not be responsible for the dust, which must have come from some distant volcano in a state of explosive eruption and discharging acid lava. The fineness of the dust, which frequently equals that of ordinary wheat flour, also indicates that it was brought from a distance by the wind, all coarse particles being dropped on the way.

Analysis of volcanic dust from Cottonwood Canyon, Idaho.

[W. F. Hillebrand, analyst.]

Constituent.	Per cent.	Constituent.	Per cent.
Silica (SiO_2)	68.95	Titanium oxide (TiO_2)	0.42
Alumina (Al_2O_3)	14.33	Zirconium oxide (ZrO_2)	0.03
Ferric oxide (Fe_2O_3)	1.17	Phosphorus pentoxid (P_2O_5)	0.10
Ferrous oxide (FeO)	1.23	Chlorine (Cl)	(?)
Magnesium oxide (MgO)	0.47	Fluorine (F)	(?)
Calcium oxide (CaO)	2.13	Sulphur (S)	Trace.
Sodium oxide (Na_2O)	5.08	Manganous oxide (MnO)	Trace.
Potassium oxide (K_2O)	2.58	Barium oxide (BaO)	0.08
Water, hygroscopic (H_2O-)	0.28	Strontium oxide (SrO)	Trace.
Water, combined (H_2O+)	3.63	Lithium oxide (Li_2O)	Trace.
		Total	100.48

The dust referred to became mingled with the soil of the plateau and served to increase its percentage of, especially, silica, potash, and soda. While the dust of the particular shower of which evidence remains can not be considered as having made a notable increase in the richness of the soil in potash, it is possible that older showers, all direct evidence of which has been lost, may have assisted in the same direction, which would explain the greater percentage of potash in the soils of the lava-covered region than is contained in the rocks from which they originated, as will be explained further on.

DEPOSITS OF LAPILLI.

When a lava flow encounters a body of water steam is generated, or the water is, perhaps, decomposed and oxygen and hydrogen are evolved, which, if ignited, cause an explosion. In either case the hot rocks are likely to be blown into fragments, which are covered by the lava in case it continues to advance. The fragments produced in this manner are angular, frequently of the size of gravel, and on account of the rapidity with which the hot magma cools they usually have a glassy texture, or when broken resemble bits of overburned earthenware. Deposits of this material known as lapilli occur in the Columbia River lava at several horizons, but usually seem to be local in their distribution. A characteristic deposit, in which the angular, glassy grains are incrusted with a yellowish coating, probably of ferric chloride, is exposed near Swallow Rock, a few miles below Asotin, along the aqueduct which supplies Clarkston with water. Another deposit can be seen above the conspicuously columnar basalt forming a colonnade along Snake River between Clarkston and Alpowa; and others of a similar character but of smaller extent and thickness and usually associated with highly scoriaceous lava, are known at a few other localities in the Nez Perce region. The lapilli is seemingly too local in its distribution to have much significance in reference to the occurrence of artesian water, but as it is associated with the scoriaceous portions of lava flows and occurs between lava sheets, it would favor the passage of water through the rocks. Its principal geologic interest lies in the fact that it furnishes a part of the evidence by which separate lava sheets may be distinguished.

SEDIMENTARY BEDS.

During each interval between the inundation which spread out the sheets of Columbia River lava, the streams from the bordering uplands brought down débris and deposited it on the newly formed surface. When the intervals between the eruptions were long, the quantity of débris swept down from the uplands would increase, and it would be deposited as alluvial cones at the mouths of valleys, or perhaps be spread out in lakes on the lava plains and form deltas or possibly widely extended layers of lacustral sediment. It is therefore to be expected that both fluvial and lacustral deposits will be found at several horizons where a number of lava sheets occur one above another. This expectation has been realized in the Nez Perce region, by the discovery of several localities where beds of clay, sand, gravel, etc., occur between sheets of Columbia River lava. One of the most instructive of these is on the farm of Ira Small, about 6 miles east of Lewiston (sec. 1, T. 35, R. 5), where a well, drilled with the hope of obtaining artesian water, passed through the following strata:[1]

[1] In the first layer of basalt mentioned an inflow of water amounting to about 4 barrels an hour was obtained at a depth of 140 feet from the surface. This fact, taken in connection with observations made elsewhere, indicates that the basalt above the sedimentary beds reported in the section is in reality composed of two separate sheets—the upper one about 140 to 150 feet thick and the lower one from 90 to 100 feet thick. When the drilling had reached a depth of approximately 300 feet, and was at about the bottom of the sand, as stated by Mr. Small, "there was an escape of air which had sufficient force to blow off a 2-inch plank when laid over the top of the well." This so-called air was not inflammable, and may have been carbonic acid gas? At the base of the clay an inflow of water was obtained sufficient for the purpose of continuing the drilling in the underlying basalt, but no water under pressure was encountered. The well is 6 inches in diameter (tool 5⅝ inches), and is cased to within about 10 feet of the surface of the lower basalt.

Section about 6 miles east of Lewiston, Idaho.

	Feet.
Soil and subsoil (decomposed lava)	10
Basalt, hard, compact, black	210
Sand (about 60 feet) and clay (from 90 to 100 feet)	160
Basalt, hard, compact, black	75
Total	455

The locality where this boring was put down is near the northern border of the plateau termed in this report the Lewiston Plateau, which at that place slopes gently downward toward the south, in conformity with the dip of the strata beneath it. To the north of the site of the boring, and from a quarter to a half mile distant, is the brink of the south wall of the canyon of Clearwater River, in which are exposed the sedimentary beds penetrated in sinking the well. At this locality, and at the head of a small ravine opening northward into the canyon of Clearwater River, a copious spring outflows at the contact of the layer of sand with the clay beneath, which has been enlarged, by excavation, so as to supply a neighboring farm with water for household use and irrigation. This spring is typical of a large number of springs in the Nez Perce region, and it will be referred to again in connection with certain suggestions for increasing and utilizing the waters of some of the porous sedimentary layers which occur between the lava sheets by excavating "horizontal wells."

The sedimentary beds penetrated in drilling Small's well, and which are exposed in the neighboring gulch, can be traced over a large extent of country in the northern and western portions of Nez Perce County and adjacent portions of Washington and Oregon. They probably extend eastward to the foothills of the Bitterroot Mountains, but as there are other similar layers in that region they have not been identified east of Craig Mountain. All along the sides of the canyon of Snake River from near Lewiston-Clarkston to Buffalo Creek on the east and to the breaks of Grande Ronde Canyon on the west, as well as on the sides of the canyons of the various branches of Asotin Creek, and of Tammany, Sweetwater, and Lapwai creeks, the sedimentary beds referred to are plainly revealed in the topography of the canyon walls. The basalt above these beds has been eroded more rapidly than the layers below, leaving a terrace which, although usually heavily encumbered with talus and landslides, can readily be distinguished. The terrace extends into each side gulch which opens out into the main canyons, and near the heads of these gulches there frequently is a spring. The position of the terrace in reference to the surfaces of the adjacent plateaus between the drainage lines varies from 200 to 380 feet. This variation is due in part to inaccuracies in determining precisely where the base of the soft beds occurs, owing to the débris that is almost invariably present, and to the differences in weathering which the plateaus have experienced. By aneroid measurement the terrace on the east border of Snake River Canyon near Waha is 200 to 220 feet below the general level of the adjacent plateau; on the border of the canyon of Asotin Creek it is 370 feet below; and on the Clearwater escarpment, which forms the south border of the Uniontown Plateau, it is about 250 feet below. The identification of the sedimentary layer which determines the presence of the terrace referred to is in places rendered somewhat difficult, owing to the presence above it of another layer of similar material, which is separated from it by a sheet of basalt. The nature of these irregularities, which are to be expected in so large an area, is shown by the following section, obtained in the south wall of Asotin Canyon nearly opposite the mouth of George Creek:

Section in Asotin Canyon.

	Feet.
Soil on the slope descending from the plateau surface, with blocks of basalt, exposures poor	120
Basalt, forming a well-defined rim rock	35
Sedimentary beds containing a large variety of well-rounded pebbles, some of them 3 to 5 inches in diameter	110
Basalt, forming a bold escarpment, in places broken off and fallen in landslides	150
Sedimentary bed, soft, apparently clay	140
Basalt, scoriaceous at top and bottom; compact in central part, but showing 4 or 5 partings on weathered slopes	390
Total	955

The thicknesses given in the foregoing section are only approximately correct, as the contacts are seldom sharply defined. Judging by the plateau surfaces, the upper layer of basalt on Asotin Creek and at Small's farm are the same, but the sedimentary beds at the former locality are separated by a sheet of basalt about 150 feet thick, and their aggregate thickness is 100 feet more than at the second locality referred to. A tentative explanation of these differences is that a lava flow occurred in the Asotin region which did not reach as far to the northeast as the locality where the drill hole was put down at Small's farm, and that to the east of Lewiston this lava flow practically separates the upper or sandy member of the sedimentary beds from the lower or clayey member. The writer confesses, however, that the difference may be owing to errors of observation, as the natural exposures are obscure and are largely interpreted from topographic forms.

What is probably a part of the sedimentary beds just considered occurs on the south side of the Blue Hills, in the walls of the canyon of Grande Ronde River, but there it appears to be thicker than in the vicinity of Lewiston, and it carries one or more beds of lignite. Its presence in the locality referred to is shown not only by actual outcrops, usually, however, in landslides, but in a conspicuous manner by the topography. On the north side of the river, where the strata dip toward it at a low angle, there have been a great number of large landslides, but on the south side, where the strata dip away from the face of the precipices, the cut edges of the beds stand nearly vertical, and the presence of the soft layer near the summit is revealed by a well-defined terrace.

An important feature in reference to these sedimentary beds is that when two beds are present, as along Asotin Creek, the upper portion of the formation is composed of sand and gravel, and is so open that water could flow freely through it. In many instances, as on the escarpment forming the south border of the Uniontown Plateau, the gravel contains well-worn pebbles 5 to 6 inches in diameter. The lower portion of the formation, however, is clay-like and is practically impervious. Water descending into the sandy and gravelly portion of the formation is arrested by the basalt or the clay beneath it, and there flows laterally, thus accounting for the springs which appear where the beds are cut by canyons. These springs occur at only certain localities, especially near the heads of small gulches, as in most places the outcrops of soft beds are covered with loose material which has fallen from above. The large number of canyons, which have been cut to a greater depth than the base of the sedimentary beds, in most instances precludes the possibility of their receiving water from the mountains, and all of the water which issues as springs, or which may be obtained by excavating tunnels, must be supplied by the local rainfall. And, on account of the deep dissection of the plateaus, it is not to be expected that the water in the porous beds referred to could exist under sufficient pressure to supply artesian wells.

At Denver and Cottonwood, situated on the Camas Prairie within the region occupied by the Columbia River lava and at a distance of from 8 to 15 miles from its eastern border, borings (the detailed records of which will be presented further on) have been made, which show, in connection with natural exposures and the topography of the walls of neighboring canyons, that sedimentary beds of considerable thickness underlie the surface sheet of basalt. At Cottonwood the surface layer of basalt is from 60 to 70 feet thick, as shown by a boring, and rests on a sheet of gravel which has been penetrated to a depth of 56 feet without reaching its base. At Denver, where several borings have been made, the surface sheet of basalt appears to be broken and largely disintegrated, as the drill penetrated only loose material to a depth of about 200 feet. Terraces on the sides of canyons and occasional outcrops in their walls in the same region indicate that over a large portion, perhaps the whole, of the Camas Prairie, layers of open and porous sedimentary material are probably present beneath the surface sheet of basalt.

Along the canyon of the South Fork of Clearwater River, from Stuart to the vicinity of Peck, there are occasional outcrops of sandstone and allied rock, mostly, however, in landslides, which indicate the presence of a thick sheet of similar material, the surface of which is about 800 feet below the general level of the adjacent plateaus. The chief evidence of the presence of this important bed of soft material is furnished by the vast number of landslides that have occurred. Where the river has not cut below the level of the bed referred to its canyon widens, as at Kamiah, and its sides are formed by hundreds of displaced masses of basalt which have fallen from above. A view taken near Kamiah (Pl. IX, *A*) exhibits some of the topographic forms referred to.

Throughout the length of Orofino Creek, from its mouth to near Pierce City, there is an almost continuous series of heavy landslides on each side of the creek, which indicates the presence of incoherent beds at least 200 or 300 feet in thickness, beginning at a depth of about 750 feet below the surface. These strata are probably a continuation of those which have so greatly influenced the topography of the wall of Clearwater Canyon near Kamiah and elsewhere. Their character is shown by outcrops of sandstone and shale carrying lignite which are exposed in the bed of the creek at several localities.

Along Little Canyon Creek, which drains a portion of the broad plateau to the south of Orofino, coarse sandstone associated with carbonaceous shale occurs just at the base of the precipitous canyon walls and beneath 800 feet of horizontally bedded basalt. The thickness of this bed is not exposed, but it evidently is considerable, as the water percolating from it is sufficient to maintain Little Canyon Creek throughout the dry summer months.

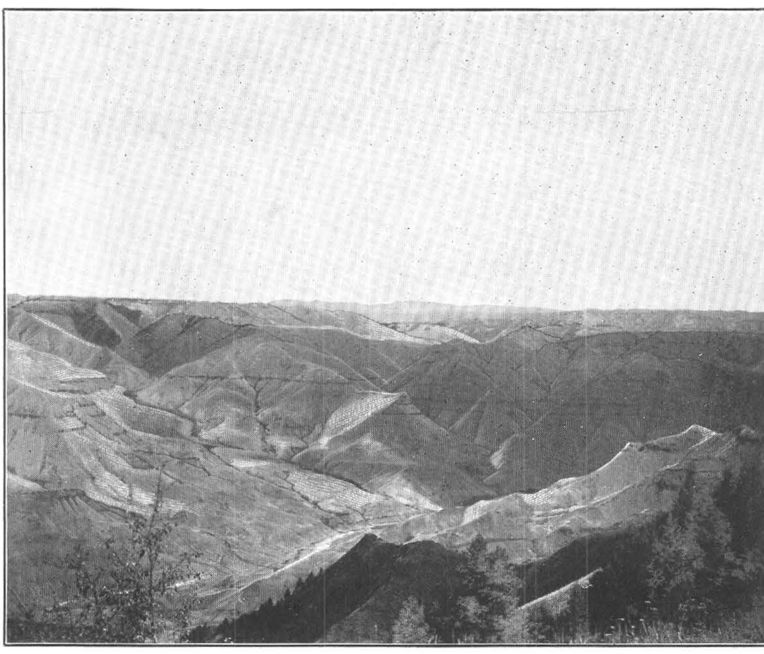
Again, in the canyon of Potlatch Creek, which joins Clearwater River from the north about 18 miles east of Lewiston, there are several outcrops of sedimentary beds interstratified with the Columbia River lava. In ascending the canyon the first of these exposures is on its western side, about 3 miles from its mouth, where some grading has been done for a wagon road. There is shown a thickness of about 25 feet of sedimentary material, consisting largely of volcanic dust, at a height of approximately 80 feet above the canyon's bottom. Neither the top nor the bottom of the deposit was seen, and it is probably a part of a large landslide. This layer is impervious, and a spring finds an outlet just above it. A half mile farther upstream, and about 250 feet above the canyon's bottom, there is a small exposure, 3 to 4 feet thick, of yellowish sandstone carrying pebbles. On the wagon-road grades which ascend the steep eastern side of the canyon near Juliaetta, there are at least three outcrops of sedimentary beds, one of which is evidently in place, or has moved but a short distance down the slope from its true position. It is 250 feet below the general level of the neighboring plateau, and consists of coarse granitic sand spangled with mica. A thickness of 8 feet is in sight. Resting on this is a layer of sandy, micaceous clay, a thickness of 2 feet of which is exposed. Two other outcrops of sedimentary material at lower levels consist mainly of volcanic dust, and are apparently portions of landslides. While owing to the prevalence of landslides and talus but little information was obtained concerning the true position of these beds, the differences between the limited outcrops observed show that at least two important sheets of sedimentary origin underlie the adjacent plateaus. One of these beds is of open texture, and permits the free percolation of water, the other, or lower, is clay-like and impervious. The direct connection of these beds with the sheets of similar material in the cliffs bordering Clearwater Canyon on the south, between Spalding and Lewiston, which are penetrated by the well at Small's ranch, has not been traced, but it is probable that they belong to the same layers. While the elevations of the outcrops at these two localities differ, owing to the movements that have occurred in the rocks, the depth of the sedimentary sheet below the surface of the broad plateaus should be in each instance approximately the same.

In the canyon of Salmon River near the mouths of Eagle and Deer creeks, for a distance of 3 or 4 miles along its western border, and extending a mile or more up the sides of each of the creeks, there are five exposures, from 20 to 55 or more feet in thickness, of coarse, yellowish sandstone containing well-rounded pebbles and fragments of silicified wood. This bed of sandstone is at a depth of approximately 3,500 feet in the Columbia River lava, and has beneath it a bed of lava with a rough scoriaceous surface. One of the outcrops referred to, on the west side of Salmon River just above the mouth of Eagle Creek, is interrupted by a promontory of crystalline rock which rises into the overlying lava sheets, having formed an island or cape in the waters in which the sandstone was deposited. Such an interruption in a porous water-bearing sheet illustrates one class of difficulties to be expected in attempting to obtain artesian water from the sedimentary beds interstratified with the Columbia River lava. That is, the old land surface over which the lava spread was irregular; the ancient peaks and ridges rise into the lava to varying heights, some of them, as already noted, remaining as steptoes when the last and highest lava sheet flowed about them, while others, and probably by far the larger number, were buried to greater or less depths and can only be discovered when denudation has unearthed them or the drill in its descent encounters them. As will be shown more fully further on, these buried peaks and ridges of impervious rock may cut off the supply of water from an otherwise favorably located porous layer.

SUMMARY.

In addition to the observations already noted, others might be cited to prove the presence of sedimentary beds between sheets of Columbia River lava, but they are of a qualitative nature and pertain princi-

A. SANDSPIT IN NORTH FORK OF CLEARWATER RIVER.



B. CANYON OF SNAKE RIVER FROM CRAIG MOUNTAIN.

pally to the presence of such material in landslides. What is desired are definite measurements of the thickness of the sedimentary deposits and their depth below the surface; but such quantitative observations are difficult to obtain, owing to the peculiar conditions which exist, especially with reference to the disintegration of the rocks in natural outcrops and the tendency of soft beds beneath lava sheets to give origin to landslides. The depth at which a widely extended layer of clay, sand, gravel, etc., occurs beneath the surface varies from place to place, owing principally to movements which have affected the rocks over broad areas and the amount of surface denudation. From such facts as are in hand it is evident that in the Nez Perce region, where extensive lava plateaus occur, the presence of porous water-bearing beds is to be expected at three principal horizons, namely, at 150 to 350 feet, at 750 to 1,000 feet, and at 3,500 to 3,600 feet. Although the beds at these approximate depths below the plateau surface in which the stratification is essentially horizontal, are widely extended, yet at certain localities where the lower beds especially might be expected to occur, they have not been found. In Snake River Canyon above Asotin, where the sedimentary beds would be expected to appear at the horizon 750 to 1,000 feet below the surface, no evidence of their presence has been obtained. A more careful search may reveal them, but it is evident that if there were present a stratum of sandstone of the thickness and character of the one near Orofino it would have a decided influence on the topography of the canyon walls, and such testimony is wanting. The conclusion to be drawn from this negative evidence seems to be that the beds under consideration did not reach the locality referred to, possibly on account of intervening ridges of the pre-lava formations which cut off the streams from the Bitterroot Mountains.

The general history to be read in these sedimentary beds is that the material of which they are composed was brought by streams from the mountains bordering the Columbia River lava on the east and spread out over the lava from time to time, during the intervals between the eruptions, as alluvial fans and as lacustral deposits. The material thus spread out should become finer and finer when traced away from the mountains that supplied it, and in the case of the beds of sand and gravel it should thin out in the same direction. Such beds should also be more numerous near the eastern border of the lava plateaus than farther west, for after each lava flow some material would be washed down upon it from the mountains, but during only the longer intervals would widely extended alluvial fans be formed. For this reason it may be concluded that the probabilities of obtaining artesian water should increase as the eastern margin of the last lava flow is approached.

While the beds of sand and gravel referred to should be considered mainly as stream deposits, they may be in part the shore foundations of lakes into which the streams flowed. There is no means of determining from occasional exposures under which of these two methods sand and gravel may have been laid down, and in fact the stream-laid beds and the layers of coarse material found in the shallow portions of lakes merge into the others by insensible gradations. The fine clays, however, such as those underlying the region about Lewiston at a depth of 280 to 300 feet below the surface of the level plateaus, were evidently deposited in lakes, and may be widely extended without exhibiting marked variations in thickness. During the intervals between many of the eruptions lakes probably existed on the surface of the lava, and they would lay down sheets of clay-like material of variable thickness, dependent largely on the length of time they existed; but the positions of the lakes can not be predicted. It is expected, however, that lacustral deposits will be found widely distributed throughout the Columbia River lava, and as they are in general composed of impervious beds, one of the conditions requisite for the storage of water under pressure—artesian—may be present in even the central portion of the lava-covered country. This statement in reference to the probable wide extent of lacustral deposits interbedded with the lava is not based entirely on general principles, as thick and widely extended foundations of the nature referred to are known to exist in west-central Washington. On the whole, what is known of the sedimentary beds, whether fluviatile or lacustral, interbedded with the Columbia River lava is favorable to obtaining artesian water over a widely extended region embracing portions of Washington, Oregon, and Idaho.

SOILS.

As is well known, the material forming soils is composed chiefly of disintegrated and more or less thoroughly decomposed rock débris. This débris either remains in essentially the position where it originated or is removed from that position and redeposited elsewhere. Two leading classes of superficial accumulations are thus produced, termed sedentary deposits and transported deposits, in each of which important subdivisions have been recognized. So far as the Nez Perce region is concerned, the representatives of the sedentary deposits are such as have originated from the disintegration and decay of rocks in place, and they may be termed residual soils; while the superficial material which has been brought from a distance and redeposited, found principally along the margins of the rivers, forms alluvial soils.

RESIDUAL SOILS.

The character and mode of origin of the soil in a typical portion of the great region occupied by the Columbia River lava has been discussed in a previous report,[1] and but little information in addition to

[1] A reconnoissance in southeastern Washington, by I. C. Russell: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4 (1897), pp. 57-64.

what was then presented can be given at this time. The soils covering the broad plateau surfaces in the Nez Perce region and streaming down their steep bordering escarpments are similar to, in fact practically identical with, the soils about Pullman, Washington, described in the report just referred to. Throughout the lava-covered portions of Oregon, Washington, and Idaho and the bordering uplands, composed of older terranes, the soils have resulted from the disintegration and decay of the underlying rocks, and in genenal have been removed but short distances, if at all, from their original positions. This conclusion is sustained by the fact that when the surface material is traced downward it is found to change, frequently by insensible gradations, into the underlying and still solid rock; also by comparing the chemical composition of the soil and subsoil with that of the unaltered rocks beneath, and by noting the surface changes in passing from one geologic formation to another. In traveling from the lava plateaus to the adjacent uplands of older rocks, such as limestone, granite, diorite, schist, etc., in the foothills of the Bitterroot Mountains, an immediate change in the character of the soil forces itself on one's attention. Above the lava the soil is fine and of a dark color, owing, principally, to the presence of organic matter, while the subsoil, equally fine in texture, is always of a dull yellow or a brownish yellow color, and is characteristically without pebbles or sand grains visible to the unaided eye, while the soils on the older rocks are usually light colored and contain sand, angular fragments of rocks, and minerals the nature of which can readily be determined and which corresponds with that of the underlying rocks. The chemical composition of these two divisions of residual soils shows marked differences, in harmony with the obvious fact that the soils of the lava plateaus are more productive than those of the older formations.

Compared with the older rocks adjacent to it, the greater rapidity with which the Columbia River lava breaks down and changes its physical characteristics is shown by the increased fineness and far more complete decay of the residual material produced. This is the more striking when it is remembered that the region composed of the older terranes above the level of the last sheet of lava has been much longer exposed to the influences which produce weathering than the more thoroughly decayed surface of the lava. That this difference is not due to differences of slope or of exposure—the surface of the lava being frequently nearly flat, while the surface slopes of the older terranes are more generally inclined, thus favoring the removal of small particles and resulting in a concentration of the larger fragments—is evident from the fact that the older land has a great variety of surface slopes and that on all of them the débris is much less thoroughly decomposed than on the lava plateaus or even on the steep escarpments forming the walls of the canyons excavated in the lava.

The fact that the soil on the lava plateaus is not mainly a dust deposit brought from a distance by the wind, as its fineness might indicate and as has been suggested by certain careful observers, is clearly shown by the abrupt change, just referred to, observable in the surface material on passing from the lava to the bordering upland and particularly on visiting the steptoes which rise in isolated positions through the lava. On Steptoe and Kamiah buttes in Washington, on Cottonwood Butte in Idaho, and on other similar island-like areas, or steptoes, of pre-Tertiary terranes rising through the Columbia River lava there is an abrupt and frequently conspicuous change between the soil of the buttes and that of the surrounding plateau. The soils on the various steptoes also differ from one another, but all contain fragments of the underlying rocks. These observations are evidently not in harmony with the suggestion that the soil of the wheat lands has been brought from a distance by the wind.

The great importance of the wonderfully rich soil on what may be termed the wheat lands of the region under consideration is sufficient excuse for repeating certain observations concerning it, which were published in the report already cited. In the following table there is given the results of analyses of a sample of basalt, a representative of the Columbia River lava, collected at Wallawalla, Washington, and of the subsoil and soil resting on the same formation at Dayton, Washington. The subsoil is from a depth of 30 feet, and the soil was collected in a wheat field at a depth of 2 feet below the surface. Each of these samples is characteristic of the material from which it was taken over a wide extent of country.

Analyses of basalt, subsoil, and soil from Wallawalla and Dayton, Washington

[George P. Merrill, analyst.]

Constituent.	Basalt.	Subsoil.	Soil.
	Per cent.	*Per cent.*	*Per cent.*
Silica (SiO_2)	47.35	65.89	63.58
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	34.38	22.19	22.36
Magnesia (MgO)	4.43	1.85	1.82
Lime (CaO)	8.27	2.36	2.76
Soda (Na_2O)	2.55	2.08	2.02
Potash (K_2O)	1.33	2.36	2.27
Loss on ignition (principally organic matter)	.95	2.60	4.37
Total	99.26	99.33	99.18

In reference to these analyses, Merrill says:

All of the material analyzed was first dried at 100° C. The analyses are not as detailed as I would like to make, but are all that the limited time permits. Perhaps the most striking fact in the analyses is the similarity in composition between the surface soil and that from a depth of 30 feet; almost the only essential difference being, apparently, the larger percentage of volatile matter of the surface soil. Not having as yet separated the iron and alumina, I am unable to account for the apparent loss of these constituents shown. From previous analyses I am led to suspect that the iron oxides have been very largely removed. I am unable as yet to account for the apparent increase in potash in the decomposed material. It is possible, though hardly probable, that this is due to errors in analysis.

The close similarity between the composition of the soil and subsoil and of the rock which occurs beneath them is instructive and sustains the conclusion that the surface material has resulted from the breaking down of basalt. In the formation of residual soils the more soluble constituents are removed in solution by percolating water, and the less soluble substances are left as a residuum. The soil and subsoil should therefore contain an increased percentage of the less soluble substances in the original rock, such as silica and alumina, and a smaller percentage of the more readily soluble substances, such as soda, potash, lime, etc. The foregoing analyses are essentially in harmony with this general principle, with the exception of the potash and soda. In the case of the potash there is an increase in the decomposed material above the amount present in the parent rock, while the percentage of soda is nearly the same. This result is so surprising that I fear more analyses should be made before accepting it as final,[1] but it is perhaps not out of place to suggest a way in which potash and soda may have been added to the soil.

Over a large portion of the United States to the west of the Mississippi there have been showers of volcanic dust in recent times. An analysis of some of this material which fell in Nez Perce County has already been given (p. 34), which shows that it carries 2.58 per cent of potash (K_2O) and 5.08 per cent of soda (Na_2O). This material falling on the surface of the plateaus would in most situations not be washed away, but would form an addition to the soil. How many showers of volcanic dust have occurred since the last sheet of Columbia River lava was poured out is unknown; but as such showers occurred during the eruption of the lava, and also at a recent period, it is reasonable to suppose that they took place in the interval referred to. The material thus added to the residual soils would be on its upper surface, although, judging by present conditions, when in general the plateaus are without surface drainage, there would be a transfer of soluble material by percolation from the surface downward. If there has been a notable

[1] In Bulletin No. 9 of the agricultural experiment station at Moscow, Idaho, by Prof. Charles W. McCurdy, and in Bulletin No. 13 of the agricultural experiment station at Pullman, Washington, by Prof. Elton Fulmer and Prof. C. C. Fletcher, a large number of soil analyses are given, and of those the samples for which came from the region occupied by the Columbia River lava, only one contains potash in excess of 1 per cent, while the average is about one-half of 1 per cent. The exception referred to is in the case of the subsoil from near the experiment station at Moscow, analyzed by McCurdy, which is reported to contain 1.83 per cent of potash. The soil at the same locality contained but 0.59 per cent of potash. This analysis is vitiated, however, for our present purpose, as "sand and silicates" are reported present to the extent of 73.77 per cent; what is included under the term silicates is questionable. In a large number of analyses of the soils of Washington by Fulmer and Fletcher, in which there seems to be no ambiguity of the nature just referred to, the potash reported is always considerably less than 1 per cent. The geologic relations of the soils analyzed is not always stated, but a number of these are certainly from localities which are underlain by the Columbia River lava. In a summary, in reference to the presence of lime, phosphoric acid, and potash in the soils of Washington, embracing the results of 45 analyses, the maximum, minimum, and mean percentage for potash are 0.6428, 0.0354, and 0.3049, respectively. There is thus a serious discrepancy between the analyses just cited and those by Merrill given on page 44, in reference to the percentage of potash in the soils of the Columbia River lava region, which will have to be diminished before the discussion of the origin of the soils from a chemical standpoint can satisfactorily be continued.

addition of volcanic dust to the surface of the residual soils on the lava, analysis may reasonably be expected to show a greater percentage of potash in the soil than in the subsoil, but this supposition is not sustained by the chemical evidence available. Again, the beds of volcanic dust interstratified with the Columbia River lava may have contributed material to the soils formed by their decay and enriched in potash. The volcanic dust referred to is of the same physical character as that of which an analysis has been given, and with little doubt is of about the same chemical composition.

A typical illustration of the nature of the soil and subsoil produced by the disintegration and decay of basalt is afforded at an excavation made for clay at a brickyard in Uniontown. The material there used for brick making is the normal subsoil of the wheat lands. It is about 35 feet thick, but the passage to the solid rock beneath was not exposed at the time it was visited. The material is fine in texture, in fact is almost without appreciable grains, and is of a uniform brownish yellow color, except that the upper 4 or 5 feet, as seen in vertical walls, is darkened by organic matter. There not only is no evidence of stratification, but the material is uniform in color, texture, etc., from the base of the discolored upper portion to the bottom of the exposure, a depth of about 25 feet. The most interesting feature is the presence of nearly vertical but somewhat tortuous tubes, having an approximately uniform diameter of one-fourth inch, which occur at intervals of, in general, from 4 to 6 inches. These tubes can easily be traced in the walls of the excavation for distances of 5 or 6 feet, and seem to be continuous from the base of the layer of soil to the bottom of the exposure. They are so nearly vertical that the gentle bends or irregularities in direction seldom cause them to depart more than 4 or 5 inches from a mean position. They do not bifurcate or send off branches, and have no definite walls. They are simply holes in the soft, clay-like material traversed by them. On their interiors there are slight irregularities, such as might be produced by the downward flow of drops or small clots of the material which they traverse, which have hardened so as to form slight elevations with well-defined and rounded lower margins.

A tubular structure like that just described is somewhat exceptional in the residual soils on the Columbia River lava, but it has been observed in a few other instances. More commonly much smaller tubes are present, similar in every way, except, perhaps, in the character of their bounding surfaces, with diameters rather uniformly about one-tenth of an inch. These small tubes were not observed in the subsoil at Uniontown, but in many other instances, in material of the same character, they were so numerous that a cubic inch of the subsoil could not be examined without finding several of them.

The origin of either class of these tubes is unknown, but it is obvious that they serve an important function in permitting the ready absorption of rain water falling on the wheat lands, and show, in fact, why there seldom is any evidence of surface rills. Slopes of fully 25 to 30 degrees, composed of soft soil in either its natural condition or plowed, harrowed, and left unsown for a year, a common custom, show no rill marks such as are usual in many regions, especially where the soil is an impervious clay. The open tubes in the subsoil insure a prompt and most effective underdrainage and aeration, and the soil in which it is presumed the tubes have been obliterated, through movements in the material, due to the beating of rain, the growth of plants, frost, etc., is so exceedingly fine—less than 2 per cent of the grains exceeding one-tenth of a millimeter in diameter[1]—that all of the water falling on it is at once absorbed. While the rate of evaporation is high, the soil does not become charged with alkaline salts, as is so commonly the case in regions of small rainfall—the water from below being raised to the surface by capillary attraction, and the salts it contains being precipitated as evaporation progresses—but on account of the prompt subdrainage by percolation, where rain occurs, the material brought to the surface during dry seasons is redistributed. The only localities on the plateaus underlain by Columbia River lava where alkaline salts are concentrated at the surface are in low basins where an excess of organic matter has rendered the soil impervious; but these places are of rare occurrence and of small area.

On the precipitous walls of the numerous canyons cut into the Columbia River lava and the older formation beneath, there is usually a mantle of soil not only on the ledges and terraces but on the steep talus slopes and irregular surfaces of landslides. These soils, although usually composed largely of disintegrated and decayed basalt, have in many instances received important additions of material derived from the layers of volcanic dust, sand, gravel, etc., interbedded with the lava, and at horizons below the base of the lava sheets they contain also the débris of the pre-Tertiary terranes. The sides of the canyons are nearly everywhere clothed with bunch grass, and in spite of their steepness they afford excellent pasturage. The commingling of débris on the steep plateau margins has led to the making of a soil which in some instances seems to be even better adapted to agriculture and horticulture than the more uniform soils of the plateau surfaces. This may be due in part, however, to more favorable exposure to the sun, but it certainly is influenced by the escape of water from the cut edges of porous layers in the lava formation.

In the case of the terranes of older date than the Columbia River lava, surface disintegration seems to be in excess of rock decay, as the soils are usually charged with rock fragments, while on the lava plateaus the reverse is true, and fragments of rock large enough

[1] See mechanical analysis of a sample of wheat-land soil from Pullman, Washington, by Milton Whitney: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4 (1897), p. 59.

to be distinguished by the unaided eye are of rare occurrence, even at depths of from 20 to perhaps 75 or more feet below the surface. The lava is plainly more prone to decay and to crumble under the influence of percolating water than is the granite, diorite, gneiss, schist, limestones, etc., of the older formations. The marked tendency of the lava to decompose in this manner and to yield a rich soil of such a physical character that it absorbs and retains all of the rain which falls on it and is easily plowed, insures a long period of prosperity for this "Inland Empire," as the grain-growing region of eastern Oregon and Washington and neighboring portions of Idaho is sometimes termed.

The peculiar and interesting surface relief of the lava plateaus will be discussed further on, in connection with other features of the physiography of the region under consideration.

TRANSPORTED SOILS.

In addition to the residual soils in the Nez Perce region, which occupy probably ninety-nine one-hundredths of the surface, there are small detached areas, principally along the margins of the larger streams, where the soil is composed of silt, sand, and gravel deposited by the streams during high-water stages. These transported soils, in which the débris from an extensive series of cliffs is commingled, contain a great variety of rock fragments, usually well rounded and assorted and deposited in an orderly sequence with reference to size and specific gravity. At present this material forms flood plains which are inundated during high-water stages, or represents ancient flood plains which have been abandoned owing to the deepening of stream channels. In excavations in these deposits the changes to be observed as the depth below the surface increases, are such as are normal to similar accumulations the world over, and result from the manner in which the material was laid down. As a rule, the surface of a flood plain is composed of fine silt or fine sand; beneath this, at a depth usually varying from 3 to 4 feet, there is a change to gravel, and at lower levels pebbles, and even cobblestones and rounded water-worn bowlders, may be found. The reason for this arrangement is that the material in the flood plains of streams is continually being worked over by the streams themselves and becomes assorted. Where streams are depositing their loads they flow in curves, cut away their banks on the outer side, and make deposits on the inner side of each bend. The material cut away at one curve is carried downstream and much of it is redeposited on the inner side of the next curve below. This process is clearly illustrated along the lower course of Clearwater River, and can be observed in almost any brook or rill. The succession of finer and finer material from the bottom of a flood-plain deposit to the surface is due to the fact that the lower portion is laid down in the central part of a stream, where the current is swift, and as the stream migrates finer and finer material is deposited upon it. The last layer is spread out during inundation. It also receives dust deposited from the air, is usually of fine quality, and forms a remarkably rich soil.[1]

Flood plains of the nature of those just described occur along Clearwater River, and are also well illustrated near Kamiah, Lewiston, Spalding, and Lapwai. They are built on deposits of the same nature, and in a few other instances, along the larger streams, there are small, nearly flat areas of a similar character; but in general the canyons are too narrow to permit the deposition of much of the material that is being transported through them. The streams in general are engaged in deepening their channels; they have not reached the stage of broadening their valleys and spreading out extensive flood plains. It is only where special conditions exist—for instance, the presence of soft beds at the level of the streams, as at Kamiah, or where a depression of the rocks has caused a widening of the valleys, as along Clearwater River near Lewiston—that flood plains of sufficient width to be of economic importance are to be found. The fact that the flat lands referred to are due to stream deposition is clearly shown in numerous instances by the presence of abandoned stream channels, some of which are in the condition of lakelets or sloughs.

Flood-plain deposits form the lands now under cultivation in Asotin Canyon, and there, as elsewhere, they are in danger of being removed by the same agency that built them. This obvious truth should be borne in mind by all who seek to cultivate the narrow flood plain in that canyon, particularly where the small, flat areas of rich land favorably situated for irrigation have tempted people to build their homes within reach of the creek when swollen by heavy rains. The canyon bears evidence of having recently been swept by floods caused by torrential rains, commonly termed cloudbursts. Similar high-water stages are sure to recur, and proper precautions should be taken to insure the safety of life, even if the risks to grain fields and orchards are accepted.

As will be shown further on, the rivers of the Nez Perce region first cut their canyons to about their present depths, then filled them with gravel to a depth of 350 feet, and have since removed the greater part of the material formerly deposited. In this process of reexcavation, in a few instances portions of old flood plains have been left, and they furnish examples of transported soils at a considerable elevation above the present streams. Clarkston is built on an alluvial deposit of this nature which has a sloping surface, owing to the fact that it is on the

[1] This and other important changes now being made by streams in the surface features of the earth are discussed somewhat fully in Rivers of North America, by Israel C. Russell, published by Putnam's Sons, New York, 1898.

concave side of a curve in Snake River, and the stream, in deepening its channel, migrated slowly eastward. In this instance there is a surface layer of fine silt-like material, about 5 or 6 feet thick, resting on coarse gravel and cobblestones. The surface layer furnishes a rich soil, and the open texture of the gravel beneath insures underdrainage, which prevents the concentration of alkali at the surface. This fortunate arrangement is favorable to the sanitary conditions, particularly as the water supply is brought from a distance.

Other areas of transported soil similar to that at Clarkston occur on the opposite side of Snake River and form the surface of the plateau on which the newer or upper portion of Lewiston is situated. Fine sections of flood-plain deposits are exposed in the margins of this plateau, especially where grades have been made along the streets connecting the upper with the lower portions of the city. Similar deposits occur near Alpowa, also in the canyon of Salmon River, near its mouth, and, of limited extent, along the borders of many small streams or where such streams enter the large canyons.

In connection with the examples of soils just cited, in which material has been brought from a distance, reference will be made to at least one somewhat conspicuous instance of wind transportation. Snake River just above Lewiston deposits on its right bank a considerable quantity of fine, white, micaceous sand or silt.[1] During low-water stages this material is exposed to the air, becomes dry, and is blown eastward by the prevailing winds. It is carried up the canyon wall, which there is low, over the sloping margin of the Lewiston Plateau for a distance of 2 or 3 miles, and is deposited largely in dunes, although much of it is widely distributed.

Some movement of the surface of the soil on even the generally level plateaus must result from the action of the wind, but in a state of nature, when the present extensive grain fields were prairies, the soil was held by plant roots and was sheltered by the vegetation growing

[1] Many of the sand bars along the borders of the larger streams in the Nez Perce region are of an exceptional character. The banks of the rivers are, as a rule, precipitous, so that gravel and sand can not be rolled along them under the influence of the current, but exceedingly find sand, particularly flakes of mica, are carried in suspension by the swift water, and are deposited in eddies where the force of the current is slackened. Conspicuous bars or spits of white sand or silt are in certain instances formed in this manner, and are attached to the shore at their downstream extremities, while their upper and usually rounded distal ends are free and are surrounded by water several feet deep. The explanation of the origin of these peculiar bars is that the fine material of which they are composed was brought down the streams in suspension by the strong central current, and when a portion of the water was deflected by changes in the direction of the shore line, an eddy was produced in which the water flowed upstream along the side of the channel. When the current slackened, on being deflected in this manner, the material in suspension was deposited and shaped into a bar or spit, with curved margins, the free end pointing upstream. A photograph of one of these spits of fine, white, micaceous silt is reproduced as Pl. VI, *A*.

The fineness and lightness of the silt forming these bars and the fact that it can be transported in suspension may be demonstrated by pushing a mass of it into the water and observing that a considerable portion of it will float, often being carried a long distance by even a gentle current before it finally sinks. Under natural conditions the bars are sometimes cut away during low-water stages, and floating silt can be seen extending from them in all directions on its way down the stream. The material will float, however, only when its upper surface is dry, and in that condition it is perhaps buoyed up by air vesicles; but when wet it settles slowly, and in a rapid stream it will be carried long distances before finding a place sheltered from the current in which it can rest.

on them, so that the transfer, through this agency, of material from one locality to another must have been small in amount. At present, when so much of the fine soil is plowed and left for a season without being sown, and roads have been established, great quantities of dust are carried in the air during the summer season.

SUMMARY.

The deep soils and subsoils on the lava plateaus and also on the terraces formed by the projection of resistant layers in canyon walls where they are bordered by the Columbia River lava, have resulted from the disintegration and decay of the lava rock, and remain in their original positions or have been removed but short distances through the influence of beating rain, changes of temperature, the pull of gravity, etc. This widely extended surface sheet of decomposed rock furnishes a typical illustration of residual soil. While it has been formed principally from the lava rock, it contains some volcanic dust which was deposited on it and has been incorporated in it. This dust is richer in potash and soda than is the lava rock, and serves as a fertilizer. On the walls of canyons where terraces occur, and, what is equally common, where landslides have found terrace-like shelves, frequently with undrained basins on their surfaces, there is in many cases an admixture of volcanic dust, lapilli, gravel, sand, clay, etc., derived from layers of these substances which are interbedded with the lava sheets through which the canyons have been excavated. In a more critical classification than is here attempted these soils might be considered by themselves as representing colluvial deposits.

The soils on the foothills of the Bitterroot Mountains, and generally throughout the mountains as well as on the steptoes rising through the Columbia River lava, are also of sedentary origin, and have resulted from the disintegration and decay of the rocks on which they rest. The rocks forming these uplands yield to the influences of the atmosphere less readily than does the basalt of the adjacent plateaus, and furnish a soil that is less homogeneous and less thoroughly disintegrated.

No soils of glacial origin occur in the region represented on the map forming Pl. II. Transported soils occur in areas of limited extent along the rivers, and are principally the deposits of the rivers in recent times, although a few remnants of ancient flood plains still remain.

PHYSIOGRAPHY.

RELATION OF SURFACE RELIEF TO GEOLOGIC STRUCTURE AND CLIMATE.

As is well understood, the present diversity in the relief of all land areas is in the main the net result of two series of changes, or of the action of two agencies which are in opposition to each other. • One of these embraces the movements in the earth's crust by which rocks are raised above sea level, or, if originally above that horizon, are folded, tilted, etc.; while the other includes the denuding action of the atmosphere and of water, and has for its object, so to speak, the carving away of all land areas to sea level. In countries where the rainfall is small the changes in relief produced by upheaval, or, more definitely, the surface irregularities resulting from the folding and breaking (faulting) of the rocks and the tilting of areas of greater or less size bounded by folds or faults, remain prominent for a long period of time, and frequently furnish the most conspicuous features in the topography; while in humid lands, particularly where the climate is warm as well as humid and vegetation is luxuriant, rock decay is rapid, and the most conspicuous features in the relief of the land are likely to be such as result from denudation. Between these two extremes there are all degrees of gradation.

In the Nez Perce region the rainfall, as already stated, is small, but streams rising in the mountains to the eastward, where precipitation is heavy, flow across it, and conspicuous features in the relief are due both to movements in the underlying rocks and to stream erosion. For these reasons a knowledge of the structure of the rocks and of the manner in which streams have excavated channels in them is essential in order to understand the significance of the larger topographic features of the surface as it exists to-day. In fact, nearly the entire history of a region needs to be considered in order to be able fully to interpret its present relief.

ORIGINAL LAVA PLATEAU.

So far as the Nez Perce region is concerned, there seems to have been no conspicuous movements in the earth's crust during the time the Columbia River lava was being poured out. In other words, so far as known there are no unconformities in the lava sheets due to movements in one portion before the next succeeding sheet was spread out above it, although time intervals between successive sheets are in some instances recorded by sedimentary and other deposits. The edges of the lava sheets exposed in canyon walls are always essentially parallel with one another.[1]

A starting point in the study of the present relief is thus furnished by the condition of the surface at the time the last sheet of lava was spread over it. At the time referred to Nez Perce County and the country adjacent to the foothills of the Bitterroot Mountains was a featureless plain, diversified only by a few island-like peaks that rose through the lava. This plain, we are justified in assuming, was similar to the surfaces of many lava sheets of recent date which have been studied, and presented a rough and moderately uneven expanse of black, sco-

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[1] An exception to this statement will perhaps be found in the northwestern portion of the Clarkston Plateau and in the region drained by Alpowa Creek.

riaceous, slag-like rock. That it was absolutely level is not to be supposed, since lava sheets may continue to flow after their surfaces have cooled and hardened, and the surface crust is frequently broken and perhaps forced up into ridges and hillocks. In a thick lava sheet shrinkage occurs after its surface has hardened, and the surface is deformed and frequently forced up into ridges or dome-like forms which crack open along their tops. For these and other reasons it is to be presumed that while the surface of the last sheet of Columbia River lava formed a plain without conspicuous inequalities, it was far from being smooth and even.

If we knew the elevation of the surface of the last sheet of lava as it existed before being deformed by movements in the earth's crust, much assistance would be gained in tracing the history of the present highly diversified topography. While a definite answer to this question can not at present be given, certain facts enable one to reach an approximate determination as to the original level of the lava plateau.

As already explained, the Columbia River lava was poured out in a molten condition, in a series of vast inundations, over a deeply eroded land surface. The contact of the lava with the formations on which it rests is always unconformable, and between the two there are no massive sediments. As the pile of lava sheets is in places more than 4,000 feet thick, it follows that the last sheet spread out must have had at least that elevation above the sea, unless the old land surface, like the region about the Dead Sea and the bottom of Death Valley at the present day, was below sea level, which is improbable. The only other escape from the conclusion just stated seems to be that movements producing a depression occurred during the time the lava sheets were being formed. If such a downward movement did occur, it was evidently not sufficient to carry the surface below sea level, for no marine sediments have been discovered between the lava sheets. Unconformities due to a folding or tilting of the earlier formed lava sheets before the succeeding sheets were spread out have not been discovered in the eastern portion of the formation under consideration, although such unconformities are known in the Cascade region. Whether the movements which caused the unconformity referred to influenced the eastern portion of the lava sheets can not at present be definitely stated.

From these considerations it might reasonably be expected that since the lava sheets in eastern Washington and Oregon and the adjacent portion of Idaho are still horizontal, the surface of the plateaus thus formed should have an elevation of at least 4,000 feet above the sea. Instead, however, we find in numerous instances that the general elevation of the plateaus underlain by essentially horizontal lava sheets is between 3,000 and 3,300 feet. This difference, approximately 1,000 feet, between the present elevation of the locally undisturbed plateaus and what is assumed to have been their original position can be ascribed in part, perhaps, to erosion, but the amount of erosion is certainly small, and in places, as will be shown further on, it is nil, for the reason that portions of the scoriaceous surface of the last lava sheet have been protected by sedimentary beds laid down upon it, and these portions of the lava sheet have essentially the same elevation as the deeply weathered portions of the same sheet. A warrantable inference seems to be that there has been a general subsidence of the eastern portion of the Columbia River lava region referred to of at least 1,000 feet, which did not disturb the horizontality of the strata. This subsidence may have gone on during the time the lava was being extruded, or may have occurred in part or wholly since the last sheet of lava was spread out.[1]

LEADING FEATURES IN THE RELIEF DUE TO MOVEMENTS IN THE EARTH'S CRUST.

Whatever may have been the amount of the broad regional movements in the Nez Perce region, the fact that large areas have not been deformed but still remain essentially level and are underlain by horizontally bedded lava sheets, permits of reaching interesting conclusions

[1] The region occupied by the Columbia River lava is of special interest in reference to the study of the manner in which the earth's crust has been deformed, as it is unique and exceptional in the geologic history of North America. At the close of the eruptions which furnished the lava there existed in that region an essentially horizontal plateau 200,000 square miles or more in area, which in itself is exceptional in the history of topographic forms; but more than this, the plateau was produced by the outpouring of lava, and was built up, layer by layer, on a land surface. The plateau has since been variously deformed, but mostly in a broad way, and the nature of the movements can readily be determined. Moreover, the region is usually bare of trees, and the changes that have been made by erosion are sharply defined and easy to separate from those resulting from movements in the rocks. In the studies of isostasy and diastrophism that may be carried on there, the influence of the vast weight of the lava poured out at the surface, and also the withdrawal of a corresponding volume of liquid rock from beneath the surface, demand attention. The importance of the field as furnishing a test of isostasy is shown by the fact that the volume of the Columbia River lava is in the neighborhood of 50,000 to 60,000 cubic miles; its weight is about 160 pounds to the cubic foot; where the lava is 4,000 feet thick the pressure on the underlying rocks is in the neighborhood of 320 tons to the square foot. It is reasonable to suppose that the effect of the extrusion of so vast a volume of lava would be to cause a regional depression of the earth's crust. That this result was produced is shown by the fact that over the central part of the lava-covered country in Oregon and Washington the surface is now but a few hundred feet above sea level. At Pasco, Washington, the elevation is 386 feet, and over a large area of the surrounding lava plain the elevation is certainly less than 500 feet. The subsidence that has occurred in this region is not less than 3,500 feet, and probably exceeds that measure by at least 1,000 feet. This downward movement began, perhaps, at an early stage in the extrusion of the lava, and continued during the time the successive sheets were being spread out; but a part of the deformation which the lava has experienced, and possibly a part of the general subsidence of the central portion, has occurred since the extrusion of the last lava sheet. Other portions of the lava formation, of even greater extent than the central depressed region, have been upraised. In the Cascade Mountains the lava sheets, with a gentle eastward dip toward the depressed region, which includes the Great Plains of the Columbia, have an elevation of from 7,000 to 7,500 feet. The lava plateaus in eastern Oregon have an elevation of from 5,000 to 7,000 feet (Lindgren), and the general inclination of the beds, as in eastern Washington, is westward. Thus portions of both the eastern and western border of the lava-covered country have been raised from 3,000 to 3,500 feet, and the central part has been depressed by about the same amount from what would have been the surface level of the lava-covered country in case there was no subsidence during the extrusion of the lava. These movements have been in large part of the nature of a tilting of broad blocks of the lava, bounded by monoclinal folds and faults.

While the foregoing statements serve to indicate the general nature of the problems presented by the Columbia River lava, a detailed study will probably show that there have been extensive movements in the rocks during the time the lava was being poured out. For example, as has been shown by George Otis Smith, on the east side of the Cascade Mountains near Clealum, there is a strongly pronounced unconformity between a lower and an upper member of the lava formation, which proves that the lower portion of the pile of lava sheets was sharply folded and deeply eroded before the nearly horizontal and later sheets were poured out.

in reference to the movements that have affected adjacent areas where the strata are no longer horizontal. About the foothills of the Bitterroot Mountains there are many small valleys which still retain the level floors given them by the last inundation of Columbia River lava. These floors are horizontal, and beneath their coverings of alluvium their scoriaceous surfaces are to be seen. In several such instances the elevation of the lava surface is, by aneroid measurement, about 3,000 feet above the sea. This is also the general elevation of the Uniontown Plateau, to the north of Lewiston, beneath which the lava sheets are horizontal. The Uniontown Plateau, although its boundaries, except on the south, have not been defined, is certainly several hundred square miles in area, and extends, without any perceptible structural change in the rocks, eastward to the foothills of the Bitterroot Mountains, and on the northwest is believed to merge, without any conspicuous change, into the still more extensive region of similar character known as the Palouse country, where the lava sheets are also horizontal, or possibly have a slight dip to the westward, and where the general surface elevation is also about 3,000 feet. This extensive region of essentially horizontal lava sheets has evidently not undergone local deformation; and where adjacent areas beneath which the strata are inclined are below its level, it seems safe to conclude that they have been depressed; and where similar areas stand above the assumed datum plane, the conclusion is that they have been locally upraised. More definite reasons for assuming that the Uniontown Plateau may be taken as a datum plane for determining the amount of differential movements that has taken place in the adjacent plateaus, will, the writer thinks, be recognized in the somewhat detailed record of facts which follows.

The lava-covered portion of the region represented on the map forming Pl. II is divided naturally into six more or less well-defined areas of primary rank, which, when inclined, illustrate the nature of the movements which have affected the rocks beneath them. These areas are the Uniontown Plateau and the Camas and Kamiah prairies, beneath which the lava beds are horizontal, and the Blue Hills, the Lewiston and Clarkston plateaus, and Craig Mountain, beneath which the lava beds are inclined.

Uniontown Plateau.—Rising from the north or right bank of Clearwater River, throughout the lower 25 or 30 miles of its course and continuing westward beyond Lewiston, is a bold escarpment which in its central part has a height of about 2,000 feet. This is one of the most pronounced topographic features in Nez Perce County, and although in some respects it resembles the walls of the deeper portions of several of the great canyons in the same region, it is plainly of a different nature and origin. For example, there is but one escarpment, not two facing each other, as in the case of a canyon, except in a minor way, as will be explained later. Then, too, the strata in the Clearwater escarpment, as it is convenient to term it, are for the most part not the edges of horizontal strata, as is commonly the case in the neighboring canyon walls, but are formed of inclined beds which dip southward. In the central and highest portion of the escarpment this southward dip is at a high angle, frequently 40 or 50 degrees, but near its extremities the inclination is more gentle. On climbing the escarpment it will be found to be the border of the nearly level Uniontown Plateau.

At the base of the Clearwater escarpment, and in general about 1,500 feet lower, are the Clarkston and Lewiston plateaus, described further on. The lava sheets, and certain sedimentary beds interstratified with them, which underlie the Uniontown Plateau, are horizontal, or essentially so; but in the Clearwater escarpment they bend abruptly downward, and at its base they flatten out beneath the Clarkston and Lewiston plateaus—that is, the escarpment is a monoclinal fold, which begins at the east, in the neighborhood of Agatha, as a gentle flexure, and increases both in height and in the inclination of the layers as one follows it westward, until near Lewiston its height is about 2,000 feet and the dip of the beds from 40 to 50 degrees. Still farther west, along

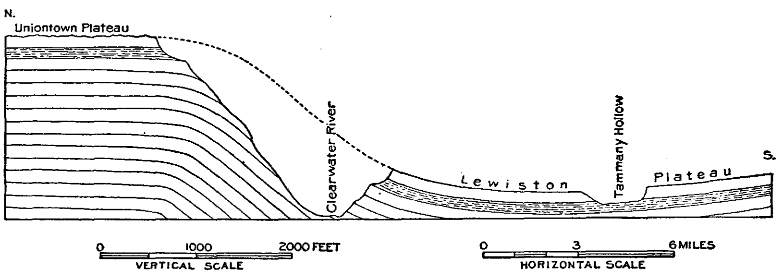


FIG. 1.—North-south section through the Uniontown Plateau, Clearwater escarpment, and Lewiston Plateau.

the north side of Snake River for 3 or 4 miles below Lewiston, the fold becomes a break or fault. How this fault terminates at the west is not known, but such facts as are in hand suggest that near Alpowa it passes again into a fold, which continues westward along the creek of the same name. The entire length of the fold, including the 2 or 3 miles where it is broken, is about 50 miles.

A peculiar and interesting fact in connection with the monoclinal fold just described is that Clearwater River flows directly along it for a distance of about 35 miles, and has excavated a canyon in it. The relation of the river to the fold is illustrated in fig. 1, which may be considered a generalized north-south section about 6 miles east of Lewiston.

At the locality referred to, and for a distance of about 10 miles upstream, the southward dip of the rocks forming the south side of Clearwater Valley is well shown. Again, to the west of Lewiston

Snake River enters this same monoclinal fold where it changes to a fault, and, bending westward at almost a right angle, continues in nearly the same course that the Clearwater has in the portion referred to above. From the abrupt bend made by Snake River just below Lewiston to the equally sharp curve made at Alpowa, the river flows along the monoclinal fold, in part a fault, which unites the Uniontown Plateau with the Clarkston Plateau. On the south side of Snake River between Lewiston and Alpowa, the southward dipping rocks form a conspicuous precipice facing north, in which a layer of columnar basalt is well exposed. The southward dip referred to may readily be seen from any commanding point near Lewiston. A north-south section midway between Lewiston and Alpowa would be similar to the one shown in fig. 1, but the southward dip on the south side of the river would be more pronounced.

The Uniontown Plateau is underlain all along its southern border, and apparently throughout practically its entire area, by horizontal sheets of basalt, which include at least one important bed of clay, sand, and gravel, at a depth of about 160 feet below the surface. The plateau is undulating, owing to stream erosion, as will be discussed further on, and at several localities on its southern border deep notches have been cut by streams flowing into Clearwater River.

Clarkston and Lewiston plateaus.—The country to the south of the Clearwater escarpment in the vicinity of Lewiston and Clarkston has been depressed about 2,000 feet below the level of the Uniontown Plateau, and the strata beneath it are inclined downward toward the north. This inclination is slight, however, but it affects the rocks for a distance of about 20 miles, so that its influence becomes conspicuous in the larger features of the surface relief. As the displacement producing the escarpment referred to dies out to both the east and the west, there is also an inclination of the beds beneath the sunken area and adjacent to the base of the Clearwater escarpment toward the center, where the movement was greatest. This center is at Lewiston-Clarkston, but the dip of the beds is too slight to be observed in rock outcrops, being only about 1,500 feet in a distance of 20 miles, although it is apparent in the surface slopes of the country.

Thus, the region to the south of the Clearwater escarpment has the form of a trough, with the axis running about north and south. This axis determined the general course taken by Snake River from the mouth of Grande Ronde River to Lewiston-Clarkston. Other movements also have affected the region. The rocks to the west of Snake River have a gentle inclination toward Lewiston-Clarkston over the broad area which is cut by the canyons of the various branches of Asotin Creek. This nearly level but deeply dissected country has been termed the Clarkston Plateau. The town for which it is named, however, is in the canyon of Snake River, about 500 feet below the general surface of the plateau.

On crossing the Clarkston Plateau from its eastern border along Snake River toward the southwest, the surface continues to rise until the plateau merges into the large dome-shaped uplift known as the Blue Hills. In this uplift the lava beds are carried about 2,000 feet higher than the surface of the Uniontown Plateau, showing that there has been a local uplifting of the lava sheets above their original position.

The country to the east of Snake River, for a distance of about 15 miles above Lewiston, has a gentle inclination toward that city, but it is roughened by stream erosion. This plateau, which has been termed the Lewiston Plateau, when crossed in a direction southeast from the town for which it is named, rises gently until the base of Craig Mountain is reached, where there is a steep ascent. The strata beneath the plateau correspond in dip with the surface slope of the broad areas between the stream-cut canyons, and at the border of Craig Mountain they are bent sharply upward. The latter mountain is formed by a monoclinal fold similar to the larger fold which determines the south border of the Uniontown Plateau, as will be described more fully further on.

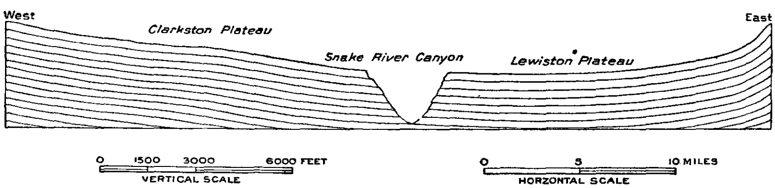
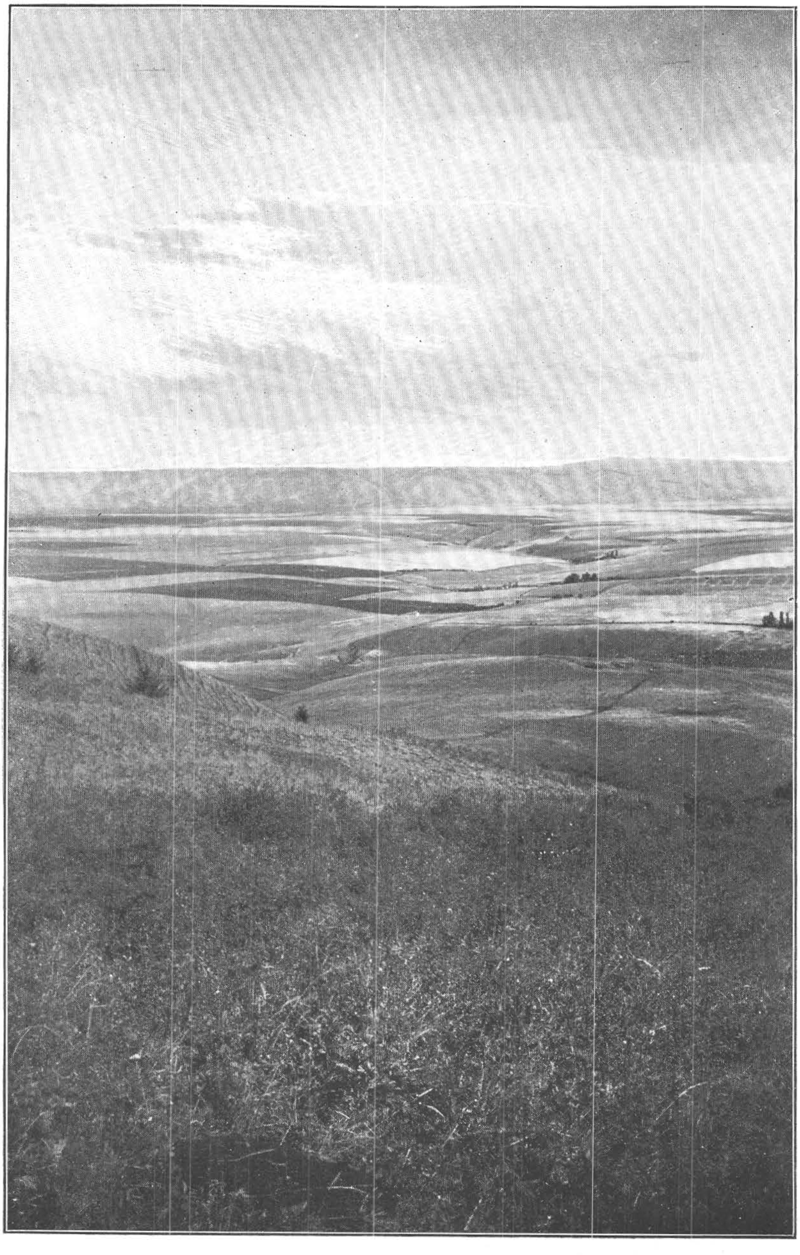


FIG. 2.—Section through the Lewiston and Clarkston plateaus.

The Clarkston and Lewiston plateaus are in reality a single topographic feature, but it is convenient to give them separate consideration, on account of the depth of Snake River Canyon, which has been excavated along the axis of the gentle north and south trough into which the rocks have been bent. Snake River, however, does not follow the axis of this trough precisely, but the northeastward slope of the rocks away from the Blue Hills extends east of the canyon, as can be seen in looking over the region from commanding points on the hills near Waha (Pl. VII), or from the summit of the Clearwater escarpment near Lewiston, and as indicated in the section shown in fig. 2. In the country on the east side of Snake River Canyon opposite Asotin, the axis of the synclinal trough formed by the junction of the strata which rise from it to the east and the west lies about 2 miles east of the course followed by the river.

It is important, in reference to the question of obtaining artesian water, to note that the surface slope of the broad remnants between the streams which have dissected the Lewiston and Clarkston plateaus, and also the inclination of the strata beneath the surface, is downward toward the towns for which the plateaus have been named.



LEWISTON PLATEAU FROM NEAR WAHA.

Blue Hills.—Included in part in the area represented on the map forming Pl. II are the Blue Hills, or mountains, as they are frequently termed, of southeastern Washington. This uplift was visited during the reconnaissance which forms the basis of this report, but the observations made give little information in addition to that contained in a previous publication.[1]

The Blue Hills have been elevated since the Columbia River lava of which they are composed was spread out in horizontal sheets. The uplift is of the nature of a broad, low dome, which attains an elevation of about 5,000 feet above the sea, or 2,000 feet above the level of the Uniontown Plateau. The strata which underlie the Clarkston Plateau, as has already been stated, rise gently toward the southwest, and pass, by insensible gradations, into the more steeply inclined portions of the same beds which have been elevated to form the Blue Hills. The differential movement which the once horizontal beds have experienced between Clarkston and the summit of the Blue Hills is about 4,000 feet. This change occurs in a distance, in a direct line, of 25 miles, but the upward movement at the southwest was sharper than the downward movement at the northeast. The strata involved in the Blue Hills uplift are inclined away from its summit portion in all directions, in essentially the same way that they are inclined to the northeast, where they pass into the Clarkston Plateau, but they dip somewhat more steeply on the south side than in other directions. The passage from the surrounding plateaus into the dome is so gentle that the eye can not distinguish where the change begins, but, in general terms, the uplift may be said to be from 50 to 60 miles in diameter from east to west, and to measure from 30 to 40 miles along its north-south axis. On the summit of the uplift the strata are so nearly horizontal that it is impracticable to measure their inclination, and on its sides the dip is seldom more than 2 or 3 degrees. If the uplift had not been eroded it would appear as a smooth dome, low in comparison with its width, but streams have sculptured it in a conspicuous manner, and its slopes are now trenched by deep canyons. The greatest change produced by erosion is on the south side, where Grande Ronde River has excavated a canyon comparable in grandeur with the finest portions of the neighboring Snake River Canyon.

Craig Mountain.—This name, although used somewhat indefinitely by the inhabitants of the Nez Perce region, will be considered as designating an elevation which extends in a northeast-southwest direction across the west-central portion of Nez Perce County, from the border of Snake River Canyon near Waha to the vicinity of Willola on Clearwater River. Viewed from the vicinity of Lewiston, the uplift appears to be a long, even-topped ridge, which begins at the northeast as a gentle swell and becomes higher and more precipitous as the eye follows it toward the southwest. On visiting the mountain,

[1] Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4.

one finds it to be the upraised border of a broad plateau which is inclined to the southeast, but which soon flattens and forms the Camas and Kamiah prairies.

The northwest border of Craig Mountain is an escarpment of the same general character as the one forming the south border of the Uniontown Plateau, but it is less pronounced. It is a monoclinal fold which unites the Lewiston Plateau on the northeast with the Camas and Kamiah prairies on the southeast. It differs from the Clearwater escarpment, principally in the fact that the two plateaus which it unites slope away from its longer axis in each direction. A section through the Lewiston Plateau, Craig Mountain, and Camas Prairie would show the relations expressed in fig. 3.

Such a fold may, perhaps, be termed a gentle anticline, but as it unites two broad plateaus in which the strata are but gently inclined, it seems more accurate to designate it a monocline.

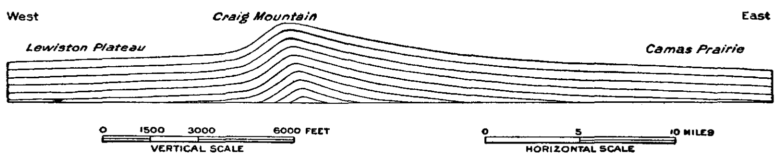


FIG. 3.—Section through Lewiston Plateau, Craig Mountain, and Camas Prairie.

At its northeastern extremity the Craig Mountain fold commences as a broad, gentle swell, and from this indefinite beginning it increases in height and steepness to the southwest until in the vicinity of Waha it is about 1,000 feet high and probably passes into a fault. In its higher portion, overlooking Snake River Canyon, Craig Mountain has an elevation of nearly 5,000 feet above the sea, and is densely forest covered. It is not a smooth plateau, but has been trenched by stream erosion. The most conspicuous change thus produced is in the case of Mission Creek, which has its source well to the southeast of the crest of the uplift, flows across it in a deep canyon, and continues, to its junction with Lapwai Creek, in a canyon cut in the Lewiston Plateau.

Camas and Kamiah prairies.—To the southeast of Craig Mountain lie the broad Camas and Kamiah prairies, beneath which the layers of Columbia River lava over an extensive area are nearly horizontal. This plateau measures about 40 miles in length from northeast to southwest, and is about 25 miles wide. The lava sheets beneath it, although horizontal throughout nearly its entire extent, are bent upward, as already stated, along its northwestern margin, to form the Craig Mountain monocline. The border of the sheets adjacent to the uplands of older rock on the south and east are also gently inclined upward from the great central area. Whether the rocks in this region form a complete basis remains to be determined by a study of the structure in the vicinity of Agatha. There the beds are nearly or quite horizontal, and the Camas-Kamiah Plateau merges into the Uniontown Plateau, with little if any line of demarcation between, except such as has resulted from erosion. The general elevation of the broad central portion of this plateau is about 3,000 feet, and its surface is deeply trenched by various branches of Clearwater River.

Summary.—The deformation of the Nez Perce region since the outpouring of the Columbia River lava has been mainly in the direction of a tilting of the once horizontal lava sheets over broad areas. The movements have been greatest along certain lines where sharp folds have been produced which at times pass into faults, as the Clearwater and Craig escarpments. The most pronounced change has taken place in the Blue Hills, where a dome-shaped uplift has been raised. This so-called dome, however, is steepest on its southern side, and from another point of view may with propriety be considered of the same type as the Craig Mountain fold, but of larger size, and without a break in its steeper side.

The class of folds represented by the Blue Hills dome, Craig Mountain, and the Clearwater escarpment may be likened to waves and swells on the ocean; some are upswellings with nearly circular bases, others are elongated and have steep slopes on one side of the crest and a gentle descent on the opposite side, while in other instances the waves break, as when a monoclinal fold passes into a fault. There are also basins between the elevations, and extending through the waves and troughs alike are the deformed layers of once horizontal lava sheets. The elevations and depressions are so broad and the inclinations of the strata in general are so gentle, that the geologic terms in current use, derived principally from the study of sharply folded regions, can not be applied to them without conveying false impressions. The generalized type of the structural features may be considered as a monoclinal fold connecting two broad plateaus in which the strata are either horizontal or gently inclined. The greatest departure from this type occurs where the fold approaches a dome in shape, or where the steeper limb of a monocline is broken and becomes a fault.

LEADING FEATURES IN THE RELIEF DUE TO EROSION.

The Nez Perce region is characteristically a land of deep, steep-sided canyons with broad, generally level, remnants of the dissected plateaus between them. The canyons are naturally divided into two classes in reference to the origin of the streams that excavated them: (1) Those through which flow rivers the courses of which were determined before the deformation of the original lava plateau occurred, and are therefore to be classed as *antecedent streams;* and (2) the canyons cut by branches of the master streams, which in most instances had their courses determined by the slopes of the secondary plateaus and the monoclinal folds which were produced by movements in the earth's crust, and which may therefore be termed *consequent streams.*

Magnificent examples of canyons produced by antecedent streams are furnished by Snake, Salmon, Clearwater, and Grande Ronde rivers. Each of these rivers flows through a profound canyon of its own making, but the height of the bordering walls varies from place to place in accordance with the movements in the direction of elevation or depression which have affected the country it crosses. Where plateaus or monoclinal folds have been boldly upraised athwart the course of a stream, its bordering walls are high and rugged; and where the rocks have been depressed the work of the stream has been less to establish a graded course to the sea, and its canyon becomes correspondingly shallow. In other words, the streams antedate the time when the plateaus were tilted or the monoclinal folds and faults came into existence, and have maintained their right of way as the country was deformed. The consequent streams represented by Asotin, Lapwai, Tammany, Lawyers, and many other creeks have had their courses determined by the slopes given to the various secondary plateaus into which the originally level lava sheets have been broken, and the depths of the canyons they have excavated have been determined by the depths of the great canyons cut by the master streams to which they are tributary.

Canyons of Snake River.—The head branches of Snake River are in southeastern Idaho and in neighboring portions of Wyoming, including the western part of the Yellowstone National Park. The river at first flows westward across southern Idaho for a distance of about 400 miles. It then bends sharply northward, and for a distance of 220 to 250 miles it follows the boundary between Idaho and the States of Oregon and Washington to Lewiston, where it again turns to the westward, and at Alpowa makes still another sharp bend, where it enters a steep-sided canyon cut in the Uniontown Plateau, and continues in a canyon to near its junction with the Columbia. The length of the river is in the neighborhood of 750 miles, and the part of its course to which attention is here invited is the northern portion of the central or northward-flowing section. Snake River is characteristically a canyon stream throughout nearly its entire length. The head of its canyon is now at Idaho Falls, in the southeastern part of Idaho, where its waters make a plunge of about 30 feet into a narrow trench in the basaltic rock. For a hundred miles above this cascade the main river and several of its branches flow over the surface of a vast lava flow, and instead of corrading their channels they are upgrading them by the deposition of alluvium brought from the mountains. Below Idaho Falls—practically all of the way to where it joins the Columbia—the river flows between precipitous walls from a few hundred to 4,000, and even 6,000, feet deep. From 30 to 60 miles south of Nez Perce County the river flows

SNAKE RIVER CANYON, SHOWING DETAILS IN WALL.

through an unusually rugged region known as the Seven Devils and Powder River (Eagle Creek) mountains, which are about 9,000 feet high and are mottled with snow throughout the summer. The combined canyon and mountain scenery is there perhaps the wildest and grandest in the Northwest, and rivals that of the finest portions of the justly celebrated Grand Canyon of the Colorado, except in brilliancy of color.

As is indicated on the accompanying map (Pl. II), Snake River follows the western boundary of Nez Perce County for from 40 to 50 miles. In this portion of its course it has excavated a canyon which may be divided into two well-defined sections of about equal length. Throughout the southern half of its course the river is in the bottom of a magnificent canyon with deeply sculptured walls 4,000 feet high and about 15 miles wide at the top. The rim rock at the crest of the walls on each side is formed by the edges of a lava sheet which immediately underlies the surface of Craig Mountain and of another similar plateau in Oregon. The northern half of the portion of the canyon referred to is narrow, being perhaps 2 miles wide at the top, and is cut in nearly horizontally bedded lava sheets; the walls, which are so steep that they appear vertical, are about 2,000 feet in height. This portion of the canyon has been excavated approximately along the axis of the trough between the Clarkston and Lewiston plateaus, which pitches to the northward, and the canyon walls decrease gradually in height as the lowest portion of these depressed plateaus is approached at Lewiston-Clarkston. The well-marked differences exhibited by these two sections of the canyon are due to the fact that in the southern section the rocks have been upraised and so profoundly dissected that the granite, limestone, etc., beneath the basalt is exposed and deeply trenched, while in the northern section the walls are entirely of basalt and the plateau through which the river flows has been depressed and the task of cutting a trench to a uniform gradient much lessened. These differences in the two sections of the canyon may be recognized by comparing Pls. IV and VI, *B*. The former is a view of the narrow, steep-sided canyon above Asotin, taken from a locality on its eastern border near Waha, and the latter is a view taken on the brink of the canyon in its deeper portion, on Craig Mountain opposite Mount Wilson, but the distances are so great that it fails to convey even a faint impression of the magnificence of the scene. Details of the walls of the canyon are shown in Pl. VIII.

Snake River Canyon in its deepest and wildest portion adjacent to Nez Perce County is joined by Salmon River Canyon, which comes in from the east and is of the same depth and character as the mighty trench excavated by the master stream. About 20 miles below the the mouth of Salmon River, Grande Ronde River joins Snake River from the west, and also flows through a magnificent canyon, scarcely second in its scenic features to that of the larger river, and, like it, about 4,000 feet deep. Near its mouth Grande Ronde River is joined by Joseph Creek, which has also excavated a canyon as deep as the one it joins. These several strong streams, acting like endless saws, have cut into the great plateau which was elevated athwart their courses. Each of their branches has also striven to deepen its canyon at the same rate as the master stream, and the result is that a once even-surfaced and monotonous plateau has been given an exceedingly rugged topography.

The impression gained by one who follows the immediate borders of Snake River and its various branches would probably be that he is traversing a mountainous region; and this conclusion is true enough, for the land forms to be seen are far more rugged and lofty than the ridges and peaks of many greatly admired mountain ranges. It is only when a commanding summit is gained, like the top of Mount Wilson or the southern border of the Blue Hills, that the relations of the topographic features of an extensive portion of the rugged country are recognized, and it is seen to be a deeply dissected plateau. In far-reaching views large areas of the unmodified plateau surface are in sight, and the change from what is termed young topography to middle-aged and mature topography can be traced in different portions of the same upraised block of the earth's crust.

One not familiar with canyon scenery may perhaps fancy that the excavations made by streams in an elevated plateau are narrow trenches with vertical walls—in fact simply ravines of larger growth. While this is to some extent true of young canyons in homogeneous and resistant rocks, yet when the trenches become deep, especially if the rocks cut through are of varied character, the original narrow excavations are widened, especially at the top, and their walls are sculptured by lateral streams and are trenched by rills and brooks originating on them so as frequently to impart to them great diversity.

In the case of the canyon of Snake River from the mouth of Salmon River to near the locality where Grande Ronde River joins it, and again a few miles farther downstream, in the vicinity of Buffalo Rock, as has already been described, the Columbia River lava forms the upper portion of the canyon walls, while the lower slopes are cut in older and for the most part more resistant formations. The upper portions of the bordering walls, composed of basalt, have receded, and the canyon has been widened there more rapidly than in the lower portions, owing to the greater rapidity with which basalt weathers, in comparison with the formations on which it rests, and also on account of its longer exposure to the atmosphere; so that a broad canyon, with sculptured walls in which the exposed edges of the lava sheets are horizontal, has in its bottom a narrower canyon with precipitous and rugged sides. This canyon within a canyon is due entirely to differences in the resistance of the rocks to weathering, and does not indicate movements in the earth's crust, as does a somewhat similar occurrence in the Grand Canyon of the Colorado.

Throughout the portion of the canyon where the rocks beneath the lava are exposed there is no flood plain and no land that is under cultivation. In the next section downstream, where only basalt occurs, although a true flood plain is lacking, there are small, moderately flat areas, composed in part of talus, which are irrigated by water derived from brooks which flow down steep side gulches, and orchards of peaches, apricots, pears, etc., are cultivated, producing a rich return of excellent fruit. The combined area of these detached fragments of flood plains that are under cultivation between the mouth of Asotin Creek and Grande Ronde River is only about 100 acres.

Downstream from where the last exposure of the terranes beneath the basalt is to be seen, the walls of the canyon are precipitous from base to summit, and although encumbered with débris are mostly grass covered. The character of the precipices is well shown in Pl. IV, in which the edges of the nearly horizontal lava sheets can readily be recognized. This portion of the canyon, as previously stated, is cut in general along the junction of the Lewiston and Clarkston plateaus, and the rocks are inclined downward toward the mouth. The walls of the canyon decrease in height as one approaches Lewiston-Clarkston, and at the same time its bottom becomes somewhat broader.

Just below Lewiston-Clarkston Snake River makes an abrupt bend to the westward. This sharp turn is due to the Clearwater escarpment, which runs at right angles to the previous course of the river and is about 2,000 feet high, with southward-dipping beds on its face which are inclined at angles of from 40 to 50 degrees or more. Evidently the escarpment was raised across the course of the river, or, more accurately, the plateau to the southward was depressed and the stream was turned aside. The river on turning to the westward follows the base of the great escarpment, but soon cuts into the fold which forms the escarpment, and flows along it for a distance of 5 or 6 miles, to Alpowa. There it makes another abrupt bend, and enters a narrow, steep-walled canyon cut in the Uniontown Plateau, similar to that shown in Pl. IV. The relation of Snake River to the monoclinal fold forming the Clearwater escarpment, in the portion of its course between Lewiston and Alpowa, is the same as exists in the case of Clearwater River. In fact, the portion of Snake River referred to is almost a direct continuation of Clearwater River, and flows along the same monoclinal fold, which there passes into a fault, leaving a large portion of the southward-dipping rocks on its southern or left border. The beds on the south side of the river dip southward at an angle of 6 to 7 degrees, but soon flatten and pass under the Clarkston Plateau, where they are nearly horizontal.

The variations in the depth of Snake River Canyon below the general level of the adjacent plateaus illustrate the relation of the river's work to the deformation which the rocks have undergone, and show that where the rocks have been lifted highest the trench cut by the river is deepest, and where the rocks have been depressed the walls of its canyon become low—at Lewiston-Clarkston they nearly disappear.

Snake River Canyon is typical of the class of larger canyons in the Nez Perce region, and to save space and avoid repetition the others need not be described at length.

Canyon of Grande Ronde River.—The country to the south of the Blue Hills is a high, deeply dissected plateau of the same general character as the neighboring region in which Snake River has excavated its magnificent canyon, except that the Columbia River lava there seems to be thicker, as the rocks beneath it are not exposed.

Grande Ronde River, Joseph Creek, and their various tributaries have excavated deep canyons, and the remnants of the original plateau have been reduced in width until in many instances they are sharp, serrate ridges. Everywhere throughout the rugged lands thus produced the edges of horizontal lava sheets are to be seen. In few places in the United States can better illustrations be found of the transformation, by stream erosion, of a level plateau underlain by a great thickness of horizontally bedded rocks into a region of excessively rugged topography. Near the junction of Joseph Creek with Grande Ronde River, and between the same creek and the canyon of Snake River, the topography is as rugged as it can be made with the present amount of uplift. Many of the ridges are sharp and along their crests are broken into pinnacles through the action of lateral rills and creeks, rain, frost, and wind. The continuation of the denudation, which has been long in progress, will tend to decrease the height of the multitude of ridges and peaks and to lessen the ruggedness of the relief. In short, the topography is mature and will slowly lose its salient features and flatten out so as to resemble its original monotonous character, unless renewed uplift occurs so as to allow the streams to cut more rapidly. Ascending the ridges between the various streams and traversing them toward the sources of the bordering canyons, they become broader and are easily recognized as portions of a vast, nearly level plateau. These broad surfaces are covered with a deep residual soil, as is common in all such instances in the Nez Perce region, and there probably has been some lowering of the general level, owing to rock decay and solution, but the amount is not known. In this connection, however, it should be remembered that the lava in changing to soil not only loses bulk, on account of the removal of the more soluble material, but may also gain in volume by reason of the change that takes place from a dense to a somewhat open texture, and also from the swelling of certain minerals because of a change to a hydrous condition.

One of the most instructive features in connection with the canyon of Grande Ronde River is the fact that the river cuts across the southern slope of the Blue Hills uplift, and there the lava sheets in each of its canyon walls dip southward. The explanation of this is that the river had its right of way established before the dome from which the present rugged relief of the Blue Hills has been produced by erosion was upraised. That is, as previously stated, the river is to be classed as an antecedent stream. The southward dip of the lava sheets in which the river in the portion of its course indicated on Pl. II has sunken its channel in an east-west direction has had a marked influence on the details of its bordering walls. On the north side of the canyon, where the lava sheets are inclined downward toward the river, there have been innumerable landslides; while on the south side, where the dip, although small, is away from the river, the bluffs in many places approach the vertical, and landslides are rare, except near the top, where occurs a bed of soft sedimentary material, which has caused a terrace to appear.[1]

Canyon of Salmon River.—At its mouth Salmon River is on a level with Snake River, into which it flows, but it is a rapid stream, throughout at least the lower 30 miles of its course, and has many swift, foaming rapids, but no actual cataracts. Where the two rivers unite there was, previous to the excavation of the profound canyons through which they now flow, about 2,000 feet in thickness of horizontal lava sheets resting on quartzite and dense igneous rocks. After cutting through the lava the streams found much more resistant rock below, and their canyons became narrow. The canyon of Salmon River for 5 or 6 miles upstream from its mouth is only wide enough for the roaring stream that rushes through it, and is quite impassable to man. Above this narrow portion, in excessively hard rock, the canyon widens, in basalt, and for about 20 miles, or to the mouth of Deer Creek, which comes in from the west, there is a narrow strip of flood plain on its western side and a series of terrace-like benches on the salients between the lateral streams; but the east wall is usually precipitous and possesses remarkably fine scenery. Beginning about 5 miles from its mouth and extending upstream 4 or 5 miles, Salmon River makes two sharp bends and passes about the base of a massive pile of basaltic rocks 2,500 feet high, which have been sculptured into castellated forms of remarkable grandeur. Here the basalt forms the bed of the stream, and on its immediate banks are exposed the summits of columns which show that the larger part of a thick sheet of lava still remains uncut. From this locality up to the summit of the remnants of the original plateau, which occur on all sides at a distance of from 5 to 15 or 20 miles, one finds only the edges of horizontal lava sheets. The portions of the original plateau remaining have surface elevations of more than 5,000 feet. The elevation at the mouth of Salmon River, according to surveys

[1] Other facts concerning Grande Ronde River and its branches will be found in a preceding report by the author—Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4 (1897), pp. 17, 25, 26.

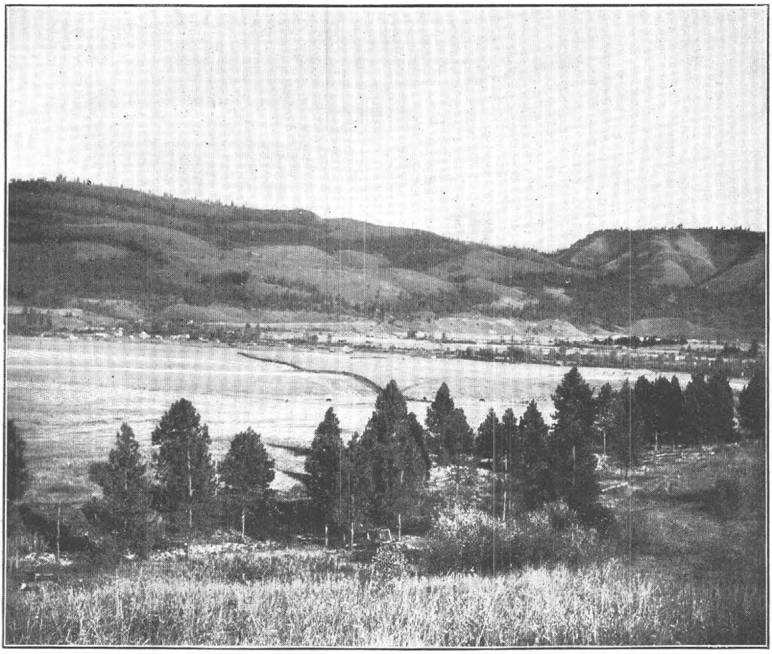
made by the Oregon Railway and Navigation Company, is 965 feet, and the thickness of the lava is not less than 4,000 feet and may be considerably greater.

Upstream from the mouth of Deer Creek, Salmon River passes through two narrow gorges of dense igneous rocks, which project upward into the lava sheets; but between these obstructions the canyon widens, and has been excavated wholly in basalt. At the great bend of the river near Keuterville, the rocks beneath the lava again become prominent in the canyon walls, forming about half of their height, and the great gulf, about 3,500 feet deep, is nearly as impressive as the wildest portion of the canyon of Snake River. The same magnificent scenery continues far up the river above the big bend, but only distant views of it have been had by the writer.[1] Each of the creeks tributary to Salmon River below the big bend also flows in a deep canyon of its own making, so that the once widely extended plateau is nearly as deeply dissected and rugged as the similar region drained by Grande Ronde River.

The remnants of the elevated plateau adjacent to the lower course of Salmon River are clothed with coniferous forests, and trees grow here and there on the sides of its canyons; in a few instances yellow pines occur at the river's margin. The canyon walls, even where precipitous, are covered with bunch grass and afford fine pasturage.

Perhaps the most instructive physiographic feature of the river is the fact that for a distance of from 10 to 15 miles above the big bend it has cut its great canyon diagonally across a sloping plateau, and flows in a westerly direction, while the plateau dissected by it slopes northward, in conformity with the gentle inclination of the lava sheets beneath it. When followed northward the lava sheets flatten out and pass beneath the level surface of the Camas Prairie. A view of the lava sheets in the canyon is shown in Pl. V, *B*. The river crosses the sloping plateau in the great sweeping curve, but is sunk in a canyon about 3,500 feet deep. The relation of the course of the river to the slope of the plateau it crosses is shown in Pl. IX, *B*, and details of the canyon walls in Pl. X. Rock Creek, which rises on Mount Idaho and crosses a portion of the Camas Prairie, joins Salmon River after flowing through a deep, rugged gorge cut in the upraised border of the basin of the Camas Prairie; that is, it flows against the slope of the country and against the dip of the rock beneath it. The meaning of these facts is the same as in the case of Clearwater and Snake rivers, which have excavated canyons in the monoclinal fold joining the Uniontown Plateau with the Lewiston-Clarkston plateaus, and, again, in the case of Grande Ronde River, which cuts into the Blue Hills dome. In other words,

[1] An account of the upper portion of Salmon River Canyon, together with much information concerning the geology of the region traversed by it, will be found in the report by Waldemar Lindgren before cited, viz, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho, published in the Twentieth Annual Report of the U. S. Geological Survey, Part III, pp. 65-256.



A. VALLEY OF SOUTH FORK OF CLEARWATER RIVER NEAR KAMIAH.

B. SALMON RIVER CANYON FROM COTTONWOOD BUTTE.

the rights of way of Salmon River and Rock Creek were established before the plateau formed by the last sheet of Columbia River lava was disturbed from its originally horizontal position.

Canyons of Clearwater River.—Clearwater River is formed by the union of many streams, the larger of which have their sources in the Bitterroot Mountains and flow westward. All of these branches, as well as the main river, flow in canyons, and in all cases where a stream passes from the region of diorite, schist, etc., into the Columbia River lava, a change in the character of the excavation it has made is at once manifest. In the older rocks the canyons are wide at the top and have less precipitous walls than where they have been cut in lava. The topography in the mountains consists of a labyrinth of sharp-crested ridges, with flaring valleys between, and the streams in the valley are swift and without flood plains. The character of the country is indicated to some extent by the fact that the trails follow the crests of the ridges persistently, there being no room for them adjacent to the streams. On entering the lava-covered region the streams are bounded by more precipitous walls, and where they have not cut through the lava their sides frequently approach the vertical, from base to summit. Some of the creeks from the mountains flow for a mile or more over the basalt, as surface streams, before plunging into a narrow canyon at its head. Between the canyons cut in the lava there are broad, nearly flat remnants of the once widely extended and undissected plateau. These differences may be briefly summarized by stating that in the rocks older than the Columbia River lava the topography is mature, but in the region floored by the lava it is young.

The particular feature in the physiography of the region drained by Clearwater River which is of greatest interest is the relation of the lower portion of the trunk stream to the monoclinal fold which unites the Uniontown Plateau with the Lewiston-Clarkston plateaus. In the portion of its course referred to Clearwater River flows directly along a monoclinal fold, in what may be termed, under a classification of valleys once proposed by J. W. Powell,[1] a monoclinal valley; that is, the rocks in each wall of the valley, as well as beneath its floor, dip in one direction, namely, southward.

On the south side of the valley the rocks are inclined upward, from the position they occupy beneath the Lewiston Plateau, at an angle of perhaps 1 or 2 degrees in the vicinity of Myrtle, which increases westward to the great escarpment overlooking Lewiston, where it is 40 to 50 degrees. Throughout this distance the crest line of the north wall of the valley is nearly level, although rendered irregular by the presence of gulches with salients between; but the south wall, which at the east is about on a level with its companion to the north, gradually declines, and at Lewiston it nearly disappears. The south wall is com-

[1] Exploration of the Colorado River of the West. Washington, 1875, p. 160.

posed of lava sheets which dip southward but soon flatten and pass under the more nearly level Lewiston Plateau, thus forming an elevated rim along the side of Clearwater River Valley. This peculiar feature of a large river apparently excavating a canyon along a steeply sloping mountain side, instead of descending to the adjacent valley, can be explained only on the hypothesis that the course of the river was established before movements in the earth's crust formed the monoclinal fold which it follows. The river has deepened its channel as the rocks beneath it were bent.

The relation of Clearwater River to the fold it follows suggests that before the lava sheets were flexed the river had cut in them a trench sufficiently deep to determine a line of weakness along which a sharp fold was produced when subsequent movement occurred. The greater part of the canyon cutting, however, was after the monoclinal fold was initiated.[1]

RELATION OF THE STREAMS TO GEOLOGIC STRUCTURE.

In the brief account of the canyons of the Nez Perce region which has just been given, references have been made to the manner in which the larger streams cross sloping surfaces diagonally, as in the case of Grande Ronde River, which cuts into the southern portion of the Blue Hills dome, and Salmon River, which sweeps in a great curve into the upraised border of the Camas Prairie but leaves that topographic basin without reaching its lower portion; and also to the fact that Snake River has cut through the Craig Mountain uplift, and again, at the depressed northern border of the Lewiston-Clarkston plateaus, on which its valley broadens and is only about 200 feet deep, it enters a canyon 2,000 feet deep in the Uniontown Plateau. In this same category is to be placed the fact that Clearwater River in its lower course, and Snake River between Lewiston and Alpowa, flow directly along a monoclinal fold in monoclinal valleys.

The important group of observations just summarized shows that the courses of the streams referred to are to a great extent independent of the structure of the rocks in which they have excavated their canyons, and are also equally independent of the larger features in the surface relief, since the inclination of the various plateaus, which are the major physiographic elements, corresponds with the dip of the underlying lava sheets. In order to make this conclusion clearer and more graphic, let us trace in outline the chapter in the history of the Nez Perce region to be read in surface geology and drainage system.

[1] In this connection the idea presents itself that if a broad plateau underlain by horizontally bedded rocks of the nature of, especially, lava sheets, which may be considered as being resistant to deformation by bending, should have a canyon cut in its surface, such a canyon, especially if long and straight, would mark out a line of weakness which would determine where maximum deformation would occur in case the beds should be warped or displaced by a tangential thrust acting at right angles to the course of the canyon; that is, in some instances streams are not only antecedent to structure, but they exert an influence on the structure itself. While the facts in hand do not warrant the unqualified acceptance of this view, they at least awaken a desire to test it by more extended observations.

SALMON RIVER CANYON, SHOWING DETAILS IN WALL.

When the last sheet of Columbia River lava was poured out it formed the surface of a nearly level plateau to the westward of the Bitterroot Mountains, across which the streams from the eastward, such as Snake, Salmon, and Clearwater rivers, had to flow in order to deliver their waters to the ocean. It is probable that lakes were formed on the lava plateau, but this and other phases of the history need not concern us at present. The rivers in time excavated canyons which were deepest near their mouths and were slowly extended upstream. After this work was well under way in the immediate region here considered, movements in the rocks began, which continued for a long time, and perhaps have not yet ceased. These movements produced a deformation of the originally level surface, of the nature of a tilting of broad blocks of the original plateau. These blocks experienced differential movement in reference to one another, and along their borders were in certain instances bent into monoclinal folds, and where the flexures were sharpest breaks occurred. The differential movements of the various blocks went on so slowly in most instances that where the rivers crossed the belts of flexure they were able to deepen or upgrade their channels as rapidly as the surface was deformed. Where the border of a tilted block rose athwart the course of a river a canyon was cut across it, as in the case of Snake River where it crosses the Craig Mountain uplift. In some cases, however, the deformation went on more rapidly than the river could deepen or upgrade its channel, and the stream was turned aside. An illustration of this is furnished by Grande Ronde River, which was turned from the course it has in its upstream portion by the elevation of the Blue Hills dome. The best example of the raising of a wall directly athwart the course of a river, and that, too, the largest river of the region, is furnished by the Clearwater escarpment, which turned Snake River aside at the site of Lewiston. This escarpment, which it will be remembered is the southern border of the nearly level Uniontown Plateau, was formed directly across the course of Snake River, and the maximum displacement occurred at the locality where the river crossed its site. For a portion of the way between Lewiston and Alpowa the Clearwater escarpment, which elsewhere is a monoclinal fold, became a fault. The break here occurred 2 or 3 miles west of Lewiston; but directly in the course of Snake River to the north of Lewiston the rocks in the face of the escarpment as it exists to-day dip southward at angles of from 30 to 50 degrees. The differential movement between the borders of the Uniontown Plateau and the Lewiston-Clarkston plateaus occurred with sufficient rapidity to deflect the river and cause it to flow westward along the break produced by faulting until it could pass about the end of the portion of the belt of disturbance where the movement was greatest. An irregular course was thus established, which the stream was able to maintain as the tilting and depression of the Lewiston-Clarkston plateaus went on. It is possible that Snake River was checked by an uprising of the Clearwater escarpment, and a lobe was formed. That such was the case, however, has not been clearly proved, although certain silt-like deposits on the Clarkston Plateau may have been laid down in such a water body. The deposits referred to have not been carefully examined.

As the deformation of the original lava plateau progressed and the larger streams deepened their channels, their tributaries, situated on rocks that were but slightly disturbed, or strong enough to maintain their rights of way where the movements were greatest, also deepened their channels, owing to the greater velocity given them by the lowering of the master streams into which they discharged and likewise excavated canyons. Most of the smaller streams, however, came into existence after the deformation of the surface was initiated, and were guided by the slopes produced. For example, all of the streams which flow from the Blue Hills to Snake River have courses such as would be determined by the present slope of the surface. These streams, and probably all others flowing away from the Blue Hills, came into existence after that region was upraised into a dome. In a similar way, all of the streams in the central portion of Nez Perce County, which enter either the Snake, the Salmon, or Clearwater River, flow through channels such as would be determined by the inclinations of the present surface and the depth of the master streams to which they are tributary.

The streams of the Nez Perce region may therefore be classed in two groups, in reference to the relation they bear to the structure of the rocks over which they flow: (1) Streams the courses of which were established before the underlying rocks were disturbed from their original horizontal positions, and which may be classed with what geographers term antecedent streams, of which Snake, Grande Ronde, Salmon, and Clearwater rivers are the leading if not the only examples; and (2) streams which came into existence on the slopes produced by deformation, and which are consequent to them and therefore are termed consequent streams, many examples of which might be named, as, for instance, Asotin Creek and its several branches, Lapwai Creek and its principal tributaries, Cottonwood, Lawyers, Little Canyon, and other creeks which drain broad portions of the deformed lava-covered country and are consequent on slopes produced by deformation. There is still another and subordinate class of streams, such as flow down the steep canyon walls, which are consequent on slopes due to erosion.

STREAM TERRACES.

In a previous report[1] the writer has directed attention to the widely distributed and frequently thick gravel desposits in the canyons of both the Cascade and the Rocky Mountain ranges in Washington and

[1] A preliminary paper on the geology of the Cascade Mountains in northern Washington, by I. C. Russell: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 173–184.

Idaho, which were formed after the rivers had excavated their channels to their present depth, but have since been reexcavated, so that in many instances only small remnants of them now remain. Several examples of these gravel deposits belonging to the Pleistocene division of geologic history occur in the Nez Perce region.

Remnants of former flood plains of Snake and Clearwater rivers occur in Lewiston and Clarkston, and may there be studied to advantage. In Lewiston sections of heavy stream-laid gravel are admirably exposed in the bluff which separates the lower portion of the city, which is built principally on the present flood plain of Clearwater River, from an old flood plain, at an elevation of 150 feet above the low-water stage of Snake River, on which the newer portion of the city is situated. The plateau referred to is an abandoned flood plain, and shows that the rivers now flowing past its base at some former period filled their channels from side to side, so as to elevate their beds at least 150 feet above their present summer levels. The plateau on which the newer portion of the city is located is triangular in shape, a mile or more broad, and on its margins facing Snake and Clearwater rivers instructive sections can be seen of the well-worn bowlders, cobblestones, gravel, and sand of which it is composed. As in the case of many flood plains, the last material deposited is a fine sand or silt. On the southern side of the plateau, where it joins the uplands at what was formerly the junction of Snake and Clearwater rivers, there are still higher gravel deposits of the same character, showing that the most conspicuous terrace now remaining was excavated in a higher flood plain, the upper limit of which is indefinite.

At the mouth of Tammany Hollow, nearly opposite Asotin, there is a well-defined gravel bar, built by Snake River, which crosses the mouth of the lateral canyon and at one time formed a dam which caused the waters of Tammany Creek to expand and form a small lake. This bar is, by aneroid measurement, 235 feet above the summer stage of Snake River. Since Snake River cleared out the greater part of its former gravel deposits, Tammany Creek has cut a narrow channel through the obstruction at the mouth of its canyon. The bar referred to, and others similar to it along the course of Snake River, shows that the main stream was at one time overloaded with débris, a large part of which was deposited in its channel, while its small tributaries were not thus loaded and could not fill in their valleys so as to elevate their bottoms at the same rate as did the master stream to which they flowed. The result was that the weak lateral streams were ponded and expanded into lakes. In a similar way lateral canyons which were perhaps without perennial streams were flooded, owing to the expansion of the main stream and the gravel carried into them.

The broad, sloping gravel plain on which Clarkston stands is similar to the gravel plateau in Lewiston, but occupies a less sheltered position in reference to Snake River, and was cut away to a considerable extent as the river deepened its channel after the period of overloading had passed. The gravel beneath Clarkston is situated on the inner or convex side of a river curve, and was left with a sloping surface as the stream migrated eastward. A similar sloping surface covered with fine silt can be seen on the inner curves of many small streams which now meander through nearly level-floored valleys.

Another remnant of the once extensive alluvial deposits along Snake River occurs just above Alpowa, forming a flat-topped terrace 150 feet above its present summer stage. Again, in the canyon of Salmon River, about 5 miles above its mouth, there are, on each side of the canyon, terraces composed of a large variety of well-worn pebbles, which have a surface elevation of 230 feet above the present level of the rivers.

The extreme upper limit of the gravel deposited in the canyon of Snake River, as determined by aneroid measurements, was stated in a previous report[1] to be 360 feet above the low-water stage of the river as it flows at present. This measure is perhaps too liberal, and may have to be reduced. The principal difficulty in determining the exact upper limit of the gravel lies in the fact that it is usually indefinite, and in some places is difficult to discriminate from the gravel derived from sedimentary beds interstratified with the Columbia River lava.

The remnants of the old gravel flood plains just described, taken in connection with similar facts observed over a wide extent of country in Idaho and Washington, furnish clear evidence that the larger canyons of the Nez Perce region, after being excavated to their present depth, were deeply filled with gravel and subsequently were reexcavated. During the last down-cutting remnants of the former flood plains were left in sheltered places, as on the inner sides of sharp bends and at the mouths of small lateral canyons. The changes in conditions which permitted the strong rivers to excavate canyons in the Columbia River lava to a depth of from 2,000 to 4,000 feet, then deposit in them gravel to a depth of at least 230 feet, probably 360 feet, and subsequently reexcavate them and renew the task of deepening the channels in the solid lava, seems to have been principally the overloading of the streams at a certain period in their history. For a long time the swift rivers rising in the mountains were able to carry their loads to the sea or to the larger rivers to which they were tributary, and the friction of the débris thus transported deepened their channels. Next came a period when the rivers had more débris delivered to them in their high-grade, and consequently swift, upper courses than they could transport through their long canyons, and some of it was dropped, thus raising the stream bed and permitting

[1] Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4, pp. 56-57.

the water to flow more rapidly. After a time the overloading ceased, and the streams, with added energy, owing to the higher gradients produced by the partial filling of their channels, were enabled to remove the débris previously deposited. This work has gone on until nearly all of the gravel, sand, etc., formerly laid aside has been carried away, and the rivers in places are down to their beds of solid rock; but in general, as can be seen in Clearwater and Snake rivers for a distance of several miles from their junction, they are still floored with coarse gravel. During high-water stages immense quantities of this bottom load are moved downstream, to such an extent in the case of Clearwater River as to show the futility of attempting to deepen that river in order to make it navigable.

The causes which led to the overloading of the rivers flowing from the mountains of Washington, Idaho, etc., during a certain period in their history, have been discussed in the previous report referred to, and can not be considered at length here. It will suffice to say that the main reason seems to have been the climatic change which brought on the Glacial epoch. Precipitation is thought to have increased at that time beyond what it was before or has been since; the mean annual temperature was lowered, and glaciers existed in the mountains. These agencies would tend to increase the loads brought by swift tributaries to the trunk streams, but would also increase the volumes of the rivers and consequently their velocities and power to transport. If the increase in load, however, was in a greater ratio than the increase in transporting power, the stream beds would be upgraded; and, according to the best interpretation of the facts that can now be made, this seems to have been the case.

LANDSLIDE TOPOGRAPHY.

Rock masses which have descended as landslides form so important a feature of the canyon walls in the Nez Perce region and have so intimate a connection with the search for lignite deposits and the question of water supply, that their nature needs to be well understood.

The distinctions between landslides, displaced rock masses, rock avalanches, mud flows, snow avalanches, etc., have been pointed out in previous reports,[1] and seemingly but little needs to be said at present in this connection, except what applies directly to the region under consideration.

A landslide is understood to be the breaking away of one or more large blocks of rock, or of a quantity of loose material, from a slope,

[1] A geological reconnoissance in central Washington, by I. C. Russell: Bull. U. S. Geol. Survey No. 108, pp. 47–49, Pls. III, IV, and V.

Topographic features due to landslides, by I. C. Russell: Pop. Sci. Monthly, Vol. LIII, Aug., 1898, pp. 480–489.

A preliminary paper on the geology of the Cascade Mountains in northern Washington, by I. C. Russell: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 193–200.

and its quick descent into an adjacent depression. The landslides in the Nez Perce region, so far as noted, are confined to the walls of canyons in the Columbia River lava. The most favorable conditions for their occurrence are where canyons have been cut in thick sheets of lava, especially where the lava is traversed by vertical joints so as to be columnar, and rests on beds of clay, sand, gravel, volcanic dust, lapilli, etc. These conditions are rendered still more favorable when a series of lava sheets with included layers of soft material are inclined toward the stream which has excavated a canyon in them. Under such circumstances, blocks of lava are likely to break away from the cliffs and to descend the slope below, perhaps even reach the stream at its base. Where a landslide comes to rest, it is usually found that the surface of the fallen block or of the mass of loose material which has descended has a slope toward the cliff from which it fell. This backward slope is frequently so pronounced that basins are formed, which under favorable climatic conditions become swamps or lakes, but in dry regions are more frequently grassy hollows, or perhaps are overgrown with bushes and trees while the drier slopes adjacent are bare. From recent landslides which retain their characteristic forms unimpaired there are in many regions, as has been described in the reports just cited, illustrations of a complete series of gradations to areas which are nearly level although having a somewhat undulating topography produced by the weathering of ancient landslides. Thus there is a series of changes in relief, due to landslides, which may be included under the term *landslide topography.* Prefixes denoting age might be used in connection with this term, to indicate the extent to which the fallen masses have yielded to weathering and erosion.

In the Nez Perce region landslides have occurred on the sides of all of the larger and many of the smaller canyons excavated in the Columbia River lava, in places frequently a score or more of miles in length, and on each side of a stream they can be counted by the hundreds in a single mile. Only a few of these many localities, however, can be referred to in this paper.

On the north side of Grande Ronde River where it cuts into the Blue Hills uplift, the conditions are unusually favorable for landslides, as the lava sheets are inclined downward toward the river and have beds of sand, clay, lignite, and volcanic dust interbedded with them. Over extensive areas, measuring in fact many square miles, the canyon wall is encumbered by heaps and ridges of material which has descended from above. From the river's bank to the rim rock which defines the border of the canyon at the top of the Blue Hills, a distance of 7 or 8 miles, there is, except on the salients, a succession of fallen blocks, some of them at least a half mile in length, which frequently have undrained basins on their gently sloping northern sides. The characteristics of young landslide topography are there well displayed, although most of the fallen masses have been in their present position long enough to be covered with a deep soil, except on the precipitous southern slopes, and are overgrown with magnificent forest trees. On the south side of the canyon the precipices are steep, in places nearly vertical for 2,000 feet above the river, and landslides are rare. The reason for this is that the lava sheets dip to the southward, or away from the river, and the tendency for blocks to fall is far less than on the opposite wall of the canyon. Near the summit of the southern wall there is a bed of soft material, reported to contain lignite, underlying the summit sheet of lava. This sheet of soft material has caused the border of the lava layer above it to recede more rapidly than the margins of the layer beneath, and a terrace has resulted, which in many places has on its surface landslides and conspicuous talus slopes.

In the walls of the canyon of Snake River the lava sheets are nearly horizontal, so far, at least, as a slope toward or from the river is concerned, and landslides are rare. So far as known there is but one bed of sedimentary material between the lava sheets that have been cut by Snake River. If two such soft beds are present, as is the case on Asotin Creek, they influence the topography in essentially the same way that a single sheet would, and for that reason the conditions are unfavorable for the development of characteristic landslide topography on a large scale. As previously stated, the sheet of soft material is at a depth of 200 to 220 feet, and, as on the south side of Grande Ronde River, has given origin to a terrace, which may be traced for a score or more of miles along the walls of the canyon below the mouth of Grande Ronde River and into many of the smaller tributary canyons and gulches. This terrace is almost everywhere deeply covered with fallen débris, and frequently exhibits the characteristic features of landslide topography. A typical example of the conditions just referred to can be seen on the east side of Snake River between Lewiston and the mouth of Tammany Hollow, where the dip of the lava sheets beneath the Lewiston and Clarkston plateaus brings the soft layer which gives rise to the landslides down to within a few hundred feet of the level of the river. On the opposite side of the river is Swallow Rock, a displaced block of lava of unusually large size and massiveness, the surface of which slopes steeply downward toward the cliff from which it broke away.

Landslides are abundant throughout the course of Clearwater River and its principal tributaries where they have cut canyons in the lava, and are especially numerous in the vicinity of Kamiah, where they impress their peculiar features on the scenery of the bluffs, which for several miles face the river on each side. The lava sheets are there nearly horizontal, but at a depth of about 800 feet, and contain an unusually thick layer of friable sandstone which has caused almost innumerable landslides. The exceptional breadth of this portion of the canyon, which is a beautiful vale 2 or 3 miles wide, with pleasingly diversified, tree-clothed bordering bluffs 1,800 feet high, is due to the widening of the once narrow gorge by the falling of its walls. The irregularities which landslides give to the escarpments, and the subdued effect of their slopes from the same cause, are illustrated in Pl. IX, *A*, a view of the eastern side of Kamiah Vale near the village from which it derives its name.

In the description on page 39, of the occurrence of lignite and its associated sedimentary beds near Orofino and along the creek of the same name, mention was made of the numerous displaced rock masses in that region. The borders of the canyon of Orofino Creek not only owe the minor features of their topography to landslides, but the character of the entire canyon has been modified by them. There is an outer canyon, bordered by cliffs and steep talus slopes, from 700 to 800 feet high. At the base of these rugged walls, in which the edges of horizontal sheets of lava appear, there is, on each side of the creek, an irregular terrace-like belt a mile or more wide, the surface of which shows the ridges, hills, and basins characteristic of landslide topography. This broken country is from 400 to 500 feet above the stream which flows through it in a steep-sided inner canyon. At a few localities the landslides have obstructed the river and caused it to flow swiftly through narrow defiles. In one of these rapids, about 6 miles from the mouth of the creek, the water descends 92 feet in a distance of about 500 feet.

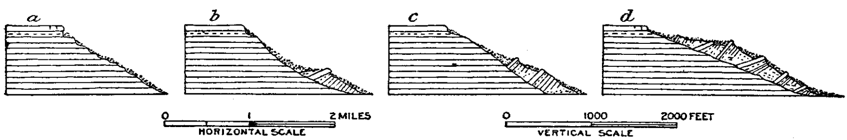


FIG. 4.—Sections of cliffs with landslides.

On the North Fork of Clearwater River, opposite the mouth of Elk Creek, the canyon wall exhibits the characteristic feature that landslides give to precipitous escarpments, and the cause of the numerous slides is revealed by the presence of sand and lignite in the fallen masses. It is stated that at this locality some movement in the displaced blocks near the river has been recognized in recent years.

It is perhaps unnecessary to attempt to give additional examples of the changes produced in canyons by the falling of their walls, for they are so numerous that once the meaning of the ridges and basins so common on steep slopes is suggested a person can readily interpret them for himself. The manner in which the faces of cliffs break away and the displaced masses descend the slopes below is illustrated in a general way in fig. 4. At *a* the nature of the canyon walls where not modified by landslides is indicated, the stratification being horizontal and the lava sheets separated in a single instance by a sedimentary bed; at *b* a single block has fallen; at *c* two slides have descended; and at *d* an attempt has been made to indicate roughly the nature of the canyon walls where many slides have occurred and where much loose material encumbers the slope. The last figure (*d*) illustrates in a rude way the condition of the precipitous slope throughout the greater part of the lava-covered portion of the Nez Perce region. The most noticeable feature in a landslide that has come to rest is the slope of the surface of the fallen mass toward the cliff from which it broke away. This characteristic backward slope is pronounced not only in solid blocks which still retain their stratification, but in masses of dislodged fragments, and it gives origin to basins which, as already noted, are frequently transformed into lakes and swamps.

The back slope in the landslides in the Columbia River lava is frequently from 3 to 5 degrees, but may reach 20 or more degrees. This peculiar feature seems to be due to the fact that the friction of the sliding mass causes its forward portion at the base to be retarded so that it is overridden by the material in its rear. Where the base of the displaced portion is of soft material it is pressed outward to the front of the descending mass and is sheared and overthrust so as to become thickened. For this reason the thickness of the soft layers in the fallen masses is deceptive and might lead to erroneous conclusions regarding, for instance, the importance of a lignite bed.

The general reason that landslides are more frequent and usually of larger size on Clearwater River and its main tributaries than along Snake River is that the soft beds to which the landslides are largely due are thicker and more numerous the nearer one approaches the mountains from which the streams brought débris and deposited it on the Columbia River lava. The beds of water-laid débris are of the nature of wedges, which are not only most numerous but thickest and coarsest at the margin of the lava-covered country adjacent to uplands, and thin out and become finer as its central region is approached. These stream-laid deposits may merge with lacustral sediments, in which event other conditions favoring landslides would result. In addition to the presence of beds of soft material between the lava sheets, conditions favoring the occurrence of landslides are produced, as already explained, where the sheets have been tilted.

So constant is the relation between landslides and the presence of sedimentary beds or sheets of volcanic dust and lapilli in the Columbia River lava, particularly where the sheets are horizontal, that the landslides furnish an indication of the extent and thickness of the soft layers.

LAKE WAHA.

The only water body in the Nez Perce region worthy to be termed a lake is 18 miles, in a direct line, southeast of Lewiston and at the base of the northeastward-facing escarpment of Craig Mountain. The lake is not only an exceptional feature in the deeply sculptured land where it occurs, but it is surrounded by attractive scenery and is charming in many ways. It occupies a steep-sided valley eroded by Waha Creek, which has been obstructed by landslides and has an area, as determined by surveys made by Mr. E. H. Libby, president and general manager of the Lewiston Water and Power Company, of approximately 100 acres, and a maximum depth of 90 feet; the average depth is about 60 feet. It has no surface outlet, but its waters escape through the great mass of broken stones which retain it and comes to the surface in springs of large volume. The main landslide which obstructs the valley came from the precipitous slope, now covered with forest, to the southwest of the northern border of the lake, and still presents the characteristics of what may be termed a landslide scar. At the base of this steep slope there is a narrow, curving, trench-like depression, convex to the north, on which side it is bordered by the back slope of the mass that fell. This trench has an irregular bottom; and although it is probably at no point more than 20 feet above the lake's surface, and is open at both ends, it never was occupied as a channel of discharge for the lake waters. The surface of the fallen mass, which occupies perhaps 30 to 40 acres, is irregular and hilly, with elevations that rise from 100 to 150 feet above the lake's surface. It contains several basins, two of which are occupied by ponds fed by springs and by percolation. Middle Lake, about 1 acre in area, is, by aneroid measurement, 20 feet lower than Lake Waha; the lowest point on its rim, where a wagon road now traverses it, is 60 feet above its surface and 200 feet above the surface of Mud Lake, which occupies an adjoining basin. The last-named lake has an estimated area of 2 acres, and, like its companion, is without surface outlet.

The lava sheets which form the steep slope of Craig Mountain in the vicinity of Waha dip northward at a steep angle, and have at least one bed of gravel interstratified with them. The presence of a bed of volcanic dust or of clay charged with that material, although nowhere exposed, is indicated by the color of the water in the largest lake. A peculiarity of springs that come from beds of volcanic dust is that their waters are milky or opalescent in appearance, due to the excessively small particles of volcanic glass held in suspension. The waters of Lake Waha have this appearance, and probably are supplied in part by springs issuing from deposits of volcanic dust. The dip of the lava sheets in the escarpment rising to the south and southwest of the lake is toward the valley it occupies, which, with the presence of sedimentary beds, and probably also of sheets of volcanic dust, is favorable to the occurrence of landslides. The only exceptional feature connected with the landslides at this locality is that they descended into a narrow valley, so as to completely dam it. The waters rose above the dam, but as it is composed mainly if not entirely of rock fragments, an escape by percolation was established before a surface outlet was reached. On account of the failure of the water to overflow, it could not cut down a channel so as to drain the lake, as has occurred in other similar instances. The lake has thus been preserved, and is a typical illustration of a class of water bodies held by landslides. The larger lake differs from the smaller ones near it in that it is retained by a landslide which descended into a previously eroded valley, while the smaller lakes are of the same type as hundreds of lakelets, swamps, and waterless depressions on the surface of fallen rock masses, which may be termed true landslide basins.

The largest spring fed by Lake Waha discharges about 15 cubic feet of water per second, which is now conducted into a ditch and used for irrigation. A fall of several hundred feet could be made available for this water, and it might then be used for power; in fact, a small mill was formerly turned by it. This and other plans for utilizing the water—among them, the supplying of Lewiston—have been considered by engineers. The main difficulties developed by the investigations are the loose condition of the natural dam and the precipitous character of the borders of the lake, which render it impracticable to greatly increase its size.

TOPOGRAPHY OF THE LEVEL PLATEAUS.

There are certain features in the relief of the level plateaus underlain by the Columbia River lava, such, for example, as the Uniontown Plateau and the country in the vicinity of Pullman, Garfield, and elsewhere in Washington, which merit attention. The plateaus referred to, it will be remembered, are covered with a sheet of residual soil, usually from 50 to 100 or more feet thick, and are not smooth plains, but nearly everywhere exhibit well-marked variations in relief. In traveling over them one crosses a seemingly endless succession of hills and valleys which have differential elevations of, in general, from 50 to 150 or 200 feet. The topography is undulating, the hills forming convex elevations with steep sides, and the valleys forming concave basins. A marked feature is the absence or extreme rarity of basins without outlets, such as sinkholes. It is evident from the gradients of the valleys, notwithstanding they are gentle, that if rain water could be held at the surface of the soil a complete system of streams would be formed and lakes would be rare or entirely absent. The valleys, however, in cross section have rounded bottoms, and in most instances are without stream channels. The convex slopes of the hills merge by insensible gradations into the concave curves of the troughs between them. The hills and vales alike are composed of fine, rich soil, and no rock fragments attract attention, except in rare instances, where the hills are unusually precipitous.

The character of the relief, however, may perhaps be indicated more clearly by saying that it is such as stream erosion gives to regions composed of soft rocks where weathering is rapid, but it has lost all of the small features due to the work of creeks, brooks, and rills. The stream courses have long been abandoned, and the movement of the soil on the bordering slopes, the beating of rain, the influences of frost, vegetation, etc., have subdued and to a great extent obliterated the minor inequalities due to stream erosion. It is evident from the nature of the larger elements in the topography, especially from the gradients of the shallow valleys, which are such as would furnish complete drainage in case water could be held at the surface, that streams at one time meandered over these nearly level plateaus. The valleys, however, have long been abandoned as avenues of drainage, and may be said to be slowly crumbling to ruin. One reason for this change, but perhaps not the most important, seems to be that rock disintegration and decay have been in excess of transportation, and such a depth of porous soil and subsoil has been produced that the rain water is entirely absorbed by percolation and evaporation, thus robbing it of the power to corrade. With the increase in depth of residual material there very likely was a decrease in rainfall which hastened the disappearance of surface streams.

As already stated, the sedimentary layers and beds of volcanic dust between the sheets of Columbia River lava in numerous instances contain abundant impressions of the leaves of Tertiary plants, and it seems safe to assume that the last and highest lava sheet was poured out before the close of that period. This being so, the lava plateaus have been exposed to the atmosphere throughout Pleistocene and Recent times, and have experienced the climatic changes which gave character to the Glacial epoch. In harmony with this conclusion is the fact that the surfaces of the plateaus have been exposed to the air throughout the immense length of time that witnessed the excavation of the neighboring canyons. There is abundant evidence to show that glaciers did not reach the Nez Perce region or the Palouse country, although they did exist during the Glacial epoch on the Cascade Mountains to the west and on the Rocky Mountain ranges to the east. It may reasonably be assumed that the atmospheric changes which gave origin to extensive glaciers on the mountains gave to the intervening lowlands a cold and humid climate. Since the glaciers disappeared or have been greatly reduced in size, the climate of the lava plateaus has become warmer and less humid. In a general way, then, it seems safe to refer the erosion of the level lava plateaus which gave them their moderately rough surfaces to the Glacial epoch, when precipitation was greater than now. The decrease in the size of the streams and the disappearance of all but the larger ones may be correlated with the climatic changes which followed the Glacial epoch and which still continue. With the decrease in the volume of the streams rock decay continued, and the depth of fine soil has become so great that all of the rainfall, although now amounting to probably 30 or 35 inches a year on the higher plateaus, is absorbed, and mechanical erosion is nil.

SOLUTION BASINS.

Among the minor physiographic features of the Nez Perce region should be noted certain shallow depressions, without outlets, in the surfaces of the plateau remnants between the streams which have dissected the Columbia River lava. In some instances these depressions hold water during the rainy season and become transformed into small lakes; but in summer their beds are dry, and perhaps are coated with an incrustation of alkaline salts or are traversed by a network of shrinkage cracks. Shallow basins of this character occur on the level plateau about 4 miles west of Waha, and can be seen to advantage from the neighboring hills. In similar situations on the Clarkston Plateau, near where it merges with the northeast slope of the Blue Hills, are other shallow basins a few rods across, the bottoms of which are grass covered and do not retain water so as to form lakelets. In one of these basins a few trees are growing, but the surrounding plateau is a prairie. On the Camas Prairie also, to the southwest of Denver, several small sheets of water can be seen from Cottonwood Butte and other neighboring elevations. While several of these are artificial ponds, there is at least one natural lake in a depression in the generally level surface. Other shallow basins of a similar nature, which are wet and swampy during the winter or are grass covered and possibly have trees growing in them, will be recalled by those who are familar with the region referred to.

These basins are of the nature of the sinkholes or shallow depressions common in limestone regions, and owe their existence mainly to the dissolution of the rocks through the agency of rain water, which escapes through fissures or other openings in their floors. After a depression has been produced by the enlarging of a fissure, the subterranean channels may become closed, by the washing into them of the surface soil, so as to prevent the downward escape of water, in which case the sinkhole will be changed to a lake. In humid regions such lakes are frequently perennial, but where the rainfall is small, or where there is an alternation of wet and dry seasons, they are likely to be ephemeral.

It should be remembered that the solution basins referred to occur on flat areas, and they should not be confounded with the somewhat similar and much more common basins produced by landslides.

TORRENT-BUILT LEVEES.

In the Nez Perce region, as in many countries having a small mean annual rainfall, there are occasional torrential rains, locally termed cloudbursts. These occur at long intervals, and are local in their extent. Frequently they leave records of their occurrence which endure for many years. Among the most conspicuous changes produced by the rush of water down steep declivities which had previously become covered with a sheet of residual soil and angular rock fragments, are alluvial cones and parallel ridges formed of angular stones left on the sides of the ephemeral torrents. The alluvial cones frequently have channels on their surfaces, showing that the water flowed over them in streams which at times bifurcated, or abandoned well-formed channels with raised borders and built new ones. The most striking results, however, are where streams originated on declivities of 10 to 15 and in places 20 to 30 degrees angle, and built parallel embankments of angular stones from a few inches to 2 or 3 feet in height. In these instances the swift streams were overloaded with coarse material, which was deposited partly on their bottoms but principally on their borders, forming levees which tended to confine the water to narrow channels. A typical example of these torrent-built levees was observed on the sides of the canyon of Captain John Creek, where in 1897 there occurred a local storm which gave birth to streams that continued less than an hour, on slopes of 20 to 35 degrees angle. The channels of these streams are still clearly defined, in fact are almost as fresh as when the waters left them. Their width varies, but in general they are from 1 to 3 feet across, and the sharp-crested ridges of stones piled up on their sides are from 24 to 30 inches high, with a width at the base but little greater than their height. The stones in the ridges are angular, and are of all sizes up to 5 inches (in some instances 8 inches) in diameter. In some cases a torrent broke through one of its embankments and sent off a distributary, which also built a well-defined pair of levees of angular stones. These parallel ridges are of the same general character as the levees of alluvial-depositing rivers, as, for example, the Mississippi in its lower course, but are sharp crested and are formed of angular stones with large spaces between them. The temporary torrents were evidently overloaded with débris, except in their swift central portions. As soon as the water which had gathered into a stream began to spread, it lost velocity as well as depth; the stones previously swept along were dropped, and an embankment was formed which tended to confine the current within narrow limits and thus enable it to build up its embankments. The small levees referred to occur on slopes where previously there were no stream channels. In the natural waterways the floods were high during the storm referred to. Captain John Creek, which in summer is a brook across which one can step, increased in a few minutes to a roaring flood charged with the branches and trunks of trees and thick with mud from 8 to 10 feet deep, sweeping along large bowlders in its path. The previously formed flood plain, which was under cultivation in at least one locality, was largely washed away and new deposits of coarse gravel were laid down. Similar floods have occurred in neighboring canyons, as has been noted in the case of Asotin Creek, and torrent-built levees like those described can be seen on some of the steep slopes along the course of Grande Ronde River.

In Part II of this paper, published as Water-Supply and Irrigation Paper No. 54, will be found discussions of the water supply and the economic geology of the Nez Perce region, also tables of elevations in the county (Appendix A), and notes concerning Portland cement (Appendix B).

[For index, see end of Part II, Water-Supply Paper No. 54.]

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