DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

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GEOLOGIC ATLAS

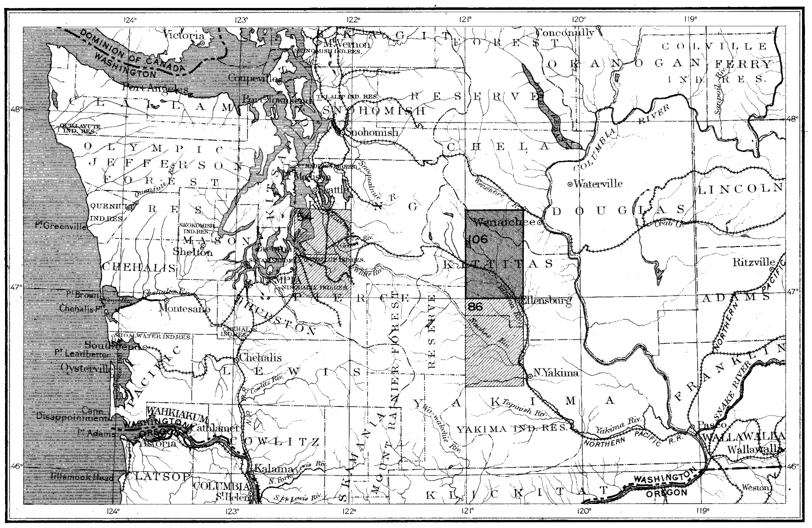
OF THE

UNITED STATES

MOUNT STUART FOLIO

WASHINGTON

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE MOUNT STUART FOLIO

AREA OF OTHER PUBLISHED FOLIOS

CONTENTS

LIBRARY EDITION

MOUNT STUART FOLIO
NO. 106

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1904

OHIO STATE UNIVERSITY

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).

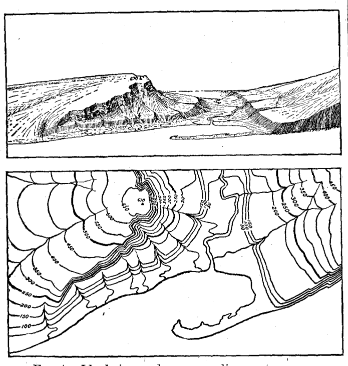


FIG. 1.—Ideal view and corresponding contour map.

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.)

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.
	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Ꞃ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	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:

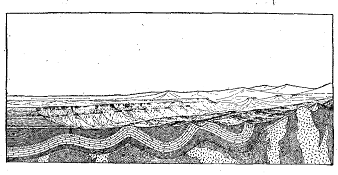


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

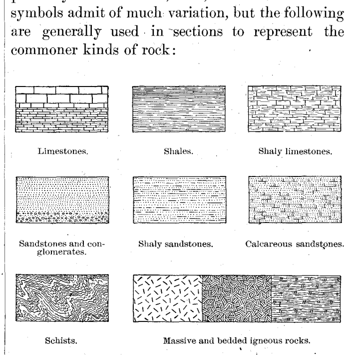


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

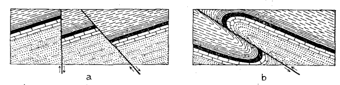


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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.

Revised January, 1904.

DESCRIPTION OF THE MOUNT STUART QUADRANGLE.

By George Otis Smith.

GEOGRAPHY.

Natural divisions of the State.—The State of Washington comprises five great divisions, which are geologically as well as geographically distinct.

In the western part of the State the Olympic Mountains overlook the Pacific and, forming apparently the northern extension of the Coast Range of Oregon, are themselves represented northward, beyond Juan de Fuca Strait, in the heights of Vancouver Island.

East of the high mountains of the Olympic group is the Puget Sound Basin, a depression which is very noticeable because of its position between parallel mountain ranges, and which extends beyond the boundaries of the State, southward in the Willamette Valley of Oregon and northward in the sounds of British Columbia. Its characteristic topography and geology are described in the Tacoma folio, No. 54.

The third division is the Cascade Range, a mountain mass having a north-south trend and forming the most prominent feature of the State. This line of uplift is a continuation of that of the Cascade Range of Oregon, but the Cascades of Washington deserve further subdivision. From Columbia River northward to the vicinity of Mount Rainier the range resembles the Oregon portion, both in topography and in geology, basaltic and andesitic lavas of Tertiary age constituting the material from which the mountains have been constructed. A portion of the eastern flanks of this type of the Cascade Range is described in the Ellensburg folio, No. 86. Farther north, however, older rocks appear in the Cascade Mountains and the topography becomes more varied than to the south. These geologic and topographic distinctions are sufficiently important to deserve recognition, and on this account the range from the vicinity of Mount Rainier northward to the forty-ninth parallel will be termed the Northern Cascades. The application of this term beyond that parallel is questionable, since there is in this vicinity an abrupt change from rugged peaks to the more rounded and lower ridges north of the international boundary. The area described in this folio is typical for the Northern Cascades. The volcanic cones of Adams, Rainier, Glacier Peak, and Baker, that dominate both portions of the Cascade Range in Washington, are of later date than the range itself, and their distribution does not affect the subdivision here proposed.

The fourth important feature of Washington is the Great Plain of the Columbia, a plateau region that extends southward into Oregon and eastward into Idaho, and includes approximately one-third of the State. In the Ellensburg folio is described the border land between the Columbia Plain and the Cascade Range.

The mountainous district bordering the Columbia Plain on the north and traversed by the international boundary constitutes the fifth natural division of the State. It includes the Colville Mountains, which apparently represent the southern continuation of higher mountains in British Columbia.

Situation and extent.—The Mount Stuart quadrangle is bounded by the meridians 120° 30′ and 121° west longtitude and the parallels 47° and 47° 30′ north latitude. The area thus included is 812.4 square miles. The quadrangle is situated nearly in the center of the State of Washington and includes portions of Kittitas and Chelan counties.

Relief.—The quadrangle lies on the eastern slope of the Cascade Mountains, and the northern half of the area includes the Mount Stuart massif and its foothills. Mount Stuart, the most prominent topographic feature of the quadrangle, is the culminating peak of an important spur of the main Cascade Range, the crest of the main range lying 15 miles to the west. This secondary range Prof. I. C. Russell has termed the Wenatchee Mountains. Mount Stuart rises to an elevation of 9470 feet above sea level, and, with its deeply carved spires and crags, more or less covered with snow throughout the summer, is the most striking feature in the varied scenery of the region. Its wildest and grandest scenery, however, lies hidden within its fastnesses.

The southern face of Mount Stuart is a precipitous slope rising 5000 feet or more above Ingalls Creek. This wall can be scaled at several points, but by only one route has the highest peak been successfully attacked by the mountain climber. This route is along the right-hand side of a well-defined gulch which debouches in a large alluvial cone opposite the mouth of Turnpike Creek. At the head of this gulch begins the true climb westward along the arête with its huge blocks of rock. The summit is about a thousand feet above, and, when reached, the peak is found to be so acute that the greater part of the available space is taken by the triangulation monument. Below, the northern and western faces are so much more precipitous as readily to convince the observer that there is only one approach to the summit.

On the north side of Mount Stuart are broad and deep amphitheaters, in which lie small glaciers and glacial lakes, draining northward into Icicle Creek. The glaciers immediately below the main peak are mere remnants, often only a few hundred yards in extent, yet as seen from the summit these exhibit the characteristics possessed by larger ice streams; crevasses cross the surface and indicate clearly the lines of flow in the lower portions of the glacier, while one terminal moraine was observed. Névé fields connect these tiny glaciers, so that they form a chain at the base of the cliff that so effectually protects them. In the Twin Lakes amphitheater there is a much larger glacier, about 2 miles in length. A nunatak rising through this sheet of ice is a conspicuous feature, and the typically rounded surfaces of this glacial basin present strong contrasts with the extremely rugged outlines of the higher parts of the range.

Southward from Mount Stuart extend the lower peaks and ridges, many of which are hardly less rugged than Mount Stuart itself. The valleys are canyon-like in character, and dissection of the land surface has reached an extreme degree of maturity. There is, however, some variety in the extent to which erosion has been carried. Rocks of varying structure and hardness have caused the details to differ somewhat, but everywhere within this zone the topography is bold. The divides are generally narrow, the crests of the ridges being often so sharp as to be almost impassable. Below, the slopes are steep, and high cliffs border many of the valleys. The larger streams in this part of the quadrangle have rather broad valleys, although a striking feature is the number of types that may be observed in a single valley. Within a few miles a stream will pass from a broad basin down over a series of cascades, then wind through beautiful intermontane meadows, only to again dash down into a deep canyon. Such a succession is found in the valley of Negro Creek, and similar alternations of level stretches and precipitous cascades characterize almost every other stream. In general the gradient as well as the width of each valley is largely determined by the character of the rock in which it has been cut. The valley of Negro Creek furnishes a good example of this. The upper basin and the lower broad and level portions of the valley are in serpentine and soft sandstone and are separated by belts of hard, igneous rock over which the stream cascades. The lower half of the valley is a narrow canyon cut in igneous rock and hard slate.

The southern half of the quadrangle includes a portion of the sloping plateau which extends from the higher parts of the Cascades on the west to the plain of the Columbia on the east. The gentle eastward slope of this plateau can be seen in the sky line as one looks southward from the peaks near Mount Stuart. The flat-topped ridge south of Yakima Valley, and Lookout and Table mountains just to the east, are instantly recognized as topographic features quite different in character from those already described. This southern region is, like the northern, deeply trenched with canyons, but the streams are much farther apart, so that the divides between the drainage lines are broad and level and the plateau character of the region is very apparent. Table Mountain and the Manastash area afford the best examples of the plateau topography. The nearly level plateau is so wanting in noticeable features as often to render it difficult to recognize particular localities. The level character of the surface generally continues to the very brink of the canyons, where the stream is several hundred or even a thousand feet below.

The valley of the upper Yakima forms the northern boundary of the western portion of this plateau, but within this quadrangle the Yakima cuts across the escarpment which marks the edge of the plateau. Thus, in the southeast corner of the quadrangle, Kittitas Valley, as this portion of the valley is called, forms an extensive depression in the plateau country. In Kittitas Valley, as well as in the upper valley of the Yakima, extensive terraces border the river, a feature also prominent in the lower portion of Teanaway Valley. Narrow terraces occur along the smaller streams which are tributary to the Yakima, such as Swauk Creek and the three forks of the Teanaway.

A somewhat uncommon topographic form which is very noticeable within the Mount Stuart quadrangle is the landslide. While occurring in almost all parts of the quadrangle and seeming to be in a way independent of geologic structure, the landslides are most abundant along the northern escarpment of the plateau country, especially on Table and Lookout mountains. Here the masses of rock which have separated from the mountain side are so extensive as to render the resultant topography at the base of the cliffs very conspicuous. The best example of this is at the western base of Lookout Mountain, where the belt of landslide topography is a mile and a half wide. Three small lakes occur here in the basins formed behind the immense blocks of rock that have slid down toward the valley. Such undrained basins are characteristic of topography that has originated in this way, and may be found in many localities within the Mount Stuart quadrangle. The landslide areas will probably aggregate a score of square miles within this quadrangle, but it has not seemed best to delineate such areas on the geologic map, since in spite of their presence it is possible to map the correct distribution of the various underlying formations.

Drainage.—The Mount Stuart quadrangle includes parts of two drainage basins. The larger part of the quadrangle is tributary to Yakima River, while nearly one-fourth is drained by streams flowing into Wenatchee River, a few miles north of the northern edge of the quadrangle. Both of these rivers are important tributaries of the Columbia.

The Yakima here is a stream of considerable size, as it receives just west of the western edge of the quadrangle the waters of Clealum River, the last and largest of its three important headwater tributaries. The flow of the Yakima at Ellensburg may be estimated from measurements taken during the year 1898 at gaging stations in the vicinity of North Yakima. Using this basis, the mean annual discharge is 2500 second-feet; the maximum discharge is about 15,000 second-feet, in February; and the minimum is less than 250 second-feet, in October. The unusually high water of 1899 would give very different results, but the discharge of 1898 is believed to be more nearly normal.

Yakima River has considerable grade—about 15 feet to the mile—while the Teanaway has a grade of 30 to 40 feet. Both rivers when at flood cut into their gravel banks at many points, and minor changes in their channels thus ensue. Next to the area drained by the Teanaway, the basin of Swauk Creek is the most important area, while Reeser, Taneum, Wilson, Naneum, and Manastash creeks are streams draining the plateau region in the southern half of the quadrangle. Naneum and Manastash creeks enter the Yakima south of the limits of the Mount Stuart quadrangle.

The three streams tributary to Wenatchee River are Icicle, Mission, and Peshastin creeks, the last having Ingalls Creek as an important feeder. These are all rapid mountain streams, the branches of Icicle Creek being fed by the small glaciers near the northern edge of the quadrangle, and Ingalls Creek draining the Mount Stuart range. The valley of Ingalls Creek shows abundant traces of former occupation by a large ice stream which extended down below the junction of this creek with the Peshastin.

Climate.—This area shares to a small extent the arid climate of eastern Washington, but it is also affected by the climatic influences of the mountain range immediately to the west. Thus, at Ellensburg the precipitation averages about 10 inches, although in 1898 it was only 3.71 inches. Twenty-five miles farther up Yakima Valley, at Clealum, which is only a few hundred feet higher, there is a much heavier rainfall. The observations recorded by the Weather Bureau for 1899, which was an exceptional year, give a total of 11.87 inches for Ellensburg and 38.47 inches for Clealum. The more elevated portions of the quadrangle doubtless have even greater precipitation than that measured in Yakima Valley. The average annual run-off for the entire basin of the Yakima is nearly 24 inches, which also indicates a much heavier precipitation than that recorded at Ellensburg and other localities in the lower part of the Yakima basin. By far the greater part of the precipitation in the higher parts of the quadrangle is in the form of snow. The summit of Table Mountain is often temporarily whitened with the first snows in September, and in the following months the snowfall is so heavy that deep drifts remain on the flat top of this mountain until the early part of July. Within the elevated area around Mount Stuart snow not uncommonly remains in banks and extensive fields throughout the greater part of summer, and the northern slopes of many of the peaks are never wholly free from it.

The mean winter temperature at Ellensburg is about 28° F., and at Clealum about the same. The mean temperature for the summer months at Ellensburg is about 60°, and a few degrees less at Clealum. The extremes of temperature at these two places in 1899 were 96° and —20°.

Vegetation.—The greater part of this quadrangle was originally wooded, but the forests are different in type from those farther west. For the most part the trees are not closely set, but form open groves, through which a horseman can ride in any direction. Along many of the stream bottoms, especially in the western half of the quadrangle, vegetation becomes more luxuriant and the thickets of small trees and shrubs somewhat resemble the forest condition on the western slope of the Cascades. The devil's club (*Echinopanax horridum*), so characteristic of the western slope, is not known in the Mount Stuart quadrangle, although it has been found at several localities within a few miles of the western boundary. The higher peaks have an alpine flora, and the few trees have the stunted and gnarled forms characteristic of growth where the struggle with snow and wind is severe.

Kittitas Valley is timberless except along the river banks, the sagebrush and other desert shrubs constituting the prevailing vegetation.

The reports of the forestry division of the Survey show that the yellow pine (*Pinus ponderosa*), the red fir (*Pseudotsuga taxifolia*), and the tamarack

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(*Larix occidentalis*) are the species that make up the forests of this quadrangle. The wooded area is estimated as 579 square miles, mostly with merchantable timber. The total stand of timber is about 370 million feet, being for the most part yellow pine.

Culture.—The main line of the Northern Pacific Railway traverses Yakima Valley, where the greater part of the population of the quadrangle is concentrated. Ellensburg, the county seat of Kittitas County, lies partly within this quadrangle and in 1900 had a population of 1737. It is the commercial center for Kittitas Valley and the neighboring region. Roslyn, situated on a branch of the Northern Pacific near the western border of the quadrangle, is the center of the coal-mining industry of the county. Its population in 1900 was 2786. Clealum, at the junction of the Roslyn branch with the main line, had a population of 762. Thorp and Teanaway are small hamlets in Yakima Valley, and Blewitt and Liberty are mining camps. The total population of the quadrangle slightly exceeds 5000.

The industries are mining, agriculture, and stock raising. There is no lumbering except to supply local demands. Agriculture is confined to the valleys of the Yakima and the Teanaway and several higher areas, as Swauk Prairie, Thorp Prairie, the southern slope of Lookout Mountain, and Camas Land. Wheat and other cereals, alfalfa, and other forage crops constitute the principal products. Small fruits grow well here, but orchard products are less important in Kittitas Valley than farther south along Yakima River. Dairying is an important industry.

Cattle and horses are raised to some extent, but perhaps less than before the advent of sheep. During the summer months bands of thousands of sheep can be seen in all the more elevated portions of this quadrangle. They even reach the slopes of Mount Stuart. The abundance of nutritious grasses has made sheep grazing very profitable, but this industry has seriously injured the region. Desolate tracts of burnt timber and rocky slopes, where sharp hoofs have cut up the turf, allowing the soil to be washed away, mark the track of the sheep herder. Such conditions can not fail to affect the natural storage of the water in the mountains, and thus to diminish the supply available in midsummer for irrigation along the lower valleys.

GENERAL GEOLOGY.

GEOLOGIC HISTORY.

General features.—It is believed that the Mount Stuart quadrangle is exceptional for this province in the completeness with which the geologic record is exhibited. It is thus a representative area for the geologic province of which it is a part, and contains both the oldest and the youngest rocks thus far discovered in the Northern Cascades. The Mount Stuart massif and the lower but rugged peaks encircling it constitute an area of the older or pre-Tertiary rocks, while to the south and east are strata of Tertiary age, under which the older formations are buried.

This separation of the rocks of the Mount Stuart quadrangle into the older or pre-Tertiary and the younger or Tertiary is at once natural and most obvious. The difference between these two groups is apparent to any close observer. The older rocks are varied in composition and kind, but all are more or less altered, and the age of no formation among them is definitely determined. Above, fossil plants afford a basis for the exact age determination of several formations. Among the formations of pre-Tertiary age, intrusive igneous rocks predominate—that is, the rocks are such as were formed at a considerable depth below the surface of the earth, consolidating from bodies of molten rock material which was forced up from below. On the other hand, the Tertiary rocks are chiefly of the kind formed at the surface, sediments and volcanic deposits. These are sandstones, for the most part, and shales, deposited as sands and muds in large inland lakes, or lavas and beds of tuff erupted from openings in the earth's crust.

The difference in age between these two groups of rocks is considerable. The older rocks had been long exposed to the influence of the atmosphere and been carved by streams into hills and valleys when the first deposits in the Eocene waters were laid down, over an uneven surface composed of rocks widely differing in character. This is what is meant when it is said that there is at the base of the Eocene sandstone a marked unconformity, representing an erosion interval. In the following portions of this descriptive text the geologic history of the region will be outlined and all of these formations, both pre-Tertiary and Tertiary, will be described in more detail.

Pre-Tertiary Periods.

Formation of the oldest rocks.—The oldest rocks in the quadrangle are probably of Paleozoic age. As will be shown more fully later, these rocks are in large measure metamorphic—that is, they have been altered from their original condition. Yet, sufficient remains of the original characters to show that the schists, slates, and greenstones of the Easton, Peshastin, and Hawkins formations represent both sediments and products of volcanic activity. The record furnished by these older rocks indicates that the conditions of sedimentation and of volcanism were remarkably similar to those prevailing at approximately the same time in the Sierra Nevada area and in British Columbia. Rocks strikingly similar to those of the Mount Stuart area are also found in the Blue Mountains of Oregon and in the Okanogan Valley south of the international boundary. The inference from these relations is that during a portion of Paleozoic time the Pacific coast region from British Columbia to California constituted a single geologic province. The absence of Mesozoic sediments in this central Washington region suggests that it became a land area during Mesozoic time. The existence of a thick mass of Cretaceous rocks in the Northern Cascades immediately south of the international boundary shows the extension of the Cretaceous sea southward from British Columbia, while rocks of similar age in the John Day basin and Blue Mountains of Oregon mark the southern limit of this central land area. Later formations conceal these older rocks over large areas, but future geologic study may furnish data for a description of the Paleozoic and Mesozoic geography, which can only be touched upon now.

Igneous intrusions.—The next recognized chapter in the geologic history is that of the injection of large masses of molten rock in these older rocks. The schists, slates, and greenstones had been folded and uplifted from their original positions when the intrusions of igneous rock began. The earlier of these was that of the extremely basic magma which crystallized to form the peridotite, now largely altered to serpentine. The masses of older rock were separated by large bodies of this intrusive rock, often nearly a mile across. Smaller bodies of the Peshastin formation were broken off and completely engulfed in the molten magma, so that now many blocks of this foreign material are found included in the serpentine.

Striking as was this display of the power of earth forces, the next exhibition of igneous intrusion was on a larger scale. The Mount Stuart batholith is a mass of intrusive granitic rock measuring many square miles in area; in fact, the limits of its extent northward beyond the Mount Stuart quadrangle have not yet been determined. The petrographic characters of the rock, as well as the metamorphic action the cooling mass exerted upon the adjacent rocks, favor the view that this intrusion was essentially deep seated, although its exact depth below the surface can not be stated. The Mount Stuart granodiorite now forms the core of the Wenatchee Mountains, and its intrusion may have initiated the uplift of this minor range. Prior to this, however, as noted above, the older rocks had been subjected to mountain-building forces, and, as will be shown later, the Wenatchee Mountains owe their present elevation to movements during Tertiary time.

Erosion.—Nothing definite can be stated regarding the age of these igneous intrusions. The nearest date that can be fixed is the beginning of the Eocene, but at that time the granodiorite, serpentine, and older rocks had suffered a considerable amount of erosion. The cover under which the granitic mass had consolidated had been removed and the rocks, of varying hardness, had been carved so as to form a region of bold relief. This interval of time during which atmospheric agencies accomplished so much is measured by the great unconformity between the older rocks and the earliest of the Tertiary sediments.

Tertiary Period.

EOCENE EPOCH.

Early sedimentation.—Conditions favoring the deposition of the waste from the eroded rock masses began early in the Eocene epoch. The coarse bowlders of granodiorite, serpentine, and other rocks accumulated near their present ledges and were successively covered with finer sediments deposited in the rising waters of the Eocene lake. The rugged topography caused the coast line to be extremely irregular, so that inclosed lagoons and narrow inlets doubtless occurred in close proximity to bold headlands. Variety in the sediments resulted, and fine muds and coarse granitic sands may have been laid down contemporaneously in adjoining areas. The higher portions of the mass of granitic rock appear to have been exposed to active weathering agencies, since the larger part of the Swauk formation is composed of fresh arkose, plainly derived from the Mount Stuart granodiorite.

Basaltic eruptions.—Elevation accompanied by a moderate amount of flexing probably terminated the epoch of sedimentation. Erosion immediately began its work and had truncated certain of the folds before the eruption of large masses of basaltic lava and tuff took place. The source of this volcanic material was deep seated, the molten rock reaching the surface through hundreds of vents. Cracks in the sandstone, serpentine, slate, and even the granodiorite appear to have been taken advantage of by the extremely fluid magma, which thus secured a passage upward to the surface. For the most part the lava spread out in great sheets, while in certain localities the presence of steam in the molten rock appears to have caused explosive eruptions, thick beds of basaltic tuff being intercalated with the lava sheets.

Later sedimentation.—The violent volcanism was succeeded by quiet sedimentation in the waters which soon covered the basaltic rocks. The sands and muds deposited in this later Eocene epoch appear to have been better sorted than the materials composing the earlier Eocene sediments. Vegetal matter, which was present in the earlier formation now became prominent, and during the later part of the epoch, represented by the Roslyn formation, the conditions of sedimentation were such as to allow the deposit of several beds of carbonaceous material, which now furnish workable seams of coal.

Sedimentation during Eocene time appears to have taken place in basins which were neither extensive nor permanent. The Swauk water body was doubtless larger than the Roslyn, while the latter basin appears to have had a position well toward the southern edge of the Swauk basin. The Roslyn waters, however, did not extend far to the south, since the Manastash formation, which is of late Eocene age, is found to have its basal sediments resting directly upon the pre-Tertiary schists. The Manastash basin was thus south of the Roslyn basin, which was south of the basin in which the Swauk sediments were deposited. This southward migration of the lake basins in Eocene time very probably had its origin in resistance offered by the Mount Stuart massif to the mountain-building movements which continued throughout the Tertiary period. The deposition of the sands and muds, now indurated and forming the rocks of the Manastash formation, closed the Eocene sedimentation, as far as the record is known.

MIOCENE EPOCH.

Basaltic eruption.—The stratigraphic break between the Eocene and Miocene epochs indicates a time of erosion in this area. The rocks of the Manastash formation were somewhat folded after their deposition late in the Eocene. Erosion followed, and this was continued for a considerable time. In the John Day region of Oregon, where definite correlations can be made with the late Eocene and Miocene formations of this area, this erosion break is represented by a thick mass of sediments, the John Day formation. This time of erosion was terminated by a recurrence of volcanic activity, the Eocene basaltic eruptions being only a prelude to the volcanism of Miocene time.

This eruption of basalt during the Miocene epoch constitutes one of the greatest of volcanic phenomena. The mass of these basalt flows, which extend beyond the boundaries of the State of Washington, is measured in terms of thousands of cubic miles, and the transfer of so great an amount of material from the earth's interior to the surface ranks as one of the greatest geologic events. However, these eruptions were for the most part unmarked by violence and of the nature of a quiet upwelling of the fluid lava from a number of vents. Dikes representing the old conduits can be seen where the older rocks underlying the basalt are exposed. These dikes, however, are not so numerous as those which fed the Eocene basalt flows.

These lava flows were poured forth over a region having considerable relief, but the surface inequalities were soon obliterated by the floods of molten rock, which filled the deepest depressions and lapped over the higher portions of the old surface. Eventually the region, which before had been diversified with verdure-covered hills and valleys, became a monotonous waste of black rock.

Sedimentation.—Even before the last flow of basalt was erupted sedimentation began again in this area. These late Miocene sediments form the Ellensburg formation, and their characters give a clue to the history of that time. They show that streams flowing down on to the lava-covered plain deposited their loads of sand and gravel on the basalt surface. The coarseness of much of the material thus laid down and the presence of stream bedding indicate that the streams were of sufficient volume and grade to transport large bowlders and that sedimentation did not take place in a lake but that the deposits are of fluviatile origin.

A feature even more characteristic of these deposits is the uniform petrographic character of the material constituting them. Both the largest bowlders and the finest particles appear to have been derived from one source—a mass of volcanic material of fairly constant composition. The evidence is that in some adjacent region, presumably to the southwest, there were eruptions of andesitic lava at this time, from which the eastward-flowing streams brought down pebbles and bowlders, together with finer sand and silt. These eruptions were altogether different in character from the fissure eruptions of the basalt, as is shown by the abundance of finely comminuted volcanic glass and of large pieces of very light pumice in the andesitic material thus transported by the streams. Such volcanic explosions furnished material readily swept away by the streams, which became overloaded wherever there was even a slight decrease in grade. Thus the stream deposits were spread out in wide alluvial fans over the generally level basin of basalt. Some of the beds of finest volcanic material may be of eolian origin, showers of volcanic dust having covered the flood plains and overloaded the streams with silt.

PLIOCENE EPOCH.

Uplift and erosion.—It seems probable that the basin in which the gravels and sands of the Ellensburg formation were deposited included only a portion of the Mount Stuart quadrangle. Along the borders of the depressed area rose higher country, and here the rocks had been exposed to erosion in parts of Miocene time. Portions of this country, indeed, had been eroded even during parts of Eocene time, since the Eocene water bodies do not appear to have had great extent. Now further uplift exposed all the rocks to fresh attack, and this degradation of the land by the streams was continued with no apparent cessation until the whole region was reduced to a lowland.

This approximately level plain, or peneplain, probably of Pliocene age, is excellently preserved immediately south of this quadrangle, and is fully described in the Ellensburg folio. In the Mount Stuart quadrangle traces of the peneplain can be seen along the southern slopes of Table and Lookout mountains and on the mesa between Yakima River and Dry Creek. In these localities the surface slopes in the same direction as the dip of the basalt sheets of Ellensburg strata, but at a smaller angle with the horizon. This surface represents the peneplain, which was developed on both basalt and sandstone, and was later uplifted so as to have the present slope to the south. Subsequent erosion has not been sufficient to prevent recognition of these peneplain remnants.

Main uplift of the Cascades.—The later uplift of the lowland surface just referred to was undoubtedly connected with the birth of the present Cascade Range. This was perhaps the closing event of the Tertiary period. To this uplift must be attributed the marked differences in the present physiographic aspect of the portions of the quadrangle north and south of Lookout Mountain. Variation in degree of uplift has strongly influenced the later geologic history. Farther south, along Yakima River, ridges were uplifted to their present elevation of 3000 to 4000 feet above sea level, but there the aridity of the climate has prevented erosion from destroying the traces of the older topography thus deformed. As stated in the preceding paragraph, the uplifted surface has been also preserved on the southern slope of the Lookout-Table Mountain ridge. North of this, however, the uplift appears to have been sufficient to raise the surface to an elevation where climatic conditions were more favorable to active erosion.

This uplift may have reached its maximum near Mount Stuart, so that the axis of this later arch may be considered as that of the transverse range which has been termed the Wenatchee Mountains. This arch becomes less prominent eastward from Table Mountain, but in its higher western portion is fairly comparable to the broader uplift of the main range. The eastern portion of the Mount Stuart massif exhibits a broad bench between 8000 and 8500 feet high, a feature that suggests the old surface which elsewhere has been deeply dissected by glacial and stream erosion. Above this, Mount Stuart itself rises as a monadnock over 1000 feet high, and with its total elevation of 9470 feet is probably the highest peak in the Northern Cascades, except the later volcanic cones. Thus it seems fair to conjecture that 8400 feet is an approximate measure of the uplift of the lowland surface along the Wenatchee Mountain axis, and this may fully equal the change of elevation in the main range. This amount of uplift was more than sufficient to enable erosion to attack very effectively the rock masses. This explanation of the rugged topography of the northern portion of the Mount Stuart quadrangle is somewhat conjectural, but it is the one which appears best in accord with the facts.

Quaternary Period.

Development of present topography.—The present knowledge of the later history of this area is too incomplete to warrant a sharp separation between Tertiary and Quaternary time. The fossil leaves contained in the Ellensburg sandstone definitely fix its age as late Miocene, but no exact date can be given for the events succeeding the deposition of these sediments. It has seemed most plausible to fix the date of the peneplain as Pliocene. The subsequent uplift of the Cascade Range inaugurated the present cycle of topographic development, and the commencement of this widespread deformation might be considered as marking the end of the Tertiary. It seems equally possible, however, that this warping and uplift were events of late Pliocene time which continued into the Pleistocene.

Whatever subdivision of post-Miocene time is adopted, the active degradation of the elevated region began with the uplift, and the work of sculpturing the mountains into their present forms was largely accomplished in Quaternary time. The streams that constitute the drainage system on the Pliocene lowland then began to entrench themselves in canyons. Several factors determined the character of the different stream valleys; of these the most important were the nature of the rock in which the stream had to excavate its valley, and the relation of the stream to the deformed surface. Modifications in the drainage system resulted as the work of dissection proceeded. The master streams have doubtless maintained their old positions and therefore may be characterized as antecedent to the uplift. The best example of this is the course of Yakima River from Teanaway to Dudley, where it has cut a canyon across the uplifted basalt. Another, but smaller, stream which shows an evident independence both of the rock distribution and of the warping of the region is Ingalls Creek. This large tributary of Peshastin Creek, while heading in the serpentine area, cuts directly across the granodiorite and also across what appears to have been the axis of the Wenatchee Mountains uplift. This lack of dependence is also noticed in the case of Peshastin Creek itself.

Other streams in this area exhibit a certain dependent relation to the deformed surface. The drainage from the slopes of Table and Lookout mountains well illustrates this, and such streams may be termed consequent in character. In the case of larger streams, such as Swauk Creek and North and Middle forks of Teanaway River, there is a similar consequent relation to what is believed to have been the slope of the uplift, but the evidence suggests the possibility that these streams, like the Yakima, have maintained for the most part courses established before the uplift began. This somewhat complex relationship of drainage and deformation is believed to have resulted from the fact that the later or post-Pliocene warping followed to some extent lines of earlier deformation, so that streams which had adjusted themselves to the earlier structure might appear to be consequent upon the warped surface, although in reality they are antecedent to the later warping.

Drainage modification by piracy has been effected to some extent within this quadrangle. The most noticeable example of this capture of the headwaters of one stream by another is on the southwestern slope of Table Mountain. Green Canyon represents the channel once occupied by a tributary of Dry Creek. This stream drained several square miles of Table Mountain and was of sufficient power to carve this deep gap across the hard basalt. First Creek, although a smaller stream, had the advantage, however, of flowing across soft sandstone, in its upper course at least, and here it rapidly cut back until it tapped Green Canyon Creek immediately north of the gap and took its waters westward into Swauk Creek. This capture was of so recent date that the former drainage conditions have been in part restored with moderate expense and the greater part of the water of First Creek has been taken through Green Canyon by an artificial ditch and conducted down into Kittitas Valley, where it is used for irrigation purposes.

In a similar way, Horse Canyon may possibly represent the channel once occupied by Swauk Creek. Again, the broad Swauk Prairie area of alluvium is believed to indicate that Teanaway River once flowed on the northeast side of Lookout Mountain and reached the Yakima through the canyon now occupied by Swauk Creek. The bowlders which occur in the Swauk Prairie alluvium plainly came from the headwaters of Teanaway River. In the light of these relations, it appears a plausible hypothesis that at the time the lower Teanaway had this former position a short branch from the east, developed upon the Roslyn sandstone, was able to capture Swauk Creek, just as later First Creek beheaded Green Canyon Creek. Following such a capture of Swauk Creek the upper part of Teanaway River itself was captured by a tributary of Yakima River, which also took advantage of the soft sandstone in its retrogressive development. The law of all these captures appears the same, and is based upon the geologic structure. The work of maintaining the gaps across the basalt escarpment during the later stages of uplift gave the advantage to the larger stream, which was able to corrade a deeper channel in the basalt, and whose tributaries, by development along the strike of the underlying sandstone, easily beheaded the smaller parallel streams. Thus the Teanaway captured the Swauk, only to become itself a tributary of the Yakima north of the basalt escarpment. Green Canyon is certainly to be explained as the result of capture by such a process, while it appears probable that Horse Canyon and the lower Swauk Canyon represent the abandoned courses of Swauk Creek and Teanaway River respectively, Swauk Creek still occupying the canyon cut by Teanaway River.

Glaciation—Evidences of glacial action are confined to the northern third of the Mount Stuart quadrangle. The two existing glaciers north and east of Mount Stuart have already been described. These are the remnants of larger glaciers for which these high mountains formed the center. The largest of these former glaciers was one which occupied the valley of Ingalls Creek, receiving the snow and ice from the southern slopes of Mount Stuart. This glacier headed against the group of peaks immediately west of Mount Stuart and flowed directly east until it reached the valley of Peshastin Creek, where it turned northward. It was a valley glacier of the alpine type, and in the amphitheater at its head has polished and scoured its bed and left morainal deposits.

Other glaciers, much less extensive, originated at the head of Fortune Creek, on the headwaters of North Fork of Teanaway River, and on Stafford Creek. These extended only short distances down the valleys and were less important factors in the modification of topography than the valley glaciers of northern Washington or the ice streams which occupied the valleys directly west of this quadrangle.

Connected with this epoch of glaciation was the deposition of the gravels which are described in a later section. The increased precipitation which is believed to have characterized this epoch greatly augmented the general degradation of the region, and large quantities of rock detritus were contributed to the streams. This loading of the transporting waters was so complete that when the gentler grades of the lower valleys were reached the streams were unable to move the whole of their load and thus began to aggrade their beds. These gravel deposits are much more extensive along the upper course of the Columbia, yet in Yakima Valley they cover many square miles.

Landslides.—An important element in the topography of central Washington is the occurrence of landslide areas. In these areas large masses of rock have become detached from steep cliffs and have pushed downward until they came to rest in the valley below. The most extensive of these landslides border the escarpments of Table and Lookout mountains, where the nearly horizontal sheets of basaltic lava and tuff furnish especially favorable conditions for the development of landslide blocks. In the northern part of Table Mountain Naneum Creek and Williams Creek are attacking the plateau from both sides, and not only are the boundary cliffs fringed with these detached masses of basalt which lie in confusion below, but above, paralleling the present escarpment, can be seen gaping cracks which mark the first stage in the development of future landslides. These landslide blocks are to be distinguished from talus. The masses involved in landslides, though they may sometimes be only a few feet in diameter, are often several acres in superficial extent. Indeed, some of the landslide areas measure several square miles, representing perhaps a succession of several distinct displacements.

The characteristic topography that results from this process is best exhibited below the western escarpment of Lookout Mountain. Here three small ponds occupy the hollows behind large blocks that have been displaced. The amount of vertical displacement of one of these downthrown blocks near Little Lake is 700 feet. Apparently these landslides are not so recent as some below Table Mountain, where vegetation has not gained a foothold on the displaced block. Near Little Lake, on the contrary, the landslide block is bordered by a river terrace belonging to the earlier stage of gravel deposition, and therefore within the Glacial epoch. It is evident both that landslides were characteristic of the Pleistocene and that along Table Mountain movements of the same kind have occurred recently and may be expected to occur in the future.

The occurrence of landslides is not confined to the basalt cliffs, although, as has been noted, the conditions are especially favorable there. Between the two forks of Teanaway River there are large areas where the Roslyn sandstone is much disturbed and the typical landslide topography is found. Undrained hollows occur, showing the extent of these surface movements. It is difficult to explain such displacements, since the sandstone has very gentle dips, not exceeding 5°. Landslides are also found in the area covered by the older rocks, the slate and the serpentine, but there they are neither abundant nor extensive. North of Thorp is an area of between 100 and 200 acres where the Ellensburg sands and gravels have fallen from the edge of the mesa-like ridge between the river and Dry Creek. Behind one of these there is a small pond, which is shown on the topographic map.

On the areal geology map these landslide areas are not outlined. In no place have these phenomena essentially modified the rock distribution or concealed the geologic structure; therefore the displaced masses have been mapped as though they represented rock in place.

DESCRIPTIONS OF FORMATIONS.

Pre-Tertiary Rocks.

Succession.—While the absolute age has not been determined for any of the pre-Tertiary formations, their relative age is determined by their geologic relations, and they will be described in that order. The oldest formations in this region are the Easton schist, the Peshastin slate and, the Hawkins volcanic rocks. Of these, the first is a metamorphic rock, probably of sedimentary origin; the others, while somewhat altered, are plainly sedimentary and volcanic respectively. The intrusive igneous rocks are the peridotite, now largely altered to serpentine, and the Mount Stuart granodiorite.

EASTON SCHIST.

Areal extent.—This formation occupies two small areas in the southwestern part of the quadrangle. The larger of the two includes a portion of the ridge between Yakima River and Taneum Creek. Here the formation is a quartz-mica-schist, a typical metamorphic rock. Though occupying only a few square miles in the Mount Stuart quadrangle, this schist extends westward into the Snoqualmie quadrangle, forming the southern wall of Yakima Valley as far as Easton, from which town the formation takes its name. Southwest of Clealum the Easton schist extends southward from the edge of the valley across the ridge, which rises 2500 feet at this point above the valley, and down across the forks of Taneum Creek. South of this point the schist is hidden beneath later formations, but reappears several miles farther south on South Fork of Manastash Creek.

Description.—Where best exposed the Easton schist is a silvery-gray or green rock, with thin layers of quartzose material separated by micaceous minerals — sericite and chlorite. The rock is extremely crumpled, and gashed and seamed with quartz veins and stringers. Associated with this quartz-mica-schist are other schists, more limited in their occurrence. These are amphibolites—schists composed largely of green hornblende, which probably have been derived from a dioritic or more basic igneous rock, dikes of which cut the rock now metamorphosed into the quartz-mica-schist. Other associated schists have epidote as a prominent constituent.

Immediately west of the base of Clealum Point the schist shows an apparent stratification and includes green and blue amphibole- (glaucophane-) schists and a jaspery quartzite, both the glaucophane-schist and the quartzite containing considerable magnetite. These rocks appear to be metamorphosed sediments. Their occurrence close to the intrusive rock of Clealum Point suggests a possible cause of the metamorphism.

PESHASTIN FORMATION.

Type occurrence.—The typical exposure of this formation is along the canyon of Peshastin Creek near the mouth of Negro Creek. The rock is generally a black slate, and a great thickness is exposed here. Cherty bands and fine grit or conglomerate also occur, but only in relatively small amount.

In the northwestern part of the quadrangle, between the headwaters of North and Middle forks of Teanaway River, there is another area of the Peshastin formation. There black chert is again found interbedded with the slate, and lenses of light-gray limestone also occur. The thin bands of chert are rather persistent, but the lenses of limestone rarely measure more than a few yards in length. Argillaceous rocks other than the black slate occur in this area. These are a red ferruginous slate and a yellowish sericitic rock, somewhat schistose.

In the region between these two larger areas of the Peshastin formation there are several smaller exposures of the slate and associated rocks. In some cases these areas are too small to be represented.

"*Nickel ledge.*"—One exceptional phase of the Peshastin formation and its mode of occurrence should be mentioned. At a number of localities on the headwaters of North Fork of the Teanaway, and on the tributaries of Peshastin Creek, may be seen narrow belts, or even ledges only a few feet across, of a bright-yellow or light-red rock. Such occurrences are locally known as the "nickel ledge" or "porphyry dike." The universal characteristic of the rock is its bright color, by which it can be recognized at considerable distance. The rock is usually very hard, and its weathered surface is extremely rough or ragged. These yellow or red "ledges" occur within the peridotite or serpentine areas or in the areas of Peshastin rocks near the contact with the serpentine. In the latter case the "ledge" is much less homogeneous and includes thin beds of slate and conglomerate. In another locality where the "ledge" occurs within the serpentine area it is associated with a bed of chert. Examined microscopically the rock exhibits no structures that afford any clue to its origin, and the only constituents seen are carbonates and iron oxide. Chemically it is a siliceous dolomitic rock, as is shown by the following analysis, made by Dr. W. F. Hillebrand:

Analysis of rock from the "nickel ledge" in Peshastin formation.

	Per cent.
SiO_2	32.12
Al_2O_3	.82
Fe_2O_3	2.05
FeO	3.50
MgO	26.73
CaO	1.81
Na_2O } K_2O }	.06
H_2O at 110°	.43
H_2O above 110°	.98
TiO_2	trace
P_2O_5	trace
Cr_2O_3	.27
NiO	.08
MnO	.14
CO_2	31.04
	100.03

Two explanations of the origin of this "nickel ledge" might be given. The bands or ledges, which have a general east-west trend, may represent mineralized zones in both the serpentine and the slate, or they may have been originally calcareous beds or lenses belonging to the Peshastin formation, in part included within the intrusive peridotite, in part situated along its contact, and thus subject to alteration by this magnesia-rich igneous rock. The latter hypothesis is the one which is better supported by the relations observed. Limestone lenses such as are called for by this hypothesis occur within the Peshastin areas, though they are not known at the serpentine contact, where, however, the peculiar magnesian rock does occur. At the western edge of the quadrangle, on the ridge next south of Hawkins Mountain, a ledge of magnesian rock, is, however, parallel with a bed of limestone within the slate series. In this area at least, the relationships plainly point to the altered condition of the former rock being directly dependent on the nearness to the serpentine, with which it is partly in contact. The enrichment of the calcareous rock with magnesia may have occurred at the time of the intrusion of the peridotite or later.

The association of chert and slate with the magnesian rock is believed to justify the mapping of the latter as also belonging to the Peshastin formation. The principal occurrences of this rock are on the northern edge of the western area of the Peshastin formation and within the serpentine area in the upper basins of Beverly, Fourth, Stafford, Cascade, Fall, and Negro creeks. Other outcrops, too small to be represented on the map, may be seen near Blewitt and near the junction of Ingalls and Peshastin creeks.

HAWKINS FORMATION.

Description.—The rocks included in this formation are breccias, tuffs, and amygdaloids. The breccia is a dark-colored rock, somewhat banded in places, but more frequently composed of pink or purple angular fragments, often with the texture of pumice, in a greenish matrix, and thus having all the characters of a flow breccia. Such a rock makes up the rugged peak known as Hawkins Mountain, on the western border of this quadrangle. In other localities green tuffs and amygdaloids are associated with the breccia, or the rock is dark green and aphanitic, having little resemblance to an igneous rock. Everywhere these rocks have a marked influence on the topography, extremely rough slopes with pinnacles and spires along the crest lines being characteristic features. The small tooth-like peak east of the basin at the head of Fourth Creek, and the crags of Sheep Mountain south of Blewitt, afford the best examples of this, topography.

Under the microscope all these rocks are found to have the textures of lavas and other volcanic deposits. While there has been considerable production of secondary minerals, such as calcite, epidote, chlorite, and quartz, through alteration of the original minerals, yet remnants of augite and plagioclase crystals show the approximate composition of the lava, and abundant traces of diabasic texture in the rock give additional evidence as to the character of the original rock.

RELATIONS OF PRE-TERTIARY FORMATIONS.

Of the three formations described above, the Easton schist is characterized by the greatest degree of metamorphism. Although it has associated with it rocks that are plainly of sedimentary origin, this schist can hardly be correlated with the Peshastin slate in the northern part of the quadrangle. In view of the evidence exhibited by this crumpled rock of having suffered a much greater amount of dynamic metamorphism than the rocks of the Peshastin and Hawkins formations, it may be well provisionally to consider the Easton schist as the oldest rock in the Mount Stuart region.

The Peshastin and Hawkins formations are intricately mingled in some of the areas, making separation difficult in some cases and impossible, as far as mapping is considered, in others, and in such places the predominating rock only is shown on the map. The two formations with their several areas often widely separated by the intrusive rocks are shown by the geologic map to have a general east-west trend, which in the western area of slate, chert, and limestone corresponds to the strike of the strata. The strata are usually vertical or have steep dips and at only one locality are the relations of the two formations such as to indicate their relative age. On Sheep Mountain, the upper portion of the peak is composed of the volcanic rocks of the Hawkins formation, with black slate and chert breccia of the Peshastin below, the contact planes having a low dip to the northeast. This evidence would indicate that the Hawkins is the younger of the two formations and that the general structure of the remnants of these pre-Tertiary strata as exposed to the north and west of this point is synclinal, although the folding is so close that doubtless minor folds are included within this syncline. The evidence is far from conclusive, however, since at Sheep Mountain the fold may be overturned, and in fact, a few miles west of this quadrangle, relations were observed which indicate strongly that the Peshastin is younger than the Hawkins with the Easton schist plainly older than either.

There is no evidence of any marked unconformity between the Hawkins and Peshastin formations, and, taken together, they have a strong resemblance to the Carboniferous rocks of British Columbia (Cache Creek series) and to the rocks of the same age in the Sierra Nevada (Calaveras formation). Careful search in the slate and limestone failed to show any fossils, by means of which the age of the Peshastin formation might be fixed. The extension of geologic work in the Cascade Mountains may furnish data for a definite age determination of these rocks as well as for their correlation with the rocks of adjoining regions, but at present they can be described only as pre-Tertiary.

PERIDOTITE AND SERPENTINE.

Areal importance.—Bordering the Mount Stuart range on the east, south, and west are two belts of peridotite. These belts are roughly parallel and are connected at a few points by dikes, one of which, at the head of Turnpike Creek, is large enough to be represented on the geologic map. The northern area is the larger and within this quadrangle measures 20 miles in length and over 4 miles in width in its widest part. Together the two areas probably measure about 50 square miles. These belts extend both to the north and to the west, so that the total area of peridotite in this region may exceed 100 square miles.

Description.—The rock which is referred to as peridotite is largely altered to serpentine and shows the greatest possible variation in color and in general appearance. In one part of the area the serpentine may be reddish brown and massive in its erosion forms, while in another locality the rock is bright green and somewhat schistose in structure. In the one case the steep slopes are covered with angular bowlders weighing tons, and in the other the rock weathers into a fine shingle resembling broken glass. Bluish black, dark green, light red, and yellow are other colors frequently noticed. A common occurrence of the rock is in bowlders a foot or less in diameter, not well rounded, but with convex surfaces which often intersect in sharp interfacial angles. The surfaces are usually striated and polished (slickensided), so that sometimes they shine like mirrors in the sunlight.

Except where markedly schistose, the serpentine has a dense, compact texture, with a somewhat waxy luster. In the massive phases it has a porphyritic appearance due to the shining cleavage faces of crystals in the dull aphanitic groundmass. These crystals may also be seen on breaking open one of the slickensided bowlders. The glistening mineral is bastite, an alteration product of enstatite, and this, with the occurrence of the mineral serpentine, which is plainly derived from olivine, shows the altered rock to have been originally an olivine-enstatite rock, the variety of peridotite to which the name saxonite has been given. The only rocks with which the serpentine might be confounded in this region are certain phases of the Hawkins volcanics, described above, and the gabbro and basalt, which will be considered later. The serpentine, however, may be readily distinguished from all of these by its greater softness, being easily scratched with the pick or hammer.

Examined microscopically, some specimens of this rock are found to contain remnants of the original constituent minerals, showing that the alteration of the peridotite to serpentine has not been complete in all cases. Olivine occurs surrounded by serpentine. The olivine is clear, but the cores are bordered with fine grains of magnetite, which has separated out in the course of the alteration of the olivine into serpentine. Mesh structure is present in the rock where this alteration has been completed. Enstatite is a less abundant constituent, and is commonly found altered to bastite, yet in a few cases it occurs unaltered. There are phases of the rock which are almost entirely composed of diallage. Such a rock belongs to the pyroxenites rather than to the peridotites, but its occurrence shows it to represent simply a variation in the peridotite mass. Magnetite is an abundant constituent, being present both in crystals and in fine grains. Pyrite and calcite occur in some specimens of the serpentine.

The following analysis, by Dr. W. F. Hillebrand, is of serpentine from the Three Brothers. This specimen is typical of the altered rock, which shows by its texture, both megascopic and microscopic, its derivation from peridotite:

Analysis of serpentine from Three Brothers Mountain.

	Per cent.
SiO_2	39.00
Al_2O_3	1.75
Fe_2O_3	5.16
FeO	1.71
MgO	38.00
CaO	trace
Na_2O } K_2O }	.10
H_2O at 110°	1.31
H_2O above 110°	12.43
TiO_2	trace
P_2O_5	trace
Cr_2O_3	.47
NiO	.10
MnO	.15
FeS_2 [a]	.03
	100.21

[a] Actual condition of sulphur not known.

The best exposure of serpentine is in the group of high peaks which forms the divide between the headwaters of North Fork of Teanaway River and of Ingalls, Fortune, and Icicle creeks. Here both the massive and the sheared phases of serpentine occur, the zones of crushed rock determining deep gaps in the crests, and the jointed character of other portions of the serpentine mass so influencing the topography as to render it much bolder than would be expected in an area of rock so soft as serpentine. The slopes of these peaks are very steep and are usually masked with heavy talus.

In the eastern portion of the serpentine belts the schistose and sheared phases of the rock prevail. Here it is more difficult to trace the distribution of the serpentine, as irregular apophyses of the igneous rock extend into the older formations, the Peshastin slate and the Hawkins volcanic rocks. Smaller areas of these older rocks are also inclosed by the serpentine, and even larger blocks are included within the mass of the intrusive rock. It is noticeable that the serpentine areas are here characterized by a much less rugged type of topography than farther west. Gentle slopes and rounded divides covered with fine sand indicate the presence of serpentine, while the older rocks form the bolder features.

The age of the peridotite is readily fixed as younger than the three formations already described. In the northern area the peridotite, now in great part altered to serpentine, was intrusive in the slates and tuffs, and in the southwestern part of the quadrangle small dikes of serpentine have been found in the Easton schist.

The alteration which the peridotite has undergone is not of the nature of surficial weathering, but more deep seated in character. Chemically it has resulted in the loss of some of the magnesia, the gain of water, and the further oxidation of the iron. Incident to such chemical change is a considerable increase in volume, to which undoubtedly must be attributed the development of the many zones of sheared material within the serpentine mass, as well as the production of the slickensided bowlders described above.

The alteration process was hydrothermal in its nature and the source of the heated waters may perhaps be the intrusive granodiorite which is described in the following paragraphs. The time of this extensive serpentinization is plainly pre-Tertiary, since the basal conglomerate of one of the Eocene sandstones, as will be shown later, is found to contain the peculiar bowlders of serpentine such as occur on the surface to-day. The crushed and jointed condition of the serpentine, therefore, is the record of an early chapter in its history rather than evidence of dynamic movements or metamorphic action in more recent time.

MOUNT STUART GRANODIORITE.

Description.—Mount Stuart is a rugged peak which owes its prominence in great measure to the character of the rock from which it has been sculptured. This is a gray granular rock, granitic in appearance. Being generally fresh and unaffected by weathering, its constituent minerals can be seen to be white feldspar, black mica, and hornblende, with a few grains of quartz. Although thus resembling granite in appearance and in composition, the Mount Stuart rock is more closely allied to a rock type common in the Sierra Nevada which has been named granodiorite.

The granodiorite of Mount Stuart is thoroughly massive and nowhere shows any gneissoid texture. It is, however, everywhere jointed and sheeted, and to this feature are due the spire and minaret details so characteristic of the crest line of Mount Stuart. The jointing also determines the angular character of the talus blocks on the lower slopes, where the surface of the rock itself has been rounded by glacial action. The granodiorite is not very uniform in its appearance. It shows considerable variation both in grain and in color, and aplitic dikes and dark segregations are common. In a few places there is a slight reddening due to alteration, but nowhere are there any indications of the subsequent introduction of any metalliferous minerals.

The granodiorite is undoubtedly the rock in this region which is most resistant to erosion. This is shown by the freshness of glaciated surfaces which have been long abandoned by the ice. On exposed summits the rock is subjected to rigorous frost action throughout the greater part of the year, and here it crumbles into a coarse sand. Examination of this sand where it has accumulated in crevices of the rock shows that the disintegration of the rock has been purely mechanical, since the mineral grains of the sand are as fresh as the constituents of the rock itself.

The principal area of granodiorite included within the Mount Stuart quadrangle is roughly semicircular in outline and measures about 11 miles along the northern edge of the quadrangle. The northern limit of the Mount Stuart massif, however, is several miles beyond, so that the granodiorite as mapped here represents only a part of a much larger area. A small area of granodiorite occurs on the east side of the valley of Peshastin Creek, but this narrow, low ridge of granodiorite projecting through the sandstone presents few, if any, of the bold features seen in the Mount Stuart range.

Under the microscope the granodiorite is seen to have the typical granitic texture, the feldspars, quartz, and darker constituents forming a closely interlocking mosaic. The rock varies somewhat in grain, but generally the constituent minerals are from 1 to 3 mm. in diameter. The most abundant is the plagioclase, belonging to the acid end of the lime-soda series. This feldspar is often zonal, and the more basic core shows a greater tendency to alteration. The orthoclase is less abundant than the plagioclase, and occurs both in large plates and in interstitial anhedra. The orthoclase is fairly uniform, however, in its distribution, and probably makes up over 8 per cent of the rock. Quartz, although inconspicuous in the hand specimen, is seen under the microscope to be an essential constituent of the rock, occurring in small irregular grains. The ferromagnesian constituents are somewhat more abundant than is commonly the case in granitic rocks. Both biotite and green hornblende are found in this granodiorite in slightly varying proportions, with perhaps, as the rule, the biotite the more important of the two. The hornblende shows a greater tendency to idiomorphic development. Magnetite, apatite, and titanite are accessory constituents commonly present, and augite intergrown with hornblende was observed in one section.

Two chemical analyses of this rock were made by Dr. H. N. Stokes, of the Survey, and are given below. I is the analysis of a rock from the southeastern slope of the Mount Stuart range, a rather light-colored phase of the granodiorite, while II is the analysis of a darker variety of the rock occurring on the southern wall of the canyon of Ingalls Creek, between Hardscrabble and Cascade creeks, near the edge of the granodiorite mass. This rock appears megascopically to be much poorer in quartz and has more of a dioritic appearance. The analyses, however, show the two phases of the granodiorite to be remarkably similar in composition. Chemically, the Mount Stuart rock is close to the typical granodiorite as defined by Lindgren, except for the higher content of magnesia. This expresses itself in the abundance of the ferromagnesian minerals. The potash is subordinate to the soda, while together the alkalies exceed the lime. The rock is therefore of an intermediate type, with the potash feldspar less important than in the monzonites, but rather too abundant to allow this rock to be included among the diorites. It has therefore been termed here a granodiorite, which approaches closely a quartz-diorite. In the quantitative classification of Cross, Iddings, Pirsson, and Washington, based upon the chemical analyses, this rock is a tonalose.

Analyses of Mount Stuart granodiorite.

	I. Per cent.	II. Per cent.
SiO_2	64.04	63.37
Al_2O_3	15.58	15.90
Fe_2O_3	1.26	1.41
FeO	3.22	3.18
MgO	3.23	3.33
CaO	4.51	4.63
Na_2O	4.01	4.05
K_2O	2.22	2.10
H_2O at 110°	.19	.18
H_2O above 110°	1.17	1.16
TiO_2	.69	.69
P_2O_5	.16	.17
MnO	trace	trace
SrO	trace	none
BaO	.11	.06
Li_2O	trace	trace
S	trace	trace
	100.39	100.23

The age of the granodiorite is shown by the occurrence on the western flank of Mount Stuart of dikes of the granodiorite intrusive in the adjacent serpentine. Elsewhere along the contact the relations between these two rocks could not be determined, but fortunately the evidence at the one locality is conclusive, and thus the granodiorite is known to be younger than the serpentine, which in turn has been shown to be younger than the other pre-Tertiary formations described.

CONTACT SCHIST.

The granodiorite is also in contact on both the eastern and western slopes of Mount Stuart with a rock quite unlike any seen elsewhere in this region. This rock is in part mica-schist and in part gneiss, more or less feldspathic. In general composition it resembles a diorite, and might be considered simply a peripheral phase of the granodiorite were it not for the fact that dikes of serpentine as well as of granodiorite are found in the schist. Although no characteristic metamorphic minerals were found in this schist or gneiss, the field relations indicate that it represents some rock, presumably as old as the Peshastin or Easton formations, which was intruded by the peridotite and later metamorphosed by the intrusive granodiorite. This explanation is supported by the occurrence near the eastern contact of small inclusions of Peshastin slate in the serpentine, while the schist occurs at the granodiorite contact in the vicinity.

In several places along the contact the granodiorite stands high above the serpentine or schist, making an escarpment so noticeable as to suggest a fault. The presence at these same points of apophyses of granodiorite which can be traced from the main mass into the serpentine and schist shows, however, that there could have been no general faulting along this contact.

ACID DIKES.

Relation to granodiorite.—In the serpentine belts encircling Mount Stuart there occur numerous dikes of a light-colored porphyritic rock. These dikes are not prominent features in the geology of the region, but are important rather from their connection with the granodiorite mass just described. In no case, however, could any of these dikes be traced into the granodiorite mass of Mount Stuart, although they are most abundant in the area immediately west of that peak. Intrusive masses of granodiorite-porphyry also occur in this vicinity and on Peshastin and Negro creeks. These are mapped with the same color as the Mount Stuart granodiorite.

The rock of these dikes and small intrusive masses varies considerably in its appearance. In the intrusive masses it is a rather coarse-grained rock, often beautifully porphyritic. Such a phase of the rock occurs on the Peshastin above Blewitt, and on Negro Creek. In the dikes the rock is finer grained, plainly porphyritic, light gray or brown in color, may or may not contain quartz, and in general resembles a diorite-porphyry rather than a granite-porphyry.

The prominent phenocrysts in these rocks are mostly feldspar, an acid plagioclase which is usually zonal. Green hornblende occurs in good-sized individuals, but biotite is rarely found, and in this respect the porphyritic rock shows a marked contrast to the granodiorite. Quartz and orthoclase also are not common as prominent constituents, although in one dike on Peshastin Creek the quartz phenocrysts are abundant. The groundmass is finely granular, sometimes with a decided tendency to the granophyric texture. In a few dikes, near the head of Negro Creek, the rock is andesitic in appearance and is also characterized by phenocrysts of a brown hornblende.

The mineralogic composition of most of these rocks points to a close relationship with the Mount Stuart granodiorite, and the chemical analysis of a typical rock of this class affords further evidence of this, showing it to be a tonalose, like the granodiorite. The specimen is from a dike on the divide between Ingalls Creek and a branch of Icicle Creek just west of Mount Stuart. The analysis, by Dr. H. N. Stokes, is as follows:

Analysis of acid dike rock from west of Mount Stuart.

	Per cent.
SiO_2	63.78
Al_2O_3	16.39
Fe_2O_3	1.12
FeO	2.76
MgO	3.27
CaO	4.07
Na_2O	3.84
K_2O	2.03
H_2O at 110°	.22
H_2O above 110	1.82
TiO_2	.44
P_2O_5	.11
MnO	.05
SrO	trace
BaO	.08
Li_2O	trace
S	trace
	99.98

Tertiary Rocks.

EOCENE ROCKS.

Rocks of Eocene age occupy over one-half of the Mount Stuart quadrangle. Three of the formations, the Swauk, the Roslyn, and the Manastash, comprise sedimentary rocks, while the Swauk and Roslyn formations are separated by an extensive series of volcanic rocks, the Teanaway basalt, with which are associated basic dikes. Another rock of Eocene age is the gabbro which occurs intrusive in the Swauk sandstone and the older formations. These formations will be described in the order of their age.

SWAUK FORMATION.

Areal extent.—The Swauk formation extends in a belt from 3 to 12 miles in width across the northern part of the quadrangle. Stratigraphically the formation is limited below by the marked unconformity where its basal beds rest on the pre-Eocene rocks and above by the overlying basalt. The formation receives its name from Swauk Creek, in the basin of which it is extensively exposed. It is also best known from its occurrence in the Swauk mining district. The rocks of this formation are known to extend northward beyond the northeast corner of the quadrangle, across the valley of Wenatchee River, and also westward across the head waters of Clealum River to the higher parts of the Cascade Mountains. Thus the total area of the Swauk formation is several times that included within this quadrangle, and it is one of the most important formations in the Cascades.

Description.—Conglomerate, sandstone, and shale are the rocks comprised in the series here termed the Swauk formation. No general section or succession can be given for the formation, since it varies widely in different parts of the area. The conglomerate naturally is confined mostly to the lower portion of the series, but the shale is found interbedded both with the conglomerate near the base of the section and also with the sandstone higher in the series. No limestone beds occur in this formation, although some of the shale may be slightly calcareous. More commonly the shale is black and carbonaceous, and at several localities it contains well-preserved fossil leaves.

The thickness of a formation in which the succession is so different in different parts of the area is necessarily more or less variable. In some places it is probable that the Swauk formation aggregates over 5000 feet, while in others 3500 feet may be a more accurate estimate. The original thickness of this sedimentary formation can not be definitely determined, since there was erosion of portions of the uppermost beds soon after their deposition.

The basal member of the formation is usually conglomeratic in character, although at a number of localities finer sediments may be found resting directly on the older rocks. In the latter case the sandstone or shale is composed of material plainly derived from the underlying rock, so that greenish-yellow sandstone containing fragments of serpentine may be seen resting on the serpentine. In a similar way the coarsest phases of the basal conglomerates are very local in their occurrence, and in their composition often bear a definite relation to the underlying formation. The serpentine conglomerate is composed of slickensided bowlders, such as occur so abundantly in some parts of the peridotite areas, with a scarcely noticeable admixture of small pebbles of slate and other rocks, the whole cemented by finer detritus of the composition of serpentine. Such a phase of the basal conglomerate is found on the east side of the valley of North Fork of Teanaway River, on Negro Creek, in the lower valley of Peshastin Creek, and on the northwestern slope of Tiptop. In all of these localities except the last the conglomerate is seen to rest directly on the serpentine, and on Tiptop the serpentine would undoubtedly be found not far beneath the surface. In the first of these occurrences the conglomerate is associated with a shale composed of serpentine and magnetite, representing residual material from the rock directly beneath this Swauk outlier.

A basal conglomerate that is composed almost wholly of granodiorite bowlders occurs on the east side of the Peshastin Valley close to the wagon road. Here the blocks of the granitic rock are several feet in diameter and are embedded in an arkose matrix. This quartz and feldspar sand inclosing the granodiorite bowlders is well cemented and makes the conglomerate closely resemble the massive granodiorite itself. Indeed, at this locality it is difficult to distinguish always the conglomerate from the parent rock, which is found directly beneath. The bowlders appear to owe their shape to weathering and thus to have been residual bowlders having undergone little or no transportation. These local conglomerates mark the position of shallow bays where the sediments deposited were derived from the region immediately bordering the shore, and thus foreign material among the pebbles is of exceptional occurrence.

The general character of the Swauk sandstone is that of an arkose. It is usually plainly bedded, and interstratified with shaly and conglomerate beds. In color the sandstone is gray, and light grains of feldspar and quartz and dark flakes of mica may be noticed. In the eastern part of the area, especially along Mission Creek and its tributaries, the Swauk formation shows a notable change in character. The shale and conglomerate become insignificant in amount, and the sandstone is lighter colored and plainly more purely quartzose. The phase of the sandstone is massive and less plainly bedded, and doubtless represents different conditions of sedimentation. In place of sheltered embayments there were exposed beaches where the sediments were subjected to wave action, so that well-washed quartz sands were formed.

Flora.—The shales of the Swauk formation contain abundant and well-preserved fossil leaves. Tiptop, the placer mines on Swauk Creek, and the ridge between Middle Fork of the Teanaway and Clealum River are localities where such fossils may be collected. These leaves from the trees that stood on the shores of the lake in which the Swauk sediments were deposited afford data as to the age of the formation. Dr. F. H. Knowlton reports as follows on the Swauk flora:

From the vicinity of Liberty I have characterized about twenty-five species, all of which are new. They are distributed among the following genera:

Lygodium.	Cinnamomum.
Sabal.	Prunus.
Myrica.	Diospyros.
Comptonia.	Zizyphus.
Populus.	Celastrinites.
Quercus.	Phyllites.
Ficus.	

Of these species a form or variety of only one was previously known, this being *Ficus planicostata*, which is a common species in the Denver and Laramie. Other forms, however, have a more or less close resemblance to certain Laramie, Denver, and Fort Union species, and on this rather insecure basis it is assumed that the age should be regarded as Eocene.

Structure.—The Swauk formation has been subjected to forces which have changed the beds from the horizontal position in which the sands and muds were deposited. The rocks are now folded, the folds being usually open, with the beds only slightly inclined. In some parts of the region, however, the folds are compressed so that the strata are steeply inclined or vertical, and in one locality even overturned.

In a general way the structure of the Swauk formation may be described as simple, consisting of anticlines or arches and synclines or troughs, the axes of which trend northwest-southeast. These folds are rather narrow, and six or eight folds may be traced in the area between Middle Fork of Teanaway River and Mission Creek. In the vicinity of Swauk Creek there is a fold with an east-west trend, and the syncline along Middle Fork of Teanaway River has a north-south axis, but the more common direction is that given above.

The folding of the Swauk rocks was plainly begun soon after their deposition. An examination of the contact of this formation and the basalt directly overlying it shows that the sandstone and shales had been folded and somewhat eroded before the Teanaway basalt covered them. This does not, however, preclude the possibility of further development of these same folds in later time; indeed, in certain cases later action of this kind appears most probable. Further evidence of deformation in these strata is afforded by slickensided surfaces and faulted pebbles in the conglomerates. Small faults can be detected in the basal beds at several localities, but in only one case is the fault of sufficient magnitude to be shown on the geologic map. On the ridge 2 miles south of Hawkins Mountain the sandstone is faulted down so that the edges of the beds abut against the serpentine. Both east and west of this point the fault passes into the crushed serpentine, where it can not be detected.

TEANAWAY BASALT.

Occurrence.—The area covered by the Swauk formation is bounded on the south by a belt, one mile or more in width, in which black basaltic lava is exposed. This rock forms the prominent escarpment bounding the Swauk Creek basin on the south and west, and here it is readily seen that the basalt overlies the Eocene sandstone. An even better exposure of the basalt is where the belt is crossed by the three forks of Teanaway River. The contacts here show that the basalt is conformably overlain by another Eocene formation, the Rosyln sandstone, which will be described in a later paragraph.

It is in view of the fact that the age of this formation is thus determinable that the name Teanaway basalt has been applied to it. In the reconnaissance surveys of central and southeastern Washington by Russell and others, the names Columbia lava and Columbia River lava have been used, including not only basalts of Eocene, Miocene, and possibly Pliocene age, but also hypersthene-andesite of Pleistocene age. In detailed areal mapping, igneous rocks of different ages must necessarily be separated, and therefore the name Teanaway has been applied to this formation, which includes only the basalt flows and interbedded basaltic pyroclastics of Eocene age and which constitutes a series that can be taken as a unit, since it represents the products of volcanic activity uninterrupted by any other important geologic process. The basalt of Miocene age, to be described later, has been termed Yakima basalt.

The Teanaway basalt continues westward beyond the boundaries of the Mount Stuart quadrangle, and occurs again farther south at "Deadmans Curve," west of Clealum, and at two other localities, where small knobs of basalt project above the alluvium of Yakima Valley. A fourth and more prominent exposure of the Teanaway basalt in this vicinity is the bold, wall-like mass east of Clealum Point.

Description.—The Teanaway basalt comprises a series of lava flows with interbedded tuffs overlying the Swauk formation. In its easternmost exposure, under Table Mountain, both flows and tuffs are present, although the formation here measures only 300 feet in thickness. Where Swauk Creek has cut through the escarpment below Liberty several thousand feet of massive basalt are exposed in the canyon walls. Westward and northward from this point tuffaceous beds become more important in the basaltic series and the succession is as variable as might be expected in a series of volcanic rocks. On Middle Fork of Teanaway River, the Teanaway basalt can be seen in its greatest development. Green tuffs and the darker lava flows are intermingled as on the slopes of a volcano, while here the lava also best exhibits the parting into prismatic columns so characteristic of basalt. The section of volcanic rocks exposed here measures several thousand feet.

The Teanaway basalt is black and very compact, breaking into extremely angular fragments. It is readily distinguished from the black shale of the Swauk formation by its greater hardness and higher specific gravity. The presence of iron oxides makes the basalt often a rusty brown on the exposed surface, and the soil derived from the disintegration of this rock is red. The lava is frequently porous, and phases of the basalt occur which are typical amygdaloids. Much of the basalt forming the red wall east of Clealum Point is as vesicular as iron slag, and similar red amygdaloid is found at other places in the area of Teanaway basalt.

The minerals contained in the basalt are not visible to the unaided eye. Microscopic examination of the Teanaway basalt shows the most abundant constituent to be plagioclase, which occurs in lath-shaped crystals and microlites and has the optical properties of labradorite. Augite is next in importance, occurring both in stout prisms and in grains. Olivine was not detected in any specimen although its former presence is suggested by alteration products. Magnetite is present in small grains as well as in fine dust, which renders much of the glassy base almost opaque. The amount of glass in the basalt varies widely, but usually forms a large part of the rock.

The outlier of Teanaway basalt on the Chelan-Kittitas county line, east of the road from Liberty to Blewett, differs from the typical rock described above in that it contains quartz in addition to the labradorite and augite. The quartz is an abundant constituent and shows magmatic corrosion with the usual resorption border of glass and augite grains. The larger phenocrysts of feldspar are also corroded and honeycombed with glass.

The following analysis of typical basalt from Middle Fork of Teanaway River was made by Dr. W. F. Hillebrand. This basalt is black and compact, with a brown glass base, and contains labradorite, augite, magnetite, and probably also iddingsite, which may represent olivine.

Analysis of Teanaway basalt.

	Per cent.
SiO_2	53.35
Al_2O_3	12.90
Fe_2O_3	2.64
FeO	11.28
MgO	2.68
CaO	6.96
Na_2O	2.83
K_2O	1.40
H_2O at 110°	.91
H_2O above 110°	1.76
TiO_2	2.44
P_2O_5	.45
V_2O_3	.04
MnO	.25
NiO	trace
SrO	trace
BaO	.05
Li_2O	trace
FeS_2	.13
	100.07

According to the quantitative classification, this rock would be termed a vaalose, and chemically and mineralogically the Teanaway basalt shows close relationship to the diabase from South Africa which is the type vaalose.

Associated dikes.—As is indicated on the areal geology map, hundreds of dikes of basic rock cut the Swauk sandstone and older rocks. These dikes extend to the Teanaway basalt and in many cases can be seen to connect with the lower sheets of that formation. It is evident that these dikes represent the innumerable conduits through which the molten basalt reached the surface. In exceptionally favorable exposures the vertical dike can be traced, as it cuts the sandstone, to a point where the narrow dike abruptly widens out and becomes a part of the horizontal or gently inclined flow. The evidence is conclusive that the Teanaway basalt was erupted through many fissures rather than from a large volcanic center.

These dikes form one of the most striking features in the geology of the region, and are also prominent topographically. As would be expected, they influence largely the detail of relief on ridge tops, but the dikes do not always determine the higher points, since in many places their position is represented by a deep gap in the crest. The dikes occur principally in the Swauk formation and in the peridotite. In the sandstone they show no constant relation to the structure, and few intrusive sheets are associated with them. They commonly trend somewhat east of north, but the variation in direction is considerable. Usually the dikes are nearly vertical. In width the intrusive material may measure a hundred feet or more or only a few inches. With this variation in width there may be a corresponding difference in texture, but other factors seem in some cases to enter and render the relation complex. Usually the rock in the wider dikes has a coarser and more diabasic texture than that in the narrow dikes, but in a few cases the finer-grained rock has been observed in the wider dike.

While in the Swauk formation the basic dikes are very regular and can be traced for miles, the same dikes change in character as they are followed into the peridotite or serpentine. Here they vary greatly in width and are extremely irregular in trend. This variation is evidently due to the difference in character of the fissures in the sandstone and in the serpentine. In the serpentine, with its many zones of sheared material, there is often a complex of connecting dikes, large and small, in striking contrast to the regularly arranged dikes in the sandstone.

In their petrographic characters the dike rocks show a certain relationship to the effusive basalt. In texture these rocks are holocrystalline and vary from diabase to diabase-porphyry. The abundant phenocrysts of the porphyry are feldspar and pyroxene. The plagioclase is mainly labradorite, some zonal crystals showing rims of more acid composition. The pyroxene is chiefly augite, with which hypersthene is sometimes intergrown. In one specimen the hypersthene was found to be more important than the augite, and was only weakly pleochroic. Commonly, however, the hypersthene is largely altered. Olivine occurs in much of the diabase, being of brownish color, but is usually altered to brown and green material resembling iddingsite, which also appears as a decomposition product from hypersthene. Olive-brown hornblende is present in several of the specimens examined. Quartz is a noteworthy constituent, not only in the hornblende- and hypersthene-bearing phases of the diabase, but also in that containing olivine. The quartz occurs in anhedra and is interstitially associated with micropegmatite. The other constituents are magnetite and apatite.

Doctor Hillebrand has analyzed a specimen which is representative of these dikes, it having been collected from the long dike on the east side of North Fork of Teanaway River east of the bench mark showing an elevation of 4248 feet. This rock is a quartz-bearing olivine-diabase, in which the constituents are labradorite, augite, olivine, quartz, with orthoclase in micropegmatite, magnetite, hornblende, and apatite. The diabase is less basic than the Teanaway basalt, and a quantitative calculation puts the diabase under tonalose rather than vaalose in the quantitative classification. There is, however, a well-marked mineralogic and chemical relationship between these two rocks, which are also genetically related.

Analysis of typical basic dike rock from near North Fork of Teanaway River.

	Per cent.
SiO_2	57.21
Al_2O_3	12.99
Fe_2O_3	3.28
FeO	10.18
MgO	1.59
CaO	5.97
Na_2O	3.07
K_2O	1.61
H_2O at 110°	.68
H_2O above 110°	1.03
TiO_2	1.72
P_2O_5	.44
MnO	.24
NiO	trace
SrO	trace
BaO	.06
Li_2O	trace
FeS_2	.13
	100.20

GABBRO.

Occurrence.—South and east of the Mount Stuart massif there are six areas of gabbro that aggregate about 10 square miles. This rock is extremely irregular in its distribution, and some masses were observed that are too small to be represented on the map. The irregular distribution is largely due to the fact that the rock is intrusive in the peridotite and in the Peshastin and Hawkins formations as well as in the Swauk sandstone. Small dike-like masses indicate that probably at greater depth the gabbro mass may extend as far west as North Fork of Teanaway River. Owing to its massive character the gabbro resists erosion well and thus stands up prominently above the other rocks.

The gabbro at Camas Land occurs in the form of an intrusive sheet in the Swauk sandstone. The structure here is a gentle syncline with northwest-southeast trend. The gabbro sheet conforms with the sedimentary beds except at one point on the northeast side, where the intrusive rock breaks across the beds and connects the main sheet with a lower and smaller sheet or tongue. The intrusive rock is probably thickest at the northwest end of the syncline, where it attains a thickness of not less than 500 feet. It is owing to the presence of the gabbro that Camas Land has been protected from the general degradation of the region and is preserved as a remnant of a valley belonging to an earlier stage in the topographic development.

The other areas of gabbro represent intrusive masses much larger than the sheet just described. The essential petrographic identity of the rocks from the different localities appears to be sufficient evidence to justify the correlation of all the gabbro masses, and since the Camas Land sheet is intrusive in the Swauk formation the gabbro is considered to be of Eocene age. The occurrence of Eocene gabbro in an area that was the scene of extensive basaltic eruptions during the Eocene is suggestive of a relationship between the two rocks. No diabasic dikes were observed cutting the gabbro, although these dikes are shown on the areal geology map in the immediate vicinity of the gabbro areas, while many dikes of fine-grained gabbro can be traced from the main mass for short distances into the serpentine. It is possible that the gabbro represents slightly later intrusions of the same magma from which the Teanaway basalt had been erupted.

Petrographic character.—The gabbro is light gray in color, with either a brownish or greenish tint, and in some places is decidedly purple. Feldspar and pyroxene can be distinguished megascopically, as the rock is medium to coarse in grain. The texture is both ophitic and granular, the latter being more characteristic for the gabbro of the western areas. Under the microscope the gabbro is seen to be holocrystalline. The most important constituent is the plagioclase, which is basic labradorite in composition, sometimes with oligoclase forming the outer portion of a zonal crystal. In the gabbro from Camas Land augite forms large plates which inclose the idiomorphic feldspar. In the more granular phase diallage is the pyroxene, the characteristic parting being well developed, although in some individuals which show the parting in the center it is absent on the rim. Olivine may have been an original constituent, but if so is now represented wholly by serpentine and other secondary minerals. Bastite is present in some slides, with a structure that strongly suggests its derivation from hypersthene. Brown hornblende occurs intergrown with the augite and diallage, and hornblende of secondary origin is also a common constituent. Quartz is found in many of the specimens, occupying interstitial spaces and forming micrographic intergrowths with feldspar, which is probably orthoclase. Magnetite, which occurs often in large masses and is in many cases titaniferous, apatite, abundant in slender needles, and ilmenite are other primary constituents. Some of the specimens from the larger gabbro mass are much altered. Green uralitic hornblende is abundant, as well as chlorite, serpentine, leucoxene, quartz, epidote, actinolite, zoisite, and kaolin. An interesting feature is the selective alteration which has affected the gabbro. This rock which has its feldspar completely replaced with zoisite and its hypersthene represented by bastite, contains augite that is hardly affected.

Analyses of two specimens of gabbro were made by Dr. H. N. Stokes. I represents the gabbro of the westernmost area, collected on the high ridge west of Fourth Creek. This rock contains labradorite and diallage, with some hornblende and magnetite. Olivine may have been a constituent, but the only other minerals present—serpentine, actinolite, and hornblende—are of secondary origin. II represents the gabbro of the intrusive sheet at Camas Land. The constituents are zonal plagioclase, labradorite to oligoclase, augite, quartz, and probably orthoclase, hornblende, magnetite, and apatite.

Analyses of gabbro.

	I. Per cent	II. Per cent.
SiO_2	48.58	51.98
Al_2O_3	20.23	15.99
Fe_2O_3	1.26	3.10
FeO	3.02	5.88
MgO	7.59	5.09
CaO	14.01	9.68
Na_2O	2.25	2.71
K_2O	.19	.81
H_2O at 110°	.28	.48
H_2O above 110°	2.68	2.08
TiO_2	.09	1.71
P_2O_5	trace	.31
Cr_2O_3	trace	none
MnO	trace	10
BaO	none	.03
Li_2O	none	trace
S	.10	.01
	100.25	99.96

In the quantitative classification both of these rocks would be termed hessose. Calculation of the norms from the analyses shows differences essentially similar to those indicated in the above description. The Camas Land phase contains quartz and has a somewhat less basic plagioclase, as well as more of the orthoclase molecule. These differences are slight in comparison with the marked general similarity of the two rocks, the basis on which they have been correlated.

ROSLYN FORMATION.

Occurrence.—The Roslyn formation is much less important areally than the Swauk. The distribution as shown on the areal geology map includes almost all of this formation that is exposed. It may extend eastward under Table and Lookout mountains, but it is not probable that much of the formation is concealed by the Miocene basalt. The alluvium of the valleys covers about 25 square miles of the Roslyn sandstone.

On the slopes north of Roslyn and Clealum the Roslyn sandstone is well exposed, and it also forms low cliffs along the southern bank of Teanaway River. In other localities the soft sandstone is not at all prominent, and in many cases, as along the north side of Swauk Prairie and at the occurrence 3 miles east of Clealum Point, the presence of this formation might not be suspected, so few and obscure are the exposures. Since there is a considerable erosion break between the Roslyn formation and the Miocene basalt which caps it on the south and east, the most eastern exposures of the Roslyn are irregular in outline and variable in thickness, and this formation is not found continuously between the Teanaway basalt and Yakima basalt. Under Table Mountain black shale and bone are exposed and these beds have been prospected for coal. On First Creek is found a greater thickness of shale with massive sandstone, from which the basalt capping has been only partially eroded.

Description.—The greater part of the Roslyn formation consists of massive sandstones, rather more yellowish in color than the typical Swauk sandstone. but not so well sorted as the eastern phase of the Swauk. With the sandstone occur shales, both fine-grained clay shales and the coarser arenaceous phase. As a rule, the stratification of these rocks is not strongly marked, and in some localities irregularities of bedding can be seen and local unconformities detected. Conglomeratic beds are not common, pebble bands in the sandstone being the coarsest material usually found in this formation. At the base of the section on Middle Fork of Teanaway River occurs a small amount of conglomerate containing pebbles of the pre-Eocene rocks, with an occasional pebble of basalt. The Roslyn formation appears here to overlie conformably the Teanaway basalt, but with basal sediments that are distinct from the basaltic tuffs. The sandstone is a quartz arkose, but is rather darker than higher beds, a feature possibly due to slight admixture of material derived from the basalt series.

The marked prevalence of landslides in the northern portion of the area of Swauk sandstone makes exact determination of stratigraphic thickness impossible. The upper part of the section is known thoroughly from the exploration work in the coal basin and will be described under the heading "Coal." An approximate estimate of the total thickness of the Roslyn formation as exposed between Ryepatch and Clealum is 3500 feet, which probably represents the thickest portion of the formation.

The structure of the Roslyn formation is very simple. Along North Fork of Teanaway River the sandstone is nearly horizontal, so that at Ryepatch the basalt is exposed beneath the sandstone. The dip here is only about 2° to the south, but increases to 20° in the vicinity of Roslyn and Clealum. The southern side of the syncline is concealed, but it undoubtedly has steeper dips. The axis of the syncline pitches to the southeast, passing under Lookout Mountain.

Flora.—Doctor Knowlton's report on the collections from the Roslyn formation is as follows:

The first fossil plants secured within this area were collected by Mr. J. S. Diller in 1892 from the Roslyn coal mine. In 1897 Prof. I. C. Russell made a considerable collection at the Clealum mine, and in the following year I made a larger collection at the Roslyn mine. The following genera are represented, all but one or two of the species being new to science.

Salix.	Ficus.
Myrica.	Benzoin.
Alnus.	Sapindus.
Castanea.	Chrysophyllum.
Quercus.	Zizyphus.
Juglans.	Magnolia.
Betula.	

The species before known are doubtfully referred to *Salix angusta* and *Magnolia californica*, both of which have been found in the Miocene. These, together with the quite modern appearance of certain other forms, indicate that these beds are younger than the Swauk formation. Apparently not a single species is common to both formations. This would seem to indicate that the plants which grew during the time the Swauk was accumulating were confined to a relatively small basin and did not survive to the time in which the Roslyn sandstone was deposited.

The conclusions reached from this study of the flora are quite in accord with the stratigraphic relations already noted. The unconformity between the Swauk formation and the Teanaway basalt is indicative of a time interval, while the eruption of the basaltic lavas over this region suggests a further reason for the lack of connection between the Swauk and Roslyn floras.

MANASTASH FORMATION.

Occurrence.—The latest of the Eocene sedimentary formations occurs on the headwaters of Manastash Creek and on Taneum Creek. In both of these occurrences the Manastash sandstone rests directly upon the Easton schist, with a well-developed basal conglomerate. Lower on Taneum Creek, about 200 feet of sandstone and shale are exposed beneath the Miocene basalt, and the position of this small area is believed to justify the correlation of the sedimentary rock with the Manastash formation. Somewhat less certain, however, is the determination of the horizon of some sandstone which is exposed immediately southwest of Clealum Point. These beds rest upon the schist and dip to the southeast. The presence of the intrusive rock at Clealum Point prevents any determination of the relation of the sandstone to the Teanaway basalt. The knowledge, gained farther west, that the Swauk sediments were not so thick in the southern part of the area as farther north makes it doubtful that this exposure belongs to the Swauk formation; more likely it is the northern extension of the sandstone exposed 2 miles southwest, on Taneum Creek.

Description.—The Manastash, like the other Eocene sedimentary formations, comprises sandstones and shales. East of Frost Mountain the sandstones are well exposed and become massive and quartzose with pebble bands, white quartz being most abundant among the pebbles. The shale is fine grained and has associated with it seams of bone and impure coal.

The structure in the Manastash formation is a broad syncline resting on the Easton schist. The central portion of this syncline, which has an axis pitching to the southeast, like the Roslyn basin, is concealed beneath the Taneum andesite. Minor parallel folds are included in the broad syncline, and the whole was eroded somewhat before the eruption of the Miocene lavas.

Flora.—The determination of the age of the Manastash formation rests largely upon a small collection of fossil plants from near the head of North Forth of Manastash Creek. Doctor Knowlton's report is as follows:

This collection consists of about twenty-five pieces of matrix, upon which a large number of beautifully preserved leaves are displayed. Their fine state of preservation makes their identification easy and certain. I am able to recognize the following-named species:

Quercus consimilis Newb.
Quercus drymeja Newb.
Castanea castaneæfolia (Ung.) Kn.
Laurus grandis Lx.
Laurus princeps Lx.
Laurus californica Lx.

Not a single one of these species, or anything closely approaching them, has thus far been found in either the Roslyn or Swauk formations.

The two species of *Quercus* occur also in the Clarno formation of the John Day basin, *Quercus drymeja* being found also in the Florissant beds of Colorado. The other species occur also at Corral Hollow, California. Upon these considerations the Manastash formation is believed to be of upper Eocene age.

MIOCENE ROCKS.

The rocks of Miocene age are practically confined to the southern half of the quadrangle. They comprise two lava formations with associated intrusive rocks and one sedimentary formation, the Ellensburg. The Taneum andesite is of only local importance, but the Yakima basalt is the most extensive formation of the State. Except where locally altered, all these Miocene rocks are fresh in appearance, and indeed some of the sands and gravels of the Ellensburg formation are hardly to be distinguished from recent alluvium, while some of the volcanic rock is as fresh as the lava found on the slopes of modern volcanoes.

TANEUM ANDESITE.

Occurrence.—In the southeastern portion of the quadrangle there occurs a grayish-green andesitic rock which has the characteristics of lava. This rock is exposed over an area of several square miles on the south branch of Taneum Creek and extending south to Frost Mountain, where it rests on the Manastash sandstone and directly underlies the Yakima basalt. To distinguish this lava from other andesites of similar composition, although of different age, which occur in adjoining quadrangles, the name Taneum andesite is here applied.

The Taneum andesite includes tuffs and tuff-breccias as well as loose-textured lavas. The series varies greatly in thickness and character within the small area, but probably has its greater development in the northern portion. Under Frost Mountain the lava and tuff measure from 200 to 300 feet in thickness. Here the andesite is pink and green as well as gray and brown in color, and is easily distinguished from the darker and more compact basalt which caps this peak.

Petrographic character—The Taneum andesite is a hypersthene-andesite, with phenocrysts subordinate in amount to the groundmass. The plagioclase phenocrysts are zonal and chiefly labradorite. The pyroxene is represented usually by replacement material, which appears to be iddingsite. These pseudomorphs generally show the characteristic outline of hypersthene, which was without doubt the principal ferromagnesian constituent. The andesite generally is considerably altered. Accessory constituents are magnetite and apatite. The groundmass is hypocrystalline, showing laths and prisms of plagioclase and replaced pyroxene. Amygdaloidal and vesicular phases of the lava are common.

Associated intrusive masses.—Clealum Point is one of the most prominent features of Yakima Valley. This bold peak projects beyond the general escarpment line, its prominence being due to a massive rock, distinct from the columnar basalt which caps the ridge. This rock is a gray porphyry in which dull-white feldspars and brown pyroxene phenocrysts can be seen. Several types of the porphyritic rock can be distinguished on the different slopes of the Point, and the rugged character of the mass is due largely to the manner in which these different rocks occur. The relations indicate that the whole mass is intrusive in the schist, sandstone, and Teanaway basalt, while contemporaneous dikes of finer-grained porphyry traverse the mass in several directions.

Microscopic examination of the Clealum Point rock shows it to be closely related to the Taneum andesite. The finer-grained phase is an andesite-porphyry containing brown hornblende in addition to the plagioclase and hypersthene, while the groundmass contains plagioclase laths and grains of quartz and orthoclase. This rock has an andesitic texture and is often vesicular, thus closely resembling the Taneum andesite. Other phases of the intrusive rock may be called diorite-porphyry. In texture they are medium grained and holocrystalline, with phenocrysts of plagioclase, pyroxene, and hornblende. The plagioclase is zonal, the outer portion being oligoclase, with labradorite within. Brown hornblende and pale-green augite occur with the hypersthene, now altered, with magnetite, apatite, and zircon as accessory constituents.

The Clealum Point occurrence may be regarded, then, as an intrusive mass from the same magma as the effusive lavas of Taneum andesite. It is somewhat doubtful whether this represents the conduit by which the lava flows a few miles away reached the surface, since there is no trace of Taneum andesite in the intervening territory, where it might be expected to have been preserved beneath the Yakima basalt.

YAKIMA BASALT.

Areal importance—The Miocene basalt is one of the most extensive formations of the quadrangle, and also perhaps the most conspicuous. Approximately one-fourth of the area is covered by the Yakima basalt, but this represents only the margin of the vast region characterized by this basalt and extending to the east and southeast even beyond the boundaries of the State. This series of basalt lava flows of Miocene age constitutes what is undoubtedly the largest volcanic formation in America.

The Yakima basalt is well exposed in an escarpment which extends from near Clealum Point northward to the northern end of Table Mountain. Through this black wall of rock Yakima River and Swauk Creek have cut their gaps, so that opportunity is afforded for study of the series of lava flows. Several sheets of basaltic lava can be distinguished, as they form benches on the canyon sides. On the plateau-like areas covered by the basalt its presence is commonly shown by the prevalence of angular fragments of the black, dense rock.

The lowermost sheet of basalt occurs at different elevations along the escarpment and at other places where the lower contact of the Yakima basalt can be seen. In many localities the relations along this contact are obscured by the presence of landslides. Yet, whether the Yakima basalt rests on the Swauk sandstone, the Teanaway basalt, the Roslyn formation, the Manastash sandstone, or the Easton schist, the contact is more or less irregular, and north of Taneum Creek the contact of horizontal sheets of lava with the underlying schist has a vertical range of 1500 feet. These relations indicate the amount of relief of the land surface on which the earlier flows of basalt came to rest. The total thickness of the Yakima within this area probably nowhere much exceeds 2000 feet, although it is known to be much thicker farther south. In several localities along the northern escarpment 1000 feet is an approximate measure of the thickness of basalt.

On the north side of Taneum Creek there are two small areas of basalt which represent remnants of a thin local flow that was erupted after the beginning of deposition of the Ellensburg sediments. In the area south of this quadrangle similar later flows interbedded with the upper Miocene sediments were important enough to be separated from the main series and given the name of Wenas basalt. Within the Mount Stuart quadrangle, however, this flow was detected nowhere else.

The structure of the Yakima basalt is very simple and is similar to that of the Ellensburg formation, as described in a later paragraph. The occurrence of the small outcrop of basalt on Dry Creek is the result of a slight change in the gentle dip of the flexed basalt and sandstone, which has enabled the stream to cut through the sandstone.

The most noticeable feature of the basalt is its columnar structure, by which the sheets of black rock are converted into regular colonnades. Huge prisms, several feet in diameter and scores of feet in length, stand out from the canyon walls in a manner so characteristic of this rock that the term "basaltic structure" is often applied to it. These prismatic columns owe their origin to the contraction of the cooling lava. The joint planes due to this shrinkage of the rock were normal to the cooling surface, so that now the columnar parting of the rock is vertical wherever the sheets remain in their original horizontal position. Horizontal cracks divide the columns into shorter blocks, which usually, however, fit so closely together as not to detract from the general effect of these rows of columns.

Petrographic characters.—The Yakima basalt is a black rock, compact and heavy. The weathered surface is often brownish in color and sometimes gray, but universally the basalt as exposed along the ridges or in the river canyons is dull and somber. Petrographically the Yakima basalt is a normal feldspar-basalt containing basic plagioclase, augite, and olivine, in crystals or rounded grains, with varying amounts of glassy base. Examined microscopically, the Yakima basalt is found to vary somewhat in the quantitative mineralogic composition as well as in texture. None of the minerals occur as megascopic phenocrysts, but the labradorite crystals are more regularly developed than either the augite or the olivine. The olivine is less abundant than the light-brown augite, and also varies more in the amount present in different specimens. Apatite and magnetite are accessory constituents, the latter often occurring in delicate skeleton crystals. Some phases of the lava, especially in the basal or surface portions of a flow, are very glassy and masses of pure basalt glass can be found. The glass fragments seen on Table Mountain have a rounded form and undoubtedly represent bombs ejected from a volcanic center. As a whole the tuff beds and the scoriaceous lavas are less common than the compact basalt.

A specimen of this basalt from Clealum Ridge, about 4 miles southwest of Clealum, was selected as representative of the different flows of the Yakima basalt and it was analyzed by George Steiger. This basalt is dark iron gray in color, aphanitic, and has a rough fracture. The thin section shows its texture to be fine grained, hypocrystalline, with intersertal glassy base. The most abundant constituent is labradorite, slightly zonal. Next in importance is the pale-brown augite, in roughly prismatic crystals, while the olivine occurs in grains. The base is a brown glass containing magnetite in fine dust and skeleton crystals, as well as slender microlites of feldspar and augite. Slender needles of apatite occur included in the feldspar. The analysis which follows shows the Yakima basalt to be closely related chemically to the Teanaway basalt. It is much less basic than typical basalt, and would be termed a vaalose in the more exact quantitative classification.

Analysis of Yakima basalt from Clealum Ridge.

	Per cent.
SiO_2	54.50
Al_2O_3	14.43
Fe_2O_3	2.17
FeO	8.80
MgO	4.24
CaO	8.01
Na_2O	3.05
K_2O	1.29
H_2O at 105°	.29
H_2O above 105°	1.09
TiO_2	1.69
ZrO_2	none
CO_2	none
P_2O_5	.21
SO_3	.11
NiO	none
MnO	.10
BaO	.06
SrO	.09
	100.13

DIABASE.

Occurrence.—In the southwest corner of the Mount Stuart quadrangle are two small areas of diabase. The larger of these is on the divide between Manastash and Taneum creeks and forms an irregular mass intrusive in both the Taneum andesite and the Manastash sandstone. The other occurrence is on the western edge of the quadrangle, being part of a large mass in the adjacent area.

In this vicinity there are several large dikes of diabase which cut the same formations as the intrusive masses just described. The connection of these dikes with the other diabase is very probable, since one can be traced to its junction with the larger mass. The largest of these dikes occurs on the west side of North Fork of Manastash Creek and is unique in that it cuts the lower sheets of Yakima basalt. This occurrence, together with the general distribution of the diabase, justifies the conclusion that the diabase originated from the same magma as the Yakima basalt, the larger masses of diabase representing the intrusive bodies of molten rock which connected upward, through conduits now indicated by the dikes, with the lava flows at the surface. As has been shown in the Ellensburg folio (No. 86), Bald Mountain, which is immediately south of the Mount Stuart quadrangle, was an important center of volcanic activity during the eruption of the Miocene basalt flows.

Description.—The diabase is dark-brown rock, with medium grain, and the diabasic or ophitic texture is plainly exhibited, especially on the weathered surface. The rock is hard and withstands erosion well, the outcrops being commonly rounded but generally projecting above the rocks with which the diabase is in contact. The dikes which cut the Manastash sandstone are readily distinguished and can be traced for short distances even where rock waste covers the surface generally.

The constituents which can be detected megascopically are pyroxene and feldspar. Under the microscope the rock is seen to be composed of plagioclase, augite, hypersthene, olivine, apatite, and magnetite. The plagioclase, chiefly labradorite, is the most abundant constituent, and the crystals are often zonal. The augite is green or brownish, with a faint violet tinge. The hypersthene occurs in phases of the diabase in which olivine is wanting, and, when unaltered, forms stout prisms or anhedral grains. The olivine is less important than the augite and is best developed in the diabase of the dike in the Yakima basalt. This rock shows the order of crystallization to have been apatite, plagioclase, olivine, magnetite, and, last of all, the augite, which forms large individuals, often a centimeter in diameter. In some thin sections the olivine is found altered to typical brown iddingsite with lamellar structure. It is probable that some hypersthene has been replaced also by iddingsite. The apatite occurs in long needles, often grouped in bundles.

ELLENSBURG FORMATION.

Occurrence.—Although the Ellensburg formation has an areal extent of nearly 100 square miles within this quadrangle, it is not at all conspicuous. Over the greater part of Kittitas Valley a thick mantle of alluvium conceals the sandstone and conglomerate of this formation. The best exposures are along the bluffs overlooking the river between Dudley and Thorp. Another locality where a typical section of the Ellensburg formation can be seen is immediately east of the Normal School at Ellensburg, where this formation stands above the general valley level. Elsewhere the soft character of the formation renders it easily eroded, so that surface wash usually conceals the undisturbed rock below.

Two smaller areas, separated from the Kittitas Valley areas, occur on the southern slope of Lookout Mountain and northwest of Horse Canyon. The latter exposure measures only 30 feet in thickness, representing the basal beds of conglomerate and tuffaceous sandstone resting on the basalt. On Lookout Mountain a square mile or more of this formation is preserved, but even here only a slight thickness remains.

Description.—The Ellensburg formation comprises light-colored sandstones and conglomerates, which are so friable and loose textured as to deserve often to be termed simply sands and gravels. The distinctive characters of the formation are its marked variations in grain, the common occurrence of pumice fragments, and the prevailing cross stratification or stream bedding. These make it readily distinguishable from the older sedimentary formations of the region.

The Ellensburg formation is composed largely of volcanic sediments, which are of foreign origin. Pebbles or bowlders derived from the underlying basalt are only rarely seen, the conglomerate beds being composed of pebbles of light-gray and purple hornblende-andesite and of white pumice of the same composition, while the sandstones and shales of the Ellensburg formation consist of finely comminuted andesitic material, which represents in part the volcanic dust from explosive eruptions. The lava from which these pebbles and bowlders were derived is not exposed within the Mount Stuart quadrangle, but undoubtedly occurs in the mountains to the southwest.

The number and thickness of the conglomerate beds and the prevalence of stream bedding indicate that the formation is largely the result of fluviatile rather than lacustrine conditions of sedimentation. South of Horse Canyon are angular bowlders of andesite measuring several feet in diameter which come from a conglomerate in the Ellensburg formation. The transportation of such material could have been effected only by powerful streams. The original thickness of this formation can not be stated. Along Yakima River several hundred feet of Ellensburg beds are exposed, while a well sunk in Kittitas Valley penetrated about 700 feet without reaching the base of the formation. Farther south, in the vicinity of North Yakima, the Ellensburg formation is known to be 1600 feet thick, so it is probable that its original thickness in Kittitas Valley was at least 1000 feet.

The deformation to which these beds have been subjected has been slight. The elevations at which the basal bed is found on Lookout Mountain and on Dry Creek indicate a low dip to the south, toward the center of the valley. Beyond the limits of this quadrangle the Ellensburg sandstone is known to dip toward the middle of the valley, so that Kittitas Valley is coincident in position with a gentle flexure, forming a basin whose longest diameter measures over 30 miles, from northwest to southeast. The occurrence of the Ellensburg formation northwest of Horse Canyon may be due to a slight fault which has thrown this bed down sufficiently to protect it from erosion.

Flora.—Fossil plants have been found in the Ellensburg sandstone at a quarry just beyond the southeast corner of this quadrangle. This locality also yielded a few teeth of *Hipparion*, a Miocene representative of the horse family.

The following report on the fossil plants from this locality has been made by Dr. F. H. Knowlton:

So far as known, the first collection of fossil plants made in the vicinity of Ellensburg, Wash., was obtained by Mr. J. S. Diller in the spring of 1892. This is a small collection, embracing only half a dozen pieces of matrix, and was made at a point about 6 miles southeast of Ellensburg. It contains several species, the most abundant and characteristic being *Platanus dissecta* Lesq.

In 1893 Prof. I. C. Russell obtained from the same locality a considerable collection, in which I was able to recognize ten species. I have recently studied this collection again, and present the following list of species:

Salix varians Göppert.
Salix pseudo-argentea Knowlton.
Populus glandulifera Heer.
Populus russelli Knowlton.
Alnus sp.
Ulmus californica Lesquereux.
Ulmus pseudo-fulva Lesquereux.
Platanus dissecta Lesquereux.
Platanus aceroides? (Göppert) Heer.
Diospyros elliptica Knowlton.
Magnolia lanceolata Lesquereux

The matrix of the specimens is a white, generally fine-grained volcanic ash, identical in appearance with that from Van Horn's ranch (Mascall beds) in the John Day basin, Oregon.

Of the 10 species above enumerated 6 are found in greater or less abundance in the Mascall beds, and I do not hesitate to refer the Ellensburg material to this horizon. The Mascall beds are regarded as being upper Miocene in age.

It may be noted that no formation has been found in this region equivalent to the John Day formation (Oligocene) of the Eastern Oregon section.

PLIOCENE? ROCKS.

RHYOLITE.

Occurrence.—East and west of Ryepatch there are several areas of rhyolitic lava. This rock weathers white or a rusty yellow and only rarely shows its true character when examined in the outcrop. In many places the rock resembles a fine shale that has suffered alteration from mineral-spring action. Microscopic examination of this rock shows its rhyolitic character, both compact lava and tuff being present. The rhyolite contains scattered phenocrysts of bipyramidal quartz and angular fragments of the same mineral. The groundmass is composed almost wholly of cryptocrystalline aggregates of quartz and feldspar with well-defined spherulitic intergrowths.

The relations of the westernmost and largest occurrence of rhyolite appear to indicate that the rhyolitic flow occurred at the close of the eruption of Teanaway basalt. Elsewhere, however, the distribution of the rhyolite, which directly overlies both Roslyn sandstone and Teanaway basalt, affords conclusive evidence that the rhyolitic lava flowed out over the eroded surface of these Eocene formations, probably in Pliocene time, and in the westernmost locality simply conceals the Roslyn-Teanaway contact.

Another occurrence of volcanic rock may be mentioned in this connection. In the extreme northwest corner of the quadrangle the peridotite is capped for an area a few yards in diameter with a breccia having all the characters of a volcanic rock. This rock is made up in its finer portions of angular fragments of crystals of quartz, feldspar, and some ferromagnesian minerals. No similar occurrence was observed elsewhere within the quadrangle, but it is very probable that this breccia is an outlier of the late Tertiary lavas that occur on the western side of Clealum River in the adjoining quadrangle.

Quaternary Deposits.

GLACIAL DEPOSITS.

The glacial deposits of Yakima Valley are directly the result of the overloading of the streams by the glaciers in the headwater tributaries, but purely glacial deposits are not important in this area. Along Ingalls Creek the floor of the valley is in places covered with immense blocks of rock which the stream is powerless to move, and a small moraine has shifted the lower part of Turnpike Creek somewhat to the east. Small moraines also occur on Peshastin Creek below Ingalls Creek.

ALLUVIUM.

The general distribution of valley alluvium is shown on the areal geology map of this folio. Several of the principal areas will be described, and of these Kittitas Valley is the largest. This structural basin has had its floor largely modified by stream erosion, and a thick mantle of stream deposits covers the greater part of the valley. Along the valley margins the coarse detritus has been derived from the basalt-covered slopes above and is very angular in character. The "scab-land" characterized by this material differs little from the surface of the basalt plateaus covered with large and small fragments of disintegrated basalt, so that the line between areas of alluvium and those of rock waste which has not suffered transportation is not always very definite. In other places are fine-grained deposits which seem in part to be of wind-blown material. Lower in the valley fine-grained alluvium becomes of general occurrence.

In the upper valley of Yakima River, north of the basalt escarpment, there are thick deposits of alluvium. On the flood-plain along the river coarse, clean gravels predominate, and there are areas of similar deposits on the upper benches, so that the amount of agricultural land can not be determined from the distribution of alluvium as mapped. Along the Teanaway the areas of alluvium outlined on the areal geology map are chiefly bottom land of fine quality. Swauk Prairie includes several square miles of very fine alluvium, comparatively free from bowlders, so that the area is one especially adapted for wheat raising. The character of the scattered bowlders and the sections of stratified gravels afforded by a few wells indicate the true alluvial nature of the surface deposits over Swauk Prairie. Another exceptional area of alluvium is Camas Land. Here a level prairie of several hundred acres with a rich loam has been preserved by the gabbro barrier on Camas Creek.

A marked feature in the more extensive valley deposits of this quadrangle is the occurrence of well-developed terraces. Below Clealum three plainly defined levels can be traced for several miles, and similar terraces extend up both Teanaway River and Swauk Creek even beyond the limits of the alluvium shown on the areal geology map. The highest of such gravel terraces mark the extent to which the streams filled their old valleys at the close of the Glacial epoch. The extent of this filling is not wholly evident, since only in a portion of their courses have the streams cut away the gravels from the rock. Indeed, the results of borings made in the vicinity of Clealum show the presence of several hundred feet of gravels and indicate that the rock floor of the valley at this point is somewhat lower than the river bottom in the basalt south of Lookout Mountain. This feature may be due to landslides at Lookout Mountain or it may indicate changes in elevation.

Stream gravels and large bowlders from the upper Yakima occur at three different levels east of Clealum Point, the highest of which is 3300 feet, and at 2680 feet the bowlders form a distinct terrace. Similar gravels at about 2600 feet were observed west of Bristol. These high-level deposits are evidence of stream work at an earlier stage, when Yakima River occupied a wide valley southwest of Lookout Mountain where now it is in a canyon.

ECONOMIC GEOLOGY.

GOLD.

HISTORY OF THE DISTRICT.

The three principal gold-mining districts of central Washington are included in the Mount Stuart quadrangle. The Peshastin placers were discovered in 1860 and have been worked intermittently ever since. The Swauk placers have been worked rather more steadily since their discovery in 1868. Gold-bearing veins were first located in the Peshastin district in 1873, and in the Swauk in 1881. The mineral veins of the Negro Creek district constitute a continuation of those in the Peshastin district.

Mining in these districts has been conducted by small owners, and it is impossible to secure any definite data regarding production. The output of gold of Kittitas County for the years 1884 to 1895, as reported by the Director of the Mint, aggregates $764,163. About $5000 of silver was reported from that county for the same period. The Peshastin district is now included in Chelan County, but during this period it was a part of Kittitas County. The years 1892 and 1895 were seasons of maximum production, and the area probably would have steadily increased its output had it not been for the exodus of miners to Alaska. In view of the activity in these districts in the years preceding 1884, as well as the production of the last seven years, it seems that $2,000,000 would be a conservative estimate of the total gold production. In the last five years companies with larger capitals have purchased the claims of the small operators, and mining operations will now be conducted more economically and probably with an increase in the gold production.

AURIFEROUS GRAVELS.

Swauk district.—The Pleistocene gravels along Swauk Creek and many of its tributaries are gold bearing. These alluvial gravels form the terraces, which are especially prominent and extensive at the junctions of Swauk and Williams creeks and of Boulder and Williams creeks. The gravel deposits are from a few feet to 70 or 80 feet in thickness, and while red or yellow at the surface, the gravel is blue below. The upper portions of the gravel also are less easily worked, since induration of the gravel has followed the oxidation of the cementing material.

While fine gold is found throughout the gravel deposits at some localities, most of the gold occurs close to bed rock and in channels other than those occupied by the present streams. The marked characteristic is coarseness. Pieces several ounces in weight are common, while a number of nuggets weighing 20 ounces or more have been found, and one or more nuggets of about 50 ounces have been reported, the largest nugget of the district having a value of $1100. These larger nuggets are usually well rounded, but on the tributary streams wire and leaf gold is found. The gold is not pure, containing considerable silver, which materially decreases its value.

The bed rock, which belongs to the Swauk formation, is usually of a nature to favor the collection of the gold. The inclined beds of hard shale form natural "riffles," and from the narrow crevices in the shale the best nuggets are often taken. The sandstone beds wear smooth, in which case the bed rock is apt to be barren. The old channels, both of Swauk Creek, and of its tributaries, vary somewhat in position from the present course of the stream, but only within definite limits. The old valleys and the present valleys are coincident, but, within the wide-terraced valleys of the present, older channels may be found, now on one side and now on the other. Thus, on Williams Creek and the lower portion of Boulder Creek the old watercourse has been found to the south of the present channel of the stream, and is in other cases below the bed of the creek. On Swauk Creek the deposits worked are above the level of the stream, being essentially bench workings. Here hydraulic plants have been employed, but elsewhere the practice has been to drift on bed rock. While the endeavor is to follow the old channels, it is found that the "pay streak" can not be traced continuously. Ground that will yield $40 to the cubic yard of gravel handled may lie next to ground that does not contain more than 50 cents to the cubic yard. In the last few years the operations in the Swauk basin have been on a larger scale. Williams Creek has been dammed and methods have been devised to handle the tailings and bowlders on the lower courses of Swauk Creek, where the gradient of the valley is low.

The source of the alluvial gold is readily seen to be the quartz veins known to occur in the immediate vicinity. These will be discussed in a following paragraph. The noticeable lack of rounding of much of the gold shows that it has not been transported far, and indeed the limited area of the Swauk drainage basin precludes any very distant source for the gold. It is only along the Swauk within a few miles of Liberty and on Williams Creek and its tributaries that gold has been found in paying quantities, and, as will be noted later, this is approximately the area in which the gold-quartz veins have been discovered. From the outcrops of these ledges the gold and quartz have been detached and washed down into the beds of the streams, where the heavier metal was soon covered by the rounded bowlders and pebbles with which the channel became filled. The conditions under which the gold was washed into the streams probably differed little from those of to-day, except that the streams were then filling up their valleys.

Peshastin district.—The gravel deposits in the valley of the Peshastin are less extensive than in the Swauk district. The alluvial filling of the canyon-like valley of the upper half of Peshastin Creek is not so deep and does not show the well-marked terraces so prominent in the Swauk Valley. The gravel appears to be gold bearing throughout, and the gold is rather uniform in distribution. The largest nuggets are found on the irregular surface of the pre-Tertiary slate which forms the bed rock. While the largest nuggets found in the Peshastin placers are less than an ounce in weight, and therefore not comparable with some of the Swauk gold, the Peshastin gold is fairly coarse and easily saved. The gold is high grade, being worth about $18 an ounce.

The principal claims on the creek, below Blewett, are owned by the Mohawk Mining Company, which is hydraulicking the gravels with water from the upper Peshastin and from Negro Creek. Work which has been done on Shaser Creek shows the gravels to be gold bearing, and here also the gold is high grade. This fact is interesting, since, while the Shaser Creek drainage basin is almost wholly in the same formation as that of the Swauk basin, the gold found in the two creeks is quite different, the Swauk gold containing a considerable amount of silver.

Stream gravels in other parts of the quadrangle, notably on North Fork of Teanaway and on Stafford Creek, have been prospected, but no gold has been found to warrant further work.

GOLD-QUARTZ VEINS.

Peshastin district.—A few mines in the vicinity of Blewett have been producers for about twenty-five years. The many changes of management and methods of operating these properties, however, make it impossible at the present time to determine accurately the character of the ore that has been mined or to estimate even approximately the product during this period. Much of the ore has been low grade, and the gold has been extracted by means of arrastres, stamp mills, and a small cyanide plant, but not always with very successful results. The small stamp mill first built in this district was the first erected in the State of Washington. Another mill, with 20 stamps, has lately been rebuilt under the Warrior General management.

The best-known property in the district is the Culver group, comprising the Culver, Bobtail, and Humming Bird claims, and now known as the Warrior General mine. This mine in its geologic relations and vein conditions is typical of the mines of the district. The country rock is the altered peridotite or serpentine, which exhibits the usual variations in color and structure. The Warrior General and the other mines are located in a zone of sheared serpentine, where the mineral-bearing solutions have found conditions favorable for ore deposition. This mineral zone has a general east-west course, and extends from east of Blewett across the Peshastin, up Culver Gulch, and across to the valley of Negro Creek.

The Warrior General vein has a trend of N. 70° to 80° E. and is very irregular in width. In the walls the serpentine is often talc-like in appearance, while the compact white quartz of the vein is sometimes banded with green talcose material. Sulphides are present in the ore, but are not at all prominent. The values are mostly in free gold, which is fine, although in some of the richer quartz the flakes may be detected with the unaided eye.

The workings in this mine consist of a number of tunnels driven at different levels in the north wall of Culver Gulch. These follow the vein for different distances, the vertical distance between the lowest tunnel (No. 9) and the highest opening of importance (No. 5) being about 650 feet, and connections have been made between most of the levels. The vein is approximately vertical, although it has minor irregularities. The quartz is 7 to 8 feet in width in some places, but pinches in others. In the upper tunnel, No. 5, the ore appears to be broken quartz of the same character as that in the lower tunnels, occurring here much more irregularly, although the richest ore has been taken from the upper workings. Some very rich ore bodies have been mined, but they are small and their connections have not been traced. The most extensive work has been done from the lowest tunnel, and the latest work here shows that the serpentine, which is so much broken in many parts of this mineralized belt, is here more solid, a remarkably well-defined and regular wall having been followed for over 300 feet.

Other properties in the same zone as the Warrior General are the Polepick, Peshastin, Fraction, Tiptop, Olden, and Lucky Queen. These have all produced ore which has been worked in the Blewett mill.

An interesting feature in the geology of Culver Gulch is the probable existence of a fault. On the north side of the gulch, at an elevation of about 3750 feet, and near tunnel No. 5, a large basalt dike, 25 feet wide, is very prominent. This dike has a trend of N. 26° E., but its continuation is not seen on the south side of the gulch. Fifty feet lower on the south side of the gulch, however, a similar dike occurs with a trend of N. 50° E., but this in turn can not be detected at the point where it ought to outcrop on the north side. If these are parts of the same dike, as seems probable, there has been faulting. Such a fault would cross the Culver vein at a low angle and probably between tunnels 5 and 6. The broken character of the ore in the upper tunnel indicates that movement has modified the vein at this point, and such movement may be connected with this supposed fault. At the time of the examination of this mine, connection had not been made between tunnels 5 and 6, and the relations of the dike to the ore body could not be determined. If the dike interrupts the vein, the mineralization is pre-Eocene in age; while, on the other hand, if the vein continues through the 25 feet of basalt, even although it may vary in character with the change in the wall rock, or if the fissure in which the quartz has been deposited follows the plane of the fault which it is believed has displaced the basalt dike, then the period of mineralization is not earlier than late Eocene, and the Peshastin gold-quartz may be of the same age as the veins of the Swauk district, a description of which is given below.

Negro Creek district.—Although this region is a continuation of the Peshastin mineralized zone, no claims in this district have become producing mines. The region has been prospected for many years and a number of small veins have been located, and some ore worked in a small mill and in arrastres. The ore is mostly quartz with some calcite and sulphurets. The veins are irregular and the wall rock is generally serpentine, much of which is sheared and jointed. Many of the locations have been on the red or yellow "nickel ledges" to which reference has been made; on page 4 is given an analysis of this rock, which has been considered by many prospectors to be itself an indication of ore.

Swauk district.—The gold-quartz veins of the Swauk are very different from those in the vicinity of Blewett. They are in part narrow fissure veins of quartz with some calcite and talcose material, the wall rock being the sandstone or shale of the Swauk formation, of Eocene age, or in some cases a diabase or basalt dike may form one wall. Quartz stringers running off from the vein are common, and at one locality thin bands of quartz follow the bedding planes of the sandstone. A peculiar type of vein material is locally termed "bird's-eye" quartz. This occurs in several mines, and may be described as a friction breccia in which the angular fragments of black shale are inclosed in a matrix of quartz and calcite. The quartz shows radial crystallization outward from the separated fragments, and often open spaces remain into which the small crystals of quartz project. The walls of such veins are sometimes sharply defined, but in other cases many small veins of quartz traverse the shattered wall rock in every direction, so as to render it difficult to draw the limits of the vein itself. This transition from the peculiar type of vein into the shattered rock shows the "bird's eye" quartz to be due to brecciation along more or less well-defined zones, followed by mineralization.

The "bird's-eye" quartz has its gold content very irregularly distributed. The values are mostly in free gold, with a small amount of sulphurets present. The gold occurs in fine grains within the quartz or next to the included shale fragments, and the approximate value of the ore may be readily found by panning, while in many cases the gold may be seen on the surface of the quartz, in the form of incrustations of leaf or wire gold; and in a specimen from the Gold Leaf mine perfect octahedral crystals of gold lie upon the ends of the quartz crystals. The silicification sometimes extends into the country rock, and some values are found there. The gold of the quartz veins, like that of the gravels, is light colored and contains a considerable percentage of silver. In the Little York this silver is reported as amounting to about 20 per cent.

The quartz veins that have been opened in the upper basin of Williams Creek have a general northeast trend, being thus roughly parallel with the basalt dikes. In the Cougar the hanging wall of the vein appears to be a badly decomposed basalt dike, while the Gold Leaf has one vein wholly in sandstone and shale and another in a large diabase dike. The relation of the veins to the dikes is therefore not constant, but it may be noted that the fractures which have been filled by the vein material are usually approximately parallel to the fractures in the vicinity which have been filled by the intrusion of basalt. That there has been more than one period of fracturing, and that the period of mineralization was not exactly contemporaneous with the time of igneous intrusion, is shown by the occurrence of veins cutting the dikes themselves. It is probable, however, that the two processes occurred within the same geologic period and that the ore-bearing solutions derived their heat and possibly their mineral content from the intrusive and eruptive basalt of the area.

A number of quartz veins on Swauk, Williams, Boulder, and Baker creeks are being prospected at the present time, and in view of the richness of the alluvial gold which has been derived from the veins in this vicinity it would seem that the prospecting is well warranted.

COPPER AND SILVER.

In the Negro Creek district both copper and silver occur with the gold in the veins already described. Many of the ores are essentially copper ores, but whether the bodies are extensive enough to warrant their development has not yet been determined. This copper belt extends westward along the headwaters of North Fork of Teanaway River and of Ingalls Creek, but at only one locality has any large amount of ore been mined. The Grand View mine, situated on the east side of Fourth Creek about 3 miles southeast of Mount Stuart, has produced some native copper. The vein is in a zone of sheared serpentine, and, as far as could be determined from an examination of the deserted workings, the ore body is very irregular. With the native copper is the red oxide, or cuprite, and the ore is reported to carry varying amounts of gold.

There have been some prospectors at work recently in the vicinity of the forks of Taneum Creek, about 5 miles south of Clealum, and copper sulphides are reported to have been found. The country rock here is the Easton schist and is everywhere more or less seamed with quartz.

As has been noted above, the gold of the Swauk district is argentiferous, the percentage of silver varying with the locality. No other silver ores are known to occur in the Mount Stuart quadrangle.

NICKEL AND QUICKSILVER.

Nickel is a metal frequently reported in the assays from the Negro Creek district. Its presence in small amounts in the serpentine which is of such importance in this area is shown by the analysis given on page 4, and this renders it probable that some nickel ores may be found. The peridotite and serpentine resemble closely the peridotite at Riddles, Oreg., where deposits of nickel ore occur. The green silicate of nickel, genthite, which is the ore at Riddles, was not detected, however, at any place within the area of serpentine in this quadrangle. The analysis of the "nickel ledge" given on page 4 shows a smaller percentage of nickel even than that contained in the serpentine itself.

Cinnabar has been found at a few points at the head of Middle Fork of Teanaway River. In a prospect on the western edge of the quadrangle the cinnabar occurs along a joint plane in the altered rock of the Peshastin formation. The richness of the ore is evident, but the fact that such bands of cinnabar are very thin may prevent the deposit from being of economic importance.

COAL.

Roslyn basin.—The most important mineral resource of Kittitas County is coal. The Roslyn basin is one of the most productive coal basins on the Pacific coast and it is included mostly within this quadrangle. The coal occurs in the upper part of the Roslyn formation, and the extent of this productive portion, together with the location of mines, is shown on the economic geology map. The upper beds of the Roslyn formation have been eroded except in the center of the basin, so that the coal field is limited to the immediate valley of the Yakima between Ronald and Teanaway. The outcrop of the Roslyn coal has been traced along the northern side of the basin, so that the outline here is accurately determined. On the southern side, however, the deep gravel filling of Yakima Valley conceals the rocks beneath, and this boundary of the basin as mapped is based wholly upon data derived from observations of the structure made elsewhere. As shown on the map, there are between 10 and 12 square miles of coal lands in the Mount Stuart quadrangle.

The structure of the Roslyn basin is simple. The dip of the coal beds is low, 10° to 20°, and no faults have been discovered in the basin. Its axis pitches to the southeast, and since the fold is unsymmetrical, with low dips on its northern side, the axis of the basin is nearer the southern edge. Thus the deepest portion of the shallow basin is probably near the line of the Northern Pacific Railway at Clealum.

Several beds of coal are known in this basin, and the section at the Roslyn mine is given in fig. 1.

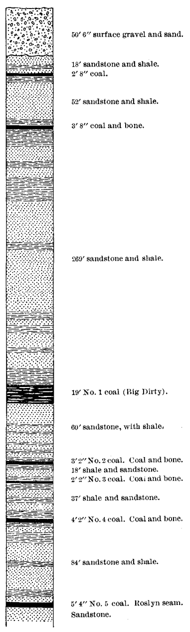


FIG. 1.—Section of upper portion of Roslyn formation at the Roslyn mine.

The Roslyn seam as worked at Roslyn contains 4 feet 6 inches of clean coal, while the seam worked at Clealum has a thickness of 4 feet 2 inches. The correlation of the Clealum coal with the Roslyn seam has been somewhat in question. The Clealum coal differs in character slightly from that mined at Roslyn, and on this account chiefly it was thought that they are separate seams and that the Clealum overlies all of the five coal beds cut by the Roslyn shaft. There is evidence now, however, that the two coals belong to the same seam. In the distance between the two mines the coal might be expected to exhibit differences in character, especially in view of the fact that east of the Clealum shaft the coal changes rapidly. Recently the outcrop of the coal has been traced from the one mine to the other, thus definitely fixing the correctness of the correlation. The coal is 640 feet beneath the surface at the Roslyn shaft and 250 feet at the Clealum shaft, but there is so nearly the same difference in elevation of the two shafts that the workings of the two mines will ultimately connect at that level. At present the developments are not sufficient to enable the exact form of the basin to be determined, but on the map its area is approximately outlined. The "Big Dirty" seam, 19 feet in thickness, occurs 200 feet above the Roslyn coal, and represents reserve supply, although the quality of this coal is such as to render it practically valueless under present conditions.

The Roslyn coal is a coking bituminous coal, well adapted for steam raising and gas making. It is an excellent fuel for locomotives, and over one-half of the product of this field is sold for railroad consumption. The cleanness of this coal and its high percentage of lump make it well fitted for shipment. Naval tests have shown that the Roslyn coal ignites quickly, combustion being rapid and thorough, the coal swelling slightly on the surface of the fire. The percentage of ash is moderate, and the clinkers formed do not cling to the grate bars, except with forced draft. The amount of soot formed and the high temperature in the uptake are the only objectionable features of this coal.

The following analyses of samples of coal collected in the Roslyn mine have been made in the United States Geological Survey laboratory by Mr. George Steiger. I represents the "run of the mine," and II and III are samples from working faces in different parts of the mine.

These analyses indicate a remarkable uniformity throughout the large mine, and a noteworthy and valuable character of the coal is its low content of sulphur. Comparative boiler tests of Roslyn coal and of a high-grade Pennsylvania bituminous coal have been made by the Northern Pacific Railway Company, and these show the former coal to have 90 per cent of the efficiency of the eastern coal under a stationary boiler, and 78 to 80 per cent in locomotives of the mogul and consolidation types, respectively. These figures indicate the value of

Analyses of coal from the Roslyn mine.

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Moisture	2.15	1.59	1.69
Volatile matter	40.93	42.54	41.69
Fixed carbon	44.03	42.91	43.84
Ash	12.89	12.96	12.78
	100.00	100.00	100.00
Sulphur	.44	.40	.49
Coke	good	good	good

the coal for steam-raising purposes. It is extensively used for gas making in Washington cities, yielding $4\frac{3}{4}$ cubic feet of 18-candlepower gas per pound of coal. The bright, clean character of this coal and the small proportion of fine coal make it well adapted for domestic use. The product of this field is largely used by the northern transcontinental railroads, and its market includes, in addition to the large cities of the State, San Francisco and Honolulu.

The mines of the Northwestern Improvement Company at Roslyn and Clealum constitute the largest colliery in the State. The shaft at Clealum has not been connected with the Roslyn shaft, 4 miles distant, and the intervening ground represents the reserve coal supply of these mines. The seam as worked measures over 4 feet in thickness, and the coal is shipped just as it leaves the breasts. The daily capacity of this colliery with present equipment is estimated as 5000 tons, and the management is now working with the purpose of enlarging the plant to obtain a greater output. The output of the Mount Stuart quadrangle in 1902 was 1,240,935 tons.

Coal has also been mined about 2 miles north of Clealum by the Ellensburg Coal Company at a point near the outcrop. Here the coal was 4 feet thick and dips S. 10° E. at an angle of 16°.

L. S. Storrs, geologist for the Northwestern Improvement Company, has made analyses of the samples of the Roslyn coal from a series of openings extending from the Clealum mine through the Roslyn mine to the northwestern extremity of the basin. These analyses, which are given below, show the change in this seam from a lignitic, non-coking coal to a fairly good coking coal. The order of the samples is from the open part of the fold toward its more steeply inclined portion, beyond the edge of the Mount Stuart quadrangle, and the change in the coal may be considered as an expression of the influence of the increasing dynamic action as the Cascade Range is approached.

Analyses of Roslyn coal sampled from east to west through the basin.

Sample.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Character of coke.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
1	4.69	38.89	44.27	12.15	Sinter.
2	4.39	38.61	47.28	9.72	Strong sinter.
3	3.50	40.35	49.08	7.07	Cokes.
4	2.12	37.64	48.13	12.11	Fair coke.
5	2.02	38.17	47.25	11.56	Fair coke.
6	2.13	36.77	46.48	14.62	Good coke.
7	1.87	32.19	44.55	21.39	Very strong coke.

Work has also been done on a coal prospect on the west escarpment of Table Mountain where the Roslyn formation is represented by about 40 feet of clay with a seam of coal and bone. This bed dips 32° to the east. Similar coal prospects are seen in the Roslyn formation at the head of First Creek. Here massive sandstone occurs with the shale, but the coal seams are very impure, and the surface displacements prevent any determination of their extent.

The black shales in the Swauk formation have been prospected somewhat for coal on Camas Creek, but without success. More extensive exploration has been made in the Manastash formation, which contains some carbonaceous beds. On Taneum Creek coal seams occur, but the work done here has not shown them to be of sufficient value to warrant further development. The conditions are similar on Manastash Creek, where prospect tunnels have been opened on the coal at several localities. The quality of the coal is very poor and quite unlike that of the Roslyn coal. One of the larger seams thus prospected is in close proximity to a large basaltic dike, which would cut off the extension of the bed.

STONE.

Building stone.—The sandstone of the Swauk and Roslyn formations is fairly well adapted for construction work. The Swauk sandstone is more thoroughly indurated than the Roslyn sandstone, but the more massive beds occur in localities which are not accessible. Sandstone from the productive portion of the Roslyn formation has been used somewhat in building, but no quarries have been opened. The tuffaceous sandstone of the Ellensburg formation has been used in buildings in Ellensburg, being obtained from a quarry a few miles beyond the southeast corner of the Mount Stuart quadrangle. Usually this stone is too soft and friable for use as a building stone.

Road metal.—The alluvial gravels of the valleys have in many cases favored the construction of good roads in this region. In some localities, on the other hand, the clayey beds in the valley deposits have rendered the roads almost impassable through part of the year. Except in rare cases no attention has been given to the use of better material for road construction. The best of road metal, however, is close at hand in much of the area. The Yakima basalt which forms the escarpment of the upper Yakima Valley and bounds the western edge of Kittitas Valley is a rock which, owing to its hardness and close texture, makes excellent material for this purpose. This basalt is too high above the floor of the upper valley to be easily obtained, but the small areas of Teanaway basalt which project through the alluvial gravels would furnish similar material. The exposure of this rock at "Deadmans Curve," on the railroad 3 miles south of Roslyn, is well situated for a supply of road metal for the country road between Clealum and Roslyn, a road which is more traveled than any other in the county. A place where this basalt may be obtained already prepared for use is near the upper road on the south side of the valley about $2\frac{1}{2}$ miles southeast of Clealum. A pit has been opened in this crushed basalt near the schoolhouse, and some of the rock seems to have been used on the road in the vicinity. This exceptional deposit of road material can be very easily worked, and at comparatively small expense the roads of this vicinity could be greatly improved.

In Swauk Valley two sources of material are available for fitting the roads for heavy teaming. The basalt through which the road is cut below Liberty is well adapted for road construction, when broken into small fragments, while above Liberty dikes of similar basalt outcrop at several points by the roadside.

The Northern Pacific Railway Company has operated a rock crusher in the canyon under Lookout Mountain. The cliffs above furnished a supply of broken basalt which was converted into a high grade of ballast for the railroad.

SOILS.

Agriculture within the Mount Stuart quadrangle is confined chiefly to the soils of alluvial origin. These areas of alluvium are outlined on the areal geology map. They include the terraces and bottom land bordering the larger streams, and the wider area of alluvium in Kittitas Valley. In such tracts the alluvial soils exhibit considerable variation in texture. Coarse, well-washed gravels occur in some localities, and these are comparatively barren. Fine silts, easily cultivated and very fertile, cover large areas and constitute the best soil of the district. Camas Land and Swauk Prairie are such areas, where very fine-grained soils occur.

On the southern slope of Lookout Mountain and on Thorp Prairie there are tracts under cultivation where the soil is derived possibly from the Ellensburg formation, which underlies these areas. In the main, however, the agricultural land of this quadrangle may be said to lie within the areas of alluvium.

WATER SUPPLY.

A glance at the map shows that the quadrangle is well supplied with perennial streams. Only in Kittitas Valley are seasonal streams found.

On Swauk and Thorp prairies, on Lookout Mountain, and in Camas Land wheat is raised without irrigation. At all these localities the soil is either alluvial or of a similar character, and if the spring rains are not exceptionally light sufficient moisture is retained to insure good crops. Elsewhere irrigation is necessary for all agriculture.

As has been stated above, the rivers and streams of this region have good grades, so that irrigation is easily accomplished. Teanaway Valley is irrigated by local ditches from the river, and this stream also contributes to the irrigation of the valley of the Yakima east of Clealum. The waters of Swauk Creek and its tributaries and of the Peshastin are used principally for hydraulic mining and arrastres.

Kittitas Valley has a number of ditches. The largest, the "town ditch," starts from the east bank of Yakima River near Thorp, and furnishes water for the region about Ellensburg and lying to the southeast. The lands to the north of Ellensburg are in part irrigated by local ditches from Reeser and Wilson creeks. First Creek, a tributary of Swauk Creek, waters a small area near McCallum, but its headwaters are diverted and made to help irrigate the Reeser Creek area. On the west side of Kittitas Valley, ditches from the Taneum and the Manastash and smaller creeks afford an abundance of water.

The supply of potable water is good generally throughout the Mount Stuart quadrangle. In addition to that afforded by the larger surface streams, which maintain their flow throughout the summer months, the ground water is in most places available, either through wells or through springs. Geologic relations govern the availability of this underground supply. Where the water-carrying beds are near the surface, as in the case of the alluvial sands and gravels, surface wells easily draw upon the ground waters. In localities where the wells are close to the stream, it is probable that the well water is derived from the underflow or underground portion of the stream.

For irrigation purposes water is obtained from Yakima and Teanaway rivers and from the smaller streams tributary to Yakima River. The supply of water can be increased by the construction of larger ditches and longer canals, but the amount of land where water is needed is not large except in Kittitas Valley, which is partly included in this quadrangle. The need of water here makes the question of an artesian supply important.

This broad valley has the basin structure, and from its great extent it appears well suited to the accumulation of underground waters. The water-bearing beds extend up on the slopes of the inclosing ridges, and must receive contributions from the precipitations over a large area. In the central part of the valley these beds lie at a depth of several hundred feet. Some years ago an experimental well was put down about 2 miles northwest of Ellensburg to a depth of about 700 feet. When abandoned it had water at 40 feet below the surface. The evidence which it afforded was unfavorable, yet it is possible that this well, like many others, was drilled inefficiently and that the record is untrustworthy.

In the Clerf Spring, at the east end of the valley, water with considerable pressure is found flowing upward through the basalt. In the summer of 1900 the drilling of a well was commenced in the immediate vicinity of this artesian spring and about 10 feet higher, and it seems probable that not far from the surface will be found water which can be used to augment the stream already issuing from the spring. The water is seen to issue from crevices in the sandstone and the honeycombed basalt beneath. It has a temperature of 62°, and may be derived from interstratified sandstone beneath an upper sheet of basalt. If any considerable flow of water is developed in this locality it can all be used to good advantage in the eastern part of Kittitas Valley.

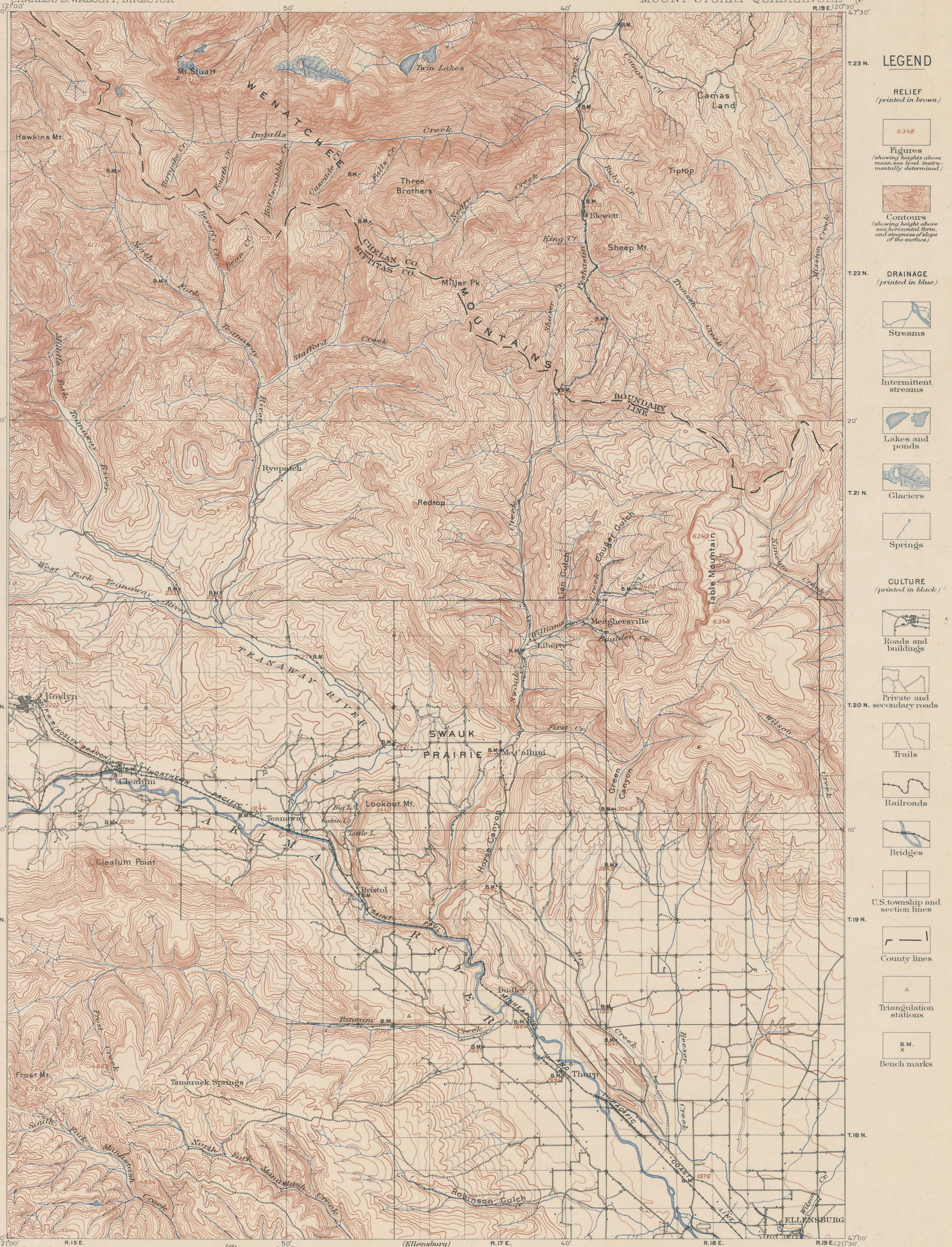
The gap where Yakima River cuts through the rim of Kittitas Valley, 5 miles below Ellensburg, is, of course, the critical point in the structure of the basin. The exposures of the Ellensburg sandstone are poor at this locality, but they are sufficient to show that the lower beds are sharply upturned. Immediately south of the edge of the valley a transverse fault gives further evidence of marked dynamic action on this side of the basin. Whether this is sufficient to prevent tapping the artesian basin can not be definitely stated. The possibility that a true artesian basin may be found here appears, however, sufficient to encourage the drilling of another experimental well in Kittitas Valley, unless larger irrigation canals taking water from upper Yakima River are built, which will obviate the necessity for artesian water in this valley.

May, 1903.

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

TOPOGRAPHY

WASHINGTON
MOUNT STUART QUADRANGLE



(Ellensburg)

R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett.
Topography by G.E. Hyde.
Surveyed in 1896-97.

TRUE NORTH — MAGNETIC NORTH — 22½°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Edition of July 1903.

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

AREAL GEOLOGY

WASHINGTON
MOUNT STUART QUADRANGLE

LEGEND

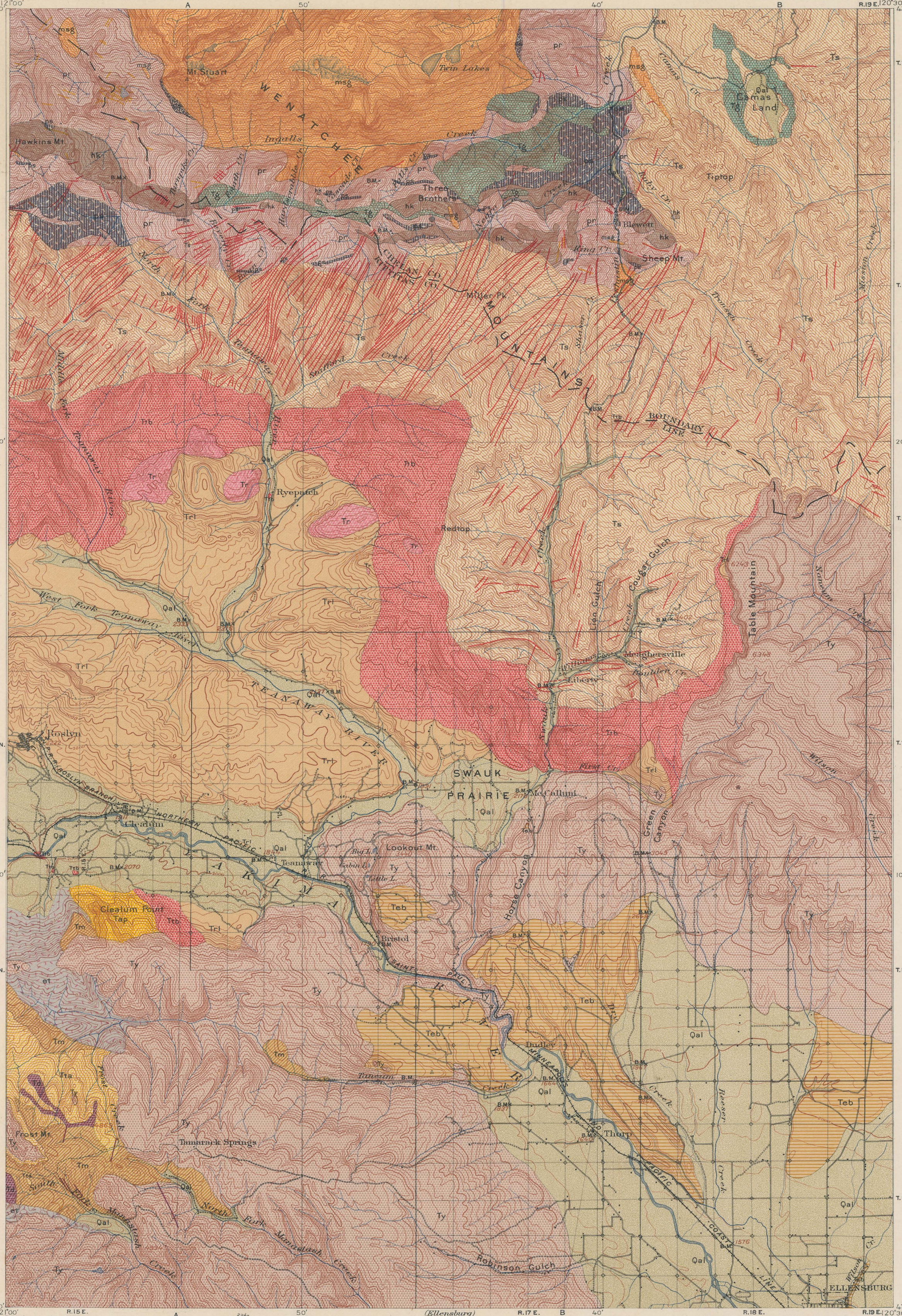
IGNEOUS ROCKS
(continued)

Metamorphic — CARBONIFEROUS ?

hk — Hawkins formation *(diabasic lavas, tuffs, and breccias)*

Faults

Sections



47°30' 121°00' — A — 50' — 40' — B — R.19 E. 120°30' (Chelan)

47°00' 121°00' — R.15 E. — A — 50' R.16 E. — (Ellensburg) — R.17 E. — B — 40' — R.18 E. — R.19 E. 120°30'

T.23 N. — T.22 N. — 20' — T.21 N. — T.20 N. — 10' — T.19 N. — T.18 N.

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31	32	33	34	35	36

Geology by Israel C. Russell, 1897;
George Otis Smith and G.C. Curtis, 1898;
George Otis Smith and W.C. Mendenhall, 1899.

LEGEND

SEDIMENTARY ROCKS
(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles; metamorphism is indicated by hachures combined with the line patterns.)

QUATERNARY

Recent

Qal — Alluvium *(fine silt and sand, with gravel near streams forming terraces)*

TERTIARY

Miocene

Teb — Ellensburg formation *(fluviatile deposits of stratified silts, sand and gravels of volcanic materials; locally indurated)*

UNCONFORMITY

Eocene

Tm — Manastash formation *(sandstone, conglomerate, and shale)*

UNCONFORMITY

Trl — Roslyn formation *(sandstone and shale with beds of coal)*

UNCONFORMITY

Ts — Swauk formation *(sandstone, conglomerate, and shale)*

UNCONFORMITY

CARBONIFEROUS ? AND OLDER

Metamorphic

cs — Contact schist *(sedimentary rock metamorphosed by intrusive granodiorite)*

ps — Peshastin formation *(black slate and grit with beds of chert and lenses of limestone locally)*

UNCONFORMITY

et — Easton schist *(quartz-mica-schist with associated hornblende-schist and epidote-schist)*

IGNEOUS ROCKS
(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Metamorphism is indicated by hachures.)

TERTIARY

Pliocene?

Tr — Rhyolite *(lava and associated tuff)*

Miocene (pre-Ellensburg)

Ty — Yakima basalt *(extensive series of lava flows with local tuff beds)*

Td — Diabase *(intrusive bodies with associated dikes, constituting Yakima basalt conduits)*

Tap — Andesite porphyry *(intrusive mass related to Taneum andesite)*

Tta — Taneum andesite *(hypersthene-andesite lava with beds of tuff and breccia)*

Eocene (pre-Roslyn)

Tg — Gabbro *(intrusive bodies of gabbro, in part olivine bearing and in part quartz bearing)*

Ttb — Teanaway basalt *(lava flows with tuff beds)*

Basic dikes *(diabase, usually quartz bearing, filling Teanaway basalt conduits)*

PRE-TERTIARY

Post-Carboniferous

msg — Mount Stuart granodiorite *(batholith of massive granodiorite with smaller masses of granodiorite-porphyry)*

Acid dikes *(granodiorite-porphyry associated with Mount Stuart batholith)*

pr — Peridotite *(intrusive body, largely altered to serpentine)*

Legend is continued on the left margin.

ECONOMIC GEOLOGY

U.S. GEOLOGICAL SURVEY
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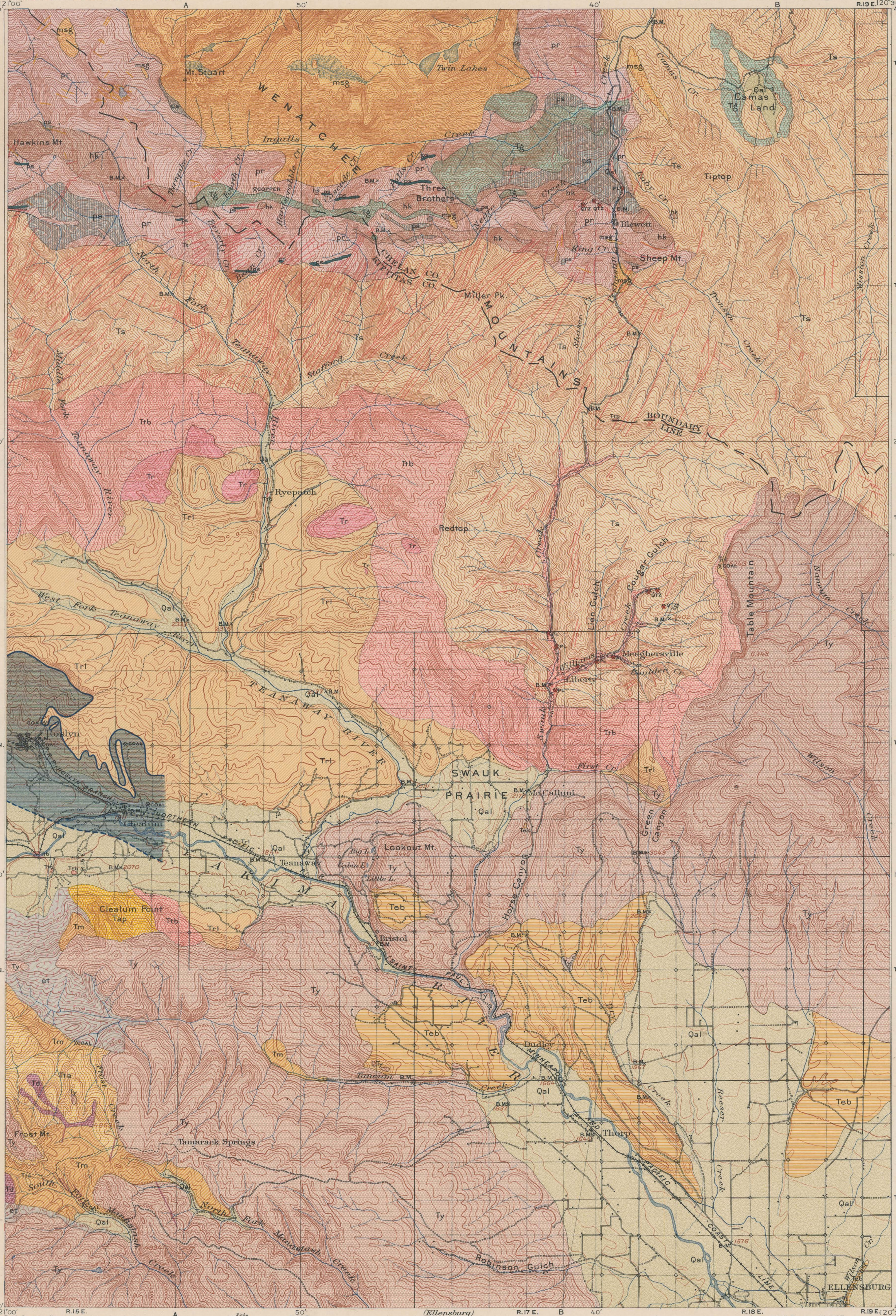
WASHINGTON
MOUNT STUART QUADRANGLE



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TRUE NORTH — MAGNETIC NORTH 22½°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

Edition of Nov. 1903.

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by Israel C. Russell, 1897;
George Otis Smith and G. C. Curtis, 1898;
George Otis Smith and W. C. Mendenhall, 1899.

LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles; metamorphism is indicated by hachures combined with the line patterns.)

QUATERNARY

Recent

- **Qal** — Alluvium *(fine silt and sand, with gravel near streams forming terraces)*

TERTIARY

Miocene

- **Teb** — Ellensburg formation *(fluviatile deposits of stratified silts, sand and gravels of volcanic materials; locally indurated)*

UNCONFORMITY

Eocene

- **Tm** — Manastash formation *(sandstone, conglomerate, and shale)*

UNCONFORMITY

- **Trl** — Roslyn formation *(sandstone and shale with beds of coal)*

UNCONFORMITY

- **Ts** — Swauk formation *(sandstone, conglomerate, and shale*

UNCONFORMITY

CARBONIFEROUS ? AND OLDER

Metamorphic

- **cs** — Contact schist *(sedimentary rock metamorphosed by intrusive granodiorite)*
- **ps** — Peshastin formation *(black slate and grit with beds of chert and lenses of limestone locally)*

UNCONFORMITY

- **et** — Easton schist *(quartz-mica-schist with associated hornblende-schist and epidote-schist)*

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Metamorphism is indicated by hachures.)

TERTIARY

Pliocene?

- **Tr** — Rhyolite *(lava and associated tuff)*

Miocene (pre-Ellensburg)

- **Ty** — Yakima basalt *(extensive series of lava flows with local tuff beds)*
- **Td** — Diabase *(intrusive bodies with associated dikes, constituting Yakima basalt conduits)*
- **Tap** — Andesite-porphyry *(intrusive mass related to Taneum andesite)*
- **Tta** — Taneum andesite *(hypersthene-andesite lava with beds of tuff and breccia)*

Eocene (pre-Roslyn)

- **Tg** — Gabbro *(intrusive bodies of gabbro, in part olivine bearing and in part quartz bearing)*
- **Ttb** — Teanaway basalt *(lava flows with tuff beds)*
- Basic dikes *(diabase, usually quartz bearing, filling Teanaway basalt conduits)*

PRE-TERTIARY

Post-Carboniferous

- **msg** — Mount Stuart granodiorite *(batholith of massive granodiorite with smaller masses of granodiorite-porphyry)*
- Acid dikes *(granodiorite-porphyry associated with Mount Stuart batholith)*
- **pr** — Peridotite *(intrusive body, largely altered to serpentine)*

Legend is continued on the left margin.

LEGEND

IGNEOUS ROCKS *(continued)*

CARBONIFEROUS ?

Metamorphic

- **hk** — Hawkins formation *(diabasic lavas, tuffs, and breccias)*

Faults

Sections (A–A, B–B)

- Coal, gold, and copper mines
- PL *Gold placer mines*
- QTZ *Gold quartz mines*
- X *Coal prospects*

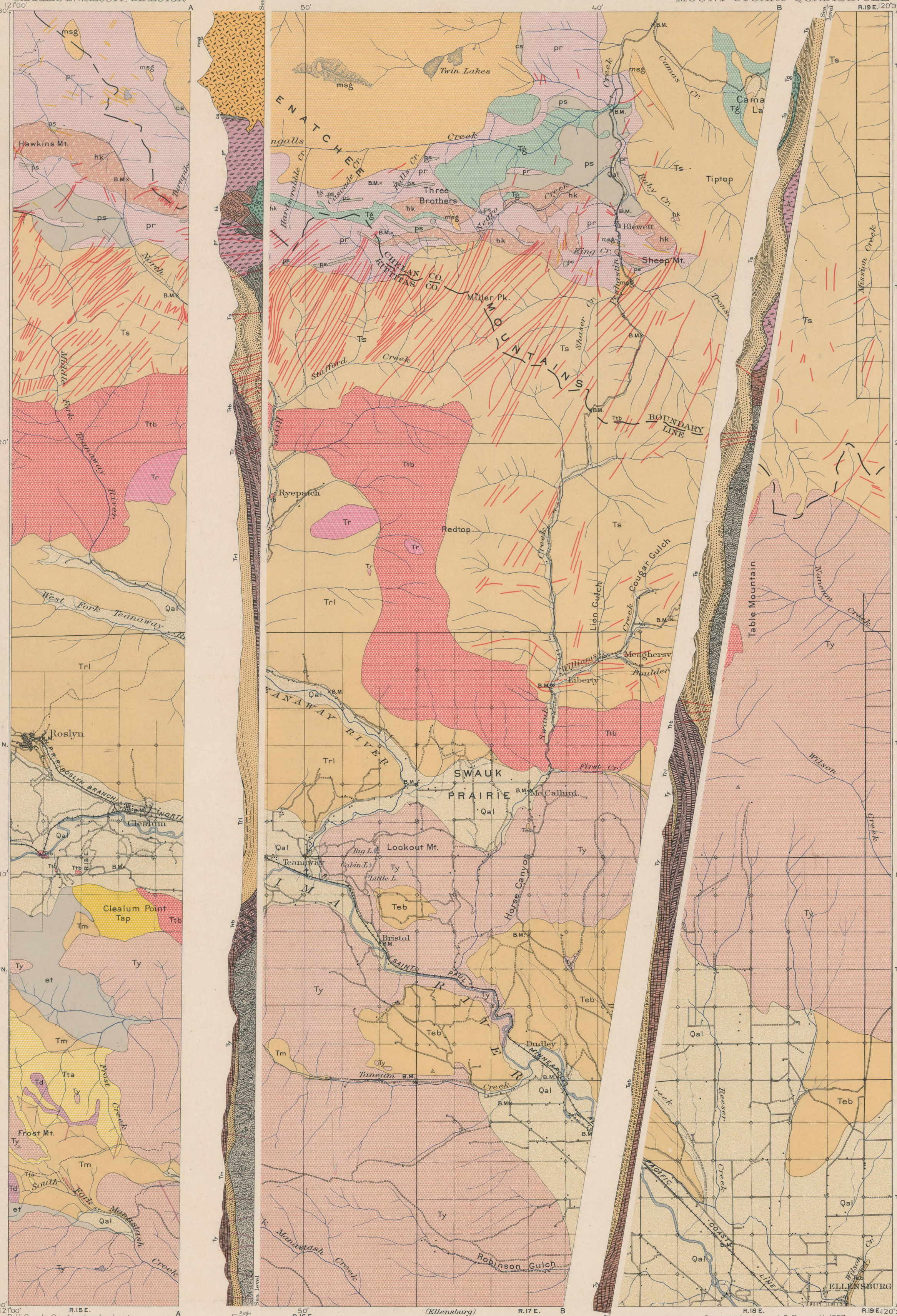
Known productive areas

- *Gold-bearing gravels*
- *Coal outcrops (dashed line indicates heavy alluvium covering)*
- *Area underlain by Roslyn coal*
- *"Nickel ledge" (metamorphosed limestone extensively prospected for precious metals)*

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

STRUCTURE SECTIONS

WASHINGTON
MOUNT STUART QUADRANGLE



R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett
Topography by G.E. Hyde.
Surveyed in 1896-97.

APPROXIMATE MEAN DECLINATION 1902.

(Ellensburg)

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

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Edition of Jan. 1904.

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LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL — SECTION SYMBOL

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UNCONFORMITY

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Acid dikes *(granodiorite-porphyry associated with Mount Stuart batholith)*

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CARBONIFEROUS ?

Metamorphic

hk — hk — **Hawkins formation** *(diabasic lavas, tuffs, and breccias)*

Faults

COLUMNAR SECTIONS

GENERALIZED SECTION OF THE SEDIMENTARY AND VOLCANIC ROCKS OF THE NORTHERN PORTION OF THE MOUNT STUART QUADRANGLE.
Scale: 1 inch = 1000 feet.

System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
TERTIARY	PLIOCENE?	Rhyolite.	Tr		100-800	Compact lava and tuff, with scattered crystals of quartz; weathers white and rusty yellow.
		UNCONFORMITY.				
	EOCENE	Roslyn formation.	Trl		3500±	Massive yellow sandstone, with clay and bony shale. Roslyn seam of coal in upper portion of formation, with other less valuable seams.
		Teanaway basalt.	Ttb		300-4000	Lava flows, with interbedded tuffs. Lava black and dark gray, compact or vesicular, sometimes weathering brown or red.
		UNCONFORMITY.				
		Swauk formation.	Ts		3500-5000	Well-stratified conglomerate, arkose and quartzose sandstones and shale, light and dark gray in color. In eastern part of area, sandstone more purely quartzose, and white and yellow in color. Cut by numerous dikes of diabase.
		UNCONFORMITY.				
PRE-TERTIARY		Granodiorite, peridotite, slate, and other rocks.				Descriptions in table of intrusive and pre-Tertiary rocks.

GENERALIZED SECTION OF THE SEDIMENTARY AND VOLCANIC ROCKS OF THE SOUTHERN PORTION OF THE MOUNT STUART QUADRANGLE.
Scale: 1 inch = 1000 feet.

System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
TERTIARY	MIOCENE	Ellensburg formation.	Teb		1000-1500	Light-colored sandstone, shale, and conglomerate, usually very friable, with many pumice fragments and pebbles, and exhibiting stream bedding.
		Yakima basalt.	Ty		1000-2000	Black lava, weathering gray or brown, compact or scoriaceous, with typical columnar partings common. Tuffs present, but not important.
		Taneum andesite.	Tta		200-300	Loose-textured lava, with tuff and tuff-breccia, pink, green, gray, and brown in color.
		UNCONFORMITY.				
	EOCENE	Manastash formation.	Tm		1000+	Massive, light-colored sandstone and pebbly conglomerate, with shale and seams of bone.
		UNCONFORMITY.				
PRE-TERTIARY		Easton schist.	et			Described in table of intrusive and pre-Tertiary rocks.

GENERALIZED TABLE OF THE INTRUSIVE AND PRE-TERTIARY ROCKS OF THE MOUNT STUART QUADRANGLE, ARRANGED ACCORDING TO AGE.

Period.		Formation Name.	Symbol.	Lithologic Symbol.	Character of Rocks.
TERTIARY	MIOCENE	Diabase.	Td		Brown, medium-grained diabase in intrusive bodies, with associated dikes.
		Andesite-porphyry.	Tap		Massive, gray, porphyritic rock, forming intrusive mass at Clealum Point.
	EOCENE	Gabbro.	Tg		Light-gray massive gabbro, with greenish to purplish tint. Intrusive bodies in pre-Tertiary rocks and sheet in Swauk formation at Camas Land.
POST-CARBONIFEROUS		Mount Stuart granodiorite.	msg		Massive, gray, granular rock of granitic appearance, varying in grain and in proportion of darker minerals. Porphyritic near contacts and in smaller masses.
		Peridotite and serpentine.	pr		Massive and schistose, according to degree of alteration to serpentine. Colors range from black to nearly white, with yellow, red, and green common. Massive peridotite, compact, with waxy luster, and somewhat porphyritic.
CARBONIFEROUS ? AND OLDER		Peshastin formation.	ps		Black slate, with bands of chert, thin beds of grit, and lenses of limestone.
		Hawkins formation.	hk		Breccia, tuff, and amygdaloid, of purplish or greenish color, usually of diabasic composition, although much altered. In some areas intricately associated with Peshastin formation.
		Easton schist.	et		Quartz-mica-schist, silvery green, crumpled, and gashed with quartz veins. Amphibolites and epidote-schists less prominent.

GEORGE OTIS SMITH,
Geologist.

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58	Elmoro	Colorado	25
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