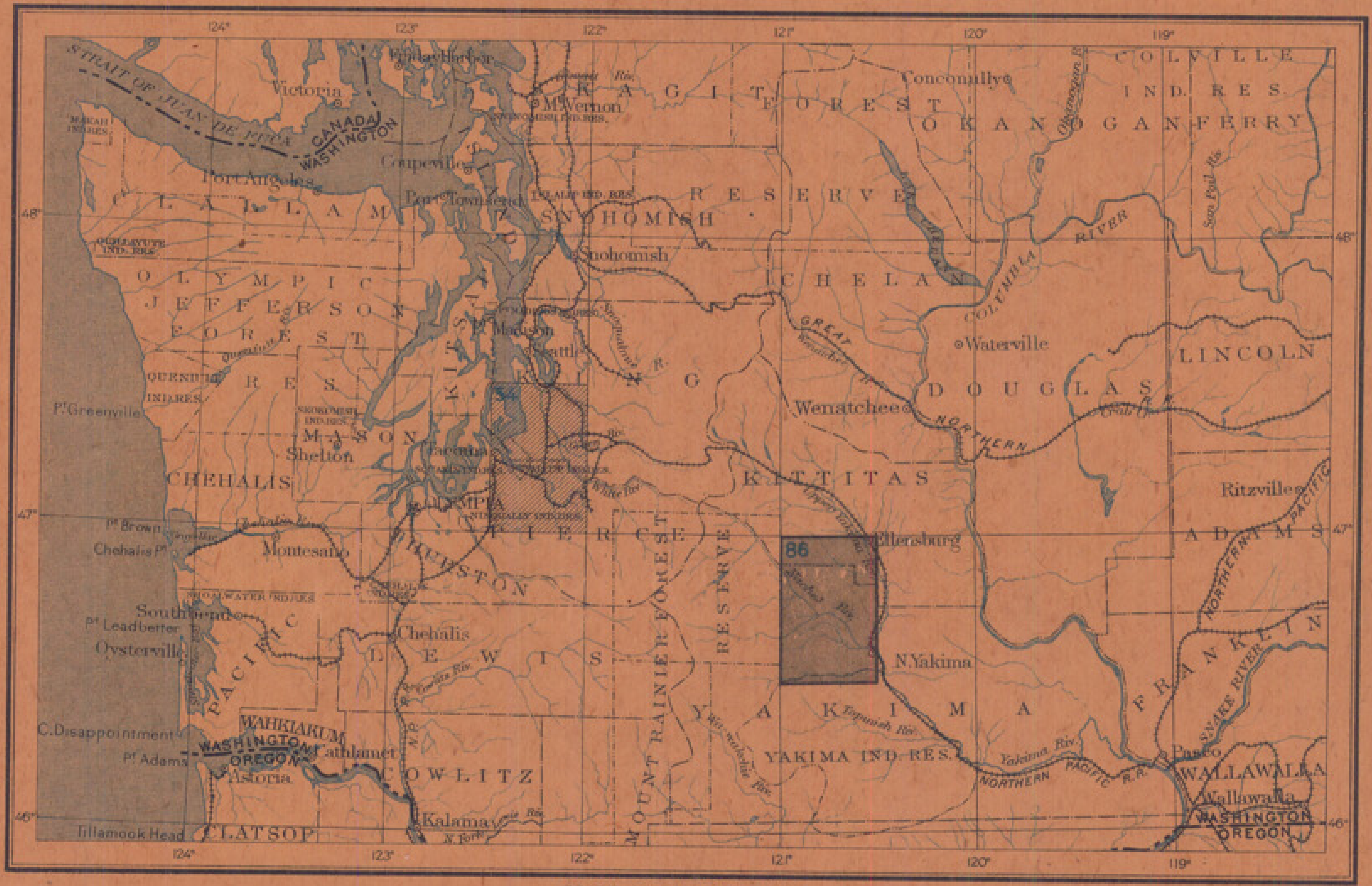
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

ELLENSBURG FOLIO
WASHINGTON

INDEX MAP



SCALE-40 MILES-1 INCH

▩ AREA OF THE ELLENSBURG FOLIO

▨ AREA OF OTHER PUBLISHED FOLIOS

CONTENTS

LIBRARY EDITION

ELLENSBURG FOLIO
NO. 86

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
1903

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical 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:

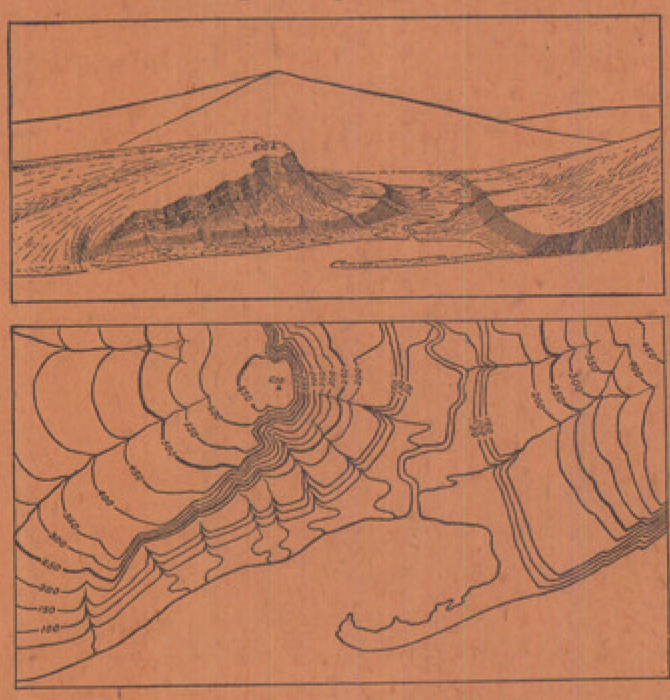


Fig. 1.—Ideal sketch and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the slope at 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 approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all 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 nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The 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 vertical 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 used 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.—Water courses are indicated by blue lines. If the streams flow the year round 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, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be 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 of "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

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 and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,500}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory 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-quarter of a square degree; each sheet on a 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or 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 sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it may consolidate in cracks or fissures crossing the bedding planes, thus forming dikes, or spread out between the strata in large bodies, called sheets or laccoliths, or form large irregular cross-cutting masses, called stocks. Such rocks are called *intrusive*. Within their rock inclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock it is younger than that rock, and when a sedimentary rock is deposited over it the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive 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 over wide expanses, and as it rises or subsides the shore lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and

DESCRIPTION OF THE ELLENSBURG 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. In this folio is described a portion of the eastern flanks of this type of the Cascade Range. 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 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 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. Its western border lies in small part in the Ellensburg quadrangle, or more exactly, this quadrangle includes 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 Ellensburg quadrangle is bounded by the parallels 46° 30′ and 47° north latitude and the meridians 120° 30′ and 121° west longitude. It measures somewhat over 34 miles in length north and south by nearly 24 miles east and west, and contains 820 square miles. It includes portions of Yakima and Kittitas counties and is situated immediately south of the geographic center of the State.

Topography.—Along the eastern border of the Ellensburg quadrangle the country, in its general aspect, suggests the Great Plain of the Columbia. The broad ridges and valleys are comparatively featureless in detail, and sweep eastward until they are seen to merge into the plateau country bordering Columbia River. In the central and western portions of the quadrangle, however, there is greater topographic diversity, and the ridges extend westward toward the more rugged mountains of the Cascade Range. The highest elevation reached within the quadrangle is 6143 feet, on Bald Mountain, in the northwest corner, and the lowest part is along Atanum Creek, which crosses the eastern edge of the quadrangle at about 1000 feet above sea level.

Several ridges having a general east-west trend divide the district into a series of parallel valleys, the western portions of which fall within the limits of the area here described. These ridges rise to elevations of from 1000 to 3000 feet above the valleys and are characterized by gentle slopes and even-topped crests. The stream channels and gulches that score their sides are hardly noticeable, and in many places an apparently unbroken slope extends from the valley floor to the ridge crest above. Between the ridges are the canoe-shaped valleys, which, with the heights, will be more fully described in a later section, in connection with the discussion of their origin (see pages 4 and 5).

The most remarkable feature of the relief of this area is the canyon of Yakima River, an important tributary of the Columbia, which is cut transversely across the ridges and has no relation to the present topography. This canyon, which is followed by the line of the Northern Pacific Railway, is very bold and deep where it cuts the higher ridges, and the scenery along the railroad line is especially fine in that section immediately beyond the eastern boundary of this quadrangle. It is represented in Selah Gap, 2 miles north of North Yakima, and is much deeper north of Selah Valley. The relation of the course of the river to the valleys is no less striking, since these also are transverse to its course, and some of them, as the Selah–Wenas and Umptanum–Squaw Creek valleys, are high above the river level and indeed not easily seen from the river bank. Thus the water gaps of Yakima River interrupt the level crests of the ridges, and the shallow parts of its canyon cut across the broad stretches of the valleys.

Drainage and water supply.—The whole of the Ellensburg quadrangle is tributary to Yakima River, and thus belongs to the Columbia watershed. It is close to the eastern edge of the humid Cascade slope, and therefore, though within the arid region, is fairly well supplied with flowing streams. The master stream of the region is the Yakima, which, like its principal tributary, Naches River, rises in the high mountains of the Cascade Range. Tieton River, an important tributary of the Naches, is likewise fed by melting snow and ice and thus maintains a fairly constant discharge throughout the summer.

The smaller streams, Umptanum, Wenas, Cowiche, and Atanum creeks, whose drainage basins lie wholly or mostly within the Ellensburg quadrangle, have more of a seasonal character, and two of these creeks, Umptanum and Cowiche, quite fail in portions of their courses during the summer months. The smaller tributaries of these creeks are wholly intermittent, being commonly represented in midsummer only by a spring at the head of the dry stream channel.

Measurements of the Yakima at the Selah bridge, 4 miles above the mouth of Naches River, made by the United States Geological Survey in 1897, showed the maximum monthly mean discharge to be 9318 second-feet, in the month of May, and the minimum monthly mean to be 700 second-feet, in the month of September. Similar measurements of Naches River continued for three years give a maximum monthly mean of 6220 second-feet, in May, and a minimum monthly mean of 362 second-feet, in September. Naches River is considered the most important stream for irrigation purposes in the State of Washington, and, as indicated on the map, canals taking water from it supply the best agricultural land within the Ellensburg quadrangle. Tieton River, which enters the Naches about 15 miles above its mouth, is especially adapted to irrigation purposes, inasmuch as it is in greater part fed by glacial streams and thus maintains a large discharge during the hot months, when its waters are most needed.

Manastash Creek, in the northern part of the quadrangle, furnishes water for the irrigation of land southwest of Ellensburg, and this supply has been somewhat improved by the construction of a storage dam at the outlet of Manastash Lake, near the northwest corner of the quadrangle. Irrigation has been developed in the valley of Wenas Creek to such an extent as to effect a complete diversion of the water during the dry season and to necessitate a division of the supply by the courts. Somewhat similar conditions obtain in the vicinity of Atanum Creek, where there is more land under cultivation than the water supply warrants. The Ellensburg–North Yakima region is already more extensively irrigated than any other district in the State of Washington, and additions are being made to the system of canals by which the available water supply is utilized. Future developments, however, must be through construction of storage reservoirs at the headwaters of Yakima and Naches rivers.

Climate.—This area shares in part the arid climate of the Great Plain of the Columbia. In the vicinity of North Yakima the annual rainfall averages slightly more than 8 inches, while at Ellensburg the average precipitation is about 10 inches. In exceptional years the rainfall may be considerably less than the amount stated; it was less than 4 inches in 1898 at Ellensburg. The western and higher portions of the quadrangle are characterized by a semi-arid climate, due to the influence of the Cascade Range. Here the precipitation is appreciably greater, as would appear were records available for the upper portions of the Atanum and Wenas valleys. In the upper Yakima Valley, records kept at Clealum and Ellensburg show that the annual rainfall is more than three times as large at the former locality as at the latter, the distance between the two places being but 25 miles. Snow persists well into the summer on the slopes of Bald Mountain.

In the lower valleys the winters are short, and very cold weather is uncommon. The mean annual temperature in the vicinity of North Yakima is about 50° F., and at Ellensburg it is about 6° less. The summers are hot and dry and the percentage of bright, clear days is so high as to especially favor agriculture.

Vegetation.—The vegetation of the Ellensburg quadrangle is scanty. Along the rivers and streams a few trees are found, cottonwood being abundant on the banks of Yakima and Naches rivers in the vicinity of North Yakima, while yellow pine (*Pinus ponderosa*) occurs in the canyon of the Yakima between Wenas and Ellensburg. The native vegetation is an excellent index of the varied climate of the region. The lower valleys and the ridges in the eastern half of the quadrangle are treeless and covered with sagebrush and associated desert shrubs, where the land is in its primeval state, and the nutritious bunchgrass is everywhere plentiful on the ridges, except where excessive grazing has destroyed it. Yellow pine occurs in the western half of the quadrangle, appearing first as scattered trees and farther west in open groves. Along the western edge of the area the pine is abundant and of good size, so that lumbering operations have been carried on in the vicinity of the headwaters of Manastash, Wenas, and Oak creeks, and on the North Fork of Atanum Creek. Red fir (*Pseudotsuga taxifolia*), cedar (*Thuja plicata*), and hemlock (*Tsuga mertensiana*) are the other forest trees in the western part of the quadrangle. Near the lower course of Atanum Creek yellow birch is found, while scrub oak and maple occur along several of the streams, these trees being especially abundant near the mouth of Tieton River. In the land classification made under direction of the Division of Forestry of the United States Geological Survey, the area at present covered with merchantable timber is estimated at 122 square miles, with a total stand of 150 million feet B. M. From 68 square miles the timber has been cut.

Culture.—The larger parts of two cities are included in this quadrangle—Ellensburg, near the northeast corner, with a population of 1737, and North Yakima, about 25 miles south, on the eastern edge, with a population of 3154 in 1900. These cities are the county seats of Kittitas and Yakima counties, respectively, and are supply centers for the surrounding country. There are several other post-offices, but the population outside of the two cities is generally scattered along the valleys. The total population of the quadrangle was about 8800 according to the census of 1900.

Some manufacturing is carried on in Ellensburg and North Yakima, but the principal industry of the region is agriculture. The crops that are cultivated are many and varied. On the irrigable land of the Kittitas and Naches valleys is raised hay—alfalfa, clover, and timothy—which commands the highest price in the Puget Sound markets. Among the cereals, wheat, oats, and barley are grown. Potatoes, sweet corn, and other vegetables are shipped in large quantities from these valleys. In the vicinity of North Yakima, apples, peaches, prunes, pears, cherries, and apricots of the finest quality are grown. The district has also long been famous for the excellent quality of its hops, and this crop continues to be an important one.

Many large herds of cattle and bands of sheep are wintered in the valleys of this region and furnish a home market for much of the hay raised here. The mountainous regions to the west furnish summer range for this stock, and in early summer the cattle and sheep graze in the higher, western portion of the quadrangle.

GEOLOGY.

GENERAL HISTORY OF CASCADE MOUNTAINS.

CRETACEOUS AND EARLIER EVENTS.

Sources of data.—The geologic history of a limited area like the Ellensburg quadrangle can not be understood without some general knowledge of the province of which it is a part. Only the younger rocks are exposed within this district, and only the corresponding chapters of the geologic record are here available; but in the Northern Cascades much older rocks are found, which furnish data for earlier chapters in the history of the province, and a brief outline of that history will be given as introductory to the more detailed account of the events within the smaller area.

Earliest known episodes.—The oldest rocks known in the Northern Cascades are of Paleozoic age and represent products of volcanic activity as well as sediments. Their characters indicate that the conditions of sedimentation and of volcanism were remarkably similar to those obtaining in the same period in the Sierra Nevada and in British Columbia.

Cretaceous seas.—During Mesozoic time sandstones and other sediments were laid down in portions of the Northern Cascade area, the most important body of Cretaceous rocks lying immediately south of the international boundary and representing an extension of the Cretaceous sea southward from the interior region of British Columbia. Farther south the nearest known area of rocks of similar age is in the John Day Basin and Blue Mountains of Oregon, and thus central Washington may have been at that time a land area with Cretaceous seas both to the north and to the south.

TERTIARY AND LATER EVENTS.

Post-Cretaceous uplift.—The deposition of the Cretaceous rocks seems to have been followed by an epoch in which they and older rocks were folded and uplifted. Thus was an early Cascade

Range outlined, although it may be that the range had an even earlier origin. Accompanying the post-Cretaceous mountain growth were intrusions of granitic and other igneous rocks, which now constitute a large part of the mass of the Northern Cascades. During all the time that any portion of this area was not covered by water the rocks were exposed to the vigorous attacks of atmospheric agencies. Thus at the beginning of the Tertiary the Northern Cascade region appears to have been a comparatively rugged country, although not necessarily at a great elevation above sea level.

Puget estuary.—During the Eocene period an extensive estuary or arm of the sea occupied the Puget Sound area and extended well over toward the present axis of the range. Other large bodies of water, probably fresh, existed in central Washington, and in some cases may even have been connected with the Puget estuary. Thousands of feet of arkose sediments were deposited at this time, and in these strata of Eocene age are included all the coal beds in the State that are of economic importance. In this period also began the volcanism that in later epochs became so characteristic of the province. The more extensive basaltic eruptions, however, occurred in the succeeding period, the Neocene, when an area measuring many thousands of square miles was buried deeply beneath the flood of lava. In portions of this vast area, sedimentation within shallow-water bodies immediately followed the eruption of basalt, and the Miocene epoch closed with slight tilting and folding of these deposits. The erosion that followed the exposure of these beds and the underlying rocks to atmospheric action continued until the whole region was planed down to a lowland surface, possessing only slight relief. This reduction of the area to what appears to deserve to be termed a peneplain marks the destruction of the earlier Northern Cascades as a mountain range, but Tertiary time probably closed with the uplift of this leveled surface to form the present Cascade Range. This uplift at its very beginning inaugurated fresh attacks upon the rock masses by the streams, and is so recent that streams and glaciers have as yet succeeded only in giving to the range an extremely rugged relief.

HISTORY OF ELLENSBURG QUADRANGLE.

NEOCENE PERIOD.

Basaltic eruptions.—In the western portion of the North American continent the early Neocene, or Miocene, was preeminently a time of volcanic activity, and nowhere are the products of this volcanism more in evidence than in the basin of Columbia River. The Miocene basalt has covered almost the whole area, and usually, as in the Ellensburg quadrangle, this rock is only to a small degree concealed by later deposits. The character of the surface over which the molten basalt was poured is shown along the margins of the vast pile of lava sheets, as in the Mount Stuart quadrangle, where, within a few miles of the northwest corner of the Ellensburg quadrangle, the basalt has been eroded so as to expose the older rocks. The contact between the lava and the underlying Manastash formation indicates that the first flows of the Yakima basalt issued upon a surface possessing considerable relief, but the inequalities were soon obliterated by the flood of molten rock which overflowed even the deepest valleys and covered the hilltops.

In the same locality dikes of coarse basalt can be seen cutting through the older rocks and connecting with the sheets of basalt above. They were the channels through which the molten rock found its way to the surface, and to a large extent the eruptions appear to have been of the nature of a quiet upwelling of extremely liquid lava, which flowed for long distances over the surface, finally consolidating as sheets 25 or 100 feet, or even more, in thickness. In the canyon of the Yakima ten or more separate flows of this character may be counted, and individual flows may be traced for great distances. Explosive eruptions do not appear to have been of common occurrence, since the beds of tuff which represent the fragmental material thrown out by such explosions are insignificant when compared with the great thickness of lava sheets. In some parts of the area, however, there was volcanic activity of this nature, one noteworthy locality being Bald Mountain, at the head of Wenas Creek. On the northeastern slope of this peak there are beds of yellow tuff, full of angular fragments of basalt glass, which aggregate several hundred feet in thickness.

The successive flows of basalt eventually covered the whole region, changing it from a beautiful area of hills and valleys to a monotonous waste of black rock. From the borders of this leveled plain of basalt rose hills covered with luxuriant vegetation, and during cessations in the eruptive activity soil probably formed upon the rough surface of the cooled lava and trees and shrubs obtained a foothold, only to be buried later by flows of molten rock or deposits of tuff. From the surrounding country the streams washed gravel and sand out upon the basalt plain, but no deposits of foreign material of this character are known at any distance within the margin of the basalt areas.

Fluviatile deposits and concurrent eruptions.—Toward the middle of the Neocene, the latter part of the Miocene epoch, basaltic eruptions ceased in this area. The piling up of such masses of heavy rock material, masses to be measured by thousands of cubic miles, was undoubtedly accompanied by more or less subsidence in the central portion of the area covered by the basalt flows, and the subsidence also appears to have continued after the cessation of the eruption of basalt, so that the central area became a basin in which sedimentary deposits accumulated. Streams flowed toward this depression and deposited their loads of sand and gravel upon the surface of the basalt. In the Ellensburg region their contribution was conspicuously of foreign origin, consisting of pebbles, bowlders, and sand derived from light-colored andesitic lava, which must have been recently erupted farther west. No other rocks seem to have been exposed to erosion within the area drained by these streams, and even pebbles of basalt are very rare in the deposits made by these Miocene rivers.

The eruptions of andesite began before the basaltic eruptions ceased, since pebbles of andesitic lava and pumice are found in the bed of Ellensburg sandstone beneath the latest sheet of basalt (Wenas basalt). The character of these eruptions to the west was quite different from the fissure eruption 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. Such volcanic explosions furnished material readily swept away by the streams, with the result that the latter became overloaded and deposited gravel and sand wherever there was even a slight decrease in the grade of the stream. Where the streams entered the generally level basin of basalt these deposits were spread out in wide alluvial fans, consisting largely of coarse material, gravels and sands interbedded, very commonly with the cross stratification characteristic of stream deposits. The portions of the Ellensburg formation included in the Ellensburg quadrangle thus represent fluviatile deposits made by eastward-flowing streams, and are marginal deposits probably of the same age as the truly lacustrine sediments laid down farther east in the same basin and now exposed at White Bluffs on Columbia River.

Sedimentation continued during later Miocene time until at last 1600 feet of strata had been accumulated. Subsidence of the basin, a portion of which was occupied by a lake, probably continued throughout this period, so that the tributary streams were able to continue to bring down coarse gravels, which indeed are rather more prominent in the later beds of these marginal deposits than in the earlier. Finer-grained sediments occur at several horizons and may be taken as indicating conditions of westward expansion of the lake waters, in which these well-stratified muds were deposited unmixed with the coarser contribution of the streams, which were checked at the western shore. Such conditions were only temporary in the Ellensburg region, and some of the beds of fine volcanic material may be of eolian origin, the showers of volcanic dust having covered the flood plains over considerable areas and also overloaded with silt the streams themselves.

Deformation and erosion to lowland.—Toward the latter part of the Neocene period, the epoch represented by the sediments of the Ellensburg formation closed with the elevation and folding of the Miocene beds. Throughout the Miocene there seems to have been intermittent subsidence of the earth's crust in this region bordering the basin wherein the basalt was erupted and where the overlying sediments were deposited. Now, probably early in Pliocene time, the movement took the form of flexing both rocks into gentle arches whose general trend was east-west. The arching was not long continued, and the streams, with increased grade, began at once their attack upon the uplifted rocks, so that erosion took the place of deposition. First, the Miocene sands and gravels were cut away until these soft beds were wholly removed from the crests of the arches, and thereafter erosion continued until even the hard basalt was taken away in considerable amount.

The degradation of the land by the activity of the streams was continued with no apparent cessation until the whole region was reduced to a lowland. Its relief now became relatively insignificant, the reduction to the approximately level plain, or peneplain, having reached such a degree of perfection that the resistant basalt was leveled off equally with the soft sandstone.

Later warping and uplift.—The peneplain resulting from this effectual erosion was next affected by orogenic forces. Along lines for the most part coincident with those of the earlier folding, the level surface was arched and at the same time the whole region was uplifted. This process was an extremely slow one, but it eventually gave considerable relief to what had been a featureless plain. The streams that had meandered over the old lowland now began to entrench themselves, and where the arches of the warped plain slowly rose athwart them the larger rivers performed the task of maintaining their channels. The deep water gaps where Yakima River cuts through these uplifted ridges afford unmistakable evidence of the success with which the river accomplished this task of keeping its right of way. The valleys between the ridges furnished natural routes for surface waters, and thus many of the tributaries of Yakima River have courses consequent upon the warped hollows of the peneplain.

PLEISTOCENE PERIOD.

Canyon cutting.—The fossil leaves contained in the Ellensburg sandstone definitely fix its age as late Miocene, but for the events succeeding the deposition of these sediments no exact date can be given. It has seemed most plausible to fix the date of the peneplain as Pliocene and to consider the subsequent warping and uplift as events of late Pliocene time, which very probably continued into the Pleistocene. The resulting canyon cutting was accomplished in large part before the latest glacial occupation of the valleys, as can be seen in the upper Yakima Valley, where the ice of the Glacial epoch has left its record, but the canyons are still being deepened in many places.

Andesite eruption.—The most important event in the later history of this district was an eruption of andesitic lava somewhere in the higher mountains to the west. One of the lava streams had its origin in the vicinity of the Tieton Basin and flowed eastward down the canyon of Tieton River, which had been excavated to a depth of from 1000 to 3000 feet in basalt, and was now filled almost to the top with successive floods of volcanic mud and of lava. The later streams of molten rock flowed out over the broad valley where Tieton River and the Cowiche creeks united with the Naches, covering the fertile bottom land and forming there the plateau which is now a marked topographic feature. The lava stream cooled as it flowed, and finally stopped about 12 miles below the point where it issued from the canyon. The eastward slope of the hummocky upper surface of this flow averages about 60 feet to the mile, which expresses the degree of fluidity of the lava at this point in its flow. At the end of the flow its thickness was about 300 feet, the lava as it cooled forming the wonderful columns at Pictured Rocks.

This eruption of andesite does not seem to have affected the course of the Naches, but the lower courses of Tieton River and of the two Cowiche creeks were essentially changed by it. The latter creeks formerly entered Naches River as separate streams, but when the lava plateau formed an effectual dam they were forced to unite their waters and to seek an outlet around the end of the andesite flow, entering the river several miles farther southeast. When the Tieton first began again to flow down the valley which had been so deeply filled, it for a brief time sent some of its water southward into the Cowiche drainage, but soon it established its new outlet farther north, where it encountered the easily eroded Ellensburg sandstone and thus could cut a channel around the upper end of the lava plateau. This new junction with the Naches is nearly 2 miles above the old, the old lava-filled channel at the point of diversion being shown in section on the east side of Tieton River opposite B. M. 1681.

Farther north similar volcanic activity gave rise to lava flows which covered much of the basalt surface between Bald Mountain and Naches River, but they did not extend far down the canyon, and caused only local changes in the drainage.

Deposition of alluvium.—The damming of the Cowiche creeks resulted in the deposition of stream gravels in the low land behind the lava barrier. The Cowiche waters were ponded until they reached the level of about 1700 feet, when they overflowed around the southeastern edge of the lava plateau. Deposition of the gravels continued until the new channel had been cut nearly to its present level, when these deposits were in part cut away and the remainder was left in well-defined terraces.

Alluvium also occurs at the lower level of the present flood plain of Cowiche Creek, and is plainly of later origin. Throughout the quadrangle the streams in their lower courses, where their fall is slight, have deposited gravel, sand, and silt, shown on the map as valley allvuium. The deposition is due in many cases to the establishment of a local base-level for a stretch above a point where the stream has been engaged in the task of cutting through hard basalt. In a large way, the extensive alluvial deposits of Kittitas Valley may thus be attributed to the period when the river was cutting across the slowly rising Manastash and Umptanum arches, so that the lower portion of the section of gravels may antedate the Pleistocene period. A good example of the origin of these deposits on a smaller scale is along Wenas Creek, where, in its lower course, the stream has cut down to the hard Wenas basalt, causing the upper part of the valley to be widened in the soft sandstone and making a flood plain a mile in width at one point. So, too, there was a wide expansion of the valley of the Naches above where the river cuts across the western end of the Selah Ridge, although later a large part of this wide valley was occupied by the andesite flow.

There are no deposits within this area directly referable to the Glacial epoch. The silts of the lower Yakima Valley may possibly indicate the existence of ponded waters in this area. Groups of large granite bowlders found in Wenas Creek and in Wide Hollow may also be referred to that time, since their size and their occurrence in valleys where no granite is exposed indicate that they must have been dropped from masses of ice floating in the ponded waters of Yakima Valley.

DESCRIPTION OF THE ROCKS.

On the Areal Geology map of this folio six formations are represented, the geologic history of which has been traced in the preceding section. In the following paragraphs these rocks will be described, especially those characters which afford a basis for the interpretation of the geology of the region, which is relatively simple.

SEDIMENTARY ROCKS.

ELLENSBURG FORMATION.

Age according to flora.—The only sedimentary formation in this quadrangle is of Miocene age. Fossil leaves have been found in the sandstone in a quarry southeast of Ellensburg and just beyond the eastern edge of the quadrangle, and in Kelly Hollow. The only other fossils which have been obtained from this locality are a few teeth of *Hipparion*, a Miocene representative of the horse family. The Manastash sandstone which underlies the Yakima basalt contains an Eocene flora. The following report on the fossil plants from the Ellensburg formation 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 1893. 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 Mr. 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.
>
> I have recently received an additional small collection made at Kelly Hollow, Wenas Valley, by Mr. Geo. Otis Smith. The following forms are represented:
>
> *Salix engelhardti* Lesquereux.
> *Salix pseudo-argentea* Knowlton.
> *Ficus oregoniana* Lesquereux. Small leaves.
> *Quercus pseudo-lyrata* Lesquereux.
> *Quercus dayana* Knowlton.
> *Diospyros elliptica* Knowlton.
>
> The matrix of the specimens in all three of these collections is similar, being a white, generally fine-grained volcanic ash. It is identical in appearance with that from Van Horn's ranch (Mascall beds) in the John Day Basin, Oregon.
>
> Of the 15 forms above enumerated 12 or 13 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.

Volcanic origin of material.—The Ellensburg formation is of the same age, therefore, as the Mascall formation of the John Day Basin in Oregon. Like it, 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 Ellensburg quadrangle, but undoubtedly occurs in the mountains to the west.

The distinctive characters of this formation, its andesitic composition, and the coarseness of the material, as well as the common occurrence of cross stratification or stream bedding, are best shown in the following descriptive section, which was carefully measured by Mr. Calkins along the bluffs north of Naches River.

Section of Ellensburg formation along the north side of Naches Valley.

	Feet.
Brown pumice sand, varying in texture and color, in part concealed, approximately....	145
Brown pebbly sandstone or conglomerate, with small basalt pebbles in a matrix of ashy sand....	100
Gray and brown sandstone and pumice sand..	90
Conglomerate, andesitic pebbles, with a few basaltic pebbles, in ashy matrix....	15
Brown tuffaceous sandstone, with much pumice....	25
Partly consolidated sand, composed mainly of pumice grains....	85
Soft, light-gray ash....	1
Brown pumice sand....	10
Porous sinter....	1.5
Coarse, brown, tuffaceous sand, partly consolidated....	3
Coarse, soft, gray sandstone, composed of angular andesite fragments....	2
Yellowish-white pumice conglomerate....	5
Fine gray sand, silt, and pumice sand well stratified....	2
Coarse- to fine-grained, brownish-gray, soft tuffaceous sandstone, with pumice and andesite fragments....	25
Pumice conglomerates and interbedded tuffaceous sandstone....	12.5
Hard, fine gray sandstone....	1
Fine brown sand, partly consolidated....	3
Grayish-brown sand, with a few pumice pebbles....	3
Reddish-brown conglomerate, with large bowlders....	20
Hard sandstone, with calcareous layers....	1
Coarse, gray, pebbly sand, cross bedded....	15
Brown tuffaceous sand, with lapilli....	1.5
Coarse conglomerate of andesite and pumice.	5
Grayish-brown tuffaceous sandstone, with pumice pebbles....	6
Well-bedded gray sandstone and shale, with pumice pebbles....	18.5
Brown tuffaceous sandstone, pebbly....	3
Andesite conglomerate and partly consolidated sand, with some pumice pebbles....	30
Pumice and andesite conglomerate....	3.5
Fine, cross-bedded soft sandstone, with bed of angular pumice....	9
Coarse pumice conglomerate....	1
Fine gray sand and silt, with much pumice..	4
Pebbly sand, with pumice pebbles....	10
Pale-lavender soft shale....	1
Gray tuff and sand....	5
Light-brown fine sandstone, grading up into chocolate clay....	7
Pebbly sandstone, in part tuffaceous, with intercalated layers of pumice pebbles and fragments....	32*
Andesite agglomerate, fine grained....	2
Medium-grained gray sandstone....	4
Andesitic gravel....	4
Coarse sand and gravel....	5
Hard sandstone....	3
Fine to coarse, medium-fine, gray and brown sands, with lapilli and pumice pebbles....	28.5
Coarse sand, with bowlders stained brown...	6
Medium-grained hard sandstone....	3
Fine andesite gravel, with coarse sand, partly consolidated....	10
Gray tuffaceous sand, with fine pumice....	6
Conglomerate pebbles, averaging about 2 inches, covered with dark-brown varnish..	20
Fine light-gray tuffaceous sandstone....	2
Dark-gray coarse sand, cross bedded, with small andesite pebbles....	5
Fine- to medium-grained, light-gray tuffaceous sandstone and silt....	6.5
Andesitic agglomerate, fine grained....	10
Dark-gray sand, cross bedded....	1.5
Conglomerate pebbles, mostly andesite, with a few of basalt, averaging about 2 inches, obscurely cross bedded, with lenses of sand	20
Sandy tuff, with fine lapilli....	6
Fine gray sand, cross bedded....	1
White tuff, fine lapilli in matrix of feldspathic sand....	2
Light brownish-gray ash....	4
Soft sand....	5
Fine white silt....	8
Fine light-gray tuffaceous sandstone and ash, coarser in upper portion....	7
Coarse agglomeratic sandstone, composed of subangular fragments of andesite interstratified with gray sandstones and pumice, tuff, and conglomerate....	38.5
Fine tuff, light gray, structureless....	4.5
Rough sandy conglomerate of andesite pebbles....	5
Fine light- to dark-gray hard sandstone, in part cross bedded with pumice pebbles....	9
Fine light-gray sandstone and brownish tuffaceous sandstone....	9
Fine light-gray tuff, with lapilli....	2
Fine light-brown tuffaceous sandstone, structureless....	4
Hard, light-gray, pebbly sandstone and interbedded tuff of fine pumice fragments....	11.5
Cross-bedded, soft gray sandstone, with abundant pumice pebbles....	6
Fine andesite agglomerate, grayish brown...	1.5
Cross-bedded, fine gray sandstone and shale, with small pumice pebbles....	10.5
White and lavender shale, passing into shaly sandstone above....	8
Fine light- to dark-gray sandstone....	10
Cross-bedded dark-gray sandstone, with pumice pebbles....	3
White shale....	1.2
Fine to coarse, gray, tuffaceous sandstone, structureless, with some pumice pebbles...	14
White shale and fine gray sandstone, interbedded....	19
Lavender and white laminated shale, in part sandy....	10
Light rusty-brown agglomeratic sandstone...	8
Cross-bedded sand and gravels, pebbles with blackened surfaces....	8
Fine-grained gray sandstone and silt....	15
Medium-grained tuff composed of lapilli....	1
Light-gray sandstone grading into silt....	15
Conglomerate, with large and small andesite pebbles and sand lenses....	60
Fine, gray, soft sandstone and silt, coarser in upper portion, cross bedded....	8.8
Medium-fine light-brown tuffaceous sandstone	9
Gray and greenish soft sandstone and sandy shale....	10
Medium to coarse light-gray sandstone, locally grading into fine conglomerate....	20
Fine, soft, light-gray sandstone and lavender shale....	1.4
Coarse brown silt....	4
Conglomerate, finer in lower portion....	6
Coarser cross-bedded sandstone, with pebbles	6
Fine conglomerate and medium-grained light-gray sandstone....	2.7
Coarse to fine, gray, cross-bedded sand....	5
Lavender silt and ash, with lapilli, white above....	7
Fine lapilli, unconsolidated....	1
Fine light-brown sandstone....	4
Coarse tuff, with rounded pumice pebbles in a sandy matrix....	3
Light-gray tuffaceous sandstone, with lapilli	2
Fine andesitic agglomerate....	3
Medium-grained, gray and yellow, soft, cross-bedded sandstone, with small pebbles....	8
Medium to fine tuffaceous sandstone, buff colored, structureless....	8
Medium to coarse-grained cross-bedded bluish-gray sandstone, with small pumice pebbles....	12
White silt....	1
Light-gray cross-bedded sandstone and silt...	10
Drab and gray tuffaceous sandstone, structureless....	15
Soft white tuff of fine pumice fragments....	1.5
Soft tuffaceous sandstone, structureless....	7
Cross-bedded gray sand, with pumice pebbles and interbedded silt....	6
Fine drab sand and lavender silt, interbedded	6
Fine lavender tuff, structureless....	1.3
Fine sand and clay, irregular stratification...	5
Medium-grained sand, with scattering pebbles of pumice....	1.5
Fine light-gray sand and lavender-colored silt	3
Dark-gray cross-bedded sandstone, with small pumice pebbles....	6
Hard, grayish to brownish, medium-grained sandstone....	2.5
Coarse gray sandstone and tuff, with lapilli in sandy matrix....	1.5
Fine sand and lapilli, partly consolidated....	1.5
Tuff, with angular fragments of andesite, pumice, and feldspar....	4
Fine light-gray sandstone, with beds of silt in upper part....	16
Lavender shale....	1
Light-yellow ash and lavender shale, passing into fine sandstone....	10
Conglomerate, with seams of sand, large andesite and pumice pebbles....	10
Medium to coarse, cross-bedded, soft gray sandstone, finer in upper portion....	10
Lavender-colored ash, feldpathic....	5
Medium-grained light-brown to greenish tuffaceous sandstone, with andesite and pumice pebbles....	4
Cross-bedded sand, with lapilli and andesite pebbles....	9
White tuff, with small angular lapilli....	.5
Interbedded silt and sand, drab colored, with lapilli....	7
Fine bluish-gray soft sandstone, with pockets of lapilli....	8
Medium-coarse gray sandstone....	3
Lavender tuff, with a medial bed of drab-colored silt....	2
Coarse sandstone, with much feldspar and fine lapilli, finer toward the top....	3.5
Coarse light-gray ash....	2
Medium-grained light-gray tuffaceous sandstone, with angular lapilli....	1.8
Medium- to fine-grained gray sandstone....	9
Coarse stream-bedded gray sandstone, with pebbles of andesite and pumice....	2.8
Conglomerate, with small pebbles of andesite and larger pebbles of pumice; some sand lenses....	4.5
Coarse buff-colored ash containing much feldspar....	7
Gray sandstone and silt....	20
Fine light-gray ash, structureless....	20
Sand and gravel, stream bedded, pebbles 2 inches average diameter, gravel finer in upper portion....	33
Fine gray ash, structureless, silky luster, composed of fine particles of glass....	4
Fine gray tuffaceous sandstone, with lapilli one-fourth inch in diameter....	3
Conglomerate interbedded with sand; pebbles of black andesite 1 to 4 inches in diameter....	10
Wenas basalt, two flows, columnar, with vesicular upper surfaces, 25 feet in thickness.	
Gray ash....	1
Light-gray tuff, with pebbles of andesite....	25
Total sediments resting upon upper surface of Yakima basalt....	1,569.5

Typical exposures of the formation.—The Ellensburg formation now occurs almost wholly in the valleys, where it is generally concealed under the alluvium. The light-colored sandstones can be seen along the banks of streams and irrigation ditches. At Ellensburg there is a bluff composed of characteristic beds of the formation near the Normal School, while in the vicinity of North Yakima the Ellensburg sandstone interbedded with the basalt can be seen in the bluffs overlooking the river at Selah Gap. The best exposure of the rocks of this formation is that along the lower course of Naches River, where the white bluffs extend for miles. It is also well preserved in the upper valley of the river, in the vicinity of Nile Creek, where cliffs several hundred feet in height can be seen. Such soft rocks as these friable sandstones and loose conglomerates can not well resist even the slight erosion of this arid country, so that over large areas the presence of the Ellensburg formation is barely noticeable and is frequently indicated only by the bits of andesitic pumice lying on the surface around badger holes.

The composition of the conglomerate beds and the prevalent stream bedding indicate that the formation is of fluviatile rather than lacustrine origin. At several points bowlders of andesite measuring several feet in diameter have been found in the Ellensburg conglomerate, indicating that powerful streams acted in the transportation of the material. The original thickness of the formation can not be stated. The section measured in Naches Valley shows nearly 1600 feet of sediments, while the Wilson well in Wide Hollow penetrates over 1200 feet of the Ellensburg formation. In both of these localities it is evident that erosion has removed the upper part of the section. The earlier sediments interbedded with the basalt vary considerably in thickness. Thus on the Naches River section the thickness is 26 feet, while on the east side of Selah Gap there are sandstones and conglomerate 130 feet thick below the Wenas basalt.

IGNEOUS ROCKS.

YAKIMA BASALT.

Definition of formation.—The oldest rock exposed in the Ellensburg quadrangle is the basalt which forms the larger part of the surface of this area. Where not exposed at the surface it is covered by alluvium or other rock, at most only a few hundred feet thick, so that the formation in reality underlies the whole area. It is a great series of lava flows, the base of which is not reached, even in the deep canyons, within the limits of this quadrangle. A few miles north of Bald Mountain, however, the South Fork of Manastash Creek cuts through the basalt, which here rests unconformably upon sandstone of late Eocene age. This fixes the age of the Yakima basalt as early and middle Miocene.

It is in view of the fact that the age of this formation is determinable that the name Yakima 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 the basalts of Eocene, Miocene, and possibly of Pliocene age, but also the hypersthene-andesite of Pleistocene age. In detailed areal mapping, igneous rocks of different ages must necessarily be separated, and therefore the name Yakima has been applied to this formation, which includes only the basalt flows and interbedded basaltic pyroclastics, which are of Miocene age and constitute a series that can be taken as a unit, since it represents the products of a volcanic activity uninterrupted by any other important geologic process.

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 on 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 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 large masses of pure basalt glass can be found. This jet-black glass also forms fragments in the yellowish tuffs of Bald Mountain. The larger of these glass fragments have a rounded form and undoubtedly represent bombs ejected from the volcanic center. As a whole the tuff beds and the scoriaceous lavas are less common than the compact basalt.

The number of lava flows composing the Yakima series can not be closely estimated. At least ten successive eruptions of basalt are indicated in the cliffs of the Yakima Canyon, but these are probably only a part of the total number. Their maximum thickness over this area is to be measured in thousands of feet. The flows are undoubtedly thinner in the western portion, though a thickness of over 1000 feet is shown north of Bald Mountain where the lava overlaps the older rocks. In the Yakima Canyon over 2000 feet of basalt are exposed, with neither the top or base of the series of lavas shown.

Columnar structure.—The most noticeable feature of the basalt is its columnar structure, by which the sheets of black rock are converted into

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*See Bull. U. S. Geol. Survey No. 108: A geological reconnoissance in central Washington, by I. C. Russell.

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.

WENAS BASALT.

Position and character.—The Wenas basalt overlies the Yakima basalt and is separated from it by a varying thickness of Ellensburg sandstone, as noted above. The two basalts do not differ much in age or in general appearance, and in fact their petrographic similarity would not justify the separation, which however is necessary from stratigraphic and structural considerations. In Kelly Hollow the Wenas basalt is about 100 feet thick and consists of two distinct flows, the upper columns being massive, while the lower columns are characterized by horizontal sheeting. At other localities in this vicinity the basalt appears to be in three flows. On the south slope of Umptanum Ridge the Wenas basalt varies in thickness from about 20 feet at the western limit of the flow to over 200 feet near the eastern edge of the quadrangle. Along Naches River the Wenas basalt occurs in two flows with a total thickness of 25 feet, but at Selah Gap the original thickness was somewhat greater.

Limitation in mapping.—In the western part of the Ellensburg quadrangle the Wenas basalt is absent at points where the section is well shown. As indicated in the preceding paragraph, the Wenas flows thin out to the west, and at several places their western limits can be accurately determined. At other localities, however, it becomes impossible, from insufficient exposures of rock, to state whether or not the Wenas basalt and the interbedded sandstone are present. On the north side of Manastash Ridge there are some indications of a thin sheet of Wenas basalt west of that mapped; so also on Atanum Ridge the presence of interbedded basalt and sandstone was ascertained; but these sheets were too thin and the exposures too poor to permit of representation on the geologic map.

Platy structure.—The basalt exposed for several miles along Atanum Creek below Tampico shows beautifully an exceptional type of columns which was commonly found in the Wenas basalt, but in the absence of any other proof the particular mass has been mapped as Yakima basalt, since the same structure has been observed in basalt undoubtedly of that age. The columns of this type are well-defined prisms that measure several feet in diameter and are peculiar from the close horizontal joints, along which, when struck with a hammer, the basalt breaks like a shale into thin plates. In view of the fact that, whether in the Yakima or the Wenas basalt, this structure is always found in flows that were soon succeeded by sediments, the development of the platy joints may have been due to the presence of surface waters. The contraction of the consolidated lava would first cause the development of the vertical joints, dividing the mass into prisms. If, then, surface waters found their way into the still cooling rock along these vertical planes, the further and more rapid contraction might cause the development of many joint cracks normal to the cooling surfaces, dividing the columns into horizontal plates.

TIETON ANDESITE.

Distinctive characters.—The lava that flowed down the canyons of Tieton and Naches rivers differs in composition from the basalts. It is generally of a lighter color, gray or purple, and when black it contains many white crystals of feldspar, making it plainly porphyritic, which is not true of the basalt. In composition this rock is less basic than the basalt and is characterized by the presence of the pyroxene known as hypersthene. Plagioclase is the other important mineral constituent, and the groundmass, while usually more or less glassy, shows the flowage texture of andesitic lavas. It is more closely related in composition to the andesites from which the material of the Ellensburg conglomerates was derived, but in the latter, hornblende is a more common constituent than hypersthene.

The Tieton andesite, however, is plainly much younger than either the basalt or the Ellensburg formation, since it occupies canyons and valleys eroded in these. The rock is remarkably fresh in appearance, and the surface of the andesite plateau between Naches River and Cowiche Creek has apparently not suffered from erosion, while the margins of this flow of andesite have been only slightly modified by the streams flowing at the base. The lava is scoriaceous in parts of the flows, like the basalt, while the columnar structure exceeds in perfection even that seen in the Yakima and Wenas basalts. At Pictured Rocks, near the mouth of Cowiche Creek, the long columns form immense aggregates, in which the individual columns curve so as to be normal to the outer edge of the flow, and near the mouth of Tieton River columns in one of the andesite flows measure nearly 200 feet in height, apparently without a break.

Occurrence of agglomerates.—Near the western edge of the quadrangle, both on Naches River and in Tieton Canyon, the Tieton andesite is commonly in the form of coarse agglomerates. Andesite tuff and conglomerate, red and purple in color, make up the conspicuous cliff known as Devils Slide. In the lower Tieton Canyon the lava predominates, and at the point where the former river valley is shown in section the andesite filling can be seen to consist of three distinct flows of lava. In other parts of the canyon there are a number of remnants of the lava, the river having practically cleared its old channel but having left these portions of the former filling hanging on the canyon wall. In such blocks of andesite the columnar parting can be observed to be at right angles to the basalt surface against which the molten lava attached itself.

Relation to Mount Rainier volcanism.—The Tieton andesite is closely related in petrographic characters and in age to the lavas of Mount Rainier. Its occurrence along the western edge of the Ellensburg quadrangle indicates the origin of the flows to have been somewhere in the high mountains of the adjoining Mount Aix quadrangle, and suggests that the volcanic center from which the hypersthene-andesite was erupted, although on the eastern slope of the Cascades, was not far distant from Mount Rainier, and, further, that this volcanic activity is also connected in point of time with that which built up the great cone of Rainier.

SURFICIAL ROCKS.

COWICHE GRAVELS.

These deposits are of only local importance, and occur in the valley of Cowiche Creek in a broad terrace which slopes to the southeast. Their deposition was caused by the damming of the Cowiche creeks by the stream of Tieton andesite lava, conditions that were both local and temporary. The presence of granite, quartzite, and grit pebbles in these gravels, as well as the occurrence of a few large bowlders of the same rocks on the brink of Tieton Canyon, serves to show that the Tieton waters overflowed into this basin for a time and contributed somewhat to the Cowiche gravels.

The surface of the terrace is covered with finer sediment, which furnishes a soil that is fertile and that would be well adapted to agriculture if water were available for irrigation.

VALLEY ALLUVIUM.

Diversity of age.—The alluvial deposits of the valleys doubtless vary much in age. In Cowiche Valley the alluvium borders the streams which have trenched the terrace of Cowiche gravels, so that here the valley alluvium is plainly the younger. Elsewhere the alluvium of the valleys may be as old as, if not older than, the Cowiche gravels, while along Naches River it consists of gravel bars which mark the extent of the last flood stage of the river. As mapped, this formation includes the deposits made by the streams upon their present flood plains or those abandoned within recent times.

Surface wash.—Surficial material more or less closely allied to alluvium covers large areas other than the valleys. The surface of much of the plateau country is strewn with basalt fragments, the result of disintegration of the underlying rock, but even upon the steeper slopes such detritus has suffered relatively little transportation. In other localities a layer of much finer material covers the surface. These surficial deposits extend down the slopes and unite with the valley deposits below, so that to some extent the mapping of the latter must be arbitrary, but in other cases the line is sharp between the rock waste of the slope and the alluvium of the bottom land.

Wind-blown volcanic sand.—Another type of surface material consists of thin layers of volcanic sand found at many localities in this and other parts of the Cascade Range. The deposits occur usually upon the flat tops of the highest peaks or in hollows upon the slopes, where there is protection from erosion by running water. The sand is composed largely of feldspar and pyroxene crystals, and is thus of a character that would suggest its derivation from some volcano of the Rainier type, the finer material having been carried by the wind to its present position.

Character of alluvium.—The valley alluvium is prevailingly fine grained, and of a character that renders it of great value for agricultural purposes. In the lower valleys there is considerable fine silt, the deposits of which become thicker farther south in the valley of Yakima River. The coarser alluvium, sand and gravel, is confined in its distribution to the vicinity of the larger streams, but nowhere are these areas of coarse material extensive. Such gravel flats can be seen near the junction of Naches and Yakima rivers, where they form low terraces, but even here the gravel contains sufficient fine soil to enable fruit trees to grow.

STRUCTURAL AND PHYSIOGRAPHIC FEATURES.

In the region bordering the lower valley of Yakima River the relation between the structure of the rock masses and the present configuration of the surface is very intimate. On this account the structural geology and physiography will be discussed together in the following descriptions of the principal features of the relief, which will be found to be directly related to structure. Five anticlinal ridges cross the quadrangle with a general east-west trend, and these are described below in turn, beginning with the northernmost.

MOUNTAIN RIDGES.

Manastash Ridge.—Manastash Ridge, with its eastward continuation, Beavertail Hill, forms the southern wall of Kittitas Valley. It has an elevation of from 1000 to 2000 feet above the valley floor, and to the west merges into the more elevated plateau north of Bald Mountain. Farther east Beavertail Hill appears to unite with other ridges to form the height known as Saddle Mountain, which is cut through by Columbia River at Sentinel Bluffs. The northern slope of Manastash appears abrupt as viewed from the vicinity of Ellensburg, but nowhere does it deserve to be termed a scarp except where Manastash Creek or a meander of Yakima River has modified the original slope. The southern slope is gentle, and hardly noticeable until the brink of the canyon of Umptanum Creek is reached.

The geologic structure of Manastash Ridge is anticlinal. Along the higher portions, wherever the dip of the basalt sheets can be determined, it is with the slope of the ridge and generally approximately equivalent to that slope, and this relation holds on the lower southern slope as well. On the northern slope the structure is less simple. Near the forks of Manastash Creek, and thence westward, the canyon walls show that the basalt plateau has been trenched by the stream, and that the ridge to the south is largely an erosion form. East of this point a syncline in the rocks can be detected, with its axis immediately south of the creek, as shown by the exposures of Ellensburg sandstone overlying the basalt. East of the mouth of the canyon this syncline gives place to two synclines with a low anticline between, all of these folds being parallel with the larger anticline of the main ridge. From this point southeastward to the gap made in the ridge by the Yakima the exposures are so poor as to render the relations obscure. East of the river the structure again consists of an anticline and syncline, with a fault along the southern limb of the latter fold. West of the gap this fault traverses the center of the syncline, while the anticline to the north is also only partially shown, because of erosion by the river. The fault may continue across Shushuskin Canyon, but the only evidence on this point is the observation of a southern dip in the next area of sandstone.

Along this northern slope the geologic structure has little or no connection with the surface configuration. There is no displacement along Manastash Creek, and the fault near the eastern edge of the quadrangle produces no scarp, and, indeed, farther east falls south of the face of the ridge, showing that it has had no part in the elevation of the ridge. Along the crest and the southern slopes of Manastash Ridge there is a nearer approach to a direct relation between structure and topography. Three small remnants of sandstone show that the present surface is near the upper surface of the basalt, and exposures of the basalt as seen in the shallow gulches indicate a general parallelism between the flows of the basalt and the sloping surface. This surface is partially covered with very fine soil, which occurs in mounds from 3 to 5 feet high and generally of irregular outline, although the smallest ones are often perfectly circular in plan. In diameter these range from 10 feet to 100 yards or more, and one mound includes an area of at least several acres and is cultivated. The soil is light colored and contains no pebbles, so that the contact between this and the underlying basalt is sharp. Between these mounds the surface is paved with angular blocks of basalt, the scanty soil being quite red in color. Wind appears to have been the effective agency in the formation of these mounds, which represent residual portions of the layer of silt-like soil that once covered the whole surface.

Umptanum Ridge.—The next ridge to the south, Umptanum Ridge, is several hundred feet higher than Manastash Ridge, and maintaining its crest at a nearly uniform elevation, is cut through by Yakima River just east of the edge of the quadrangle in a gap whose brink is nearly 1000 feet higher than that of the corresponding gap in Manastash Ridge. Again, the ridge is unsymmetrical, the northern slope being the steeper. At its western end it apparently divides, one part extending westward and the other northwestward and connecting with Manastash Ridge. The structure of the ridge is plainly anticlinal, as is shown in the very perfect arch at Umptanum Gap, where over 2000 feet of Yakima basalt is exposed. At some points the crest of the arch and the crest of the ridge coincide, but at others the upper portion of the fold is wanting, the flat-topped crest being cut across the upturned sheets of basalt. In the western continuation of Umptanum Ridge the anticlinal structure is well shown where the North Fork of Wenas Creek has cut through the arched basalt, and also in the smaller canyon 2 miles east of that point. The anticline forming the main part of the ridge has a low pitch to the west, so that the upper flows of the basalt are found near the western end. Along the northern face of the ridge there is a prominent outcrop of black basalt, making a scar that suggests a fault. This line is parallel to the strike, and any displacement must have been on the plane between two sheets of basalt. At another point, however, an even more prominent feature of this sort was seen in section and there was no displacement, while at Umptanum Gap it is evident that if any faulting of the nature suggested is present on the steep north limb of the anticline it is of minor importance, and in no respect is Umptanum Ridge of the nature of a faulted monoclinal fold.

On the south side of the ridge the upper slopes are gentle and, as nearly as can be determined, have the same inclination as the basalt sheets. Nearing Wenas Valley, however, there is a sharp change in the slope and an even greater change in the dip of the rocks, so that the upper sheets of Yakima basalt, as well as the overlying beds of sandstone and sheet of Wenas basalt, are successively crossed. At the western end of the ridge these dips reach 45°, but east of Kelly Hollow they are only 20°, or even less.

Cleman Mountain.—While Cleman Mountain is the highest of the ridges in the quadrangle, it is also the shortest if taken by itself. As will be shown later, however, the Cleman Mountain anticline extends eastward, forming the ridge south of Roza Creek, which some distance east of Yakima River unites with Umptanum Ridge and reaches the Columbia in the vicinity of White Bluffs. On the west the connection with the higher region is in part interrupted by the upper valley of Naches River. Cleman Mountain attains an elevation of 5000 feet, and for several miles its crest line is remarkably even, the basalt sheets appearing to be practically horizontal. On the side facing Wenas Creek the mountain has a remarkably uniform and gentle slope, and when one looks along this featureless inclined surface extending from the ridge crest to the valley floor below he can see nothing to indicate the presence of the many narrow gulches that traverse it. On the opposite side of Cleman Mountain the slopes are steeper. Along the eastern end this is due to steeper dips in the rock, which become gentler to the west. In the central portion of the southern slope a steep escarpment over 1000 feet high faces Naches River. This is the site of a huge landslide, a block nearly 6 miles long having broken away and pushed into the valley below. The hummocky topography below the escarpment, the low hills and inclosed basins, showing no definite arrangement, are characteristic forms resulting from such a landslide, and the river shows evidences of changes due to obstructions in its course. This portion of the mountain had a structure especially favoring such a landslide, the basalt having a sharp change in dip, and tuffaceous beds being present which would facilitate undermining of the block by the active river. At the eastern end of Cleman Mountain the dips of the rocks indicate that the arch pitches down, so that the basalt passes beneath the sandstone of Wenas Valley. The interbedded sheet of Wenas basalt is present in this part of the area, thus making the structural relations more evident. Southeast of Kelly Hollow the surface slope shows no indication of the underground structure, but just north of the low hill having an elevation of 2319 feet the Wenas basalt appears from beneath the Ellensburg sandstone, and the arch is seen to extend eastward, becoming more prominent in the high ridge at the eastern edge of the quadrangle. On the crest of this ridge the arched basalt has been cut through, exposing the interbedded sandstone beneath. About 2 miles to the southeast Yakima River cuts across this ridge, and in the deep gap the anticlinal structure is well shown.

Cowiche Mountain.—Between Naches River and the South Fork of Cowiche Creek there are at least two anticlinal folds traceable in the basalt. These, however, are less important than the structural features that have been described above, and do not extend across the quadrangle. They have a general parallelism with the other folds, and are succeeded on the south by the fourth important ridge, Cowiche Mountain. Near the southwest corner of the quadrangle this ridge, both as a topographic and as a structural feature, unites with the basalt plateau, the southwestern portion of the ridge becoming monoclinal. The southeastern dips extend along the southern side of the ridge from the high region between the two forks of Atanum Creek to the eastern end of Cowiche Mountain, where the dips are to the south. The ridge continues to the east as Selah Ridge, interrupted, however, by the deep gaps of Naches and Yakima rivers. At the latter the structure of the ridge is exhibited, and the anticline is seen to be flat topped, with steep sides, so that its cross section is comparable to an inverted **U**. The southern portion of this fold, however, is absent here, having been cut away by Naches River west of Selah Gap and by Yakima River for over a mile east. That this steep escarpment bordering the ridge is not due to a fault is demonstrated by the presence of a remnant of the fold south of Naches River, where sandstone is found with a steep dip to the south, and even slightly overturned, while beyond Yakima River the fold is perfect. In a similar way, the river has cut away the northern side of the ridge for nearly 2 miles east of Selah Gap. At Selah Gap the anticline shows a slight sag or cross fold, the anticline pitching differently on the two sides of the river.

A special feature of Cowiche Mountain is the spur making off to the north, forming Cowiche Basin in the angle between the spur and the main ridge. This structure and the consequent preservation of the sandstone lying on the basalt surface are due to folding, there being no possibility of the presence of a fault. Two local domes southeast of Cowiche Mountain have caused the basalt to appear from beneath the Ellensburg sandstone.

Atanum Ridge.—The most southern of the ridges here considered is Atanum Ridge, which also begins in the high plateau to the west and extends almost due east about 70 miles to the vicinity of the Columbia, the eastern half of the uplift being known as Rattlesnake Mountain. The crest of the ridge is narrow, and presents a regular sky line, with slight eastward slope. Structurally Atanum Ridge closely resembles the ridges to the north, and the broad arch in the basalt is well exposed at Union Gap, a mile east of the edge of the quadrangle, where the Yakima has made a steep-sided cut, a mile in length and 800 feet in depth, across the ridge. Five miles farther east the arch pitches down, so that the basalt disappears beneath the sandstone in a low pass not over 100 feet above Moxee Valley to the north. The ridge becomes more important again east of this point, and in this feature a similarity may be noted with the Cleman Mountain ridge, described above. On the northern side of this anticline, near the eastern edge of the quadrangle, the dips are steep and the strata are even overturned for short distances.

VALLEYS.

The valleys of the Ellensburg quadrangle are not less interesting features than the ridges, and in large part they are closely related in origin. Two types of valleys may be distinguished in this area: the broad valleys, which extend generally east and west and are transverse to the course of Yakima River, which crosses them in their medial portions, and the narrow canyons, much less prominent, but occupied by the larger streams and rivers. The former type is characterized by a noticeable correspondence between topography and structure, so that these valleys deserve to be termed structural, while those of the latter type are largely erosional in origin.

Structural valleys.—The characteristic of the structural valleys is their independence of the important streams of the area. To no considerable extent are they the result of stream erosion, and when occupied by streams it is because the valleys afford natural drainage lines, not because the streams represent the agency producing the valleys. Kittitas Valley is an example of this type, but since only a portion of it is included in the northeast corner of this quadrangle, it will be described but briefly. It is a basin of somewhat irregular outline, with longest diameter over 30 miles, from northwest to southeast. Yakima River drains the valley, but is close to its western margin, while much of the eastern part is occupied only by small seasonal streams. The rocks on all sides of Kittitas Valley dip inward, while in the bottom of the basin they are nearly horizontal.

Umptanum Valley is a rather shallow depression between the two ridges, with its floor high above Yakima River. East of the river the valley of Squaw Creek marks the continuation of this structural valley, which extends almost to the Columbia.

South of Umptanum Ridge the short valley occupied by Roza Creek has a synclinal structure and is continued east of the Yakima as Burbank Canyon. The valley of Wenas Creek between Umptanum Ridge and Cleman Mountain is also plainly synclinal. The rock fold underlying the valley is unsymmetrical, the steeper dips being on the northern side, and opposite the eastern end of Cleman Mountain the structure is complicated by the occurrence of a minor anticline along the center of the syncline. The surface distribution of the sheet of Wenas basalt in this part of Wenas Valley shows the presence of the fold and its relation to the larger syncline. The lower valley of the Wenas finds its eastern continuation in Selah Valley, a broad topographic feature that extends eastward as far as Columbia River.

The valley of Atanum Creek and Wide Hollow is the next valley that is predominantly structural in character. Moxee is the corresponding valley east of Yakima River, and the same structural line is continued across the divide into Rattlesnake Valley, which slopes eastward toward the Columbia. In this extensive system of east-west valleys the topography is directly related to the folds, and the rocks dip down from the bounding ridges at angles somewhat steeper than the surface slopes, with the result that the Ellensburg formation floors the valley, although it is absent from the ridge tops. In the lower part of Wide Hollow the thickness of sandstone remaining in the valley is over 1200 feet.

Erosional valleys.—Certain of the stream valleys have characters that show them to have had a less simple origin than that given above. Manastash Creek, for instance, enters Kittitas Valley from a straight canyon, above which Manastash Ridge rises abruptly. Examination of the basalt section exposed in the canyon walls shows that the canyon does not follow any line of displacement, but is near a synclinal axis. Stream terrace deposits occurring nearly 500 feet above the present stream level indicate an earlier and broader valley of synclinal character, in which Manastash Creek has trenched the present canyon. In a somewhat similar manner, Umptanum Creek in its lower course has excavated a canyon over 500 feet below the floor of the broader Umptanum Valley, the canyon being near but not coincident with the synclinal axis. Kittitas Valley, also, while a structural basin, does not preserve its original surface, but has been modified by stream erosion, which has lowered the floor of the valley and in some parts covered it with a thick mantle of stream deposits. The mesa on the east side of Ellensburg doubtless represents a remnant of the old floor of this structural basin.

In the Wenas drainage there are erosional features in the valley that is itself broadly structural. The North Fork in its upper course traverses a syncline, but before joining the South Fork it cuts through an arch of basalt in a short canyon, which is in marked contrast with the broader valleys both below and above. About 5 miles below, the main creek flows in a narrow valley cut in the basalt of the small anticline mentioned above. The presence of a well-marked parallel valley next to the slope of Umptanum Ridge in this portion of Wenas Valley, as well as a less perfect one on the Cleman Mountain side, both of these side valleys being unoccupied by streams, renders the central canyon more noticeable, yet serves to assist in its explanation. The Wenas drainage occupied a synclinal valley, which, however, suffered later structural modifications. An arch rose across the North Fork, but so slowly that that stream maintained its right of way and cut the 500-foot canyon in the basalt. Below, along the axis of the wide synclinal valley, another anticline was upraised, and again the movement was so slow that the course of Wenas Creek was not shifted. The upward movement continued, but the stream kept on cutting, until now the creek flows in its narrow canyon-like valley, several hundred feet below the level of the upraised portion of the old valley floor, which is preserved in a number of mesas on either side of the creek, well shown on the topographic map. The back valleys represent parts of the synclinal valley unaffected by this central uplift. The small streams from the ridges cross these back valleys and reach the main creek by short, steep-sided cuts between the mesas. In one case a seasonal stream of this type at times divides upon the alluvial fan it has thrown out into the back valley and reaches Wenas Creek by way of two of these cuts.

The course of Naches River south of Cleman Mountain is approximately parallel with a synclinal axis. Above Nile, however, the river is north of the center of the syncline, while within a few miles of North Yakima, as has been noted, it cuts directly across the anticline of Cowiche Mountain and Selah Ridge. The Naches and its principal tributary, the Tieton, have canyons that are the result of very effective stream erosion, and structure has played a subordinate part in the location of these drainage lines. The latter river has reexcavated its canyon to a depth of about 2000 feet since the Pleistocene eruption of andesite. Atanum Creek with its South Fork has mainly a structural valley, but the North Fork crosses the southwestward continuation of Cowiche Mountain, and its canyon-like valley is plainly erosional in origin.

The master stream of this region, Yakima River, is a good example of a stream whose course antedates the structure. While this river touches this quadrangle at only two places, it is close to the eastern boundary, and along it the structure of the ridges is the same as that already described in this text. Yakima Canyon between the cities of North Yakima and Ellensburg is one of the impressive canyons of the country. Traversed by the main line of the Northern Pacific Railway, it affords an excellent opportunity to observe the picturesque structure of the basalt, the rows of prismatic columns being often so regular as to suggest the work of human hands. The winding canyon, moreover, reveals no less clearly the broader structures. The arches in the basalt—Manastash, Umptanum, Selah, and Atanum ridges—are cut directly across, and the evidence of the river's independence of the geologic structure is conclusive. This purely antecedent character of the river is also shown by the fact that the gaps are cut, not across lower portions of the ridges, except possibly at Selah Gap, but in several instances where the ridge is higher at the brink of the gap than elsewhere. The most striking case is at Union Gap, south of North Yakima, where the river has cut to a depth of 800 feet, and yet a few miles to the east there is a low gap of structural origin. Had there been ponding of the Yakima water by reason of the uplift of the Atanum Ridge, the lower gap would have been the natural point of overflow. Thus Yakima River has maintained its course during the uplift of the region, and traverses both the ridges and the valleys, its own valley or canyon being of purely erosional origin.

RELATION OF PENEPLAIN DEFORMATION TO ROCK STRUCTURE.

In the foregoing discussion of the ridges and valleys of the Ellensburg quadrangle it has been shown that, while these features are mainly structural in origin, yet the surface slopes do not exactly correspond with the rock dips. The crests of the ridges as well as the floors of the valleys are eroded surfaces, so that nowhere probably is the total original thickness of the rocks preserved. The lack of conformity between surface and structure shows that the origin of these anticlinal ridges and synclinal valleys has not been a simple one. The process has consisted of two orogenic uplifts separated by a period of erosion. As stated under the heading "History of the Ellensburg quadrangle," the earlier flexing of the rocks was followed by reduction of the region to a lowland surface, the perfection of the peneplain being shown in localities where basalt and sandstone have been equally reduced. The warping which followed the period of erosion uplifted the peneplain somewhat and converted it into a succession of parallel ridges and valleys. Subsequent erosion has modified this structural surface so little that throughout the greater part of the area the warped peneplain can be easily seen in the many remnants of its actual surface.

Amount of earlier folding of the rocks.—The discordance noted between surface slope and rock structure is a measure of the earlier flexing of the rock. Where the surface slope is parallel with the rock dip the conformity of surface and structure indicates that during the period of planation the rocks at this point were horizontal, so that the erosion surface coincided with a structural surface. Such a relation undoubtedly holds in portions of the basalt plateaus in the western part of the quadrangle, showing the absence of earlier flexing. Upon the tops of the ridges and along the centers of the valleys there are also places where this conformable relation holds, indicating lines of parallelism between the folding and the subsequent warping. In these cases of the crests of the arches and the bottoms of the troughs there has been vertical movement, locally unaccompanied by tilting. On the sides of these ridges, as well as on their crests where the arch in the rock has been an unsymmetrical anticline rather than an open symmetrical fold, the erosion surface cuts directly across structural planes in the rock masses. Here the difference between the present slope of the eroded surface and the dip of the rock is a measure of the amount to which the basalt and sandstone were flexed. The water gaps cut by Yakima River in the several ridges afford opportunity for observing these features.

Coincidence of axes.—This simple relation between surface and structure as given above depends upon the coincidence of axes of deformation in the two periods. The extent to which this rule holds within the Ellensburg quadrangle is remarkable, since it is true that the warping of the peneplain took place almost wholly along the lines of the earlier flexing of the rocks. The forces involved in the two processes appear to have been the same, and thus the period of uplift might be considered one, with an interruption of sufficient length for the reduction of the flexed rocks to a peneplain. The major features of the area, Manastash, Umptanum, and Atanum ridges and Cleman and Cowiche mountains, were outlined in the anticlines of the earlier episode of uplift, and after the complete destruction of these structural features by the subsequent erosion they were again slowly uplifted to the elevations they now have. There are, however, some exceptions to the general rule here stated. These have been indicated in some degree in the foregoing descriptions. Thus, on the northern slope of Manastash Ridge the small synclines, one of which is faulted longitudinally, are represented by the rock distribution, but do not materially affect the surface configuration. The later uplift was approximately along the axis of the larger anticline, and was simple and broad, while the earlier uplift involved minor folds and a fault. The Cleman Mountain anticline was described as continuing across Wenas Creek. As can be seen on the topographic map, the surface shows no later warping along this axis until the western end of Selah Ridge is reached, about 5 miles east of Cleman Mountain. Between the two the slope of Umptanum Ridge continues nearly to the level of Wenas Valley. The discordance between the rock structure and the inclined peneplain surface is very well shown here, and the manner in which the erosion surface cuts across basalt and sandstone alike makes this an important locality for the determination of the true peneplain character of the surface.

HISTORY OF YAKIMA RIVER AND ITS TRIBUTARIES.

The relative age of certain of the features due to this later surface warping can be determined by study of the drainage, as in the case of Wenas Creek, which has been discussed in an earlier paragraph. The influence of structure upon the drainage system may also be mentioned. The course of Yakima River was established before the later warping of the surface, since it cuts directly through the ridges that rose across its course, with meanders developed upon its old lowland. With its tributaries this river was efficient in the production of the peneplain, and indeed it appears probable that the north-south course of Yakima River antedates the earlier flexing of the rocks, so that the river is antecedent with respect to all of the structural features described above. The tributaries of this master stream are to a large extent consequent upon the later warping. In the case of Manastash and Umptanum creeks, this statement can be made without qualification, since these streams occupy natural drainage lines in the warped surface. They do not, however, exactly follow the axes of the synclines of the earlier folding, for there is a slight discordance in the position of the axes of the two deformations. Atanum Creek, with its south fork, is a consequent stream, but its north fork and Nasty Creek may have once belonged to the Cowiche drainage, being later diverted southeastward by the development of the monocline of this portion of Cowiche Mountain. The history of the North Fork of Wenas Creek may have been somewhat similar, this stream being originally a part of Umptanum Creek, the capture of Wenas Creek occurring at the beginning of the uplift of the peneplain to form Umptanum Ridge. This diversion was rendered possible by the development of the northwest spur of Umptanum Ridge, connecting with Manastash Ridge, and the southward course of the North Fork, as well as of the seasonal stream about 2 miles east, was established before the uplift of the west spur of Umptanum Ridge.

The course of Naches River is plainly antecedent to the present configuration of the surface, since it cuts diagonally across the Cowiche Mountain–Selah Ridge uplift, and in its upper course the river canyon is in part north of the axis of the synclinal depression south of Cleman Mountain. There is reason to believe, however, that the course of this river was largely determined by the earlier structure, and it was then a consequent stream, occupying the center of the syncline. In the development of the peneplain its course may have changed, so that at the time of the subsequent warping of the surface along the same axes the river had left the syncline and was forced to cut through the ridge rising across its course. If this be true its junction with the Yakima is now about 3 miles south of its former position. On the uplifted plateau between Wenas Creek and Naches River, where the former course of the Naches River would have crossed, there are remnants of the peneplain, but no river gravels could be identified on this old surface, since the Ellensburg formation here is largely conglomeratic, and the pebbles on the surface may be derived from that source.

ECONOMIC GEOLOGY.

Absence of metalliferous ores and coal.—Within the Ellensburg quadrangle no deposits of metalliferous ores or of coal have been found, and there are no indications warranting the search for such products. There is a a small amount of iron oxide along the fault in the basalt, south of Thorp, but the occurrence is not of economic importance.

Building stone and road metal.—The basalt and andesite found in the vicinity of North Yakima furnish easily quarried building stone. The basalt has been used for one church in that city, but is too dark colored to be effective for such use. For foundations these compact igneous rocks are of value. They also furnish an abundant supply of material for road building. The basalt makes the very best quality of road metal, and where it can be found broken into small blocks little crushing is required to render it available for use upon the valley roads. Broken basalt is superior to gravel for this purpose, since the angular fragments will pack together, making a hard and enduring road surface.

The Ellensburg sandstone is usually too soft and friable for use as a building stone. At a few localities, however, it has been found sufficiently compact to be successfully quarried. One of these quarries is in the Naches Valley about 2 miles from North Yakima; another locality is in Kelly Hollow, where sandstone has been cut and used for fireplaces and chimneys; a third is just outside the quadrangle, about 2 miles east of Thrall, where stone was quarried for a large business block in Ellensburg.

Soils.—The agricultural land of the Ellensburg quadrangle is largely confined to the areas of alluvium shown on the Areal Geology map. Except in narrow strips along the stream courses, it is fine and makes a fertile soil. Soil analyses show an abundance of the constituents essential to plant life. The fine texture of the soil is a characteristic doubtless even more important than its chemical composition, for it not only facilitates cultivation, but renders soluble and available a greater percentage of the mineral matter. The aridity of the climate has also doubtless had a beneficial effect, in that the soil has not lost its most valuable constituents by leaching. In this connection it is necessary to mention the excessive irrigation which has already injured certain portions of the lower valleys in this region. Not only does the constant presence of water result in leaching out some of the more soluble of the valuable soil elements, but in the lower levels the action of this water is to bring to the surface certain salts that are injurious to vegetation. Such waste of water in irrigation is thus a double evil.

The thin mantle of soil on the ridges of basalt and sandstone is fertile and supports luxuriant bunchgrass, where excessive grazing has not destroyed the natural vegetation. In some localities the covering of soil is deep enough to be cultivated and winter wheat has been raised successfully. On the lower slopes alluvial soil is found, which merges with that of the bottoms, and is equally fertile. The alluvium of the Cowiche terraces is not well situated for irrigation, but dry farming is practiced here.

Ground water.—In an arid region the underground supply of water becomes of great economic importance. Upon the presence of artesian water depends largely the value of some large tracts of agricultural land, and even small springs may constitute a valuable resource of a valley insufficiently supplied with surface waters.

The supply of potable water is good generally throughout the Ellensburg 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 water. 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. This is plainly the case on the North Fork of Cowiche Creek, which is a seasonal stream, with only the underflow persisting throughout the summer. Here shallow wells dug in the stream bed reach the underflow and thus insure a better water supply during the dry season.

Where the water-saturated beds reach the surface the ground water makes its appearance as springs. Some of these springs occur high on the ridges at the heads of gulches and derive their supply from surface waters which have collected in the surficial detritus and the somewhat broken upper portions of the basalt. Along some of the smaller synclinal valleys the ground water in the Ellensburg sandstone reaches the surface in the vicinity of the creek, and often these springs are unnoticed on this account. Large springs of this character occur on Wenas Creek on the Cleman ranch, where the lowest beds of sandstone are cut across by the creek. Nine miles farther up this valley there are other springs with the same geologic relations, the base of the sandstone being exposed in the center of the valley. In this vicinity this supply of ground water is utilized at a somewhat higher level, a horizontal well having been driven into the hill slope, and the water permeating the sandstone thus collected and piped down to the ranch house.

Artesian water.—This class of underground water differs from the ground water in that it is under pressure. The essential conditions of artesian water involve both the underground structure and the surface configuration — the occurrence of permeable or porous rock beds or strata between other beds relatively impervious, the disposition of these strata in basin-like form, and the relatively high outcrop of the edges of the permeable strata. The presence of a porous stratum between impervious strata is necessary because it constitutes the storage reservoir for the underground water. The water-carrying bed may be sand or sandstone, the interstices of which often afford ready passage for the circulating waters. When confined by underlying and overlying impervious rocks, such as clay, shale, or some dense and compact igneous rock, the porous stratum becomes saturated with water, which can find outlet only through the porous bed itself. The basin structure is a controlling factor, in that the water-carrying strata must in no place reach the surface at a lower level than the elevation of the well. A lower outlet would prevent the storage of water under pressure, with the result that the water would fail to rise in the well. The outcrop of the porous beds at the surface constitutes the area of supply or inbibition. Here surface and ground waters pass downward and enter the artesian basin or area of accumulation.

If all the conditions specified obtain in a region, an artesian water supply is assured, and the water which is stored in the artesian basin can be tapped by a well driven through the confining cover, thus affording an outlet for the water that saturates the porous beds. The height to which the artesian water will rise in the well is dependent upon the head or pressure, which in turn is directly controlled by the elevation of the upper end of the water body, or the point where the water-saturated beds reach the surface. If the mouth of the well is relatively lower than the point where the beds receive their supply, the pressure will be sufficient to force the artesian water to the surface, and the well will be a flowing well.

Within the Ellensburg quadrangle but one artesian basin is known, and as yet but little advantage has been taken of this supply. The structure of Atanum Valley and Wide Hollow has already been mentioned. With Moxee Valley, east of the Yakima River, this constitutes a reservoir for artesian water. The underground structure of this basin is more accentuated than the form of the valley, and the basalt, which is more than 1200 feet beneath the valley floor 2 miles east of Atanum, appears at the surface 6 miles west of that village, and west of Tampico the upward slope of the basalt is even greater. The water horizon of the Ellensburg formation is near this contact with the basalt. Along the northern and southern sides of the valley the rocks are also upturned, and on the north side of Wide Hollow near Naches River and on the south side of the valley on both sides of Union Gap the lower beds of sandstone are very sharply upturned, and at a few points are vertical or even overturned. This structure, with the consequent compression of the sandstone, is important, since it probably explains an anomalous feature of this basin. Yakima River has cut across the rims of the basin at points approximating 1000 feet above sea level, and it would presumably follow that the artesian basin should be drained at about this level, above which no flowing wells could be possible in the vicinity. It is probable that the compression has so compacted the sandstone, which is elsewhere open textured and porous, that on the steep sides of the fold it has become relatively impervious. As noted in a preceding paragraph, this sandstone on the north side of the basin is compact enough to be quarried, while in the flat bottom of the basin it is an extremely soft sandstone, or in places even a quicksand.

In Moxee Valley there are over a score of flowing wells, having an aggregate discharge of about 12 second-feet. The only successful well in the Ellensburg quadrangle is in Wide Hollow, near the southwest corner of the SE. ¼ sec. 29, T. 13 N., R. 18 E., on the ranch of George Wilson. It was completed in August, 1899, and cost $2500. The well is very successful, is of fairly good size, and is well cased, the diameter of the casing being from 5⅞ inches to 3½ inches. When completed it had a pressure sufficient to force a strong stream through the drill rods to a height of 42 feet above the surface, equivalent to 1207 feet above sea level. The drilling was extended until basalt was struck, about 200 feet below the lowest flow and about 100 feet below sea level. The well has shown no variation in flow, and its discharge is estimated to be three-fourths of a second-foot and is sufficient for the irrigation of 50 acres. The water is used with that from a ditch to irrigate 80 acres, but as the flow in the ditch is very small after July 1, the artesian water does most of the work. This pioneer well has demonstrated the presence of artesian water in three flows at a depth of about 1000 feet below the surface.

The water of the Wilson well is warm, like that of the Moxee wells. Its temperature of 80° F. is high for water coming from an average depth of about 1000 feet, but does not indicate that the source of the water is in fissures extending through the thick basalt flows to underlying water-bearing beds, in which case the depth would be such that the water would be hot rather than warm. This artesian supply of water more probably has its source in the surface waters entering the underground circulation at the outcrop of the water-carrying beds. These lower strata of the Ellensburg formation outcrop on the flanks of Cowiche Mountain and Atanum Ridge, where there is greater precipitation than in the valley to the east, as is shown by the groves of large pines. The occurrence of surface springs also shows the presence of a good supply of ground water, so that the contribution to the artesian basin is an important one.

An even more important contribution, however, comes from the leakage from streams crossing the outcrop of the water-carrying beds. Several seasonal streams flow down the sides of the western part of the Atanum–Moxee valley, but these are small, and their contribution may well be included under that mentioned above. Atanum Creek, however, drains a large area to the west, and in the early part of the year it is an important stream. It enters the synclinal basin at a point where the strata have gentle dips and where the sandstone at the base of the Ellensburg is open and porous. At the points where the stream crosses these upturned beds the water might seep downward into the artesian basin. Similar seepage is shown where ditches have been dug in both the surficial alluvium and in the Ellensburg sandstone. The green vegetation along the lower sides of such ditches testifies to the presence of water which has escaped through the soil and the sandstone. The fact of the seepage from Atanum Creek, however, is conclusively proved by other evidence. Stream measurements which have been made have an important bearing on this question when studied in connection with the geologic relations along Atanum Creek. As will be seen by reference to the geologic map, the two forks of Atanum Creek enter the sandstone area above Tampico, but the stream again encounters the basalt below that place. The first measurement of the north fork of the creek was made above the point where the stream crosses the base of the sandstone, and this volume is seen to exceed, by 10 second-feet, the total volume of both forks measured below their junction and within the sandstone area. The loss by seepage is partly returned when the stream again flows upon the basalt basement, as is shown by another measurement. This gain doubtless represents the return of a part of the underflow of the stream to the surface. Additional measurements farther down show further loss after the sandstone again becomes the floor of the valley, showing seepage into the sandstone. This contribution of several second-feet of water is an important one, and since these measurements were taken late in July they represent a minimum of flow and probably also of seepage. At time of flood the amount flowing into the artesian basin from this source would be even greater. Taking into account the aggregate discharge of the wells of the basin, which is about 12 second-feet, the part played by seepage can at once be seen.

The practical question of the permanence of this supply of artesian water is answered in part by the preceding paragraph. The artesian basin is not to be considered as containing an unlimited supply, any more than if it were a surface reservoir for the storage of water. The total discharge of the basin probably can not be much increased by putting down new wells, although this may result in an economical division of the artesian supply. New wells in Wide Hollow, where water is needed, may be expected to be successful if located below the 1200-foot contour. If too great demands are made upon the underground supply the pressure will be lowered until some of the higher wells will cease to flow. Recent legislation has made it necessary to practically close the wells between October 1 and April 1, and this arrangement ought to result in a very satisfactory conservation of this important supply of water, which, with the fertile soil, is the most valuable natural resource of the region.

In Wenas Valley geologic conditions do not appear to warrant the expectation of an artesian supply. The basin structure is present to a large extent, and the sandstone beds extend upward on the ridge to the north, but the lowest portion of this basin is drained by Wenas Creek. As already noted under the heading "Ground water," large springs occur near where the creek crosses the lowest beds of sandstone. The evidence is to the effect that the water in the sandstone finds a natural outlet throughout the length of this valley and is not stored in an artesian basin.

The other important valley of this area is Kittitas Valley, a portion of which comes into the northeast corner of the Ellensburg quadrangle. 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 precipitation over a large area. In the central part of the valley the water horizon lies at a depth of several hundred feet. Some years ago an experimental well was put down about 2 miles northwest of Ellensburg and reached basalt at about 700 feet. When abandoned it had water at 40 feet below the surface. The evidence which it afforded was unfavorable, yet it is quite possible that this well, like many others, was drilled inefficiently and that the record is untrustworthy.

At 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.

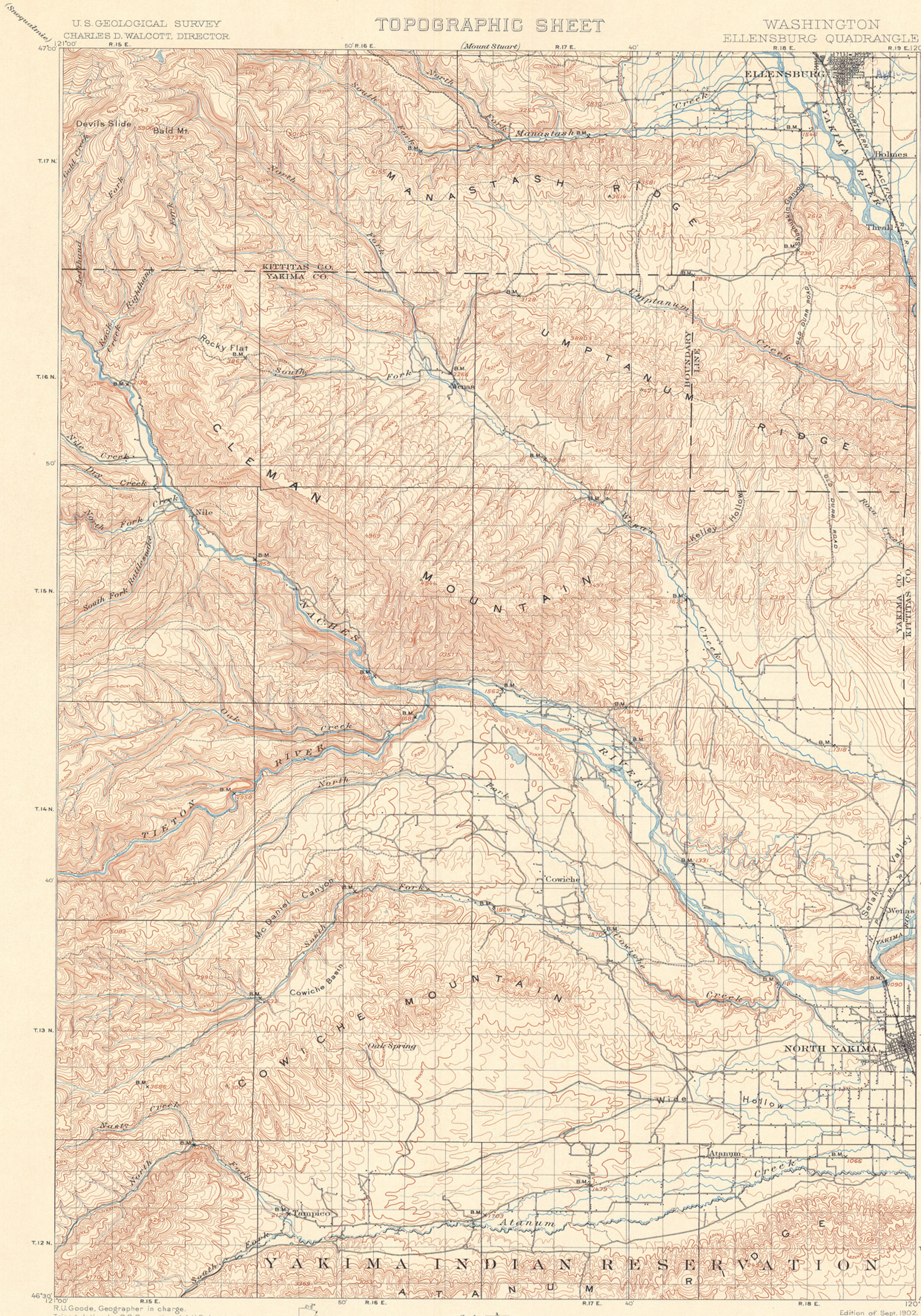
The gap where Yakima River cuts through the rim of the Kittitas Basin, 5 miles below Ellensburg, is, of course, the critical point in the structure of the basin. The exposures of the Ellensburg sandstone are poor at this locality, but they are sufficient to show that the lower beds are sharply upturned. 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, as appears to be the case at Union Gap, south of the Atanum–Moxee 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, which should be put in charge of the most experienced and reliable well-man available. Larger irrigation canals taking water from upper Yakima River may possibly be built in the future, which would obviate the necessity for artesian water in this valley, in which event it would not be economical to expend any money in searching for an artesian supply.

May, 1902.

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

TOPOGRAPHIC SHEET

WASHINGTON
ELLENSBURG QUADRANGLE



R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett and A.H. Sylvester.
Topography by A.E. Murlin.
Surveyed in 1899.

TRUE NORTH
MAGNETIC NORTH
21½°
APPROXIMATE MEAN DECLINATION 1900

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 Sept. 1902.

LEGEND

RELIEF
(printed in brown)

5906
Figures
(showing heights above mean sea level instrumentally determined)

Contours
(showing height above sea, horizontal form, and steepness of slope of the surface)

DRAINAGE
(printed in blue)

Streams

Intermittent streams

Canals and ditches

Lakes and ponds

Intermittent lakes

Springs

CULTURE
(printed in black)

Roads and buildings

Private and secondary roads

Trails

Railroads

Bridges

U.S. township and section lines

County lines

Reservation lines

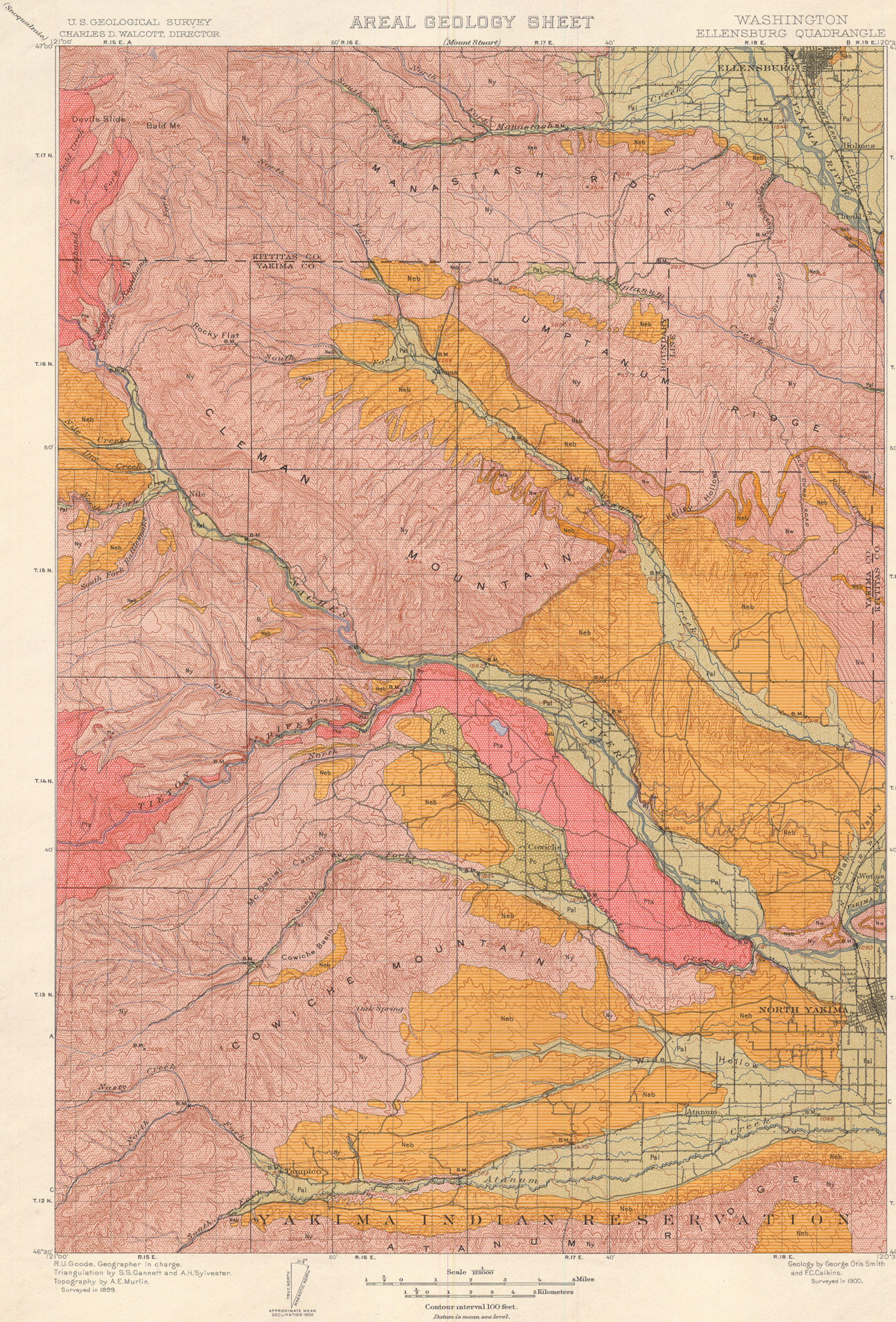
Triangulation stations

B.M.
×
Bench marks

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

AREAL GEOLOGY SHEET

WASHINGTON
ELLENSBURG QUADRANGLE



R.U.Goode, Geographer in charge.
Triangulation by S.S.Gannett and A.H.Sylvester.
Topography by A.E.Murlin.
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TRUE NORTH
MAGNETIC NORTH
21½°
APPROXIMATE MEAN DECLINATION 1900

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. 1902.

Geology by George Otis Smith
and F.C.Calkins.
Surveyed in 1900.

LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles)

PLEISTOCENE

Pal
Valley alluvium
(fine river silt and sand, with gravel near the larger streams)

Pc
Cowiche gravels
(coarse gravel and sand with covering of silt, forming terraces produced by dammed streams)

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines)

MIOCENE — NEOCENE

Neb
Ellensburg formation
(fluviatile deposits of stratified silts, sands, and gravels of volcanic material, locally indurated. Earlier beds in part overlain by Wenas basalt)

IGNEOUS ROCKS

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

PLEISTOCENE

Pta
Tieton andesite
(flows of lava with associated agglomerate, occupying old valleys)

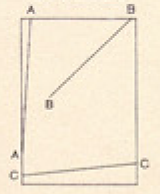
MIOCENE — NEOCENE

Nw
Wenas basalt
(lava flows interbedded with Ellensburg formation)

Ny
Yakima basalt
(extensive series of lava flows and associated tuffs)

Faults

Sections



U.S. GEOLOGICAL SURVEY
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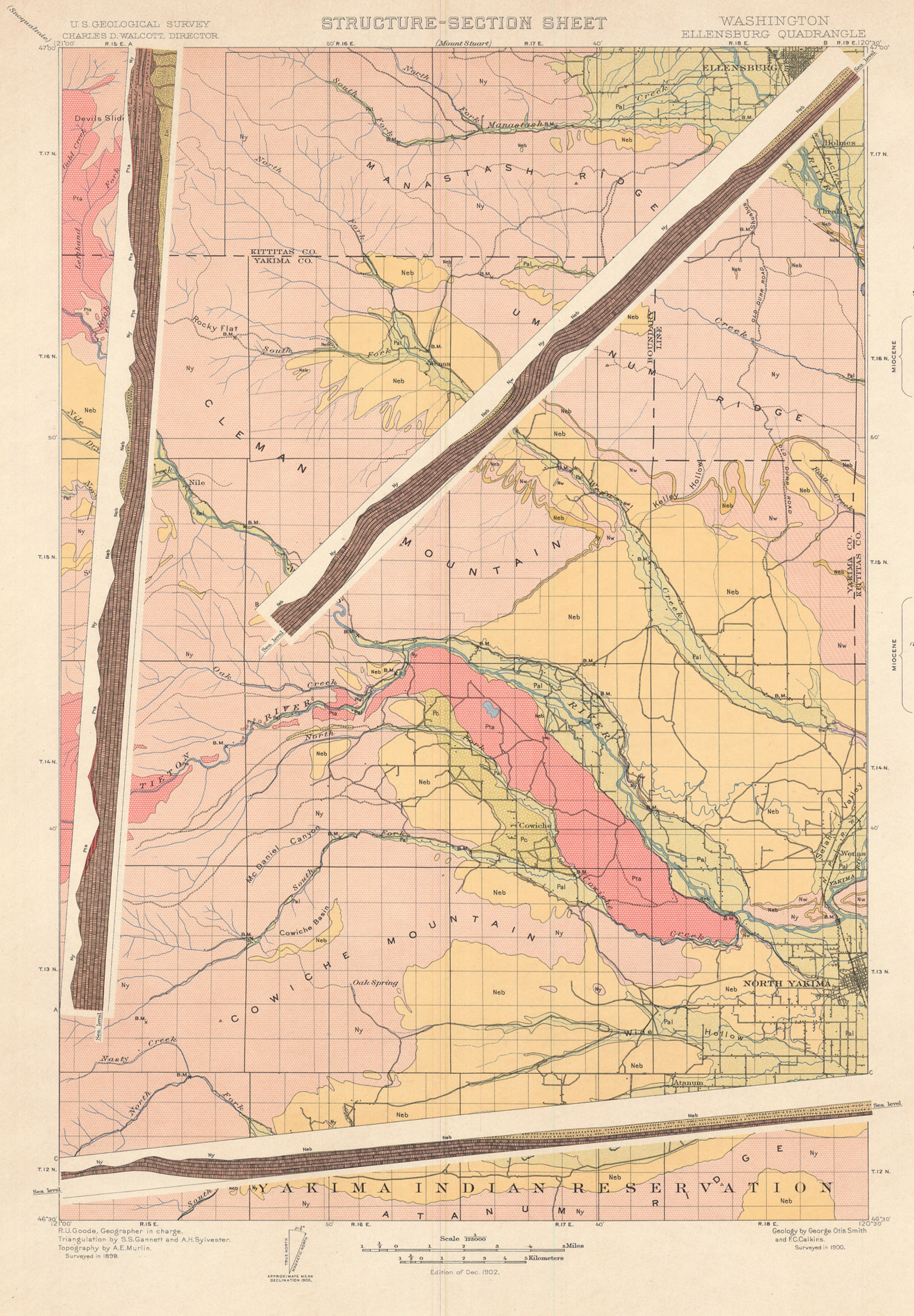
STRUCTURE-SECTION SHEET

WASHINGTON
ELLENSBURG QUADRANGLE



R.U. Goode, Geographer in charge.
Triangulation by S.S. Gannett and A.H. Sylvester.
Topography by A.E. Murlin.
Surveyed in 1899.

Edition of Dec. 1902.

Geology by George Otis Smith
and F.C. Calkins.
Surveyed in 1900.

LEGEND

SURFICIAL ROCKS

SHEET SYMBOL	SECTION SYMBOL	Name	Period	Age
Pal		Valley alluvium *(fine river silt and sand, with gravel near the larger streams)*	PLEISTOCENE	
Pc		Cowiche gravels *(coarse gravel and sand with covering of silt, forming terraces produced by dammed streams)*	PLEISTOCENE	

SEDIMENTARY ROCKS

SHEET SYMBOL	SECTION SYMBOL	Name	Period	Age
Neb	Neb	Ellensburg formation *(fluviatile deposits of stratified silts, sands, and gravels of volcanic material, locally indurated. Earlier beds in part overlain by Wenas basalt)*	NEOCENE	MIOCENE
	Em	Manastash formation *(sandstone and conglomerate)*	EOCENE	

IGNEOUS ROCKS

SHEET SYMBOL	SECTION SYMBOL	Name	Period	Age
Pta	Pta	Tieton andesite *(flows of lava with associated agglomerate, occupying old valleys)*	PLEISTOCENE	
Nw	Nw	Wenas basalt *(lava flows interbedded with Ellensburg formation)*	NEOCENE	MIOCENE
Ny	Ny	Yakima basalt *(extensive series of lava flows and associated tuffs)*	NEOCENE	MIOCENE

Faults ——— — —

redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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 formations are remote one from the 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 rocks of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions and groups of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the one at the top of the column (Pleistocene) and the one at the bottom (Archean). The sedimentary formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint is printed evenly over the whole surface representing the period; a dark tint brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol composed of the period letter combined with small letters standing for the formation name. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

Period.		Symbol.	Color.
Cenozoic	Pleistocene	P	Any colors
	Neocene { Pliocene Miocene }	N	Buffs.
	Eocene, including Oligocene	E	Olive-browns.
Mesozoic	Cretaceous	K	Olive-greens.
	Juratrias { Jurassic Triassic }	J	Blue-greens.
Paleozoic	Carboniferous, including Permian	C	Blues.
	Devonian	D	Blue-purples.
	Silurian, including Ordovician	S	Red-purples.
	Cambrian	Є	Pinks.
	Algonkian	A	Orange-browns.
	Archean	AR	Any colors.

The number and extent of surficial formations, chiefly Pleistocene, render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the metamorphic rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology sheet.—This sheet 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 particular colored pattern and its letter-symbol on the map 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet 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 symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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 name 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 the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting 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:

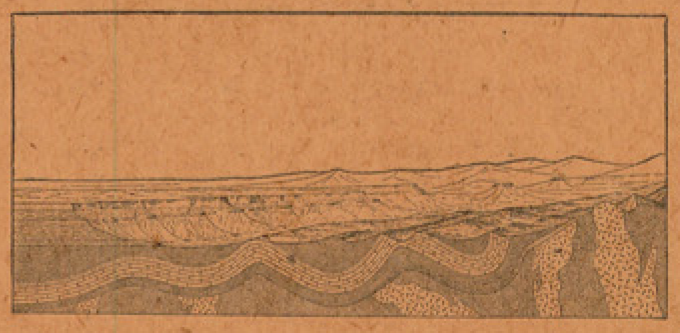
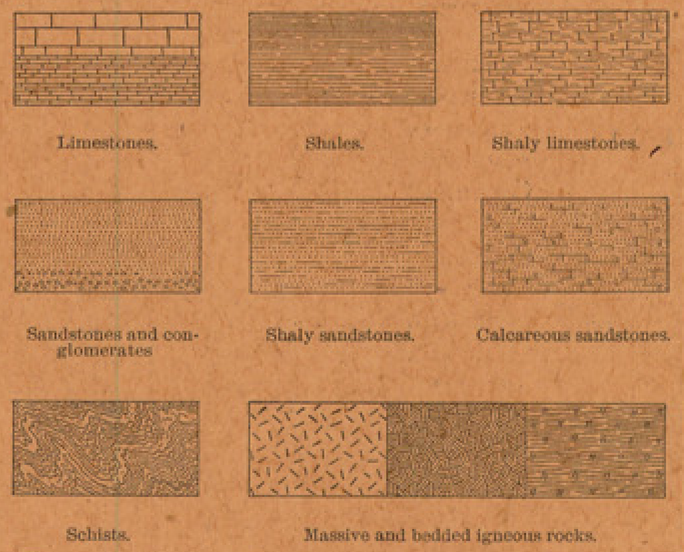


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane, so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section 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:



Limestones.

Shales.

Shaly limestones.

Sandstones and conglomerates

Shaly sandstones.

Calcareous sandstones.

Schists.

Massive and bedded igneous rocks.

Fig. 3.—Symbols used to represent different kinds of rock.

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 beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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*.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. 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 regarded as proof that forces exist which 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 slipped past one another. Such breaks are termed *faults*.

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

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the 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 swelled upward 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 horizonal 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 strata thus rest upon an eroded surface of older strata 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 this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration 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, marking a time interval between two periods of rock formation, is another unconformity.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond 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 rock formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thicknesses of the formations, and the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given in figures which state the least and greatest measurements. The average thickness of each formation 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 is placed at the bottom of the column, the youngest at the top, and igneous rocks or surficial deposits, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

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

CHARLES D. WALCOTT,
Director.

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