DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

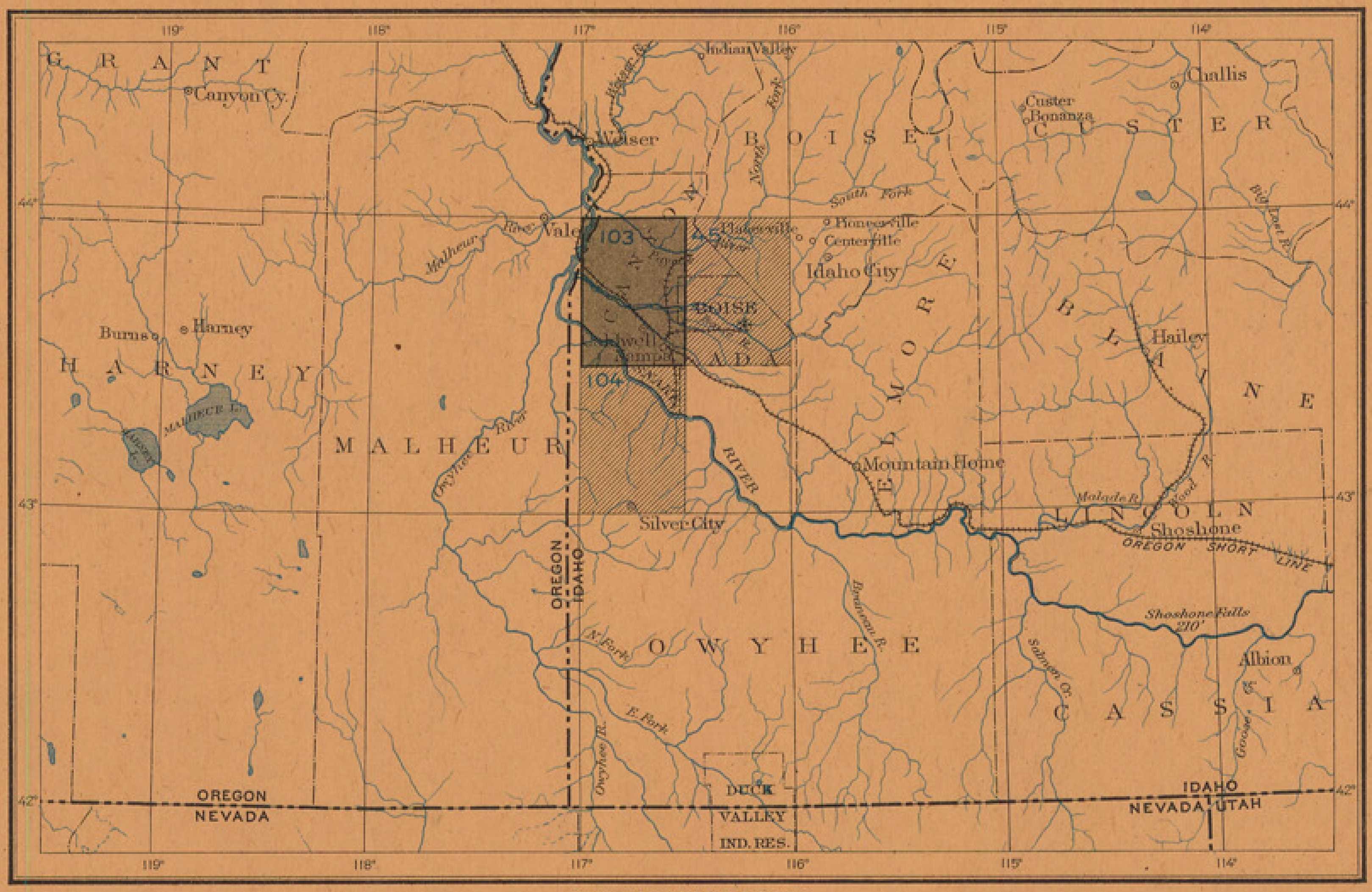
OF THE

UNITED STATES

NAMPA FOLIO

IDAHO-OREGON

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE NAMPA FOLIO

AREA OF OTHER PUBLISHED FOLIOS

CONTENTS

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NO. 103

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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER

1904

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

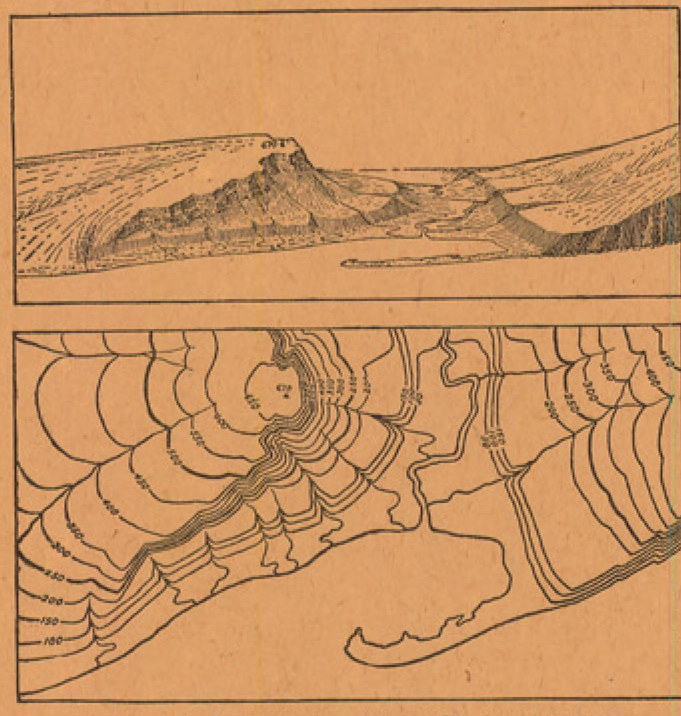


FIG. 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply, forming a precipice. Contrasted with this precipice is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. These relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The altitudinal space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire year the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles in English inches, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land, and the structure sections show their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. In smaller portion the materials are carried in solution, and the deposits are then called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind; and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

(Continued on third page of cover.)

DESCRIPTION OF THE NAMPA QUADRANGLE

By Waldemar Lindgren and N. F. Drake.

GEOGRAPHY.

Location and area. — The Nampa quadrangle lies between meridians 116° 30′ and 117° west longitude and parallels 43° 30′ and 44° north latitude. It is 34.5 miles long and 25.1 miles wide, and has an area of 863.82 square miles. The quadrangle embraces a large part of Canyon County, Idaho, and a small fraction of Ada County, while the southwest corner is occupied by a portion of Owyhee County. A few square miles of Malheur County, Oreg., are included in the northwest corner.

Relief.—The Nampa quadrangle is situated near the lower end of the great Snake River Valley, which here is bordered by the Boise Mountains on the north and the Owyhee Range on the south. The very lowest foothills of the latter lie in the southwest corner, while the northeast corner does not quite reach the corresponding foothills of the Boise Mountains. The width of the valley here is between 35 and 45 miles. The highest elevations are naturally found in these foothills; they reach 3600 feet in the southwest and 3400 in the northeast corner. The lowest elevation is found in the northwest corner, where Snake River leaves the quadrangle, and is approximately 2140 feet. Flat relief characterizes the whole quadrangle. Flood plains 2 to 4 miles wide, bordered by broad terraces, cross it along Payette, Boise, and Snake rivers. These flood plains and terraces are separated by gently rolling complexes of hills or dissected low mesas. In places the higher lands are sharply eroded, gulches and bluffy drainage borders remaining as secondary features. The southern half of the quadrangle has the flatter relief, while the divide between Boise and Payette rivers rises 200 to 600 feet above the stream, and the hills north of the Payette and near Emmett attain an elevation of 1000 feet above the river. The main complex of hills between the Boise and the Payette forms a sloping plateau gradually descending westward from an elevation of 3100 to 2750 feet, until it abruptly drops off toward Snake River. A broad, low ridge separates Boise and Snake rivers, having a comparatively steep slope southward and a more gentle descent toward Boise River.

Drainage.—The main watercourse is Snake River, which flows across the southwest corner of the quadrangle and again enters it near the northwest corner. Snake River, as is well known, is the largest affluent of Columbia River; it has a drainage area of about 22,600 square miles and carries a large volume of water in a channel which usually is deep and well defined. A short distance south of the Nampa quadrangle it emerges from a canyon cut about 700 feet in the lake beds and the intercalated basalt flows. This canyon, which is 220 miles long, begins below American Falls, where the Oregon Short Line crosses the river. In the southwest corner of this quadrangle the river still flows in a well-defined channel and is apparently eroding its bed. Along this part of its course the bottom lands are of slight extent and the course is relatively straight. The grade here is approximately 5 feet to the mile. The nearest point at which the volume of water has been measured is at Montgomery Ferry, 175 miles east-southeast of Nampa, and there the river carries considerably less water than in the Nampa quadrangle. The maximum flow at Montgomery Ferry for the year 1899 was 29,200 second-feet, in June, while the minimum, 5400 second-feet, was measured in March.

Below the junction with the Boise the narrow valley widens to a well-defined flood plain, reaching to a point 10 miles below Weiser, where the great canyon of Snake River begins. In this distance the river receives five important tributaries, the Boise, the Owyhee, the Payette, the Weiser, and the Malheur. The river grade in this valley is less than 2 feet to the mile.

Boise River, a large tributary of the Snake, joins the latter just beyond the western boundary of the quadrangle. It drains 2500 square miles, embracing much of the mountainous region of central Idaho. In the Boise quadrangle, adjoining the Nampa quadrangle on the east, the river emerges from a deep granite canyon and, turning to the northwest, continues to Snake River across a broad alluvial valley of sediments brought down from its upper watershed. The river banks are usually but 1 to 2 feet above the river level, and the stream swings in frequent meanders across the wide flood plains down a grade of 10 feet to the mile. The quantity of water measured at the mouth of the canyon varied in 1899 between a maximum of 12,200 second-feet, in June, to a minimum of 1150 second-feet, in September, the average flow being 4000 second-feet. In 1895 the amount varied from 916 second-feet in December to 6026 second-feet in May.

In general position, direction, and grade Payette River is entirely similar to the Boise. Like the latter, it has an extensive watershed in the central mountain regions of Idaho. It flows across the northeastern part of the Nampa quadrangle and joins the Snake at the town of Payette, a few miles north of the northern boundary line, in the Weiser quadrangle. In 1895 its mean flow was 988 second-feet in November and 13,137 second-feet in May. Since that date no measurements have been made. By comparing the data it will be seen that Payette River ordinarily carries a considerably greater quantity of water than the Boise, and that its flow is more regular.

Besides these three streams there is practically no watercourse which carries permanent water, except, possibly, Succor Creek, which enters Snake River from the southwestern side. All the rest are either dry gulches or contain water only during the wet season.

Climate.—Snake River Valley is entirely in the arid belt and its climate and vegetation are closely allied to those of the Great Basin. The Pacific meteorologic influences make themselves strongly felt, so that the climate of the valley may be characterized as comparatively mild. The precipitation is somewhat larger than in the Great Basin. In the valleys the temperature may exceed 100° F. for a few days in summer; in winter the mercury rarely sinks to 0° F., though occasional invasions of cold waves from the north may drive it down to —27° F. This, however, happens very rarely. At Boise the mean annual temperature ranges from 50° to 53° F. The winds are generally southwesterly and seldom very strong, but they often carry great quantities of dust.

The normal rainfall at Nampa is reported to be 10.06 inches, but this average does not cover many years. Most of the rain falls between September 1 and June 1 and is fairly well distributed through these months. During the summer months there is scarcely any precipitation. In ordinary winters but little snow falls in the valley and it does not remain long on the ground.

Vegetation.—The vegetation is, on the whole, very scanty and the entire quadrangle might be briefly characterized as a sagebrush desert. Along the river bottoms of the Boise and the Payette cottonwoods, alders, and aspens grow, and the fact that the water stands within a short distance of the surface makes irrigation in many places unnecessary. Snake River, flowing in a deeper bed, is not bordered by trees, and the fringe of grasses is confined to the immediate vicinity of the stream bed. The river terraces and flats are covered by a luxuriant growth of sagebrush. The higher hills and dissected mesas are exceedingly barren; white lake beds appear for long distances, bright in the sunlight and only occasionally half hidden by scanty desert brush.

Culture.—The population of Canyon County, which occupies the greater part of the quadrangle, was 3143 in 1890, and 3951 in 1900. The Oregon Short Line traverses the quadrangle diagonally from southeast to northwest. On this railroad are located the towns of Nampa and Caldwell, the latter being the county seat of Canyon County. Smaller towns or settlements are Emmett, Falks Store, and New Plymouth on the Payette, and Middleton and Parma on the Boise.

A little gold placer mining is done along the principal streams, and the hilly lands separating the rivers afford a somewhat scant range for stock, but the principal industry is agriculture. Naturally the agricultural lands are the bottoms and the terraces bordering the rivers. On the flood plains of Boise and Payette rivers there is, as stated above, a natural subirrigation that keeps vegetation growing and in places makes good grazing and forest lands without care. In some places along Willow Creek the underground water provides a similar subirrigation, so that wheat, corn, and fruit trees are grown without artificial watering. With these exceptions the agricultural lands of the quadrangle must be irrigated.

GENERAL GEOLOGY.

GEOLOGIC HISTORY.

Before a detailed description of the formations is given it is desirable to present a brief review of the principal events that have taken place in the geologic history of the Snake River Valley.

The present valley stretches across the whole width of southern Idaho in a broad curve that opens toward the north and has a radius of about 160 miles. The length of the valley from the base of the Teton Mountains in Wyoming to near Weiser, where the river enters a deep and narrow canyon, is over 400 miles, and its width ranges from 35 to 125 miles. The mountains of central Idaho clearly define the limits of this valley on the north, while its southern border in places merges into the lava plains and Quaternary silted valleys that separate the desert ranges of southern Idaho. For a long distance below Weiser, Snake River has cut a very deep and often very abrupt canyon through older rock, which usually is referred to as the great Snake River Canyon. This continues to a point above Lewiston, whence the river pursues its way to its junction with the Columbia in a trench of lesser depth, cut in lava of early Tertiary age—the Columbia River lava.

The old Snake River Valley.—During early Tertiary time the valley must have formed a broad and deep depression, north of which the mountains of central Idaho rose with an abrupt scarp, very probably due to faulting. Toward the south rose narrow, isolated mountains, like the Owyhee Range, with abrupt, deeply eroded outlines and with the general trend and character of the desert ranges of the Great Basin, of which, in fact, they are the most northerly outliers. The whole indicates an early Tertiary or pre-Tertiary fault differentiating the central Idaho mass from the area of fractured and dislocated blocks lying farther south. Both the northern mass and the southern ranges were of granite, to which, according to observations made on Wood River and in the Blue Mountains,[1] a post-Carboniferous and most probably post-Triassic age should be ascribed. From analogy with other similar granite areas in Montana and California this intrusion may very likely be assigned to the Cretaceous period. No lava flows had yet covered the eroded flanks of the granite mountains. The main rivers of central Idaho, such as the Boise and the Payette, had already been developed and had eroded their canyons to a depth as great as or greater than their beds of to-day. That this deep valley had an outlet to the sea seems probable from the fact that in its great canyon below Lewiston the Snake runs for long distances over basaltic bed rock and that its walls consist largely of flows of the Columbia River lava. This being so, it probably follows that a large part of this region has been depressed since the eruption of the lava, for the depth of the valley sediments near Weiser (elevation, 2100 feet), as proved by borings, is more than 1200 feet. Early Tertiary time, just before the deposition of the lake beds, was a period of active erosion and but little sedimentation, and even assuming that the above figure represents the deepest point of the valley (which is not probable) it would place the bottom only 1000 feet above sea level.

[1] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900; and Twenty-second Ann. Rept., pt. 2, 1901.

First lava flows.—At some time during the earliest part of the Tertiary great changes took place. The flanks of the Owyhee Range, the western part of the Boise Mountains, and the Blue Mountains became flooded by lavas, at first by diabasic basalts and rhyolite flows of limited extent, then by basaltic outbursts of immense volume. These basalts are usually referred to as the Columbia River lava, and the bulk of them has been considered as of Miocene age. As most of the older basalts in this region antedate the lake beds, and as the older lake beds have been recently redetermined as Eocene, it would follow that a large part of the Columbia River lava in this portion of Idaho is of early Eocene age.

Earlier lake epoch.—The effect of the accumulation of these masses of lava was a damming of the upper drainage basin of Snake River. Our knowledge of this region is not yet extensive enough to enable us to decide just where this barrier was thrown across the older drainage lines, whether at Deschutes Gap or across an old and deep depression approximately following the present great canyon. At all events, a great interior basin was formed and rapidly filled with sediments from the central granite area of Idaho. While the outpouring of the main mass of lava evidently must have preceded the deposition of the lake beds, the eruptions continued during the earlier part of their accumulation, for tuffs and basalt flows are intercalated with the lower part of the lake beds. In the lake beds, especially near the shore lines, in bays and basins, abundant plant remains are found, which were first determined by Dr. Knowlton as of late Miocene age. A revision of the material has lately led him to consider them as Eocene and as equivalent to the Bridge Creek beds of the John Day Basin in Oregon. The flora gives evidence of a moist and warm climate.

Until the whole region is studied in greater detail it will not be possible to indicate with certainty the exact contour of the lake. Along Boise Ridge the lake beds reach an elevation of 4600 feet; at the mouth of Boise Canyon they rest against the granite at an elevation of 4100 feet; on the western side of the Owyhee Range they lie at 5400 or 5500 feet, and on the eastern slope of the same range at 4200 feet. In many places, of course, erosion has carried away the highest beds, but it seems probable that slow crust movements have deformed the once horizontal line of highest lake deposits. A small remnant of waterlaid (Eocene?) deposits containing leaves of *Sequoia angustifolia* has been found on the slope of Wood River Valley, 100 miles east of Boise, at elevations up to 6900 feet. This deposit seems to belong to the Payette lake beds, and if so confirms the theory of considerable crust movements, consisting of a gradual uplift of the eastern part of the valley. Within the central mountain mass and not far from the border of the Eocene lake smaller valleys are often found—such as the Idaho Basin in Idaho, the Mormon Basin and Rye Valley in Oregon—which clearly represent local depressions outlined by fault lines and which are usually filled with lacustrine sediments.

These sediments, of early Tertiary age, have been called the Payette formation, and because of its plant remains this formation is one of the few in this region whose age can be determined with a fair degree of certainty.

Erosion epoch.—Given a moist climate and no further orographic change, the lake could not long remain a closed basin. An outlet was formed along the line of the present great Snake River Canyon. The reasons determining this line of drainage across elevations that in places now exceed those of the highest known shores of the lake in this vicinity can not, at this stage of our knowledge, be accurately stated. It is probable, however, that the area through which the great canyon runs has been subjected to gradual uplift or warping since the river's course was established, and that erosion has kept pace with the uplift. If so, Snake River below Huntington is of antecedent character.

The erosion of the canyon was most energetic, and during Miocene time a depth of from 2000 to 4000 feet was attained. The lake was drained, a large part of its deposits carried away, and the tributary rivers, prominent among which is the Boise, had scoured their old canyons to about the same depth that they have to-day. As the lake receded fluviatile deposits spread over the lake beds in places. Of such character are, for instance, the great gravel beds that form the upper part of the Payette formation near the mouth of the Boise River Canyon. There is no evidence of volcanic action in this region during this epoch of erosion.

Later lake epoch.—The progress of erosion in the valley was checked at this time by some cause, as yet unknown. The central part of the valley along Snake River again became a lake, probably shallow and marshy at times. A number of thin and very fluid sheets of basaltic lava poured down from the lower flanks of the Owyhee Range, from the foothills of the granite area north of the valley, and from numerous points of eruption within the valley itself, southeast of Nampa. These, one after another, became covered by sandy sediments, and thus originated the striking alternation of white lake beds and black basalt flows so well exposed in the deep trench which Snake River in Quaternary time has cut for a long distance above Walters Ferry.

In the vicinity of Nampa the later lake beds and basalt filled the valley to elevations of 2700 or 2800 feet, and the sediments contain numerous bones of mammals and of fishes. Especially common are bones of *Equus*, also those of *Mastodon*. Plant remains either are missing or, when present, indicate a flora consisting principally of grasses.

The age of the scant fauna has been determined as Pliocene by Professor Lucas, and the name Idaho formation has been given to these beds. Similar beds of alternating sands and basalt flows extend at least 100 miles up Snake River Valley from the point where the Boise joins the master stream. At Glenns Ferry these deposits reach an elevation of 3700 feet along the brink of the Snake River Canyon. If they really are lacustrine, which seems almost certain, these relations would again indicate a tilting movement by which the beds at Glenns Ferry have risen nearly 1000 feet relatively to those near Walters Ferry.

For practical purposes the Tertiary lake beds form one continuous series, for it is not always possible to separate with certainty the deposits of the Payette formation from those of the Idaho.

Recent lava flows.—The highest basalt flow covering lake beds in the central part of the valley, in the Nampa and Silver City quadrangles, and the highest basalt flow at the mouth of the Boise Canyon, are taken as the datum plane separating the Pliocene epoch from the Quaternary period. It marks the beginning of the present period of erosion and degradation of the whole valley. In the upper part of the valley, from American Falls to Walters Ferry, the Quaternary was a period of erosion, for during that time the deep trench of Snake River was cut through lake beds and basalt flows. This canyon is still being deepened. From the vicinity of Nampa down to the great canyon Quaternary erosion was very slow, because of the large masses of débris brought down by tributary rivers. The gradually deepening channels are lined by a terrace, or a series of terraces, remnants of old flood plains over which the rivers swung in changing curves and for a long time cut their banks in a lateral direction only.

Résumé.—Summing up the Tertiary history of deposition and erosion in this basin, we have first an early Tertiary epoch of erosion, followed by outbursts of rhyolite and basalt and the deposition of the Payette lake beds, which, near the margins of the basin had a thickness of probably about 2000 feet. The fossil leaves of this formation are now regarded as Eocene, and as the same flora has been found at several levels throughout the series the whole of the Payette formation should be assigned to the Eocene epoch. The deposition of the Payette lake beds was followed by an apparently short and active epoch of erosion, during which the rivers cut down through the lake beds to the same depth that they have to-day. Causes as yet undetermined checked this erosion and produced a lake of smaller dimensions and shallower depth than the Payette sheet of water. In this shallow lake the beds of the Idaho formation were deposited in alternation with basaltic flows. The fauna of the Idaho formation is assigned to the Pliocene epoch.

The draining of this lake is considered to close the Tertiary period. Since then this region has been dry land, and a slow, frequently checked erosion has cut into the lake beds and deposited extensive areas of Quaternary sand and gravel.

It should be noted that on the former assumption of a Miocene age of the Payette formation this history fitted in well with the paleontologic sequence. Accepting, however, the latest determination of the Payette formation as Eocene, there remains a long time-interval—the whole of the Miocene epoch—to be accounted for between the Eocene and the Pliocene, and this would seem to be somewhat inadequately represented by the epoch of erosion between the two series of lake beds. The excavation of the great Snake River Canyon below Huntington would, according to these last data, be placed in the Miocene and would occupy the larger part of that epoch. The upper canyon, from American Falls nearly to the edge of the Nampa quadrangle, was cut during the Quaternary period.

GEOLOGIC FORMATIONS.

TERTIARY ROCKS.

LAKE BEDS.

Extent of the lake beds.—As indicated above, the lake beds of the Payette and Idaho formations once covered the whole of the area of this quadrangle. Even now, though largely hidden under Quaternary deposits, they occupy about one-half of the quadrangle. Intercalated lava flows form a very insignificant part of the beds, although farther east in the Snake River Valley they become much more abundant.

In the Boise quadrangle, adjoining on the east, the lake beds rest against the steep granite slope of the Boise Range. The only place where an older underlying rock is shown in this quadrangle is in the southwest corner, where the lake beds rest against an outlying ridge of the great rhyolite area of the Owyhee Range; here they attain a maximum elevation of 2800 feet.

Characteristics of the lake beds.—The reason for dividing these lake beds into an Eocene (or Miocene) and a Pliocene series (the Payette and Idaho formations) is indicated more fully below. Practically, it is not possible to separate these two terranes, and in a large degree the same description applies to both. This is apparent since the material for both came from the same source—the great granite area of central Idaho; and further, a large part of the Idaho formation is simply Payette sediments worked over and redeposited. If clearly defined beach lines once existed they would soon have been obliterated owing to the soft and sandy character of the older, as well as of the younger, deposits. The majority of the deposits are unquestionably of lacustrine origin. This is proved by their uniform appearance as well as by the very even stratification and the persistence of certain strata over large areas. Gypsiferous beds are of very common occurrence in the Pliocene division of the lake beds. Near the margins of the lake, and especially near the débouchure of the canyons, gravels and other fluviatile deposits are, however, mingled with the lake beds. Delta deposits, especially, were formed during the recession of the Payette lake, as indicated, for instance, by the heavy gravel deposits at high levels in front of Boise River.[1]

In general, the strata consist of quartz sands with slight admixture of small mica flakes, and thin strata of clays; for the most part they are light gray, buff, or nearly white in color. Strata in which clay is predominant probably make up only one-tenth of the whole amount of the lake beds. Occasionally thin interstratified conglomerates and small deposits of pebbles occur. These pebbles consist of granite-porphyry and quartz, more rarely of basalt and rhyolite. Toward the northern part of the quadrangle the strata are more sandy; angular quartz grains one-tenth of an inch, or less, in diameter are scattered through fine sediments showing imperfect assortment and rapid accumulation; rare and thin lignitic streaks appear in places and seem to be chiefly made up of carbonized grasses, indicating that at various times the lake was shallow and marshy. In the extreme northeast corner of the quadrangle and immediately north of this the strata up to an elevation of 3000 feet contain, along with the loose, friable sand, some white, compact, sandy clays and thin intercalated white or gray tuffs which resist weathering so as to form slight breaks in the otherwise smooth, steep hill slopes. These tuffs doubtless connect with the volcanic areas of Miocene age north of Square Butte. When well exposed the lake beds nearly always show smooth bedding planes. Cross bedding and lenticular structure are not common, but when occurring may be of considerable local extent. Usually the sands are but slightly consolidated and the exposures easily crumble to smooth, sandy slopes. On the east side of the rhyolite ridge in the southwest corner of the quadrangle is a nearly continuous outcrop of rather coarse-grained, well-consolidated sandstone. This sandstone belt, which again appears farther south, in the Silver City quadrangle, is about one-fourth of a mile wide, but is not shown regularly on account of débris coming down from the rhyolite hills, and because of a covering of softer lake beds. It is believed that these hard cemented sands are only a local development of the Payette formation, possibly due to hot springs. It is clear that the sediments of the lake were very largely derived from the granite areas to the northeast. The valley thus became the general dumping ground for coarse and fine granitic débris.

Thickness of the lake beds.—The visible thickness of the lake beds is fully 700 feet in the complex between Payette and Boise rivers, and as much as 1000 feet north of the Payette. Along Snake River a thickness of 200 to 300 feet is shown. How deep the beds extend is not ascertained, as no well in this vicinity has yet passed through the formation. At the Ballantyne well, near the eastern edge of the quadrangle, a thickness of 600 feet of sandstone was penetrated. The Nampa well exposed 320 feet of similar material.

Detailed sections.—In a general way the section of the hills south of Emmett shows the characteristics of the lake beds in this area.

Section south of Emmett, Idaho.

	Feet.
At top, highly micaceous fine sand, with occasional argillaceous thin strata	15
Argillaceous fine sand with thin layers of highly argillaceous sand and occasional layers of coarse-grained sand	15
Coarse, micaceous quartz sand containing quartz and occasional feldspar pebbles ¼ to ¾ inch in diameter	25
Fine-grained, argillaceous sand	5
Coarse, loose sand with small pebbles ¼ to 1 inch in diameter	5
Gray, argillaceous, fine sand with scattering quartz pebbles ⅛ to ¼ inch in diameter	5
Loose micaceous quartz sands with occasional streaks or thin layers of argillaceous sands. This group of strata shows alternations in degrees of fineness, but otherwise is almost uniform. Usually the sands are coarse and the quartz grains angular	200
Gray, fine-grained, highly micaceous quartz sands	2
Highly argillaceous, gray, fine sands	1
Loose micaceous quartz sands, at bottom	50
Total	323

The following section, as seen in the escarpment about 3 miles northwest of the point where the Caldwell–Rockville road crosses Snake River, will suffice to show the general uniformity of the strata underlying the Nampa quadrangle. About 250 feet of the lake beds are here exposed.

Fifty feet from the base of the section 2 or 3 feet of clay sands contain a little lignite; the rest of the section shows very little variation. The beds are very sandy, loose, buff or light-gray colored, and practically free from the coarse quartz grains and small pebbles so common in the northern part of the field. Some of the beds are made up of almost pure sand, but usually there is a slight admixture of clay. Bones of fossil horse, *Equus*, are common throughout the section, except in the upper 5 to 10 feet, which is composed of water-worn pebbles and coarse sand. This pebble deposit is clearly Quaternary, and appears to be laid unconformably upon the lower beds.

The following section occurs on the north side of Sand Hollow, north of Payette River, about 2½ miles from the mouth of the deep gulch:

Section in Sand Hollow, north of Payette River.

	Feet.
At top, sandy loam	5–10
Well-rounded pebbles. Most of the pebbles are granitic, but some consist of quartz and feldspar porphyries. A few pebbles of obsidian, as well as others of diabase and basalt, are found in this bed, which is clearly of Pleistocene age	3– 5
Sand, with occasional minor strata of argillaceous sand. Most of the sand is coarse-grained or a mixture of coarse- and fine-grained sand. This imperfect assortment appears characteristic of the section. Small flakes of mica are common throughout In the coarser sands small pebbles of quartz or quartz-porphyry one-half inch, and less, in diameter are of rather common occurrence	250

A well bored at Nampa (elevation, 2490 feet) gave the following section:

Section of well at Nampa, Idaho.

	Feet.
At top, hardpan and loam	60
Basalt, below which roots, leaves, and vegetable mold are found	15
Bowlders and sand	100
Clay seam	½
Sand	40
Clay seam	½
Sand	30
Clay	15
Sand. (From the lower part of this stratum the sand pump brought up a small image similar to a roughly shaped doll, which at the time created much interest, as the statement was made on seemingly good authority that the find was genuine. Further substantiation of this remarkable occurrence has not been forthcoming, and the image may have been dropped into the wellhole by someone wishing to perpetrate a practical joke)	40
Coaly material at the bottom of this stratum. More consolidated sandstone at bottom of section	19
Total	320

Thus there is in this well, below the 60 feet of Quaternary material, 15 feet of basalt and 220 feet of sands with some clays. The latter probably represent the Idaho formation. Near the bottom, at an elevation of 2170 feet, was a layer of lignitic material. Finally, below this came a harder sandstone, which may represent the Payette formation.

The Ballantyne well, having an elevation at the top of 2575 feet, located on the mesa north of Boise River and 2 miles east of the eastern boundary line of the Nampa quadrangle, shows the following section:

Section of Ballantyne well, Ada County, Idaho.

	Feet.
At top, sand with bowlders (Pleistocene)	35
Sand with clay streaks	595
Total	630

At the bottom was found loose mud with leaves, fir cones, and fish bones, some of the fir cones being encrusted with pyrite. A large tree trunk was also bored through at this depth. The elevation of this stratum of carbonaceous matter was 1900 feet.

Age of the lake beds.—Fossil leaves indicating an early Tertiary age (probably Eocene) occur not uncommonly near the base of the Payette formation in the adjoining Boise quadrangle. In the Nampa quuadrangle no well-preserved leaves have thus far been found, the only fossils noted being vertebrate mammalian bones, as follows:

Vertebrate mammalian bones found in Nampa quadrangle.

(1) North side of Indian Creek, 4½ miles northwest of Nampa; elevation, 2400 feet; at base of small bluff of Quaternary, in sand probably belonging to Tertiary lake beds: *Equus*.

(2) One and one-half miles north of Jump Creek, in bluff on north side of Snake River; elevation, 2400 feet; in soft lake beds: *Equus* bones, fairly common throughout the section.

(3) East side of Snake River, 2 miles northeast of Nyssa; small bluff, probably of lake beds, underlying Quaternary; elevation, 2200 feet: *Mastodon*.

(4) Two and one-half miles north-northwest of ferry where Caldwell-Rockville road crosses Snake River; soft lake beds forming bluffs facing Snake River; eleva-

[1] Lindgren, W., Description of the Boise quadrangle: Geologic Atlas U. S., folio 45, U. S. Geol. Survey, 1898.

tion, 2500 feet: *Equus; Procamelus*, size of *P. major; Mastodon*, not *M. americanus; Castor*, possibly n. sp.; *Olor*, size of *O. paleocygnus; Pappichthys*.

(5) On west side of Sand Hollow, near the northern boundary of the quadrangle; elevation, 2700 feet; in the sandy lake beds: *Cervus*, possibly new, slightly smaller and more slender than *C. canadensis*.

All the species are considered to indicate Pliocene age.

If the paleontologic evidence is considered as a whole, it certainly would seem that the beds are divisible into two sections, since:

First, an older series consisting of strata accumulated to a level of 4000 to 5000 feet in the lake during the first period of filling. In these beds mammalian remains are certainly scarce; fresh-water mollusks, of little value for purposes of determining the age of the strata, occur in places; very abundant, especially near the shore lines and toward the base of the series, are impressions of deciduous leaves, indicating Miocene or, according to the latest determinations, Eocene age.

Second, the mammalian remains are found chiefly in the center of the valley near Snake River and in beds the elevation of which seldom exceeds 2600 feet. In some sections along Snake River bones of *Equus* are very common—may, indeed, be said to be characteristic of the beds. *Mastodon mirificus* and *Equus excelsis* have been found in a similar position on Sinker Creek in the Bisuka quadrangle. Fish bones are frequently found, and twenty-two species of a clearly Pliocene age have been determined by Cope. Fresh-water shells and beds of *Unio* shells are very common. All this is certainly in distinct contrast to the lake beds appearing at higher elevations but apparently lower stratigraphic horizon in the Nampa, Weiser, Boise, and Silver City quadrangles.

From a stratigraphic standpoint it might at first glance seem most probable that the lake beds of this quadrangle were deposited in one continuous series, and were subsequently degraded and covered by Quaternary gravels. From this quadrangle alone no positive evidence against such a view can be adduced, but when one considers the exceptionally clear record of happenings which is apparent in the succession of rocks near the mouth of the Boise Canyon it becomes evident that the sequence of events was not so simple.

It is shown in the text of the Boise quadrangle that the canyon of the Boise existed practically in its present shape before any lake beds were deposited in the valley. After the accumulation of the Payette formation to an elevation of 4200 feet or more, erosion began. During the gradual establishment of an outlet to the lake the canyon of Boise River was scoured of its accumulations down to practically the present depth—that is, down to an elevation of about 3850 feet. This evidently very active erosion must have removed the lake beds along newly established river courses throughout this part of the Snake River Valley. As is shown by the long ridge between Boise and Payette rivers, these earlier (Eocene) lake beds attained an elevation along the shore line of at least 4500 feet, and from this point their surface sloped down very gradually to an elevation of 2750 feet. To this level, then, it must be considered that the whole valley was filled with deposits of the Payette formation. From the depth and evidently intense action of the post-Payette erosion it follows that the whole valley, at a period closely following the highest stage of the lake, was dry land, the newly deposited lake beds being deeply dissected by the newly established river courses. Probably the depth to which erosion had progressed in the center of the valley was about the same as at present. To some degree corroborating this we find in the Nampa well section a layer of lignitic material at an elevation of 2170 feet. The section of the Ballantyne well is entirely different from that of the Nampa well, and from its position in relation to Boise River it may be conjectured that it penetrated exclusively sandstones of Payette age, and that the coaly material found near the bottom, at an elevation of 1900 feet, is situated near the base of that formation.

Next followed several basaltic eruptions, the flows of which came down the canyon of Boise River and are separated by considerable masses of gravel. The lowest of these flows rests on granite and is probably the oldest, showing a somewhat steeper grade of the river than that which obtains at present. The uppermost flow spread out in considerable volume in front of the canyon, on top of the heavy gravels which had already dammed the canyon at an elevation of 3100 feet. This basaltic flow rests on one side against the deeply eroded gravels of the Payette formation, and the Quaternary gravels on the other side rest against the black cliffs of the lava. Further, it is clear that the basalt flows on Boise River and those exposed near Nampa and along Snake River are identical, or practically identical, in age. Evidence of this is their position, one being almost directly adjoined by the other; also, their vesicular and generally fresh character, and, finally, the characteristic of several thin flows superimposed and separated only by thin sediments. In both cases the only deposits on the top flow are thin Quaternary gravels and loam, and in some places thin lake beds.

At the mouth of the Boise Canyon the basalt rests at an elevation of 3000 feet on clearly fluviatile gravels. Along Snake River the same flows are intercalated with lake beds which ordinarily show no cross bedding or other evidence of fluviatile action and which contain remains of mammals of Pliocene age. At Nampa the same flow rests on coaly vegetable soil, forming the top stratum of a considerable thickness of sands.

All these facts taken together force us to conclude that, following the first erosion of the lake beds, to a depth equal to that of the present erosion, another period of sedimentation began, during which heavy gravels accumulated along the base of the mountains, and the central part of Snake River Valley was a shallow lake, or perhaps, in part, at times a marshy swamp.

The elevation to which these second lake-bed deposits reached can not be positively stated, but it is believed that they did not extend to a higher altitude than 2700 feet, which elevation is reached by the white lake beds along Snake River in the Nampa and Silver City quadrangles.

Another important fact tending in the same direction is the presence of large quantities of gypsum, indicating a slowly drying body of water, which occur in these later lake beds along Snake River in the Silver City quadrangle.

Although this chain of reasoning seems conclusively to prove the division of the lake beds into an older, Eocene or Miocene, series (Payette formation) and a younger, Pliocene, series (Idaho formation), still it is impossible to separate the two divisions in the field. If this conclusion be not accepted, the only alternative is that the lake beds and basaltic flows of Snake River were laid down in the regular succession of the Payette beds during the Eocene epoch. On this assumption the lowest beds along Snake River southwest of Nampa, at an elevation of 2300 feet, would be, stratigraphically speaking, 450 feet below the top of the Payette formation as exposed between Boise and Payette rivers. It is believed that the reasons indicated above are strong enough to completely refute this theory. There is, moreover, a marked difference in appearance between the basaltic flows which are intercalated in the Payette formation and were erupted during its deposition and the thin basalt flows of the Boise Canyon and Snake River. The more recent geologic age of the latter is clearly indicated by their great freshness and unoxidized condition, by their black color, by their extreme fluidity at the time of eruption, and by the general absence of secondary minerals, such as chlorite, serpentine, opal, and calcite.

RHYOLITE.

Occurrence of rhyolite.—The only area of rhyolite observed in the quadrangle occupies a few square miles in the southwest corner. This is the very edge of an extensive flow which occupies a large area of the foothills of the Owyhee Range. Along the contact with the lake beds it is clearly seen that the latter overlie the eroded face of the rhyolite. This agrees with the observations made along the foothills on the other side of the valley north of Boise, where heavy flows of rhyolite cover the granite of the range, the rhyolite in its turn being covered by lake beds of the Payette formation. Although the age of the lake beds at the rhyolite ridge in the Nampa quadrangle is not positively known, they are probably Pliocene, and the rhyolite and dacite are consequently pre-Pliocene. But from the exposures in the adjacent Silver City quadrangle it is evident that these lavas were erupted just prior to the deposition of the Payette formation, which would establish their age, according to latest determinations, as pre-Eocene. In the Silver City quadrangle the dacite is later than the rhyolite.

Character of the rhyolite.—The rhyolite is of a felsitic type, consisting chiefly of a very fine-grained, microcrystalline to cryptocrystalline mass of quartz and alkali feldspar, in which a few small, scattered phenocrysts of the same minerals are embedded. The groundmass is often characteristically streaky by irregular alternation of coarser and finer aggregates. Biotite is of rare occurrence. The rock is generally vesicular, in places also tuffaceous; the cavities are often filled by opal and other forms of silica.

Associated dacite.—On the northeast side of the rhyolite area appears a dike of somewhat different and apparently less acid rock. It is very similar to certain dikes in the Silver City quadrangle which have been determined as dacite or acidic andesite. This rock is light gray or brownish and contains small phenocrysts of orthoclase, andesine, biotite, and hornblende in a very fine-grained, microcrystalline groundmass. The dike does not break through the lake beds—although such is the appearance on the map—but is older and projects through the lacustrine beds, forming a somewhat prominent little ridge.

BASALT.

The Pliocene basalt occupies small areas on both sides of Indian Creek near Nampa, and local patches are also encountered at various points in the lake beds overlooking Snake River. Some of the latter may be due to small local eruptions. The basalt flow which occurs at Nampa extends far into the adjoining Boise quadrangle and almost connects with the large flow spread out at the mouth of the Boise Canyon. The two flows may not have originated from the same vent, but it can not be doubted that the two were erupted at practically the same period. The flow at Nampa extends far into the Bisuka and Silver City quadrangles. It is possible that its origin is to be sought in that basaltic dome or buckle which rises a short distance south of the railroad station of Kuna. According to borings near Nampa, the basalt is from 15 to 50 feet thick and rests on sandy beds. Immediately below it roots and coaly matter were found, indicating that it was poured out on a floor sustaining some vegetation—most probably of marshy character. Along Snake River, however, there is no indication of such coaly deposit, the basalt resting directly on well-bedded sands of probably lacustrine origin, except at Walters Butte (Silver City quadrangle), where the underlying deposit is a pebble bed. In some places, for instance about 2 miles southwest of Nampa, some of this basalt thins out to layers 6 to 12 inches in thickness and is so smoothly bedded that slabs of the rock are taken up and used for culverts and other rough constructions. Over a large part of the area indicated as basalt on the map the solid rock is really covered by a varying depth of loam, soil, or sand. The basalt is of black color, very fresh, and exceedingly vesicular; it is a normal feldspar basalt with small, closely crowded crystals of labradorite and grains of augite, occasionally also olivine embedded in a scant groundmass of glassy character. This lava was evidently extremely fluid when poured out. The basalt in the Nampa quadrangle, except the occurrence on Boise River near Caldwell, is probably Pliocene in age, as it is interbedded with or covers sediments belonging to that epoch. The basalt at Caldwell is described in connection with the Quaternary deposits.

QUATERNARY ROCKS.

RIVER DEPOSITS.

General description.—Deposits of Quaternary age cover about one-half of the Nampa quadrangle and may be subdivided into several formations. In all cases the beds cover lake beds or basalt of Tertiary age, and are spread over them as a thin mantle. The Quaternary deposits accumulated in the valleys of Snake, Boise, and Payette rivers, which gradually deepened their channels and eroded the sides of the valley as the watercourses swung across the flood plains. This accumulation of river deposits has been steadily going on since the close of the Pliocene, assuming arbitrarily that this time limit is marked by the upper basalt flow in the Boise Canyon.

Over the whole quadrangle the Quaternary deposits consist of river gravels of moderate depth covered by fine sands and loams; sometimes, also, by hardpan to a depth as great as 50 feet. These gravels and loams are not a part of the lake beds, but rest unconformably by erosion on the latter. The mantle of gravel closely conforms to the present topography and is rarely broken except at erosional escarpments. On the highest terraces the pebble deposit is only 5 to 10 feet thick, but is found generally to thicken considerably toward the present rivers. All of this gravel-covered area is more or less distinctly terraced, the terraces becoming more plainly indicated and more extensive as the present rivers are approached. The grades of the old river deposits, where clearly indicated, are about the same as those of the present rivers. In the Boise quadrangle, however, it appears as if the modern river had a somewhat steeper grade than its early Quaternary predecessor. The pebbles are well rounded, of moderate size, and consist mainly of quartz and older porphyritic rocks, more rarely of rhyolite and basalt. The covering of the gravels sometimes consists of sand, but more commonly it is a fine, brownish or reddish loam. This loam is a persistent feature of the terraces, and is important economically on account of its excellent qualities as a soil. The origin of this deposit of loam is not quite clear in all cases; to a great extent it is probably of fluviatile origin, sometimes showing distinct cross bedding, but in part, especially on the higher lands and on the basalt areas near Nampa, it is probably an eolian deposit accumulated by the dust-laden winds which so frequently sweep this region. The thickness of the loam varies from a few feet to 50 or 60 feet, and to the southwest of Nampa it is not uncommon to find a basalt flow underlying it. In nearly all places elsewhere it is underlain by 5 to 40 feet of gravel.

Broadly speaking, three stages of river deposition may be distinguished, represented by (1) the early terrace gravels, (2) the late terrace gravels, and (3) recent alluvium. The outlines of the gravel areas, especially where they cover the lake beds, are very indistinct and most difficult to map; the boundaries outlined on the map are, therefore, only approximately correct.

Early terrace gravels.—These deposits really form a series of terraces or shelves, often indistinct and gradually merging one into another. North of the Payette there are several terraces of comparatively coarse gravels below an elevation of 3000 feet. No deposits of this formation are found on the south slope of the Payette Valley, and there are but few of them north of the Boise. On the south side of Boise River they are, however, strongly developed at elevations ranging from 2400 to 2800 feet. They appear here as a thin sheet spread over the lake beds, which gradually slope from the escarpment near the Snake toward the first terrace south of Boise River. The deposits probably may be separated into several terraces, although on the gently sloping ground a distinction between each of them is difficult.

Late terrace gravels.—These spread over sloping shelves on both sides of the rivers and rise to elevations of 100 to 150 feet above the stream. The line between the late terrace gravels and the alluvium is usually marked by a steep bluff. These terraces are extensively developed on both sides of Boise and Payette rivers, but to a less extent along Snake River. Along Boise River the highest elevations of the lower terrace range from 2300 to 2600 feet, following the river from east to west; along Payette River similar benches descend from 2750 feet near the eastern edge of the quadrangle to 2500 feet near the junction with Snake River.

Recent alluvium.—This forms strips of almost level land along the present rivers, over which the Boise and Payette meander in swinging curves, often changing their channels. The river bottoms are 2 to 3 miles wide and gradually slope up to a height of approximately 50 feet above the river. Along Snake River the deposits are narrower and very sandy, with but little gravel. North of the junction with the Boise, as mentioned above, the alluvium widens to a flood plain of considerable extent.

River courses.—On the whole, Boise and Payette rivers appear to be more unstable in their courses than Snake River and are characterized by the possession of wide bottom lands and lower banks. Snake River, on the contrary, is confined between more distinct banks, carries a little gravel, but principally sand, in its sediments, and is evidently eroding its channel more actively than the other two. This takes place notwithstanding the fact that Snake River has a considerably slighter grade than the others, but may be due to the relatively small quantity of material which it transports, since the Boise and the Payette are overloaded with the products of disintegration of the Boise Mountains. The evidence of changes in the river courses is very clear. It has been shown that in the Boise quadrangle, adjoining eastward, Boise River during the earlier Tertiary had an almost due westerly direction from the mouth of its canyon, and that during the Quaternary period it has gradually swung northward to the course which it now occupies. Similar relations are noticed in this quadrangle. During early Quaternary times the river apparently ran south of Nampa, as indicated by the heavy and persistent gravel deposits in that vicinity; it probably emptied directly into the Snake near this point (see text of Silver City folio), but has since then gradually worked its way westward and northward. Payette River, in the eastern part of the quadrangle, has moved southward since the deposition of the upper terrace gravels. Snake River has gradually worked northeastward, but apparently has been more stationary than either of the other rivers.

Since the retreat of the rivers from the upper benches, rains and winds have worked over the surface to a certain extent and have formed at least a part of the now universal mantle of loam that covers the river gravels.

Detailed sections.—A few sections may be selected to represent the Quaternary deposits in the Nampa quadrangle.

Section of the face of the mesa east of Phyllis canal north of Pipe Gulch.

	Feet.
Soil	2
Light-colored sands	2
Brownish sands	3
Hardpan (sand, clay, lime, etc., in nodules and irregular layers)	12
Waterworn gravel	12
Argillaceous and micaceous white sand	4
Grayish white sand	10
Bluish-white clay, slightly arenaceous	3
Total	48

This section is on the lower terrace.

A section from Snake River at Gravelly Point to Boise River, south of Parma, would show the relations illustrated in fig. 1.

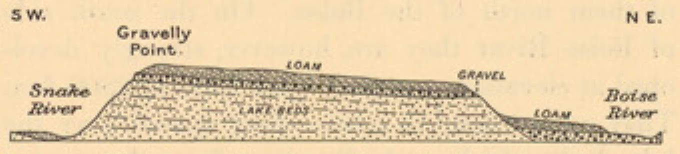


FIG. 1.—Sketch section from Gravelly Point northeast to Boise River.
Shows the high gravel terrace.

Entirely similar would appear a section from Snake River to the Boise between Guess Gulch and Pipe Gulch. These sections are 8 miles apart.

Wells at Eastman's ranch, on the Ridenbaugh canal, $5\frac{1}{2}$ miles southwest of Nampa, show 40 feet of soil and loam, the thickness varying greatly at closely adjoining places; below lies 65 feet of basalt.

On the first terrace south of Boise River and south of Parma 15 to 25 feet of stratified sands overlie gravel. As the first terrace is comparatively low at this place the gravel is probably the same as that underlying the flood plains of the river.

About half a mile east of the first railroad bridge across Snake River, below Parma, there is an exposure in the east bank of the river showing 50 feet of strata. At the top of the section is 10 to 12 feet of conglomerate and gravels. Below the gravels the strata consist of rather fine, compact sand in thin layers, often showing cross bedding. At the south end of this section are other sand deposits, unconformable upon the older sands and having the appearance of wind-blown deposits.

A section extending eastward from Snake River at a point 2 miles north of Nyssa shows sand overlying 10 feet of waterworn gravel, which in its turn is underlain by argillaceous sand. The gravels in this section consist of well-rounded pebbles of granite-porphyries, basalt, and more rarely rhyolite; probably one-half of the bulk of the deposit consists of pebbles that are 2 to 6 inches in diameter. The overlying sand and loam deposits are stratified, but where seen well exposed along the river they often show the wavy and flaky cross bedding characteristic of eolian deposits. This does not apply to the whole area in this vicinity, for the strata as a whole are too extensive and smoothly bedded to be other than water-laid deposits. The sands below the gravel bed appear like the regular Pliocene lake beds, and a bone of *Mastodon* was found in this part of the section.

Section on east side of Snake River in northwest corner of Nampa quadrangle.

	Feet.
At top, sand. The upper few feet of this stratum is of eolian origin	50
Calcareous sand and clay containing nodules and concretions of indurated material. This bed is what is commonly referred to as "hardpan"	25
Gravel mixed with coarse sand. The pebbles consist of granite-porphyry and some basalt	15
Very uniform, light-gray, compact clay sands. The bottom of this stratum is 15 feet above the level of Snake River	50
Total	140

It is believed that the material below the gravel bed belongs to the Payette formation and is of lacustrine origin. It may be seen that this section bears a strong resemblance to the preceding one. In fact, this succession occurs regularly along the east side of Snake River in the northwestern part of the quadrangle.

Well sections in the sloping lower terrace of the Payette Valley, about 2 miles east of the preceding section, pass through 30 to 50 feet of soil, sand, and hardpan, and then into the gravel bed.

A northeast-southwest section across the Payette Valley near Falks Store is shown in fig. 2.

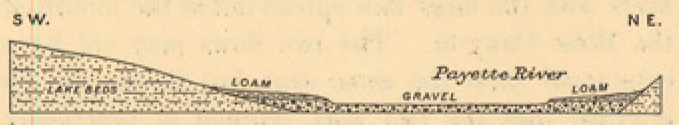


FIG. 2.—Sketch section across Payette Valley near Falks Store.
The river gravels underlie the whole width of the valley.

The figure shows that the pebble deposits underlying the bottom lands of Payette River probably occupy the whole width of the valley, but are covered by sand and loam a short distance from the river.

Section in east bank of Indian Creek about halfway between Nampa and Caldwell.

	Feet.
At top, sandy loam, streaked with horizontal seams of hardpan. This stratum has in part the appearance of wind-blown deposits	5
Coarse, angular quartz and granite sand, with occasional small pebbles, up to $1\frac{1}{2}$ inches in diameter, of granite and vesicular basalt. The basalt pebbles are probably derived from the rock outcropping east of Nampa. The bedding of this stratum is wavy, lenticular, and has the appearance of being Pleistocene river deposits	10
Uniformly textured, fine-grained, slightly clayey sand. This part of the section is regarded as probably a Pliocene lake deposit. *Equus* bones were found in it	5
Total	20

A north-south section extends across Boise River north of Nampa as seen in fig. 3. It shows the

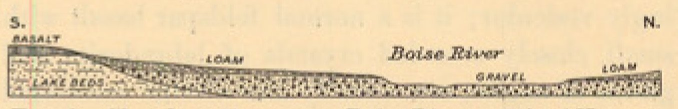


FIG. 3.—Sketch section across Boise River north of Nampa.
The gravel of the present river beds is shown as continuous with that of the lower terrace.

gradual thinning of the loam toward the river and the probable identity of the gravel bed which underlies the present river bottom with that below the lower terrace.

Section on north bank of Payette River $1\frac{1}{2}$ miles below Bissel Creek.

	Feet.
At top, loamy deposits. The lower part of this bed is somewhat sandy	15
Gravels. Nearly all the pebbles consist of porphyry and are from 2 to 6 inches in diameter; they are well rounded, and bedded with a small amount of coarse sand, and contain occasional small lenticular streaks of sand	15
Sands and argillaceous sands, slightly coarse bedded. Most of the bed is coarse quartz sand, with occasional pebbles	30
Total	60

Northwestward along the escarpment containing the above section the same succession was found to run very regularly for 6 or 7 miles. The pebble bed gradually becomes a little lower or falls a little more rapidly than the river.

The lake beds lying north of Payette River are marked by terraces which are less conspicuous as higher elevations are reached. An ideal northeast-southwest section north of Payette River between Sand Hollow and Bissell Creek is shown in fig. 4.

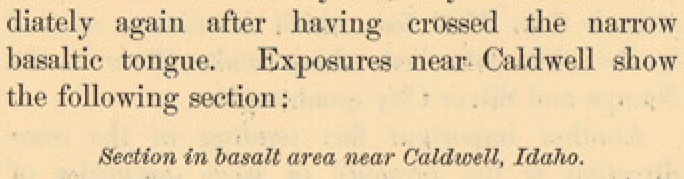


FIG. 4.—Ideal sketch section of the north bank of Payette River between Sand Hollow and Bissell Creek.

From this section it is seen that the pebble beds are not continuous, but that they form the closely underlying bed rock of each terrace. The lower the terrace the greater is the thickness of the gravel bed. The gravel beds also slope slightly toward the river. Thus it seems that the original nearly level surface of the country, consisting of lake deposits, was more or less covered with gravels, and that, as erosion trimmed down the level plain to basins and these basins into successively narrower valleys, the gravels have been gradually lowered and only slightly transported.

LATE BASALT.

The basalt areas in the Nampa quadrangle are largely of Pliocene age, as explained in preceding paragraphs, but there is one flow which in its position and association indicates a later (Quaternary) age. This area is the thin flow of basalt appearing near Caldwell on both sides of Boise River. The hardness of this basalt flow is evidently responsible for the local contraction of the flood plain of the river at this point. It narrows suddenly from 2 miles to a few hundred yards, only to widen immediately again after having crossed the narrow basaltic tongue. Exposures near Caldwell show the following section:

Section in basalt area near Caldwell, Idaho.

	Feet.
Loamy soil	3
Vesicular basalt	10–20
Gravel and sand. The bottom of this stratum is at the level of the alluvium of Boise River	50
Total	63–73

From this it appears that this thin flow rests at an elevation of 2380 feet on typical Quaternary gravels, whereas the other flows in this quadrangle are intercalated with beds which are referred to the Pliocene lake beds. The flow is small in extent and can not be correlated with any of the other basaltic masses. In petrographic character it is a black, dense, vesicular rock, entirely similar to the Pliocene basalts previously described.

ECONOMIC GEOLOGY.

GOLD.

Placer gold is found in the gravels and sands of Snake, Boise, and Payette rivers and is occasionally worked in a limited way. The production of gold in Canyon County is given in the recent Mint reports as from \$7000 to \$10,000 per year. Most of this is probably derived from operations on a small scale along these rivers. Washing for gold is frequently done by persons from farms in the vicinity of the rivers, who have short periods to spare from their ordinary work, and who find it remunerative to wash the gravels for a limited time during the winter. Recently a dredging plant has been built near Nyssa and, it is stated, operated with satisfactory results. About ten years ago a dredge was built on Payette River below Emmett, but the results were found unsatisfactory. At that time, however, the dredging industry was in its infancy, so that the enterprise may not have been a fair test of what can be accomplished at the present day.

The gold along Snake River is extremely fine, flaky or floury, and occurs in thin and not very persistent pay streaks intercalated in the sands along the bends of the river. This fine gold is contained in the sandy bars all the way down from the headwaters, and its origin has been the source of much speculation. It is now believed to have been set free by the erosion of large bodies of old conglomerates near the head of the river in northwestern Wyoming. The sandy bars contain gold varying in value from a few cents to several dollars per cubic yard. The latter values are ordinarily of very limited extent and the best bars have long since been worked out. Frequently, however, more gold is deposited by the action of the stream in the same place, so that after a certain time interval the same bars may be washed over again. The gravel ranges in size from fine sand to bowlders which are seldom larger than a man's head. The current has a velocity of 3 to 5 miles per hour. The gold is very unevenly distributed through these bars, being generally found in strata of medium-sized gravel, from a few inches to a few feet thick, and usually overlain by 2 to 10 feet of barren sand or gravel. Below these strata, also, the gravel may be worthless. Depth does not seem to cause any increase in values; where the bed rock has been reached at a few points on the rim it holds but little gold. The Snake River gold above the mouth of Boise River is very fine, averaging about 1200 colors to one cent, and is worth from \$17 to \$19 per ounce. Below the mouth of the Boise the gold is not quite so fine, averaging about 900 colors to one cent; the value is said to be lower, being from \$14 to \$16 per ounce. The gold is always accompanied by much black sand or magnetite and ilmenite, probably derived from the basalt. When the gold and the black sand are carefully separated the latter contains but small values. The method of mining employed by men working on a small scale is usually the so-called "burlap" system. The sluices are made about 20 feet long and much wider than the ordinary box. The bottom is covered by burlap and the screened material allowed to pour over it in a thin, even stream. At intervals the burlaps are taken out and washed. The gold does not always amalgamate easily, and processes based on amalgamation on copper plates, or by forcing the sand through mercury, are generally failures.

In dredging the Snake River sands and gravels it has been found that the pay gravel contains from 5 to 15 cents per cubic yard. In order to make a profit on sand containing 10 cents per cubic yard, at least 1000 cubic yards must be handled daily. The gravel is screened to $\frac{3}{8}$-inch size and the gold caught in broad and shallow burlap sluices with an area of 1300 square feet. The cost of dredging by means of suction pumps with a capacity of 2500 cubic yards per day is stated to be 4 cents per cubic yard. The ladder dredge is said to work somewhat cheaper, or at the cost of about 3 cents per cubic yard. The practical test now being carried on at Nyssa and at several points on the upper river will soon demonstrate whether large areas of dredging ground of remunerative grade are available.

COAL.

No coal beds of any importance have been found in the Tertiary lake beds, although layers rich in lignite are not uncommon. It is not likely that beds of commercial importance will be found. In the Boise quadrangle coal of fair quantity and of some commercial importance has been found at several places in these lake beds, but these localities are near the shore line or in sheltered bays of the lake, where there was more opportunity for the development of an abundant vegetation.

OPALS.

The rhyolite of the Owyhee Range, in the southwest corner of the Nampa quadrangle, contains considerable quantities of milk opals and has been prospected for fire opals, some of which are said to have been found, but the quantity was so small that no further work has been done. The opals usually occur as fillings of the cavities of the vesicular rhyolite, but some occur as filling of small veinlets. Good stones have been found in the adjacent area of rhyolite in the Silver City quadrangle.

BUILDING STONE.

The building stones are confined to two small areas. At either place fairly good building stone for ordinary purposes may be obtained. One of the localities is along about half of the eastern border of the rhyolite area in the southwest corner of the quadrangle; there the sandstones are rather coarse grained, forming strata of varying thickness and light-buff color. This belt of hard sandstones is about 2 miles long by one-fourth of a mile wide. The other area lies in the escarpment on the east side of Snake River at and near the south line of the Nampa quadrangle. At this point there is a bed, about 50 feet thick, of rather coarse-grained, indurated sandstone. Some of the strata are thin, but more commonly they are massive, and cross bedding is a marked feature. The rock grades from friable to very hard, and from gray to buff colored.

The basalt is locally used for culverts and other rough work.

SOILS.

The soils may be classed under three headings, as follows: The highland soils, the river-terrace soils, and the flood-plain soils.

The highland soils are the thinnest and most sandy of the three and naturally are subjected to the most rapid erosion.

The river-terrace soils are confined to the terraces bordering the flood plains of Snake, Boise, and Payette rivers, as well as to the flood plains or Quaternary deposits of Snake River. This soil has a good mixture of sand and clay for agricultural purposes and is very productive and easily tilled.

The alluvial soils are nearly all confined to the flood plains of Boise and Payette rivers and to a little of the lowlands of Snake River in the northwest corner of the quadrangle. These soils have more organic matter than either of the above, and also more or less alkaline salts, so that they are often unfit for cultivation. They are also damper, heavier, and more difficult to till.

The soil of the terraces and flood plains is exceedingly fertile, and when water is applied it transforms the dreary sagebrush desert into beautiful and prosperous farming districts. The total amount of irrigable land along Payette River in this quadrangle is about 100 square miles. In the valleys of the Boise and the Snake, in this quadrangle, there is a total area of 240 square miles below the canals already constructed. Taken together with the 117 square miles below the ditches in the adjoining Boise quadrangle, this makes a total of 357 square miles of irrigable land in the Boise Valley. It is not believed, however, that the water in Boise River is sufficient to irrigate this amount of land. Already a scarcity of water is felt during occasional dry seasons. In order fully to utilize the available land, it will be necessary to construct reservoirs to store some of the flood waters of the river. In this quadrangle a large part of the lower terraces along the Boise is already irrigated, as well as some parts of the uplands south of Nampa. Not much more land is available for irrigation in this valley, except some parts of Deer Flat and the top of the ridge separating the Boise from the Snake. There would be some difficulty, however, in carrying water to these localities. The hills of lake beds to the north of Boise are practically nonirrigable. Along the Payette a large part of the southern terrace, as well as the river bottom, is already under irrigation and supports prosperous communities. The northern terrace, also, could easily be watered by a ditch from the same river.

The crops most generally cultivated on the irrigated farms consist of alfalfa, more rarely of grain. Fruits, also, such as apples, pears, and prunes, do well, and large orchards have been planted in this and the adjoining Boise quadrangle.

Snake River is not as yet utilized for irrigation. Although some of its bottom lands and lower terraces would be well adapted to agriculture, the difficulty of taking out the water from its channel is great on account of its low grade and the precipitous character of its canyon, along which the ditch must be conducted. A body of good land is located at the mouth of Jump Creek and would seem to include at least 30 square miles. It is said that part of this, at least, could be irrigated by storage of water on Jump and Succor creeks. The problem is complicated by the fact that these water-courses in great part flow through the State of Oregon, though their heads and lower courses are in Idaho.

WATER SUPPLY.

Surface waters.—The quantity of water available in the rivers has been referred to. If all the water that flows across the quadrangle could be utilized, there would be ample to irrigate all the fertile lands in the quadrangle and much more. Payette River probably carries more than enough water to irrigate the whole valley below Emmett, but in the case of Boise River a shortage is anticipated unless storage reservoirs are constructed. On September 1, 1898, measurements were made on the Boise by the United States Geological Survey, which showed that a total of 1160 second-feet of water was being taken out by the ditches in Boise Valley below the canyon, while the river a short distance above the mouth of the canyon contained a total of 734 second-feet. This year, however, was one of unusual scarcity of water. A certain amount of this water, which was taken out by the canals, returned to the river by seepage; the gain by seepage per mile was estimated to be 7.65 second-feet.

There are few natural springs in the quadrangle, and those are of slight volume. However, another source of water is available—that is, the large quantity of underground water which is present throughout a large part of the quadrangle. In the flood plains of Boise and Payette rivers water is usually found at depths varying from 4 to 10 feet. In the lower lands of the valley of Willow Creek, also, water is found from 4 to 6 feet below the surface. In the mesa lands bordering the river flood plains the water level is from 25 to 50 feet below the surface. At Nampa water stands 15 feet below the surface in the deep well sunk to 320 feet. Finally, in the hills between Boise and Snake rivers, water is reached at about 100 feet below the surface. It will thus be seen that the surface of the ground water to some extent follows the contour of the surface, but, as might be expected in this arid climate, the water surface is much flatter than the topographic surface. Much of the ground water could doubtless be obtained by means of windmills. Regarding the amount used for irrigation, it should be noted that there is a considerable waste, many farmers using much more water than is necessary.

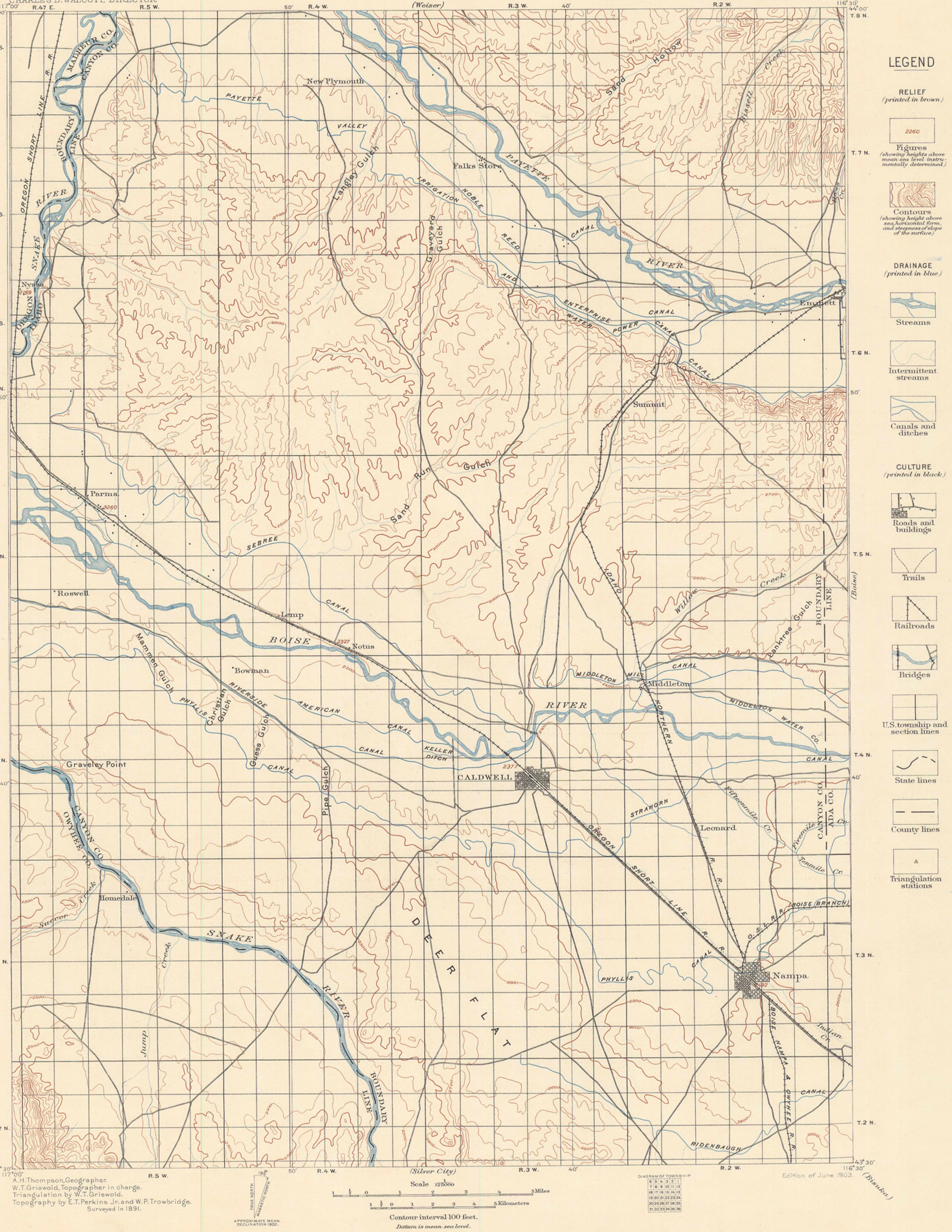
Artesian wells.—The gravels and underlying sands of the valley are saturated with ground water, and there is no difficulty in obtaining large amounts by pumping. The deepest well thus far sunk in this quadrangle is that at Nampa, which attained 340 feet. Water is said to stand within 15 feet of the top. Owing to the sandy character of the strata, the apparent absence of water-tight, clayey strata, and the relatively small precipitation of the region, it is not likely that flowing wells will be found in the higher parts of the quadrangle. In the Boise folio attention was called to the probability that the Snake River Valley is a tectonic trough and that the conditions are favorable for artesian wells in the lower parts, provided that clayey beds are found in depth, to retain the water within certain limits. Along Boise and Payette rivers there is, however, little need for more water. On the south side of Snake River near the mouth of Jump Creek, where there is a considerable body of good land available less than 100 feet above the river level, artesian water in moderate amount may be obtainable. It would also seem possible to obtain artesian flows in Willow Creek, near the eastern edge of the quadrangle, and also in the small alluvial valleys on the western slope of Squaw Butte, a high basaltic mountain in the Boise quadrangle, close to the northeast corner of the the Nampa quadrangle.

August, 1902.

U.S.GEOLOGICAL SURVEY
CHARLES D.WALCOTT, DIRECTOR.

TOPOGRAPHY

IDAHO-OREGON
NAMPA QUADRANGLE



A.H.Thompson, Geographer.
W.T.Griswold, Topographer in charge.
Triangulation by W.T.Griswold.
Topography by E.T.Perkins Jr. and W.P.Trowbridge.
Surveyed in 1891.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.

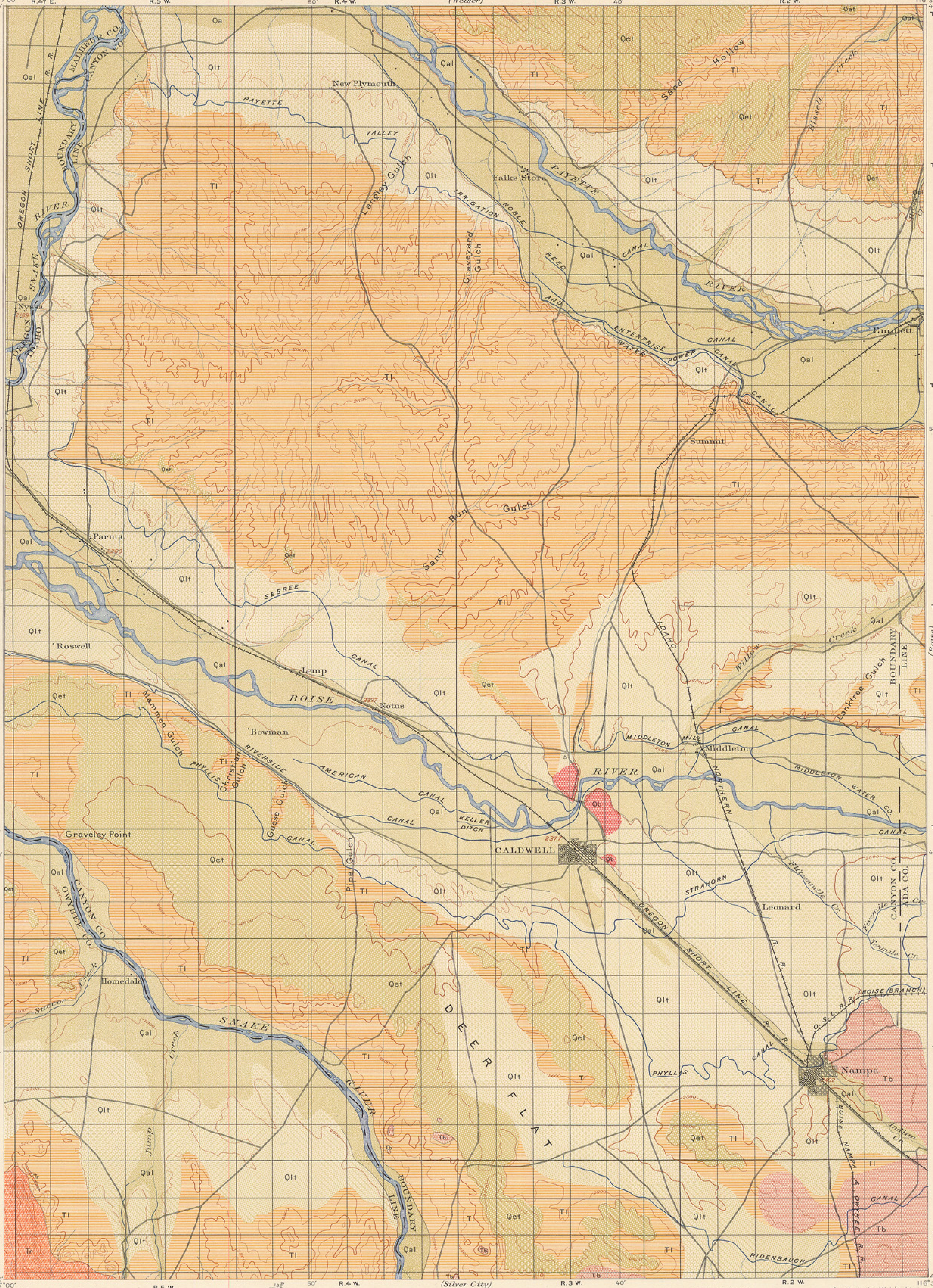
DIAGRAM OF TOWNSHIP

Edition of June 1903.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

AREAL GEOLOGY

IDAHO-OREGON
NAMPA QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines, subaerial deposits by patterns of dots and circles.)

QUATERNARY

Recent

Qal — Recent alluvium *(river gravel and sand occupying bottom lands)*

Pleistocene

Qlt — Late terrace gravels *(river gravels covered by loam and sand.)*

Qet — Early terrace gravels *(higher river gravels covered by loam and sand.)*

TERTIARY

Eocene? and Pliocene

Tl — Lake beds. Payette and Idaho formations undifferentiated *(sands, clays, and fine gravels)*

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs.)

QUATERNARY

Pleistocene

Qb — Basalt

TERTIARY

Pliocene

Tb — Basalt

Eocene?

Tr — Rhyolite

A.H.Thompson, Geographer.
W.T.Griswold, Topographer in charge.
Triangulation by W.T.Griswold.
Topography by E.T.Perkins Jr. and W.P.Trowbridge.
Surveyed in 1891.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.
Edition of Sept. 1903.

DIAGRAM OF TOWNSHIP

Geology by W. Lindgren and N.F. Drake.
Surveyed in 1897.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be determined by observing their positions. This relationship holds except in regions of intense disturbance; in such regions sometimes the beds have been reversed, and it is often difficult to determine their relative ages from their positions; then *fossils*, or the remains and imprints of plants and animals, indicate which of two or more formations is the oldest.

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent; Pleistocene	Q	Brownish-yellow.
Cenozoic	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
Mesozoic	Jurassic		J	Blue-green.
Mesozoic	Triassic		Ћ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
Paleozoic	Devonian		D	Blue-gray.
Paleozoic	Silurian		S	Blue-purple.
Paleozoic	Ordovician		O	Red-purple.
Paleozoic	Cambrian	Saratogan; Acadian; Georgian	€	Brick-red.
	Algonkian		A	Brownish-red.
	Archean		Æ	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface, and can draw sections representing the structure of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

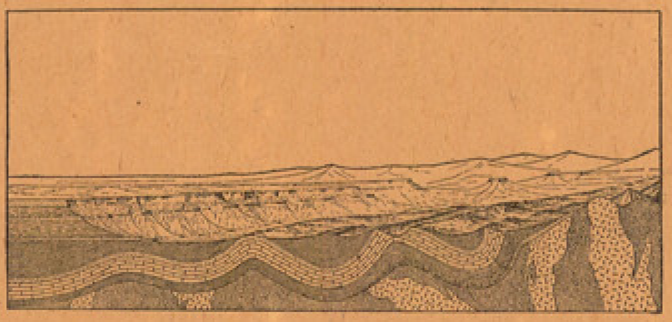


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

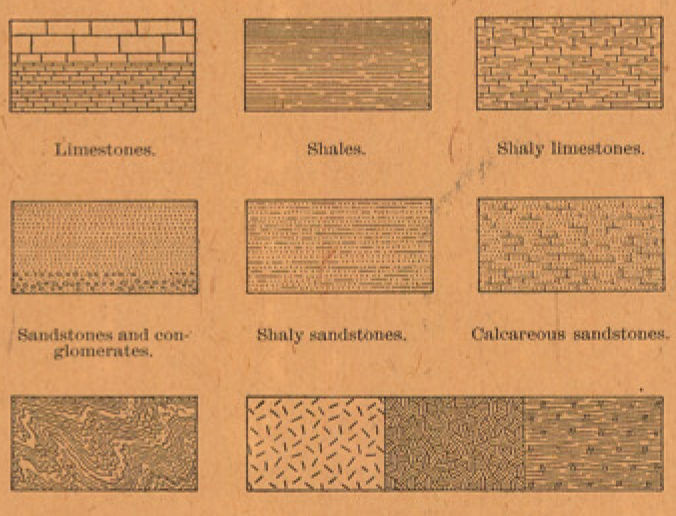


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

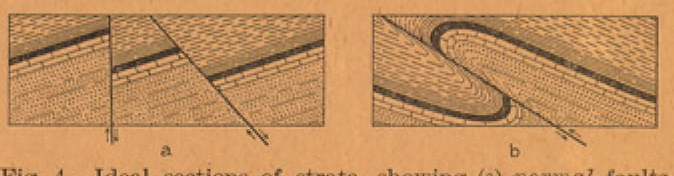


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

CHARLES D. WALCOTT,

Director.

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