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GEOLOGIC ATLAS

OF THE

UNITED STATES

RIDDLE FOLIO

OREGON

BY

J. S. DILLER AND G. F. KAY

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WASHINGTON, D. C.

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RIDDLE FOLIO
NO. 218

GEOLOGIC ATLAS OF THE UNITED STATES.

UNITS OF SURVEY AND OF PUBLICATION.

The Geological Survey is making a topographic and a geologic atlas of the United States. The topographic atlas will consist of maps called *atlas sheets*, and the geologic atlas will consist of parts called *folios*. Each folio includes topographic and geologic maps of a certain four-sided area, called a *quadrangle*, or of more than one such area, and a text describing its topographic and geologic features. A quadrangle is limited by parallels and meridians, not by political boundary lines, such as those of States, counties, and townships. Each quadrangle is named from a town or a natural feature within it, and at the sides and corners of each map are printed the names of adjacent quadrangles.

SCALES OF THE MAPS.

On a map drawn to the scale of 1 inch to the mile a linear mile on the ground would be represented by a linear inch on the map, and each square mile of the ground would be represented by a square inch of the map. The scale may be expressed also by a fraction, of which the numerator represents a unit of linear measure on the map and the denominator the corresponding number of like units on the ground. Thus, as there are 63,360 inches in a mile, the scale 1 inch to the mile is expressed by the fraction $\frac{1}{63,360}$, or the ratio 1:63,360.

The three scales used on the standard maps of the Geological Survey are 1:62,500, 1:125,000, and 1:250,000, 1 inch on the map corresponding approximately to 1 mile, 2 miles, and 4 miles on the ground. On the scale of 1:62,500 a square inch of map surface represents about 1 square mile of earth surface; on the scale of 1:125,000, about 4 square miles; and on the scale of 1:250,000, about 16 square miles. In general a standard map on the scale of 1:250,000 represents a "square degree"—that is, an area measuring 1 degree of latitude by 1 degree of longitude; one on the scale of 1:125,000 represents one-fourth of a "square degree"; and one on the scale of 1:62,500 represents one-sixteenth of a "square degree." The areas of the corresponding quadrangles are about 4,000, 1,000, and 250 square miles, though they vary with the latitude, a "square degree" in the latitude of Boston, for example, being only 3,525 square miles and one in the latitude of Galveston being 4,150 square miles.

GENERAL FEATURES SHOWN ON THE MAPS.

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

Relief.—All altitudes are measured from mean sea level. The heights of many points have been accurately determined, and those of some are given on the map in figures. It is desirable, however, to show the altitude of all parts of the area mapped, the form of the surface, and the grade of all slopes. This is done by contour lines, printed in brown, each representing a certain height above sea level. A contour on the ground passes through points that have the same altitude. One who follows a contour will go neither uphill nor downhill but on a level. The manner in which contour lines express altitude, form, and slope is shown in figure 1.

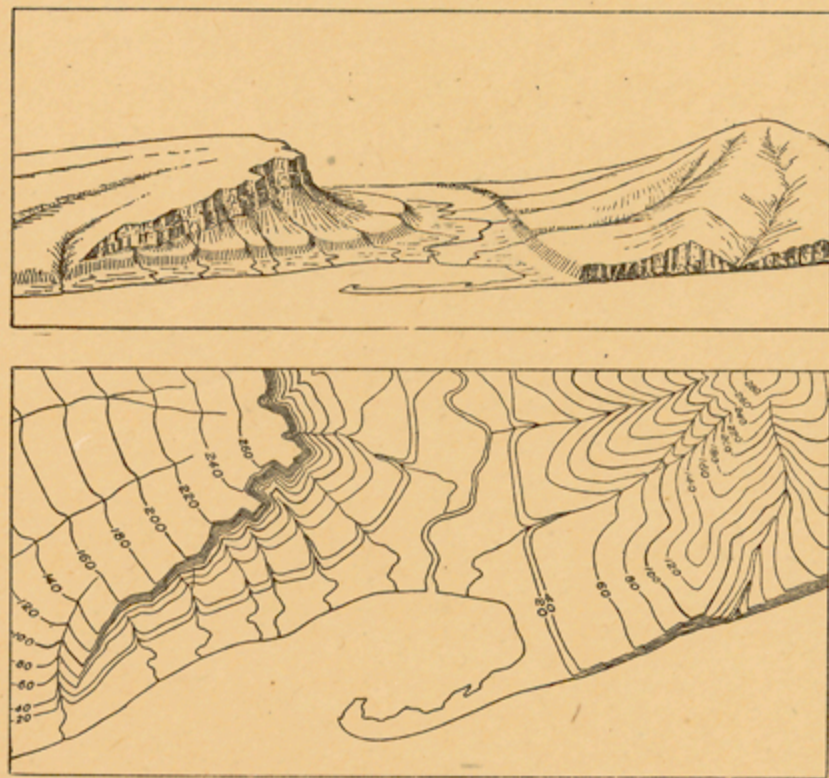


FIGURE 1.—Ideal view and corresponding contour map.

The view represents a river valley between two hills. In the foreground is the sea, with a bay that is partly inclosed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle upward slope; that on the left merges into a steep slope that passes upward to a cliff, or scarp, which contrasts with the gradual slope back from its crest. In the map each of these features is indicated, directly beneath its position in the view, by contour lines. The map does not include the distant part of the view.

As contours are continuous horizontal lines they wind smoothly about smooth surfaces, recede into ravines, and project around spurs or prominences. The relations of contour curves and angles to the form of the land can be seen from the map and sketch. The contour lines show not only the shape of the hills and valleys but their altitude, as well as the steepness or grade of all slopes.

The vertical distance represented by the space between two successive contour lines—the contour interval—is the same, whether the contours lie along a cliff or on a gentle slope; but to reach 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 slopes.

The contour interval is generally uniform throughout a single map. The relief of a flat or gently undulating country can be adequately represented only by the use of a small contour interval; that of a steep or mountainous country can generally be adequately represented on the same scale by the use of a larger interval. The smallest interval commonly used on the atlas sheets of the Geological Survey is 5 feet, which is used for regions like the Mississippi Delta and the Dismal Swamp. An interval of 1 foot has been used on some large-scale maps of very flat areas. On maps of more rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used, and on maps of great mountain masses like those in Colorado the interval may be 250 feet.

In figure 1 the contour interval is 20 feet, and the contour lines therefore represent contours at 20, 40, 60, and 80 feet, and so on, above mean sea level. Along the contour at 200 feet lie all points that are 200 feet above the sea—that is, this contour would be the shore line if the sea were to rise 200 feet; along the contour at 100 feet are all points that are 100 feet above the sea; and so on. In the space between any two contours are all points whose altitudes are above the lower and below the higher contour. Thus the contour at 40 feet falls just below the edge of the terrace, and that at 60 feet lies above the terrace; therefore all points on the terrace are shown to be more than 40 but less than 60 feet above the sea. In this illustration all the contour lines are numbered, but on most of the Geological Survey's maps all the contour lines are not numbered; only certain of them—say every fifth one, which is made slightly heavier—are numbered, for the heights shown by the others may be learned by counting up or down from these. More exact altitudes for many points are given in bulletins published by the Geological Survey.

Drainage.—Watercourses are indicated by blue lines. The line for a perennial stream is unbroken; that for an intermittent stream is dotted; and that for a stream which sinks and reappears is broken. Lakes and other bodies of water and the several types of marshy areas are also represented in blue.

Culture.—Symbols for the works of man, including public-land lines and other boundary lines, as well as all the lettering, are printed in black.

GEOLOGIC FEATURES SHOWN ON THE MAPS.

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

KINDS OF ROCKS.

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

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or *magma*, within these channels—that is, below the surface—are called *intrusive*. An intrusive mass that occupies a nearly vertical fissure which has approximately parallel walls is called a *dike*; one that fills a large and irregular conduit is termed a *stock*. Molten material that traverses stratified rocks may be intruded along bedding planes, forming masses called *sills* or *sheets* if they are relatively thin and *laccoliths* if they are large lenticular bodies. Molten material that is inclosed by rock cools slowly; and its component minerals crystallize when they solidify, so that intrusive rocks are generally crystalline. Molten material that is poured out through channels that reach the surface is called *lava*, and lava may build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and contain, especially in their outer parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows are also usually made porous by the expansion of the gases in the magma. Explosions due to these gases may accompany volcanic eruptions, causing the ejection of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic material deposited in lakes and seas, or of material deposited in such bodies of water by chemical precipitation or by organic action are termed *sedimentary*.

The chief agent in the transportation of rock debris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits they form are called mechanical. Such deposits are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits composed of these materials are called organic if formed with the aid of life or chemical if formed without the aid of life. The more common rocks of chemical and organic origin are limestone, chert, gypsum, salt, certain iron ores, peat, lignite, and coal. Any one of the kinds of deposits named may be formed separately, or the different materials may be intermingled in many ways, producing a great variety of rocks.

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

Most sedimentary rocks are made up of layers or beds that can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be *stratified*.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks with reference to the sea, and shore lines are thus changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land surface is in fact composed of rocks that were originally deposited as sediments in the sea.

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

Metamorphic rocks.—In the course of time and by various processes rocks may become greatly changed in composition and texture. If the new characteristics are more pronounced than the old the rocks are called *metamorphic*. In the process of metamorphism the chemical constituents of a rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressure, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structural features may have been lost entirely and new ones substituted. A system of parallel planes along which the rock can be split most readily may have been developed. This acquired quality gives rise to *cleavage*, and the cleavage planes may cross the original bedding planes at any angle. Rocks characterized by cleavage are called *slates*. Crystals of mica or other minerals may have grown in a rock in parallel arrangement, causing lamination or foliation and producing what is known as *schistosity*. Rocks characterized by schistosity are called *schists*.

As a rule, the older rocks are most altered and the younger are least altered, but to this rule there are many exceptions, especially in regions of igneous activity and complex structure.

GEOLOGIC FORMATIONS.

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

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

DESCRIPTION OF THE RIDDLE QUADRANGLE.

By J. S. Diller and G. F. Kay.

INTRODUCTION.

Location and area.—The Riddle quadrangle is in southwestern Oregon, between 42° 30' and 43° north latitude and 123° and 123° 30' west longitude. It is 35 miles from north to south and 26 miles from east to west, and its area is 910 square miles. The quadrangle is named from a village within its borders and embraces parts of Douglas, Jackson, and Josephine counties. (See Fig. 1.)

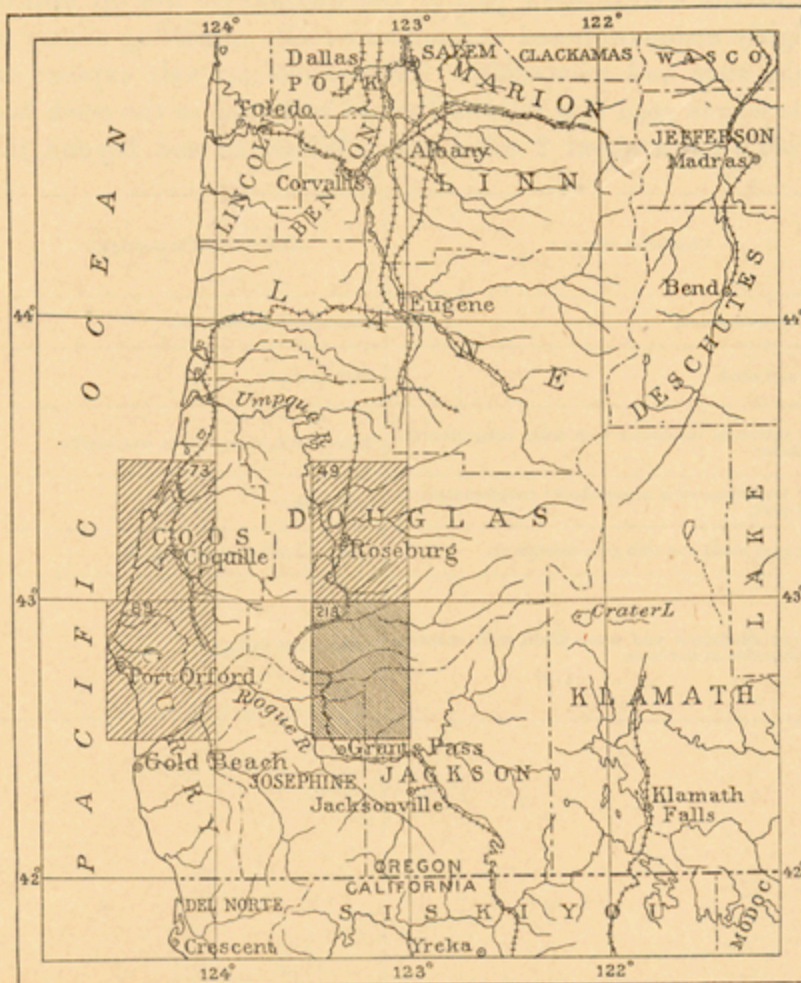


FIGURE 1.—Index map of southwestern Oregon. The location of the Riddle quadrangle (Folio 218) is shown by the darker ruling. Published folios describing other quadrangles, which are shown by lighter ruling, include Folios 49, Roseburg; 73, Coos Bay; and 80, Port Orford.

Outline of the geography and geology of the region.—From Alaska to Lower California the western coast of North America is bordered by a belt of mountains from 100 to 200 miles wide. This belt as a whole has been named the Pacific Mountain system. It separates the Pacific Ocean from the interior plateau region, and its general character is shown in Figure 2.

For its entire extent from Alaska to Lower California the Pacific Mountain system may in general be divided lengthwise into three parts—two long lines of mountain ranges and an intervening belt of valleys that may be called the Pacific Valley belt.

In Oregon the Willamette Valley lies in the Pacific Valley belt, between the Coast Range on the west and the Cascade Range on the east. (See Fig. 2.) Between the head of the Willamette Valley and the north end of the Great Valley of California, the next large member of the Pacific Valley belt, there is a tract of generally mountainous country with transverse drainage, where for 200 miles the threefold longitudinal division of the Pacific system into two ranges and an intervening valley is less evident than elsewhere. The Umpqua Valley, Rogue River valley, and Shasta Valley, lying between the Cascade Range on the east and the Klamath Mountains toward the coast, are not continuous. Nevertheless they represent the Pacific Valley belt interrupted by transverse ridges, spurs from the Klamath Mountains to the Cascade Range. Across one of these spurs, as shown in Figure 2, lies the Riddle quadrangle, between the Umpqua Valley and that of Rogue River.

The Klamath Mountains, which extend from southwestern Oregon for 160 miles into California, are composed of rocks which, like those of the Sierra Nevada, are older and generally harder and more complicated in structure than the rocks of the overlapping portions of the Coast Ranges in Oregon and California. It is this difference in the rocks of which they are composed that forms the basis on which the mountain ranges are distinguished. The Cascade Range is made up essentially of Tertiary volcanic rocks, the Sierra Nevada and Klamath Mountains consist mainly of Paleozoic rocks, and the Coast Ranges of Oregon and California are for the most part composed of Mesozoic and Tertiary sediments. The general distribution of the rock groups and their relation to the mountain ranges and to the Riddle quadrangle is shown in Figure 3.

During early Mesozoic time the Paleozoic rocks were greatly compressed and upheaved into mountains. Then followed a long period of comparatively little change of sea level, and the

streams by long-continued erosion washed away the mountains and reduced the landscape to an approximate plain or peneplain, which on account of its topographic importance has been designated the Klamath peneplain.

Climate.—The Riddle quadrangle has the relatively warm, dry climatic characteristics of the Pacific Valley belt. But the Coast Range and Klamath Mountains opposite Riddle, being scarcely 3,500 feet in altitude, do not shut out completely the prevailing moderate winds (south and southwest in winter and northwest in summer) from the sea that temper the heat and cold and increase the precipitation on the windward side.

There are no Weather Bureau stations within the Riddle quadrangle, but an average of observations for 20 years at Grants Pass, near the southern border, and at Roseburg, near the northern border, which differ but little, will closely approximate the mean monthly temperature and rainfall for the intervening towns of the Riddle quadrangle.

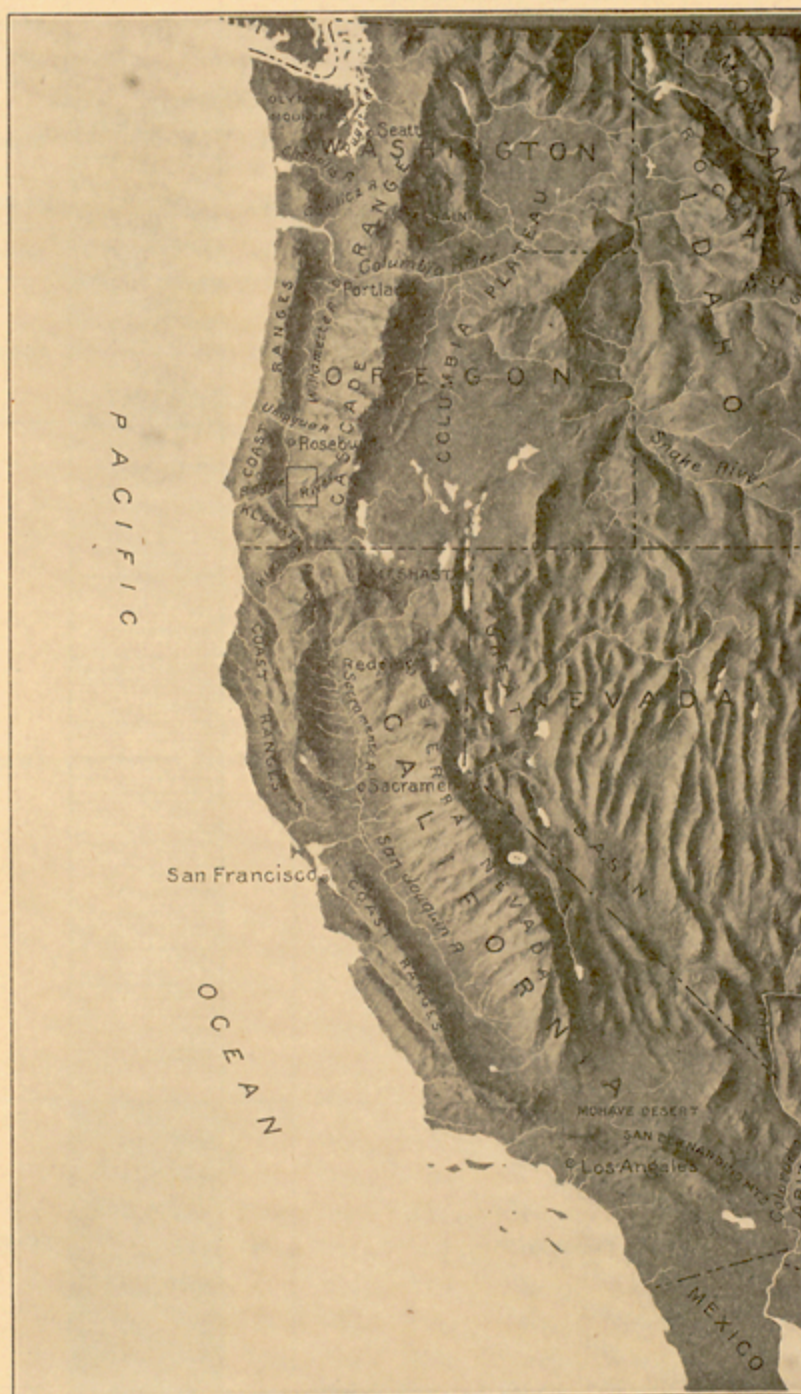


FIGURE 2.—Relief map of the Pacific Coast border, showing the location of the Riddle quadrangle (small rectangle in southwestern Oregon) and its relation to the mountain ranges. Photographed from a relief model.

Average of the mean monthly temperature and rainfall for 20 years at Roseburg and Grants Pass.

	Temperature (°F.)	Rainfall (inches)
January	39.8	5.64
February	42.7	4.88
March	46.3	3.86
April	51.1	2.01
May	56.5	1.92
June	62.1	1.08
July	68.0	.22
August	67.5	.33
September	60.9	.99
October	53.6	2.36
November	45.3	4.34
December	41.2	5.85
Annual	52.9	33.43
April to October (warm, dry season)	61.0	6.50
November to March (cool, wet season)	44.8	26.93

The area has a mean annual temperature of 52.9° and a range in the mean monthly temperature of only 28.2° from January, the coldest month (39.8°), to July, the warmest month (68°). The highest temperature recorded in 20 years is about 108° and the lowest 3° below zero. There are occasional frosts from the middle of October to May.

The characteristic feature of the climate is that there are two seasons—a warm, dry season and a cool, wet season. About 80 per cent of the precipitation occurs in the six cooler months from November to March. Most of the precipitation is in the form of rain. Light snows fall in the valleys and soon disappear. Snows are heavier in the wooded hills and linger.

In brief, the climate of the Riddle quadrangle is mild, without harmful extremes, and well suited not only for comfortable residence but for intensive agriculture and fruit culture.

Vegetation.—Except in the narrow alluvial valleys that are used for farms and orchards and in a few sterile tracts of serpentine rocks the Riddle quadrangle is well forested throughout. In many places on the hill slopes the timber is interspersed with buck brush (*Ceanothus velutinus*), California lilac (*Ceanothus thyrsiflorus*), and other forms of the same genus, making an abundant chaparral, but generally along the ridge summits the forest is open and parklike. Manzanita appears here and there among the shrubbery, and madrone with its reddish bark and evergreen leaves is a bright feature in the forest.

By far the larger part of the trees are evergreen conifers. Those of commercial value are chiefly Douglas fir (*Pseudotsuga taxifolia*). Cedar and hemlock are also commercially valuable. There are small amounts of sugar pine (*Pinus lambertiana*), yellow pine (*Pinus ponderosa*), silver fir (*Abies grandis*), red fir (*Abies nobilis*), and spruce. Among the broad-leaved varieties the oak, ash, maple, mountain mahogany (*Cercocarpus ledifolius*), aspen, cottonwood, and balsam are most common.

Population.—The Riddle quadrangle has a population of about 5,000, most of whom live in the valleys. Glendale, the only city, has a population of 548. Canyonville (population 156) and Riddle (population 268) are the only other incorporated towns.

Industries.—As would be inferred from the large forested areas, lumbering is the principal industry of this area. The leading center is Glendale, but large mills are scattered throughout the quadrangle.

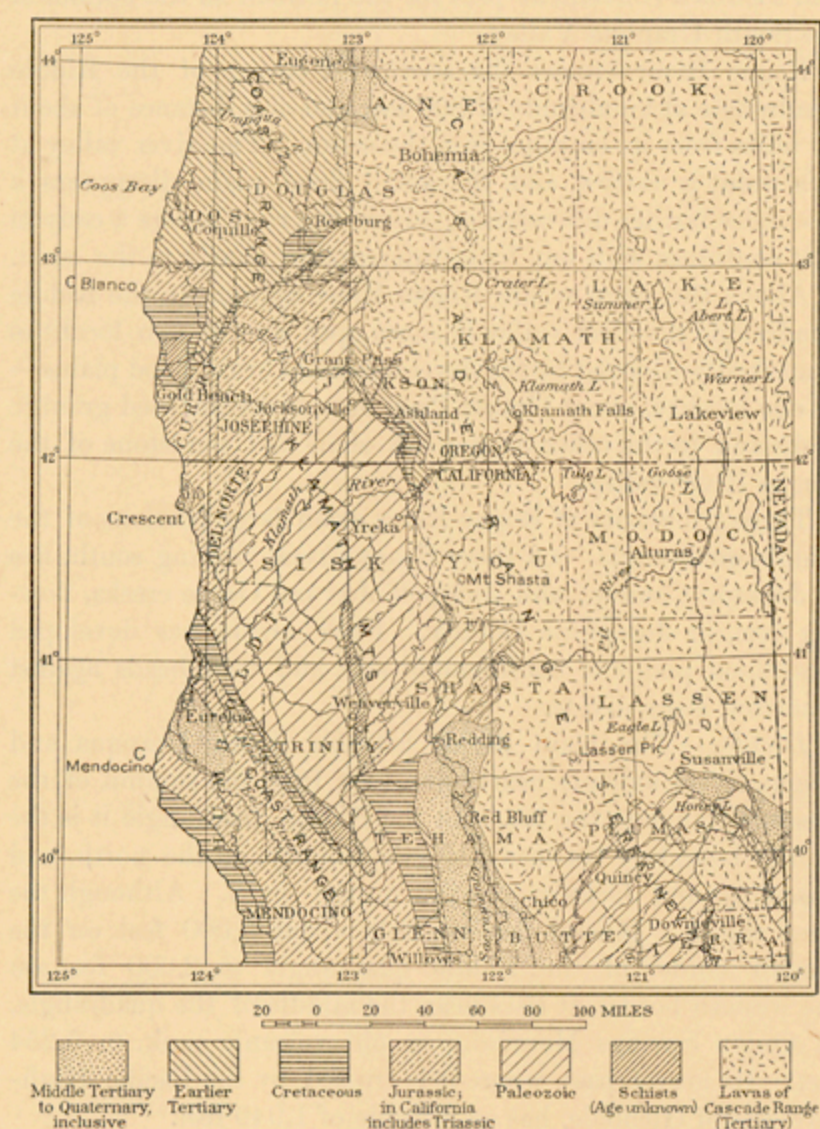


FIGURE 3.—Geologic map of the Klamath Mountains and adjacent ranges in southern Oregon and northern California.

Facilities for transportation are afforded by the main line of the Southern Pacific Railroad and the Pacific Highway, which run across the western portion of the quadrangle. Wagon roads traverse all the principal valleys and connect with trails among the mountains.

Mining is a scarcely less important industry than lumbering. Both lode and placer mines are in operation, and during the rainy season the placers are especially active.

In the valleys agriculture and fruit growing are carried on. Wheat, oats, barley, rye, and corn are cultivated, but mainly for "grain hay." Alfalfa, clover, timothy, and other grasses

are grown successfully by irrigation. The hills and mountains east of the quadrangle are snow clad during much of the year and furnish an abundant supply of water for irrigating farms and orchards. The principal fruits raised are apples and prunes, but peaches, grapes, cherries, and many kinds of berries and other fruits also are grown in large quantities.

TOPOGRAPHY.

The larger features of the topography of the Riddle quadrangle are portions of the South Umpqua and Rogue River drainage basins and a divide between them which is a spur of the Klamath Mountains.

Streams.—South Umpqua River drains the northern half of the quadrangle. Above Perdue the river bed has an altitude of about 1,000 feet. By a series of gentle rapids across the bands of hard rocks and long reaches on the softer rocks the South Umpqua descends nearly 300 feet in a distance of about 40 miles to Missouri Bottom, which at a distance of only 47 miles from the sea has an altitude of nearly 700 feet. The stream has worn down its bed to a gentle grade and along most of its course is now widening its flood plain, but this plain, though nearly a mile wide in Missouri Bottom, is not yet so large and flat as to allow the river to meander. Farther downstream, in the Roseburg quadrangle, meandering has already begun, and the river may be said to be mature. Still farther down, where the river runs northward in the Coast Range from Coles Valley to Elkton, it has developed a remarkable succession of meanders, now deeply entrenched in the canyon which the river has cut across the Coast Range to the sea.

The only large tributary from the north to South Umpqua River in the Riddle quadrangle is Days Creek, which follows the trend of a belt of soft rocks. The largest tributaries are on the south side of the stream, and they increase in size from east to west. By far the largest and most noteworthy of these branches is Cow Creek, which is especially remarkable on account of its curved course. In the upper 25 miles it runs southwestward, making a small angle with the general trend of the rocks, and for the greater part of this distance has built up an agricultural valley half a mile in width. Near Glendale Cow Creek enters a narrow canyon-like valley, which it traverses for 25 miles, curving in succession from west to northwest, north, and finally northeast as it enters the broad valley cut in soft rocks about Riddle, where it joins the South Umpqua. The open valleys in which it flows southwestward from the head and northeastward to the mouth are in strong contrast with the intermediate canyon, in which Cow Creek curves from one course to the other in a descent of 700 feet and affords a convenient pass for the railroad to the bottom of the South Umpqua Valley.

Rogue River crosses the southwest corner of the Riddle quadrangle at an altitude of 800 feet and at a distance of about 90 miles from its entrance into the ocean. The river valley at this point is narrow, and the small flood plain disappears a few miles farther downstream, where the river enters a canyon that continues with but little interruption nearly to the coast.

Above the point where Rogue River appears in the Riddle quadrangle the river valley is more open and at two localities is markedly widened by the development of broad flood plains—in one locality, about Grants Pass, on soft decomposed granitic rocks and in the other on the soft shale and sandstone of the Rogue River valley.

Three tributaries of Rogue River drain large portions of the Riddle quadrangle. Of these Evans Creek, flowing south, lies in Jackson County; and Jumpoff Joe and Grave creeks, flowing west, in Josephine County. Each stream has developed local flood plains of considerable size, and each heads against a narrow, steep divide.

Divides.—The main divide between South Umpqua and Rogue rivers extends nearly due west from the summit of the Cascade Range to the sea. In the Riddle quadrangle it is the county boundary between Douglas County, on the north, and Josephine and Jackson counties, on the south. Although the crest shows a general decline from about 4,000 feet on the eastern border of the Riddle quadrangle to 2,600 feet on the western border, it rises near the middle of the quadrangle, in Onion Springs Mountain, an old volcanic peak, to 5,254 feet. Its lowest pass, where it is crossed by the Pacific Highway east of Glendale, has an altitude of 1,949 feet.

Although the crest in general follows the belts of harder rock from northeast to southwest the belts are too small and irregular to exert a controlling influence. The position of the crest is due more largely to variation in the opposing tributaries of South Umpqua and Rogue rivers. As these rivers are about equidistant from the divide in the Riddle quadrangle, their lateral streams average about the same length, but the fact that the South Umpqua has already cut down its valley 100 feet lower than that of Rogue River shows that the South Umpqua must have some advantage over the Rogue. The explanation may be found in the fact that the South Umpqua has softer rocks to erode and carries a larger volume of water, but on the other hand it has a much longer course to the sea. It does not

appear probable that the divide in the Riddle quadrangle has been greatly shifted, or that either stream has been able to capture much area from the other in the general process of erosion.

The peaks that rise above the generally narrow divides in the Riddle quadrangle range from about 3,000 to more than 5,000 feet in altitude. The higher peaks have the gentler slopes, because they are remnants of an earlier plane of erosion, the Klamath peneplain, formed near sea level before the Klamath Mountains were raised to their present altitude. This feature is illustrated in the southwestern part of the quadrangle by Sexton, Walker, and Elk mountains and by the divide surrounding the head of Jack Creek. Onion Springs Mountain, the highest summit in the quadrangle, is the flattest, and gentle slopes are prominent above 4,000 feet on the main divide about Green Mountain, Skeleton Mountain, and Angels Camp and in the Cow Creek divide from Silver Butte to Grayback.

West and southwest of the Riddle quadrangle this feature of flat summits belonging to the Klamath peneplain is much more fully developed in Table Mountain, west of Nichols Station, and in a more extensive area at an altitude of about 4,000 feet in Josephine County.

southwest, in the Grants Pass quadrangle, are thought to be of Devonian age.

The igneous rocks comprise both intrusive and extrusive rocks and occupy much the larger part of the area, though more widespread in the southern than in the northern half. Associated mainly with the igneous rocks but also to some extent with the sedimentary rocks are ore deposits, chiefly of gold but some of copper. Much of the gold has been taken from placers, although gold-quartz mines have produced gold to the value of several million dollars. In the northwestern part of the quadrangle, in the vicinity of Nickel Mountain, interesting deposits of nickel silicates are found in metamorphosed basic eruptive rocks.

SEDIMENTARY ROCKS.

PALEOZOIC ROCKS.

DEVONIAN (?) SYSTEM.

MAY CREEK FORMATION.

In the southeastern part of the quadrangle lies an area of highly metamorphosed sedimentary rocks consisting chiefly of mica slate and mica schist. These rocks are well exposed on the wagon road that follows Evans Creek and in the creek bed from a point about 2 miles above Wimer to and beyond the

System.	Series.	Formation.	Symbol.	Section.	Thickness (feet).	Character of rocks.	Character of topography.
Quaternary.		Alluvium.	Qa		10-100	Silt, sand, and gravel.	Flood plains of streams.
		High terrace gravels.	Qg		50	Gravel and sand.	High terraces.
Tertiary.	Eocene.	Umpqua formation.	Tu		30-1000	Chiefly yellowish sandstone with some conglomerate and shale.	Table-lands, steep slopes, and bluffs.
	Upper Cret.	Chico formation.	Kc		50-300	Chiefly sandstone with some shale; conglomerate in lower part.	Low hills.
Cretaceous.	Lower Cretaceous.	Horseshoe formation.	Kh		100-400	Chiefly gray shale and thin gray sandstone.	Low rounded hills and valleys.
		Knoxville formation.	Kk		500-1000	Dark-gray sandstone and some shale, with massive conglomerate at the base.	Ridges and valleys.
		Dothan formation.	Jd		1000-6000	Chiefly hard sandstone with some conglomerate and dark-gray shale.	Prominent hills and narrow valleys.
Jurassic.		Galice formation.	Jg		1000-2000	Chiefly fine-grained dark slate with some sandstone and conglomerate.	Hilly country with steep slopes.
		May Creek formation.	Dmc		1000±	Micaeous slate and mica schist with associated meta-rhyolite lava flows.	Rugged hilly country.
Devonian?							

FIGURE 4.—Columnar section of the sedimentary rocks in the Riddle quadrangle.

In the southwestern part of Josephine County there are high bodies of auriferous gravel in close relation to the Klamath peneplain,¹ and a very small area of similar gravel occurs on the main divide of the Riddle quadrangle, near the head of Big Boulder Creek, at about the level of the Klamath peneplain.

GEOLOGY.

The rocks of the Riddle quadrangle consist of sedimentary and igneous formations of various types and ages. As shown on the areal-geology map, they lie in irregular elongated patches or bands with a general northeast-southwest trend. Their succession in age is shown by their vertical relation in the columnar section of Figure 4.

The sedimentary rocks are mainly of Mesozoic and Cenozoic age, but in the southeastern part of the quadrangle there are highly metamorphosed sedimentary rocks, in which no fossils have yet been found but which because of their relation and resemblances to fossiliferous rocks occurring farther to the

¹ Diller, J. S., Mineral resources of southwestern Oregon: U. S. Geol. Survey Bull. 546, p. 96, 1914.

mouth of May Creek and for about 3 miles along May Creek, which is taken as the type locality of the formation. To the west of these sediments are intrusive rocks; to the east of them and apparently in part interbedded with them are strongly metamorphosed schistose rocks, mostly siliceous, which are thought to be of volcanic origin and are mapped as meta-rhyolite.

The mica slate and mica schist are almost everywhere much fractured, and the stratification where it is discernible is parallel to the schistosity. In the planes of schistosity lenses of quartz are prevalent.

The strike of the rocks ranges from a few degrees east of north to N. 75° E., but the prevalent strike is about northeast. The dips range from 30° to more than 75° to the southeast. The greatest width of an outcrop belt at right angles to the prevailing strike is between 3 and 4 miles. At and near the contact with intrusive igneous rocks chialstolite and staurolite have been developed in the slate and schist.

No fossils have been found in these rocks within the Riddle quadrangle, but farther southwest, in similar rocks that contain lentils of limestone, there are fossils which have been

tentatively identified as *Favosites nitella* and *Cladopora robustus* and a gastropod resembling *Loxonema bella*. These determinations, if correct, indicate that the rocks are of Devonian age.²

These Paleozoic rocks are separated from the next younger sedimentary beds by igneous rocks, as shown on the map.

MESOZOIC ROCKS.

The Mesozoic rocks of this region belong to the Jurassic and Cretaceous systems. The Jurassic rocks include two distinct formations, which in southwestern Oregon have been named the Galice and the Dothan.³ The Cretaceous sediments are similar to the Cretaceous deposits of California and, as in California, are subdivided into the Knoxville, Horsetown, and Chico formations. In the Roseburg quadrangle, north of the Riddle quadrangle, the Knoxville and Horsetown formations were mapped together as the Myrtle formation.

JURASSIC SYSTEM.

GALICE FORMATION.

The rocks to which the name Galice formation was originally applied are well exposed along Rogue River near Galice, southwest of the Riddle quadrangle. This type area extends into the west-central part of the quadrangle, in the vicinity of Reuben. Between the type area of the Galice formation and the Paleozoic areas of the Riddle quadrangle there are several bands of sedimentary rocks that are interbedded in part with lava flows and fragmental igneous rocks and are in places intruded by igneous rocks. These rocks are here included in the Galice formation, although no fossils have been found in them and they may be older than the Galice.

The areas of the Riddle quadrangle that have been mapped as the Galice formation are as follows:

1. An area south of Reuben, which is part of the type area of the Galice.
2. A small band of slate extending from the east slope of Canyon Creek across O'Shea Creek and down Beal Creek where the slate unites with a wide belt of slate to the east.
3. A belt of slate extending from Rogue River, in the southwestern part of the quadrangle, to and beyond South Umpqua River. On Rogue River this slate belt is more than 6 miles wide at right angles to the strike; south of South Umpqua River it is of nearly the same width; at intermediate points the width varies with the presence or absence of interbedded and intruded igneous rocks.

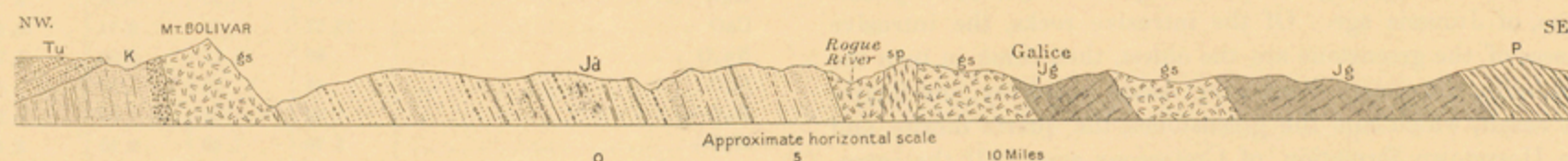


FIGURE 5.—Generalized structure section across the belt of Jurassic rocks southwest of Grants Pass. Tu, Umpqua formation, Eocene sandstone and conglomerate; K, Cretaceous formations; gs, greenstone (Jurassic); Jd, Dothan formation; Jg, Galice formation; P, Paleozoic rocks; sp, serpentine.

4. A band of slate extending northeastward from Green Mountain to and beyond South Umpqua River.
5. Isolated irregular-shaped patches of slate surrounded by igneous rocks.

The Galice formation consists chiefly of slate and subordinately of sandstone and conglomerate, usually with fairly definite stratification. The slate is generally dark colored, commonly shows distinct slaty cleavage, and in places where shearing has occurred breaks readily into fragments. The sandstone is light gray, and the layers are usually not more than 1 foot thick. The conglomerate consists chiefly of small quartz pebbles but includes some fragments of sandstone and limestone.

The prevailing strike of the rocks of the Galice formation is between N. 30° E. and N. 50° E.; the dips are mostly between 40° and 60° SE., but lower and higher dips are recorded.

In some places numerous quartz veinlets, most of them parallel to the schistosity, are present in these rocks; in other places the quartz veinlets are absent.

Within the Riddle quadrangle recognizable fossils have been found in this formation only on Cow Creek near the mouth of Rattlesnake Creek, a quarter of a mile below Reuben. The collection from that locality contained, according to T. W. Stanton, the following fossils:⁴

Aucella erringtoni.
Ctenostreon ? sp.
Pecten ? sp. (may be a Lima).
Turbo ? sp.
Perisphinctes ? sp.

Rocks containing the striated *Aucella* (*Aucella erringtoni*) are considered by paleontologists to be of Jurassic age.

Although it is not possible to determine the relation of the Galice formation to the Paleozoic rocks in the Riddle quadrangle, the two formations occur in contact in the Kerby region, 30 miles southwest of Grants Pass. In that region, as

² Diller, J. S., and Kay, G. F., Mineral resources of the Grants Pass quadrangle and bordering districts, Oreg.: U. S. Geol. Survey Bull. 380, pp. 50-51, 1909.

³ Diller, J. S., The Mesozoic sediments of southwestern Oregon: Am. Jour. Sci., 4th ser., vol. 23, p. 402, 1907.

⁴ Diller, J. S., The Mesozoic sediments of southwestern Oregon: Am. Jour. Sci., 4th ser., vol. 23, pp. 404-405, 1907.

Riddle.

shown in Figure 5, the Paleozoic rocks overlie the Galice formation, which has been overturned and on which the Paleozoic rocks have been overthrust.

The Galice formation is thought to be equivalent to the Mariposa formation of California.

DOTHAN FORMATION.

The name Dothan formation was first applied to rocks which lie northwest of the type area of Galice formation and which are well exposed west of the Riddle quadrangle in the vicinity of Dothan post office, on Cow Creek. Here continuous exposures may be studied along the railroad for more than 10 miles. The rocks of this type extend into the Riddle quadrangle and cross it in a northeasterly direction. Where they enter the quadrangle the width across the strike is more than 6 miles; but to the northeast they pass beneath a cover of later rocks, so that in the vicinity of Canyonville the width is only a fraction of a mile. From Canyonville northeastward the formation again widens, and beyond Beal Creek it appears to overlap the belt of Galice rocks. Another area of rocks of Dothan age is in the northwestern part of the quadrangle, mainly west of Nickel Mountain.

The Dothan formation consists predominantly of sandstone, but it includes also shale, conglomerate, and chert. The strata are as a rule thin bedded, yet in places beds with a thickness of about 100 feet are found. Most of the rocks are distinctly lithified, and in places they have a schistose structure. Many of the strongly lithified rocks contain veinlets of quartz parallel to the schistosity. Where the sandstone is not strongly lithified it breaks with a somewhat rough surface.

The sandstone is gray and weathers to a yellowish brown. The shale is usually gray to dark gray and is distinctly slaty. The conglomerate occurs in thin beds; the pebbles are predominantly siliceous. The chert occurs in small lentils.

Although diligent search has been made at many places in the rocks of the Dothan formation, few diagnostic fossils have been found. Radiolaria occur in the chert lentils, and at various horizons there are problematic worm tracks and leaf fragments. Apart from these, the only definite fossils from Dothan rocks within the quadrangle were found on O'Shea Creek 1½ miles east of Canyonville and in a small area on Doe Creek and Thompson Creek, northwest of Nickel Mountain, where *Aucella erringtoni* occurs. The same species has been found just west of the quadrangle, near Nichols station, in a

large area of the Dothan formation that extends into the Riddle quadrangle.

The Dothan formation is thought to be equivalent in age to the Franciscan formation of California.

The relation of the Galice formation to the Dothan formation has not been fully established, although they are believed to be unconformable. Between them nearly everywhere except at the east there is a considerable thickness of igneous rocks, a large part of which consists of interbedded volcanic rocks. Near the contact of the Dothan with the main belt of volcanic rocks there are thin sheets of volcanic rock within Dothan sandstone. This feature is well shown on Middle Creek.

Near the northeast corner of the Riddle quadrangle, beyond the volcanic rocks, the Dothan area widens across the strike of the Galice, and this appears to indicate an unconformable overlap of the Dothan upon the Galice.

The Knoxville and Horsetown formations of the Cretaceous system overlap the Dothan formation, and the stratigraphic evidence indicates strongly that the Dothan (Jurassic) is separated from the Cretaceous by a great unconformity.

CRETACEOUS SYSTEM.

The Cretaceous rocks of the Riddle quadrangle include the Knoxville, Horsetown, and Chico formations. The largest area is in the northern portion of the quadrangle, in the valley of South Umpqua River and Cow Creek, but there are two small areas in the southern portion which indicate that a large part if not the whole of the quadrangle was once covered by an unconformably overlapping blanket of Cretaceous rocks that has since been eroded.

KNOXVILLE FORMATION.

Occurrence.—The Knoxville is best exposed along South Umpqua River below the mouth of Cow Creek and also in the hills east and west of Missouri Bottom. It enters the Riddle quadrangle from the Roseburg quadrangle, on the north, and the structure of the mass is synclinal. The formation occurs also in areas farther southwest, along Shoestring Creek and about Jerry Flat, and farther east, on the South Umpqua at the mouth of Days Creek.

Character and relations.—The Knoxville formation consists chiefly of massive conglomerate overlain by sandstone and a smaller amount of shale. In contrast with the rocks of the Dothan formation those of the Knoxville are generally not firmly lithified. However, the degree of lithification alone is not sufficient to differentiate them, for in places the Knoxville formation is as completely lithified as the normal Dothan, and on the other hand the Dothan is locally as free from lithification as the normal Knoxville. The cementing material most common in the rocks of the Knoxville formation is calcium carbonate, but here and there siliceous cement is abundant.

The contact of the Knoxville with the Dothan in the Riddle quadrangle is not well exposed but is believed to be a marked unconformity. This relation is indicated especially by the way the Knoxville overlaps the Dothan about 3 miles south of Riddle.

The Knoxville formation carries a fauna similar to that of the same formation in California, of which *Aucella piochii* and *Aucella crassicolis* (Fig. 6) are characteristic and widely dis-

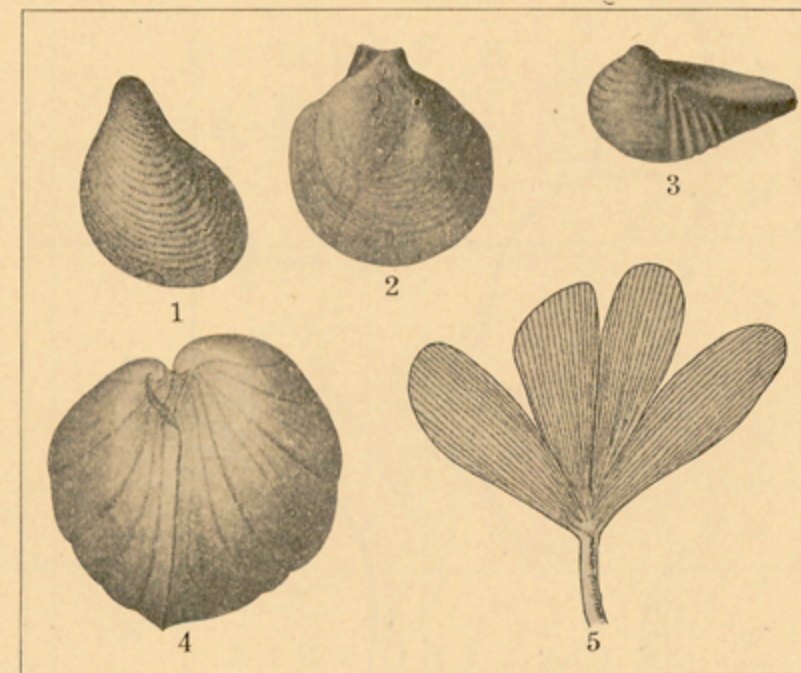


FIGURE 6.—Characteristic Cretaceous and Jurassic (?) fossils from the Riddle quadrangle and vicinity. 1, *Aucella piochii*; 2, *Pecten operculiformis*; 3, *Trigonina aequicostata*; 4, *Aucella crassicolis*; 5, sketch of a *Ginkgo* leaf.

tributed forms. A fossil flora of eight species found in the Knoxville in the vicinity of Riddle has been described by Ward and Fontaine.⁵ It agrees with the fauna in supporting the correlation of the Knoxville rocks of the Riddle quadrangle with the Knoxville of California.

HORSETOWN FORMATION.

The principal areas of the Horsetown formation are in the vicinity of Riddle, where it occupies the greater part of the Cow Creek valley, although covered by alluvium near the stream and overlapped by the Umpqua (Eocene) formation about the southwest end of the valley. The Horsetown formation is well exposed also near Canyonville and in the lower part of the valley of Days Creek.

The Horsetown formation is composed mainly of thin beds of sandstone and shale, and the shale predominates. These soft beds are in places compressed to a vertical position by the pinch within the syncline of the Knoxville formation.

The Horsetown and Knoxville formations appear to be conformable in position but not in extent, for the Horsetown in places overlaps the Knoxville formation and rests on the older rocks.

The fauna of the Horsetown beds of Oregon is not as rich in species as that of the corresponding beds in California, but it contains some characteristic forms, of which *Pecten operculiformis* and *Trigonina aequicostata* (Fig. 6) are among the most common. The fauna indicates that the formation belongs to the upper part of the Lower Cretaceous series.

CHICO FORMATION.

In the Cretaceous period the coast land of southern Oregon and northern California subsided and the ocean advanced upon the continent, so that during the Chico epoch the sea spread much farther inland than during Horsetown and Knoxville time. However, the Chico formation, as the result of erosion in southeastern Oregon is now represented by only a few remnants of the original widespread formation. (See Fig. 7.) In the Riddle quadrangle the remnants of the formations lie on pre-Cretaceous rocks.

The only mappable areas of the Chico formation within the Riddle quadrangle are one that covers nearly 6 square miles in the valley of Grave Creek, about 6 miles above the village of Placer, and another much smaller area near the head of Ditch Creek.

The rocks are chiefly sandstone, with considerable conglomerate at the base and some shale. Compression has tilted the strata in some places to a nearly vertical position, with a strike of N. 30° E.

⁵ Ward, L. F., Fontaine, W. M., and others, Status of the Mesozoic floras of the United States: U. S. Geol. Survey Mon. 48, pp. 221-277, 1905.

Fossils are common and are of types found in the Chico rocks of the Rogue River valley, where *Trigonia* and other characteristic forms are abundant. The Chico is of Upper Cretaceous age.

CENOZOIC ROCKS.

TERTIARY SYSTEM.

UMPQUA FORMATION.

There are three areas of early Tertiary (Eocene) rocks within the Riddle quadrangle—one along Cow Creek, near the northwest corner, and the other two on the edge of Sams Valley, in the southeast corner. They are separated by the broad belt of Paleozoic and Mesozoic rocks that forms the main divide between Rogue River and the South Umpqua.

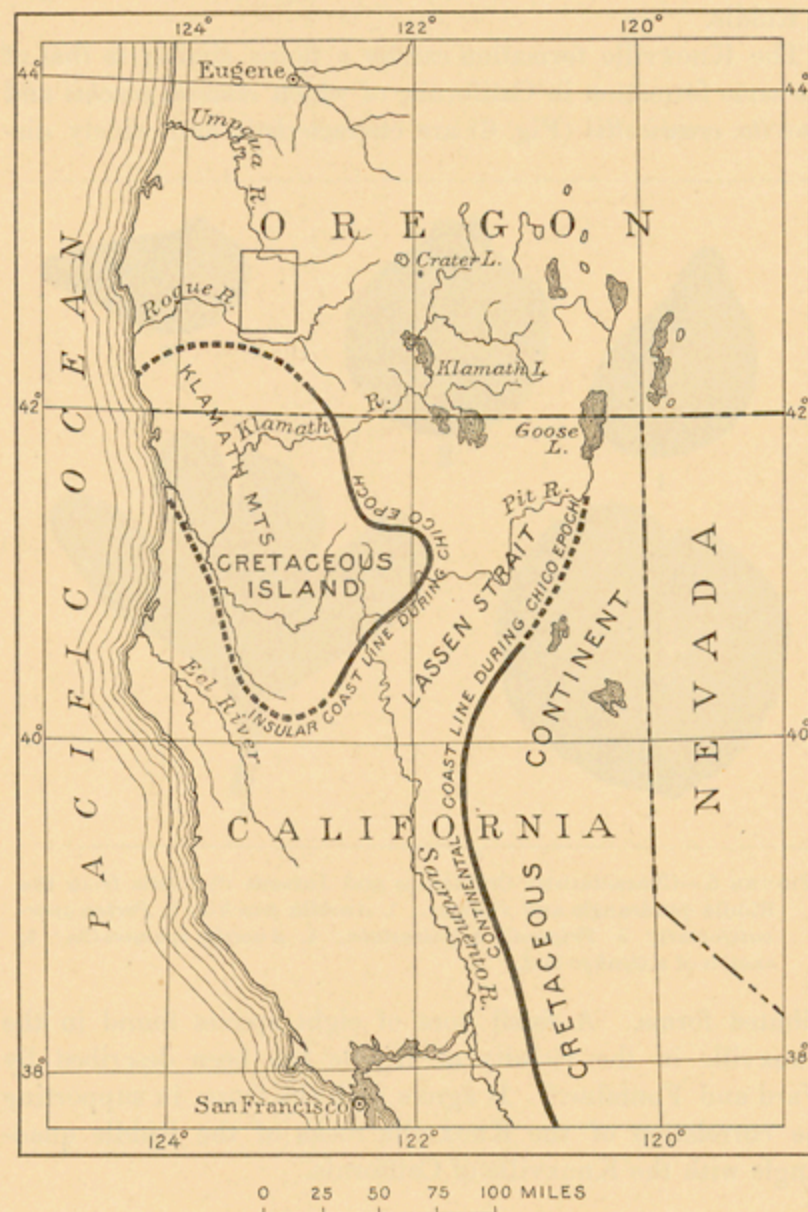


FIGURE 7.—Paleogeographic map of the Klamath Mountain region during the Chico epoch. Riddle quadrangle shown by small rectangle in southwestern Oregon.

On Cow Creek these rocks include shale in places but consist for the most part of soft yellowish sandstone, massive and in some places pebbly, passing into conglomerate. They have a total thickness of about 1,000 feet and form prominent bluffs. The stratification is well preserved and generally horizontal, but dips as high as 30° have been observed. Northwest of the Cow Creek area the Umpqua formation is extensively developed, forming the bulk of the Coast Range, where it contains beds of coal and is closely related to the Eocene coal-bearing strata about Coos Bay.

On Cow Creek the beds contain numerous Eocene marine fossils, among which *Cardita planicosta* and *Turritella uasana* (Fig. 8) are characteristic forms.

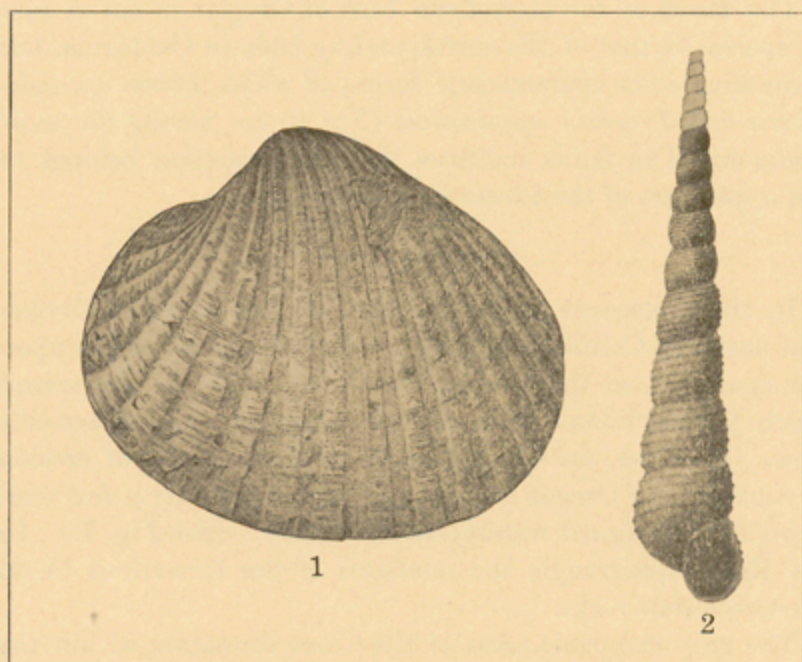


FIGURE 8.—Characteristic Eocene fossils from the Riddle quadrangle. 1, *Cardita planicosta*; 2, *Turritella uasana*.

In the Sams Valley areas, at the southeast corner of the Riddle quadrangle, the Eocene rocks comprise shale and sandstone. In some places the shale is carbonaceous and contains traces of coal, which farther southeast, along the border of the Rogue River valley, become more abundant. The general dip of the formation is easterly, beneath the lavas of the Cascade Range.

The only fossils that have been found in the Eocene strata of the Rogue River valley consist of leaves and wood.⁶ The complete absence of marine shells indicates that the leaf beds are of fresh-water origin and were separated from the ocean by the northeast spur of the Klamath Mountains.

QUATERNARY SYSTEM.

HIGH TERRACE GRAVEL.

Nearly 2 miles southeast and south of Riddle there are three areas of gravel on the summits of the flat-topped hills between Cow Creek and South Umpqua River, about 500 feet above the stream level. This gravel contains pebbles of lava from the Cascade Range and was deposited mainly by the South Umpqua when the bed of that stream was about 500 feet above its present level.

ALLUVIUM.

Since the high gravel was deposited South Umpqua River and Cow Creek have cut down their beds about 500 feet. The streams have much gentler grades at the present time than formerly and consequently are depositing finer material. They are now widening their flood plains, especially in the softer rocks, and giving to the Riddle quadrangle the arable land that is so valuable for human industry.

IGNEOUS ROCKS.⁷

The igneous rocks of the Riddle quadrangle are of several kinds and differ somewhat widely in age. They occur in irregular-shaped areas and in dikes. Some are intrusive, others show undoubted effusive characteristics. In the field the chief types were mapped as basalt, dacite porphyry, quartz diorite, serpentine, peridotite, and greenstone. A detailed office study of the microscopic and chemical features of these rocks has permitted a greater refinement of classification than was possible in the field and has revealed many interesting facts with regard to the variations within each group and the relations of the groups to one another.

RELATIVE AGE OF THE IGNEOUS ROCKS.

The oldest igneous rocks of the quadrangle are the ancient rhyolite and related rocks associated with the Paleozoic sediments of the May Creek formation. Some of the greenstone lavas and possibly some of the intrusive greenstones may also be of Paleozoic age. Next younger are the basaltic lavas, included on the geologic map in the greenstones, and rhyolitic lavas, of Jurassic age. Of the intrusive rocks, the intrusive phases of the greenstone are the oldest, then come in turn the peridotite, the quartz diorite, the dacite porphyry, and finally the basalt, which cuts the greenstones, the quartz diorite, and the Horsetown formation, of Cretaceous age. All the intrusive rocks, except the basalt and the possibly Paleozoic greenstones mentioned above, appear to be of late Jurassic or early Cretaceous age. The basalt is probably related to the volcanic rocks of the Cascade Range and if so is of Tertiary age.

ANCIENT RHYOLITE AND RELATED ROCKS.

Associated with the May Creek formation, which is of Paleozoic age, are highly altered siliceous igneous rocks, probably metarhyolite. Some of them contain both hornblende and mica and are well exposed along the Evans Creek road east and west of Bybee Springs.

GREENSTONE.

TYPES.

There are many irregular bodies of greenstone widely distributed in the Riddle quadrangle, and together they occupy a much larger area than any other rocks.

The general name greenstone was applied in the field to igneous rocks of more or less greenish color which are in many places so greatly altered that they are unsatisfactory for microscopic study. These rocks are so closely associated in the field that it was practically impossible to map them separately. The normal type is a gabbro consisting essentially of pyroxene and a lime-soda variety of plagioclase, but under this designation were included not only granular igneous rocks closely related to the gabbro, such as diorite and diabase, exposed chiefly in the southern half of the quadrangle, all of which appear to be intrusive, but fine-grained, compact basaltic rocks, which in many places, particularly in the northern half of the quadrangle, are notably vesicular and which are locally closely associated with volcanic breccias and other fragmental igneous rocks. In the west-central part of the quadrangle there are a few somewhat lens-shaped areas of rhyolite. All these rocks show evidence of extensive crushing and veining.

GABBRO AND RELATED ROCKS OF PLACER-WINONA AREA.

General character.—A typical greenish-gray gabbro made up where unaltered of about equal parts of augite and plagioclase is the chief rock of the area around Placer and Winona, but

⁶ Diller, J. S., Guidebook of the western United States, Part D, The Shasta Route and Coast Line: U. S. Geol. Survey Bull. 614, p. 57, 1915.
⁷ The account of the igneous rocks has had the benefit of critical revision by E. S. Larsen.

this area includes several other kinds of intrusive rock that are thought to be related to the gabbro both genetically and in time of eruption. In some places the gabbro is coarser than usual and contains considerably more feldspar than pyroxene. In others the fabric is distinctly ophitic, and on the south slope of Sexton Mountain and elsewhere primary hornblende is the chief dark mineral and the rock is a hornblende gabbro.

Petrographic detail.—In the typical gabbro from Eastman Gulch the grains are about 1 millimeter in diameter and the essential minerals are a pyroxene, probably diopside, and a highly calcic feldspar; the secondary minerals are hornblende, chlorite, kaolinite, zoisite, and pyrite. The hornblende gabbro from the south slope of Sexton Mountain differs from the normal gabbro chiefly in having primary hornblende as the principal dark mineral.

Most of the gabbro shows considerable alteration; zoisite and kaolinite are derived from the plagioclase; calcite and titanite from the dark minerals. In the hornblende gabbro there is considerable chlorite and magnetite.

In certain parts of this area the close association of irregular masses of serpentine with the gabbro strongly suggests that there are more basic phases of gabbro than those already mentioned, including olivine gabbro and possibly peridotite and pyroxenite. However, as will be shown later, much of the serpentine of this area, as well as of other areas in this quadrangle, has come from peridotite and related rocks that are clearly intrusive in the gabbro and hence is younger than the gabbro.

A chemical analysis of the normal gabbro from Eastman Gulch is shown in column 1 of the accompanying table, and an analysis of the hornblende gabbro from Sexton Mountain in column 2. Chemically the two rocks are very similar, though there is more ferrous iron and correspondingly less magnesia and more titanium in the hornblende gabbro; the higher water content of the pyroxene rock is probably due to partial alteration.

Analyses of greenstones from Riddle quadrangle.

[George Steiger, analyst.]

	1	2	3	4
SiO ₂	45.86	46.36	50.90	52.58
Al ₂ O ₃	15.52	16.88	16.71	15.58
Fe ₂ O ₃	1.84	2.23	.40	2.07
FeO.....	3.22	6.29	8.50	8.68
MgO.....	11.71	8.15	5.14	5.75
CaO.....	15.57	15.66	9.74	10.37
Na ₂ O.....	.86	1.17	3.50	1.79
K ₂ O.....	.12	.10	.60	.82
H ₂ O.....	1.38	.21	.03	.22
H ₂ O+.....	3.70	1.48	2.12	3.13
TiO ₂.....	.22	1.29	1.80	.89
S.....	.06	.01		
MnO.....	.07	.10	.13	.15
CO ₂.....			.51	.22
P ₂ O ₅.....			.07	.09
BaO.....			.02	.03
	100.13	99.93	100.17	100.37

1. Normal gabbro from Eastman Gulch.
2. Hornblende gabbro from Sexton Peak.
3. Ophitic gabbro from sec. 2, T. 30 S., R. 6 W.
4. Basaltic greenstone from sec. 23, T. 31 S., R. 6 W., near Silver Butte.

GABBROIC ROCKS IN THE NORTHWESTERN PART OF THE QUADRANGLE.

The gabbroic rocks of the northwestern part of the quadrangle are best studied in the valleys of Judd Creek and Thompson Creek. They include normal gabbro, hornblende gabbro, ophitic gabbro, and intermediate rocks, all of which are closely related. Some fine-textured rocks of this area are believed to be older lava flows.

In many places the augite has been altered to hornblende, and it is not always possible to distinguish between this secondary hornblende and primary hornblende. The ophitic gabbro is perhaps the prevalent rock of this area.

A specimen of ophitic gabbro from sec. 2, T. 30 S., R. 6 W., is a light to dark gray rock with grains 1 millimeter in diameter. The rock is considerably altered. It is made up chiefly of labradorite and augite in about equal amounts and contains secondary hornblende, chlorite, zoisite, kaolinite, and magnetite.

A chemical analysis of this rock is shown in column 3 of the table. As compared with the two gabbros from the Placer-Winona area it carries somewhat more silica, less magnesia, much less calcium, and more sodium.

DIORITIC GREENSTONE NORTH OF SOUTH UMPQUA RIVER AND DAYS CREEK.

A considerable part of the greenstone area north of South Umpqua River and Days Creek has somewhat gentle slopes covered with soil and vegetation. The rock outcrops are therefore comparatively few, and it is somewhat difficult to procure specimens that are satisfactory for study. The rocks are more siliceous than those of the two areas already described. The area contains much quartz diorite, but it could not be mapped separately. Diorite is found also, and in a few places

the rocks contain considerable alkali feldspar. Locally biotite is present as one of the ferromagnesian constituents. In many respects these rocks show relationship to the quartz diorite and related rocks described below.

Some fairly fresh quartz diorite was taken from the bed of Morgan Creek about 2 miles above its junction with South Umpqua River. This rock is made up of grains 1 millimeter in diameter and contains plagioclase of the composition andesine-labradorite as the chief mineral. Green hornblende is abundant, and quartz less so. Accessory apatite and magnetite and secondary kaolin and chlorite are present.

FINE-GRAINED EFFUSIVE BASALTIC GREENSTONES.

Most of the fine-grained greenstones are effusive rocks, which lie between the Galice and Dothan formations or are interbedded with the Galice formation or with the rocks of the lower part of the Dothan formation. Some of them may be of Paleozoic age. They attain their best development in a belt that is in places more than 6 miles wide and that extends in a southwesterly direction from Beal Creek, on the north, to and beyond the limits of the quadrangle. Within this belt rise several prominent peaks, among which are Canyon Mountain, Tellurium Peak, Silver Butte, Buckhorn Mountain, Grayback, and Panther Butte.

The characteristics of the rocks are well seen near the head of Middle Creek, in the valley of the West Fork of Canyon Creek, in the valley of Wolf Creek below Wolf Creek station, and along the trails that cross these valleys. Most of the rocks are of a greenish color and weather to grayish soil. Perhaps the most prevalent variety is a fine-grained aphanitic rock to which the name basalt has been given.

Phenocrysts of augite and plagioclase, from 1 to 3 millimeters across, make up nearly half the rock. In most specimens augite is somewhat more abundant than feldspar, but in some it is less abundant. The feldspar is commonly too much decomposed for accurate determination, but in some specimens it is clearly andesine. The chemical analyses indicate a much more calcic feldspar, and the decomposition has reduced the lime content. The groundmass is too much altered by saussurization for definite determination, but it was probably made up originally of augite and feldspar. Extensive alteration has developed from the feldspar much kaolin, some zoisite, and a small amount of quartz. The augite is less altered and has yielded chlorite and iron oxide.

A chemical analysis of this basalt is given in column 4 of the table. Its composition is rather near that of the ophitic gabbro (analysis 3), but the basalt contains a little more silica and considerably less soda.

In the field many of the basalts and related rocks exhibit a more porphyritic facies than that described above. Some of the rocks are distinctly amygdaloidal, many of the vesicles having been filled with quartz, calcite, and epidote. In some parts of the area there are clearly fragmental rocks—volcanic tuffs, breccias, and agglomerates, the pyroclastic products of volcanism. When these rocks are viewed in the field in large masses they give in places a strong suggestion of the sheeted structure characteristic of eruptive rocks. Especially near the contacts of the volcanic rocks with the Dothan and Galice formations, the basalt has been profoundly sheared, and the shearing has resulted in schistose slaty igneous rocks that are chloritic, talcose, or strongly sericitized. Such rocks closely resemble slate of sedimentary origin.

In addition to the main area of basalt and related rocks described above, there are interbedded with the rocks of the Galice formation smaller bodies of igneous rocks that are thought to be closely related genetically to the basalt. Three fairly large areas may be mentioned, as follows:

1. A somewhat irregular-shaped band of igneous rock extending from the vicinity of Grave, on Grave Creek, northward to Galesville, on Cow Creek, and beyond to Shively Creek.

2. A band more than a mile in average width, extending from the vicinity of Green Mountain to and a short distance beyond Perdue.

3. An area extending southwest and northeast from Bland Mountain.

Many of these rocks are notably schistose, and associated with them are rocks of varying texture that are undoubtedly intrusive. These intrusive rocks where they are schistose are difficult to differentiate from the effusive rocks.

In addition to the physical variations, there are chemical variations in the effusive rocks. The basalt lying between the Dothan and Galice formations, here mapped as greenstone, is in places dacitic, being more siliceous than the normal phase.

RHYOLITE.

Within the area of basaltic and dacitic greenstones are bands of reddish or pinkish rocks that have the characteristics of rhyolite. The largest of these bands of rhyolite extends about 12 miles northeastward from the vicinity of Glendale. Microscopic study of this rhyolite shows that it contains considerable alkali feldspar and quartz. Some of these rocks within 5 miles

northeast of Glendale are much altered and have been mapped as metarhyolite, but they are probably much younger than the metarhyolite associated with the May Creek formation.

SERPENTINE, PERIDOTITE, AND SAXONITE.

Peridotite is a basic intrusive rock whose chief constituent, olivine, is altered readily by hydrothermal action to serpentine. Peridotite and serpentine are therefore so intimately related in the field that it is not practicable to separate them in areal mapping.

Within the Riddle quadrangle there are several areas of peridotite or its alteration product, serpentine. Among these the largest are an area that extends for several miles northeast and southwest from Nickel Mountain and a very irregular-shaped area that extends for several miles southwest from the vicinity of Cedar Springs Mountain. Several other irregular-shaped masses are indicated on the map.

The largest area of unaltered or slightly altered peridotite in the quadrangle is in the vicinity of Nickel Mountain. It should be stated, however, that in intimate association with the freshest rocks there are not only altered rocks that have passed to the serpentine stage, but the serpentines themselves have been weathered to iron oxides and quartz and in some places to hydrous nickel magnesian silicates. This feature is discussed more fully in connection with the ore deposits.

The Nickel Mountain peridotite, where unaltered, is a compact, homogeneous, granular rock of dark yellowish-green color, vitreous luster, and high specific gravity. The predominant mineral, olivine, is vitreous and has no distinct cleavage, but a less abundant mineral, enstatite, has shiny cleavage faces and a bronzelike luster. A few scattered grains of metallic mineral are present. The rock breaks with an irregular fracture. The essential minerals are olivine and enstatite; the accessory minerals are magnetite and chromite; the secondary minerals are serpentine and ferric oxides in small amounts. Olivine is much in excess of enstatite, the proportions in some sections being more than 3 to 1. The olivine crystals average about 0.5 millimeter in diameter, but some measure more than 2 millimeters. Some of the enstatite crystals have diameters of 4 millimeters. An inclusion of olivine in the enstatite here and there indicates that the enstatite crystallized later than the olivine. Magnetite and chromite are present in small quantities; the magnetite is bluish black, and the chromite a coffee-brown color with reflected light. The rock is saxonite; locally it approaches dunite.⁸

Chemical analysis of peridotite from Nickel Mountain.

Loss on ignition	4.41
SiO ₂	41.43
Al ₂ O ₃	.04
Cr ₂ O ₃	.76
Fe ₂ O ₃	2.52
FeO	6.25
NiO	.10
CaO	.55
MgO	43.74
	99.80

The serpentine associated with the peridotite and derived from it decomposes to reddish soil, on which as a rule vegetation is scanty. In places the slopes of the serpentine are somewhat even, but many of the weathered surfaces are rough and jointed. The serpentine when broken exhibits shiny slickensided surfaces. The rock is compact, is of dark yellowish-green color, and has a dull to waxy luster. Distinct veinlets of chrysotile, many of which are about 1 millimeter in width, traverse the rock without definite arrangement. The chief mineral is serpentine, in felted aggregates. Where both the olivine and the enstatite have been serpentinized completely, those parts of the rock that have been derived from the olivine have a mesh structure, but those derived from the enstatite have a lamellar or bastite structure. Locally there are somewhat large deposits of magnetite and chromite resulting from the differentiation of the peridotite magma.

Outside the Nickel Mountain area fresh peridotite was not found, but only its secondary product, serpentine. However, thin sections of rocks from many parts of the serpentine areas show remnants of olivine and enstatite. Moreover, some marked variations from the typical peridotite or saxonite were found. For instance, some of the peridotite is a lherzolite, the orthorhombic pyroxene being accompanied by small amounts of monoclinic pyroxene, diallage. Again, some of the rock contains only olivine and diallage and is thus a wehrlite; or the rock consists wholly of diallage and is a pyroxenite. Locally the decomposition of the diallage has resulted in the development of secondary hornblende, actinolite, or chlorite in addition to the serpentine. Near Red Mountain and in the vicinity of Devils Creek, a tributary of Cow Creek, in the east-central part of the quadrangle, talc is present with the serpentine, in some places in sufficient quantity to produce a talc schist. The talc was found only in those areas in which the basic rocks from which the serpentine has been derived had been intruded by siliceous igneous rocks.

QUARTZ DIORITE AND RELATED ROCKS.

The Riddle quadrangle contains several fairly large irregular-shaped areas of intrusive quartz diorite or related rocks, and similar rocks, though usually somewhat finer grained, are found in dikes. The largest areas of rocks mapped as quartz diorite include one in the eastern part of the quadrangle extending several miles north and south from the divide which separates the drainage of South Umpqua River from that of Rogue River; an area of several square miles in the vicinity of Wimer on Evans Creek; an area within which are the villages of Hugo and Merlin; and a much smaller area northeast of Perdue.

Microscopic study shows that the most prevalent type of rock in these areas is a quartz-mica diorite. In many places very little orthoclase feldspar accompanies the plagioclase. However, in some places—for example, in the Hugo-Merlin area—orthoclase is present with the plagioclase in sufficient quantity to justify the name granodiorite.

A specimen of quartz-mica diorite from sec. 26, T. 30 S., R. 3 W., in the Perdue area, is a compact dark-gray rock with grains 1 millimeter in diameter. Andesine feldspar in laths is the most abundant mineral. Orthoclase was not observed. Quartz is subordinate to the feldspar and is interstitial. Biotite and green hornblende are present in about equal amount, and together they comprise considerably less than half the rock. Apatite and magnetite are accessory, and kaolin, chlorite, and epidote are secondary. An analysis of the quartz-mica diorite is given in column 1 of the following table.

Chemical analyses of quartz diorite and related rocks from Riddle quadrangle.

	1	2	3	4
SiO ₂	58.25	57.87	57.06	70.65
Al ₂ O ₃	20.52	16.76	8.50	15.57
Fe ₂ O ₃	.68	2.21	1.11	.57
FeO	3.88	4.60	5.40	1.26
MgO	2.03	3.29	11.19	.48
CaO	7.88	6.23	12.04	3.28
Na ₂ O	4.25	4.07	1.39	4.91
K ₂ O	.50	2.17	.95	1.77
H ₂ O	.24	.32	.18	.14
H ₂ O+	1.10	.91	1.25	.86
TiO ₂	.57	1.21	.52	.21
ZrO ₂	.01	.02		.01
P ₂ O ₅	.16	.34	.05	.07
MnO	.10	.09	.13	.06
BaO		.02		.06
FeS ₂		.23		
	100.17	100.34	99.77	99.97

1. Normal quartz-mica diorite from sec. 26, T. 30 S., R. 3 W. George Steiger, analyst.

2. Quartz diorite, near granodiorite, from sec. 24, T. 35 S., R. 6 W. R. C. Wells, analyst.

3. Quartz gabbro from Evans Creek, near the mouth of Sykes Creek. George Steiger, analyst.

4. Dacite porphyry from sec. 5, T. 30 S., R. 6 W. George Steiger, analyst.

A specimen approaching a granodiorite in composition from sec. 24, T. 35 S., R. 6 W., is a dark-gray rock, consisting of grains 1 millimeter in diameter, in which feldspar is the most abundant constituent and oligoclase-andesine is more abundant than orthoclase. Quartz is subordinate to the feldspar and is interstitial. Biotite and hornblende are present in about equal amounts. Apatite, magnetite, and titanite are accessory, and kaolin and epidote are secondary. A chemical analysis of this quartz diorite is shown in column 2 of the table. It differs from the typical quartz diorite chiefly in its higher content of potash.

Rocks of several other kinds are so closely associated in the field with the quartz diorite that they are undoubtedly differentiations from the same magma. They are not limited in their occurrence to the large intrusive areas, but some of them are found in dikes. Biotite and hornblende are not invariably present in these rocks; the hornblende is absent more commonly. With the biotite and hornblende there may also be muscovite. Rock that contains muscovite and quartz with feldspar of which much is orthoclase is muscovite granite. Much rock of this type contains garnet, and here and there graphic fabric is seen.

There are at a few places in the quadrangle rocks mapped with the quartz diorite in which the ferromagnesian constituents exceed the light-colored constituents. Such rocks are seen near the mouth of Sykes Creek, about 2 miles above Wimer. Here, within a comparatively small area, both dark and light colored rocks occur. In fact, in some places within an area of a few square feet may be found rocks containing but small quantities of ferromagnesian constituents and rocks consisting almost wholly of ferromagnesian minerals. In some localities the dominant ferromagnesian mineral is pyroxene, and the rock approaches a pyroxenite; in others the ferromagnesian constituent is hornblende, and the rock approaches a hornblende. Beautiful crystals of hornblende more than 2 inches in length were observed. Dikes of light-colored rocks cut both light rocks and dark rocks. A specimen that was thought to be somewhat intermediate in character, taken near

⁸ Clarke, F. W., Am. Jour. Sci., 3d ser., vol. 35, p. 485, 1888.

the mouth of Sykes Creek, was found to contain pyroxene, quartz, plagioclase, and a small amount of orthoclase and is a quartz gabbro. An analysis of this rock is given in column 3 of the foregoing table. This rock is much lower in alumina, somewhat higher in iron, much higher in magnesia, considerably higher in lime, and lower in soda than the normal quartz-mica diorite.

Some of the dikes are pegmatitic, and in these the constituents vary widely. Some dikes contain only coarse quartz with a little feldspar. Others contain quartz, muscovite, and feldspar, all coarsely crystallized; in a few dikes quartz, feldspar, and beautiful crystals of dark hornblende were seen.

DACITE PORPHYRY AND RELATED DIKE ROCKS.

Dacite porphyry is found only in small irregular-shaped, knoblike masses and in dikes. It is closely related to the dominantly feldspathic phases of the quartz diorite. Another kind of dike rock, which occurs much more rarely, is considerably more ferromagnesian than the dacite porphyry. It has the characteristics of camptonite and is thought to be related to the ferromagnesian phases of the quartz diorite.

Much of the dacite porphyry is porphyritic, but in places it is fine-grained and has the appearance of quartzite. Both phases are dominantly feldspathic, the only ferromagnesian constituents consisting, as a rule, of a few frayed crystals of hornblende or, more rarely, of biotite.

A specimen of dacite porphyry taken from a dike cutting serpentine in sec. 5, T. 30 S., R. 6 W., is a compact rock showing phenocrysts of feldspar and quartz in a light-colored aphanitic groundmass. The phenocrysts make up nearly half the rock. The feldspar phenocrysts are chiefly plagioclase, more calcic than oligoclase, but a small amount of orthoclase is also present. The plagioclase is considerably decomposed. The quartz phenocrysts, which are less abundant than those of feldspar, have a maximum diameter of about 3 millimeters. Their outlines are very irregular and show corrosion. No ferromagnesian minerals are present. The groundmass, which is somewhat porphyritic, also consists mainly of plagioclase and quartz in grains averaging 0.1 millimeter in diameter. Apatite occurs in small prisms. The chief secondary minerals are kaolin, epidote, zoisite, and a small amount of magnetite. An analysis of this dacite porphyry is given in column 4 of the table above. As compared with the granodiorite, the dacite carries more silica, less lime, and more potash.

BASALT.

Basalt is found in narrow dikes and is the youngest igneous rock of the region. It is probably of Tertiary age. Only a few dikes of this rock were found, and these were limited to the eastern half of the quadrangle.

The characteristics of this rock are well shown in a specimen taken from a dike 20 feet wide cutting Cretaceous shale on South Umpqua River just below the mouth of Days Creek. The rock is compact and dark gray, has a dull luster, and contains a few inconspicuous crystals of a dark-greenish mineral. It is holocrystalline, and the minerals present are plagioclase, augite, and magnetite. The plagioclase consists of very narrow lath-shaped crystals, some of which have a length of more than 0.4 millimeter. It is apparently labradorite or a somewhat more calcic variety. The augite is almost colorless, and the prismatic euhedral to subhedral crystals range in size from a very small fraction of a millimeter to about 0.3 millimeter. The larger crystals give the rock a somewhat porphyritic aspect. The magnetite occurs as irregular-shaped grains somewhat uniformly distributed. The chemical composition of this rock is shown in the following analysis:

Chemical analysis of basalt from a dike below the mouth of Days Creek.

SiO ₂	50.01	H ₂ O	2.61
Al ₂ O ₃	15.25	H ₂ O+	1.35
Fe ₂ O ₃	2.72	TiO ₂ .....	.68
FeO	5.35	P ₂ O ₅ .....	.63
MgO	9.35	MnO .....	.12
CaO	10.44		
Na ₂ O	1.50		100.01
K ₂ O .....	.60		

EFFECT OF THE INTRUSIVE IGNEOUS ROCKS UPON THE INTRUDED ROCKS.

The oldest intrusives, the gabbro and related rocks, appear to have produced no distinct changes in the rocks penetrated by them. For instance, the slate in immediate contact with the greenstone is not noticeably different from the slate at some distance from the contact.

The peridotite in the Nickel Mountain region, where it intrudes the greenstone, produced somewhat distinct schistosity in the greenstone parallel to the contact.

The granodiorite produced much greater changes than any of the other intrusive rocks. Where large masses of this rock intruded greenstone, the greenstone is changed, as a rule, to hornblende schist. This alteration is perhaps seen best in the area that lies between the Wimer area of granodiorite and the much larger area of granodiorite to the northeast. The hornblende schist is also well developed as inclusions in the granodiorite in the Red Mountain region and elsewhere.

Where the metamorphism was more intense mica is developed in the hornblende schist. In the vicinity of Red Mountain the hornblende schist in intimate contact with granodiorite contains garnet, some well-formed crystals of which exceed half an inch in diameter. The granodiorite was equally effective in changing the slate. In certain areas hornfels is the result of the metamorphism, and in places perfect cubes of pyrite are developed in the slate. Where more intense changes have occurred, staurolite and chiastolite are found in the slate. In places the chiastolite crystals reach a length of nearly an inch. Elsewhere the resultant rock is a distinct mica schist in which, as a rule, garnet is found. Locally, where the granodiorite has intruded peridotite or its resultant rock, serpentine, talc has been developed.

The basalt produced but little change in the rocks it intruded. Near the mouth of Days Creek the intruded shale was somewhat hardened.

STRUCTURE OF THE REGION.

In all rocks of the region older than the Cretaceous the prevalent strike is northeast, parallel to the trend of the rock belts. Most of the dips are southeast. These facts alone would suggest that the oldest strata should be found in the northwestern part of the quadrangle, and successively younger rocks should be found toward the southeast. From the evidence presented in the structure sections and in Figure 5 it has been seen that the reverse is true. The oldest rocks (the Paleozoic strata) are in the southeastern part of the quadrangle; younger rocks (Jurassic and Cretaceous) are in the northwest. To account for this apparent reversal of the natural order, it is necessary to assume that repeated folding and overturning of the strata or faulting has caused the older rocks, either actually or apparently, to overlie the younger rocks. As has been stated by Diller,⁹ it is probable that both folding and faulting have contributed to the complex structure of this and adjacent regions, and with present knowledge it is difficult to state which of these processes has played the more important part. Perhaps the evidence most suggestive of faulting is found at the contact between Dothan sandstone and volcanic rocks, along which an apparent scarp extends for many miles. The stresses to which the igneous rocks have been subjected have produced a distinct slaty structure, and in places the resulting rocks closely resemble altered sediments.

GEOLOGIC HISTORY.

PROTEROZOIC (?) ERA.

The geologic history recorded in the terranes of the Riddle quadrangle should be prefaced by a statement concerning earlier events recorded in other portions of the Klamath Mountains, where there are exposed a series of schists, for the most part mica schists, containing small lenticular masses of crystalline limestone derived by regional metamorphism from sedimentary rocks. No traces of fossils have been found in these schists. They are older than the Devonian and give evidence not only of long-continued and extensive sedimentation but also of an epoch of metamorphism which preceded any of the events recorded in the Riddle quadrangle and which suggests that they may belong to the Proterozoic era.

PALEOZOIC ERA.

The earliest events recorded in the rocks of the Riddle quadrangle occurred in the Paleozoic era and included both the deposition of fine sediments and the eruption of siliceous lavas. The sediments have been metamorphosed into mica slate and schist. The ocean covered the Klamath Mountain region during much of the Paleozoic era, and lenticular masses of limestone that now contain traces of Devonian and Carboniferous fossils were formed among the other sediments. The bulk of the Paleozoic record, however, marks a time of profound volcanism, both explosive and effusive and at least in part submarine.

The Paleozoic era was long, and the Klamath Mountain region may have been dry land part of the time, especially about the end of the Devonian period and the beginning of the Carboniferous, but the fact that the Paleozoic sediments are all fine and not of shallow-water origin suggests that the region was beneath the sea during most if not the entire era.

MESOZOIC ERA.

JURASSIC PERIOD.

From the end of the Paleozoic through the Triassic period and well on into the Jurassic the Klamath Mountains, except the southeastern portion, appear to have been dry land and received, so far as yet known, no marine deposits.

Later in Jurassic time the sea returned and swept northeastward across the land. The residual waste of the land surface furnished a large amount of fine sediment and sand with residual fragments of quartz to make up fine conglomerates, such as are found in the Galice and Dothan formations.

⁹ Diller, J. S., and Kay, G. F., Mineral resources of the Grants Pass quadrangle and bordering districts, Oreg.: U. S. Geol. Survey Bull. 380, p. 54, 1909.

Between these formations there is a great mass of volcanic rocks, basalt and rhyolite, and the basalt is largely changed to greenstone. This basalt is very similar to the great flows of lava poured out so copiously in the Klamath Mountain region during the Paleozoic era. During the later portion of the Dothan epoch Radiolaria became an especially abundant form of life in the sea, and the cherty deposits formed of their siliceous tests constitute a prominent feature of the late Jurassic sediments.

Near the end of the Jurassic period came one of the great mountain-building epochs of the Pacific coast province of the United States. The rocks were greatly folded, faulted and crushed, and uplifted, so that the Sierra Nevada and the Klamath Mountains attained much greater altitude and extent than they had before. These ranges probably extended northward beyond the present coast line and occupied a portion of what is now the Pacific Ocean.

The intense dynamic action that uplifted the mountains was accompanied by vigorous igneous intrusion, for all the beds older than the Cretaceous are intersected by batholiths or dikes of granitic, porphyritic, and aphanitic rocks, which must have intruded them before the deposition of the Cretaceous sediments of that region, either in late Jurassic or early Cretaceous time.

CRETACEOUS PERIOD.

When the epoch of mountain building and igneous activity ended the Pacific coast of northern California was farther west than it is now. The land then began to subside, and the subsidence continued more or less irregularly throughout the Knoxville, Horsetown, and Chico epochs. The sea advanced, with interruptions, upon the land, depositing with marked unconformity a blanket of Cretaceous sediments on the older rocks, until toward the end of Cretaceous time the waves of the ocean beat against the western base of the Sierra Nevada in California and of the Blue Mountains in Oregon. That the Klamath Mountains were chiefly if not entirely covered by the advancing Cretaceous sea is indicated by the fact that not only are they practically surrounded by Cretaceous sediments but isolated patches of Cretaceous strata occur at a number of points in these mountains—for example, at the head of Trinity River in California and about Waldo and on Grave Creek in Oregon. The evidence is thus conclusive that a large part if not the whole of this region, including the Riddle quadrangle, was beneath the sea at the end of the Cretaceous subsidence.

The same thing is true also of the foundations of the Cascade Range, and the fineness of the later Cretaceous sediments in the Sacramento Valley indicates that the Sierra Nevada region was reduced by long-continued erosion to an area of low relief. The planation was even greater in the Klamath Mountain region, which was swept by the ocean waves.

At the end of the Cretaceous period the Klamath Mountains were again uplifted and the Cretaceous strata were for the most part broadly folded. This uplift formed the Onion Springs Mountain divide between the drainage basins of South Umpqua River and Rogue River in the Riddle quadrangle.

CENOZOIC ERA.

At the beginning of Tertiary time the Klamath Mountains were above the sea, and they have remained above ever since. During the Tertiary period and the Pleistocene epoch of the Quaternary period there were many oscillations of the land alternating with long or short epochs of comparative stability. These movements are registered partly in the distribution of formations but mainly in the topographic forms sculptured by erosion.

During early Tertiary time the Onion Springs Mountain divide formed the barrier between the ocean waters of the South Umpqua River region, where thick deposits of marine sediments were laid down, and the lacustrine waters of the Rogue River valley, where with other sediments carbonaceous deposits that later became coal beds accumulated.

As a result of the long-continued erosion during the Eocene epoch the blanket of Cretaceous strata was largely removed. The uplands of the Klamath Mountain region were washed away, and the country was reduced nearly to sea level, to a plain of low relief, the Klamath peneplain. The succeeding long epoch of low relief and slight erosion permitted the deep decay of the rocks and the liberation of their gold-bearing quartz veins to furnish material for the earliest auriferous gravel of the Klamath peneplain.

Near the end of Eocene time there was a disturbance which folded the strata more or less and uplifted the country slightly before the deposition of the Miocene sediments. No marine Miocene strata occur within or near the Riddle quadrangle. As a result of the uplift the streams at first cut shallow canyon-like valleys, but these widened to gentler slopes up to the Klamath peneplain. These earlier valleys received much of the waste that had accumulated by erosion on the Klamath peneplain, and thus were formed the earlier gravel deposits in these valleys as well as upon the peneplain itself.

Gradual uplift by faulting of the Klamath Mountains athwart the major stream courses ensued at intervals during the Tertiary period, but the vigorous streams were able to cut down their beds as rapidly as the land rose and thus maintained the antecedent drainage directly across the ranges to the ocean.

The remnants of the Klamath peneplain are the oldest topographic features of the Klamath Mountains. They are scarcely discernible in the Riddle quadrangle but are distinct to the southwest, between Waldo and the coast. All the rest of the surface is younger and has been carved out by the present streams.

The great uplift of the Klamath Mountains in middle Tertiary and later time rejuvenated the streams and enabled them to cut down later valleys from the beds of the earlier valleys, many hundreds and in some places even thousands of feet below the peneplain level. As the uplift was irregular, with stable intervals, so was the erosion. There were pauses in the downward cutting, and the streams widened not only the earlier valleys, as already noted, but also the later valleys. Where the rocks are hard and the erosion relatively slow, as along Rogue River below the southwest corner of the Riddle quadrangle, the valleys are narrow and canyon-like, but where the rocks are soft, as in the areas of Cretaceous shale along the South Umpqua and about Riddle and along Rogue River in the Medford region, the valleys are wide.

About Grants Pass and in Pleasant Valley there are apparent but not real exceptions to this rule. The rock of the region is granitic and at a considerable distance below the surface it is hard, but near the surface it weathers rapidly and becomes soft. It is thus easily eroded, and as a result the valleys are wide.

At one stage in the valley cutting the deepening decreased and the widening for a time prevailed, so that along each of the principal stream courses was formed a distinct terrace, which is generally capped by auriferous gravel. In the South Umpqua Valley this terrace is represented by the gravel on the hills a few miles southwest of Riddle at a level of 500 feet above the stream. Farther up Cow Creek, beyond the limits of the Riddle quadrangle, it is represented by the Cracker Jack and Cain gravel bodies on a terrace at about the same height above the stream, but still farther upstream, between West Fork and Reuben, the gravel is only 150 feet above stream grade. Along Rogue River there are corresponding terraces, as illustrated by the gravel of the Big Four mine.

Since the terrace epoch ended the streams have deepened and widened their valleys to their present form.

ECONOMIC GEOLOGY.

ORE DEPOSITS.

GOLD.

The history of gold mining in southwestern Oregon dates back for more than 70 years, the first discovery having been made about the middle of the nineteenth century. From that time to the present this portion of the State has yielded a considerable percentage of the total gold production of Oregon. From 1900 to 1912 Oregon produced \$15,663,258 in gold alone, and of this amount approximately \$5,448,941 came from southwestern Oregon. From 1903 to 1921 the placer mines of southwestern Oregon produced \$2,831,778 in gold and the gold-quartz mines \$1,808,060. The two counties from which most of the gold has come are Josephine and Jackson, both of which lie partly within the Riddle quadrangle.

GOLD-QUARTZ MINES AND PROSPECTS.

GENERAL FEATURES.

The chief gold-quartz mines and prospects of the Riddle quadrangle are in Josephine and Jackson counties. The gold-bearing quartz is found in small veins, veinlets, and stringers in several kinds of rock. Within Josephine County all the paying veins occur in greenstone; a few prospects but no mines have been opened in serpentine. A striking feature of many of the gold-bearing veins in the greenstone is their proximity to serpentine, but as a rule the veins are cut off sharply at the contact of the greenstone with the serpentine. This may indicate either that the rock from which the serpentine was derived was younger than the veins or that displacement has occurred at the contact of the greenstone and its decomposition product, the serpentine. Most of the paying veins that have been found in metamorphosed sediments are within short distances of dikes or irregular areas of greenstone.

Quartz veinlets occur also in the granodiorite, but no mine has yet been developed in these rocks within the Riddle quadrangle. A few hundred yards south of the southern boundary, in the granodiorite, is the Granite Hill mine, which has been for several years a notable producer of gold.

The evidence suggests that all the gold-bearing veins are younger than early Cretaceous and older than Eocene. However, some of the veins in the metamorphosed sediments may be pre-Cretaceous.

Riddle.

The vein filling consists chiefly of quartz, much of which is of milky-white color. In many of the veins the quartz has crystals with perfect outlines, indicating that the deposition took place in open fissures. Calcite is frequently found with the quartz, and subordinate amounts of sulphides, chiefly iron pyrites but not uncommonly arsenopyrite, chalcopyrite, and galena, are present also. A few of the veins contain pyrrhotite.

A study of the fillings of the veins in different kinds of rock suggests that the country rock has not to any appreciable extent influenced the contents of the fissures. The gold is present as free gold in the quartz and also associated with the sulphides.

Few valuable deposits have been found in the country rocks adjacent to the veins. These rocks are in some places only slightly altered, but in others they have been chloritized, and in still others the products of alteration consist of carbonates, albite, quartz, and pyrite. The presence of albite rather than sericite, a mineral frequently found in the wall rocks of the gold-quartz mines of California,¹⁰ is due, no doubt, to the fact that the Oregon rocks, as indicated from the analyses thus far made, are considerably richer in sodium than in potassium.

The gold-producing veins range in width from mere seams to veins more than 4 feet wide, but the average width of all the veins examined was less than 1 foot. In the best mine that has been developed in the region, the Greenback, the average width of the vein is about 18 inches. In many places there are sheared and brecciated zones, in which occur several veinlets and stringers that are as a rule parallel to one another but locally irregular and running in various directions. In general, individual veins and veinlets are continuous for short distances only, and in many localities the continuity of veins has been further interfered with by considerable faulting along planes at various angles to one another. The walls of some of the veins are fairly well defined for short distances, but many of the veins show no distinct boundary between the vein material and the country rock.

Although the gold-bearing veins and veinlets run in various directions, those that have been most productive trend about east. The dips of the veins range from nearly horizontal to vertical, but most of them are fairly high.

The gold is found chiefly in the quartz of the veins and veinlets, but in the brecciated zone some gold is obtained in the fragments of chloritized rock that carries pyrite. The gold is mostly free, but the sulphides also carry gold in amounts differing considerably in different veins and in different parts of the same vein.

Some of the gold-bearing quartz veins are later than others that carry no gold. In some places where veins that are themselves barren are intersected by younger gold-quartz veins the tenor of the younger veins is said to be enriched.

Many of the veins and veinlets did not contain large bodies of ore but only "pockets." Some of these pockets, however, although filling but small spaces, were remarkably rich, much of the gold having been coarse. In general, most of the gold obtained in these pockets has been taken from depths of less than 25 feet from the surface.

PRINCIPAL MINES.

Among the mines of the quadrangle that have produced considerable gold, by far the largest producer has been the Greenback mine, on Tom East Creek, a branch of Grave Creek. Others include the Martha, Baby, Silent Friend, Daisy, Mount Pitt, Orofino, and Corporal G mines and the Lucky Bart group.

SUMMARY.

The work that has been done on many veins and veinlets within the Riddle quadrangle has developed comparatively few profitable mines. The chief reason is to be found in the structural features of the rocks in which the ores occur. The Paleozoic and early Mesozoic sediments, with the associated igneous rocks, were subjected, prior to the mineralization of the region, to earth movements of such a nature that no definite, continuous fissures were formed but rather, in general, innumerable minute and irregular fractures running in various directions. Later, when the mineral-bearing solutions, which may have been connected with one or more of the igneous intrusions, passed through these rocks and deposition from these solutions took place, the gold was not concentrated in definite lodes but was widely distributed through the rocks in small veins, veinlets, and stringers, few of which are continuous except for short distances. Furthermore, in those places where fairly distinct and rich veins were formed, subsequent faulting has been so prevalent that it is difficult and costly to follow the ore. Notwithstanding these unfavorable conditions, however, the gold-quartz veins have yielded and will probably continue to yield considerable amounts of gold. But the prospect of finding vein deposits that can be developed into large and profitable mines is not encouraging.

The veins and veinlets have been subjected to erosion for many thousands of years, during which an immense amount

¹⁰ Lindgren, Waldemar, *Am. Inst. Min. Eng. Trans.*, vol. 30, p. 665, 1901

of material has been freed of its gold. Much of this gold has been deposited in the neighboring streams, from which it has been and is being mined as placer gold.

PLACER MINES.

The placer mines of the Riddle quadrangle¹¹ are all in gravel closely associated with the present streams. By far the greater number of the mines are in the present stream beds or low terraces. Only a few are in gravel of the higher terraces, which rise from 100 to 400 feet above the streams. Among the hills on the valley border between Riddle and Canyonville there are a number of small mines which appear to derive at least part of their gold from the decomposition of the Cretaceous beds on which the gravel rests.

The pebbles of the gravel vary much in form. On the higher terraces and in the steeper portions of the larger streams they are generally well rounded, though some are subangular, but in the portions of gentler grade and especially on the smaller lateral branches they are subangular to angular.

The grades of the present streams range from 10 to 333 feet to the mile. Most of the placer mines are on grades of not over 100 feet to the mile; a smaller number are on grades between 100 and 200 feet, and a few on grades greater than 200 feet.

The records of the highest terrace are few, but if they are reliable they seem to indicate that when the gravel of the highest terrace was deposited the grade of the streams was probably lower than that of the present streams; moreover, the gravel of the highest terrace is, on the whole, not so coarse as that of the lower terraces and the present streams.

The chief placer mines are in the Riddle, Cow Creek, Wolf Creek, Grave Creek, Jumpoff Joe Creek, and Evans Creek districts.

The source of the placer gold is in the auriferous quartz veins, which are most abundant in the greenstone, though they occur in the slate also. All the veins, both large and small, have contributed gold to the placer gravel. The greater number of placers are on slate bedrock. This does not necessarily indicate that the slate has been the chief source of gold in the placers, but that in the process of stream erosion the slate is more readily terraced so as to preserve the gravel for mining.

NICKEL.¹²

For more than 30 years deposits of hydrated nickel-magnesium silicate, genthite, have been known to occur on Nickel Mountain, near Riddle. The deposits are very similar in mineral content, modes of occurrence, and associations to the deposits of New Caledonia, whose mines are the second largest producers of nickel in the world, but no commercial deposits have yet been found at Riddle. Numerous surface openings were made, shafts were sunk, and more than 600 feet of tunnels run. It is estimated that between 3,000 and 4,000 tons of material has been taken from the several openings and placed on the dumps. Only a few small shipments of ore were made to the smelters, and these merely for experiments.

The nickel silicates are associated with saxonite, a variety of peridotite that consists chiefly of olivine and enstatite. Olivine constitutes more than two-thirds of the whole rock. Chromite and magnetite are present, as a rule in disseminated grains, though in places within the peridotite area there are segregations of almost pure chromite and magnetite. The peridotite readily breaks down to a dark-greenish serpentine, a rock that in the Nickel Mountain region is distributed widely as small isolated patches and elongated masses that trend northeast. Such an elongated mass of serpentine extends for several miles to the northeast and southwest of Nickel Mountain. In some places the band is narrow; in others it is more than a mile wide. The serpentine has but a thin covering of soil, which is comparatively free from vegetation.

Practically all the known deposits of nickel silicate in this region are within an area of 1½ square miles. They occur chiefly as flat-lying deposits on the surface of the peridotite and subordinately as veinlets in the peridotite and serpentine. The only nickel mineral known to occur in these deposits is genthite.

COPPER.

Copper minerals have been found at several places within the Riddle quadrangle, but only a small quantity of ore has been shipped. The deposit worked in the Copper Queen mine was discovered by Maloney & Strong in 1905. Some ore was removed in 1912, and a small cyanidizing plant was erected. A larger amount (6 carloads) was removed and shipped from Leland in the summer of 1915 under the management of P. Wickham. The mine is 2½ miles southeast of Leland and is in greenstone within a few hundred yards north of its contact with Galice slate. The locality is directly north of a large mass of granodiorite, which has altered the slate in places to

¹¹ Diller, J. S., and Kay, G. F., *Mines of the Riddles quadrangle, Ore.*; U. S. Geol. Survey Bull. 340, pp. 147-151, 1908.

¹² Kay, G. F., *Nickel deposits of Nickel Mountain, Ore.*; U. S. Geol. Survey Bull. 315, pp. 120-127, 1907.

chrysolite slate and may have had much to do with the development of the copper ore in the greenstone. The ore is chiefly pyrite with a mixture of chalcopyrite and pyrophyllite. The strike of the ore lately removed is northeast, approximately like that of the rock belts in that region, and the dip is steep to the southeast. The plane of the ore body is one of faulting, as shown by the slickensides of the hanging wall. The pyritic ore occurred near the surface, where there is much gossan, containing more or less of the blue and green carbonates of copper. The mine is developed by a number of open cuts and short tunnels at the top of a ridge and down the north slope, but the possible extent of the occurrence of such beds of ore is not yet sufficiently demonstrated.

A deposit somewhat similar to that of the Copper Queen occurs in greenstone on the northwest slope of Green Mountain, 15 miles east of Glendale. The country rock is typically greenstone that has been greatly shattered and altered but still preserves its original structure and composition sufficiently to show its diabasic character. It is cut by serpentine. The greenstone belt is nearly a mile wide from the summit of Green Mountain. The copper-bearing rock impregnates the green-

stone and forms lenses. It is usually incased in deep-green chloritic material. The chief copper mineral is chalcopyrite, which is intermingled with a large portion of pyrrhotite and pyrite, but the deposit, although opened several years ago, has not reached the stage of commercial production.

Work has also been done on several copper prospects, one of which, the Joseph Ball prospect, is of considerable interest. This prospect is on the southwest slope of Cedar Springs Mountain, at an altitude of about 4,250 feet. Some ore has been carried by pack trains to Glendale, on the Southern Pacific Railroad, a distance of more than 20 miles. The country rock is serpentine, which has been greatly fractured and sheared and which locally, where it has been decomposed, contains magnesite with some strontianite. The ore consists of native copper, copper glance, cuprite, and the copper carbonates. It occurs in a faulted zone in the serpentine, which shows numerous slickensided surfaces carrying vertical striae. Within the workings the faulted zone varies in direction and the plane of shearing is very irregular. On this plane have been found flat pieces of native copper as large as the hand, also copper glance and cuprite as nodular masses and as scattered fragments.

WATER RESOURCES.

The waters of South Umpqua River, Cow Creek, and tributaries of Rogue River, which drain the west slope of the Cascade Range, are used for irrigation and for placer and hydraulic mining. One of the largest ditches takes water from the head of Grave Creek and has been used chiefly to supply the Columbia mine, near Placer post office.

The only stream-gaging station in the Riddle quadrangle was on Cow Creek at Riddle, where the following observations of discharge were recorded: August 20, 1911, 32.8 second-feet; December 19, 1911, 304 second-feet; September 9, 1912, 120 second-feet.

At present little water power is developed in the Riddle quadrangle, but on Rogue River near Gold Hill and at Prospect there are power plants with transmission lines leading into the Riddle quadrangle, where the power is used for lighting and mining. Riddle is lighted by electricity from the Prospect plant of the California Oregon Power Co.

September, 1923.



EXPLANATION

- RELIEF**
printed in brown
- Altitude
above mean sea level
instrumentally deter-
mined
- Contours
showing height above
sea horizontal form,
and steepness of slope
of the surface
- DRAINAGE**
printed in blue
- Streams
- Intermittent
streams
- Spring
- Ditch
- CULTURE**
printed in black
- Roads and
buildings
- Church or
schoolhouse
- Poor road
- Trail
- Railroad
- Tunnel
- Bridge
- U.S. township and
section lines
- County line
- Reservation
line
- Trangulation
station
- Bench mark

R. U. Goode, Geographer in charge.
Triangulation by W. T. Griswold.
Topography by A. B. Searle and J. G. Hefty.
Surveyed in 1901-1902.

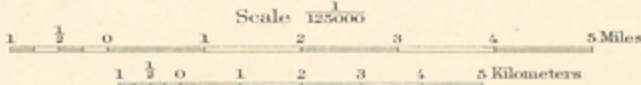
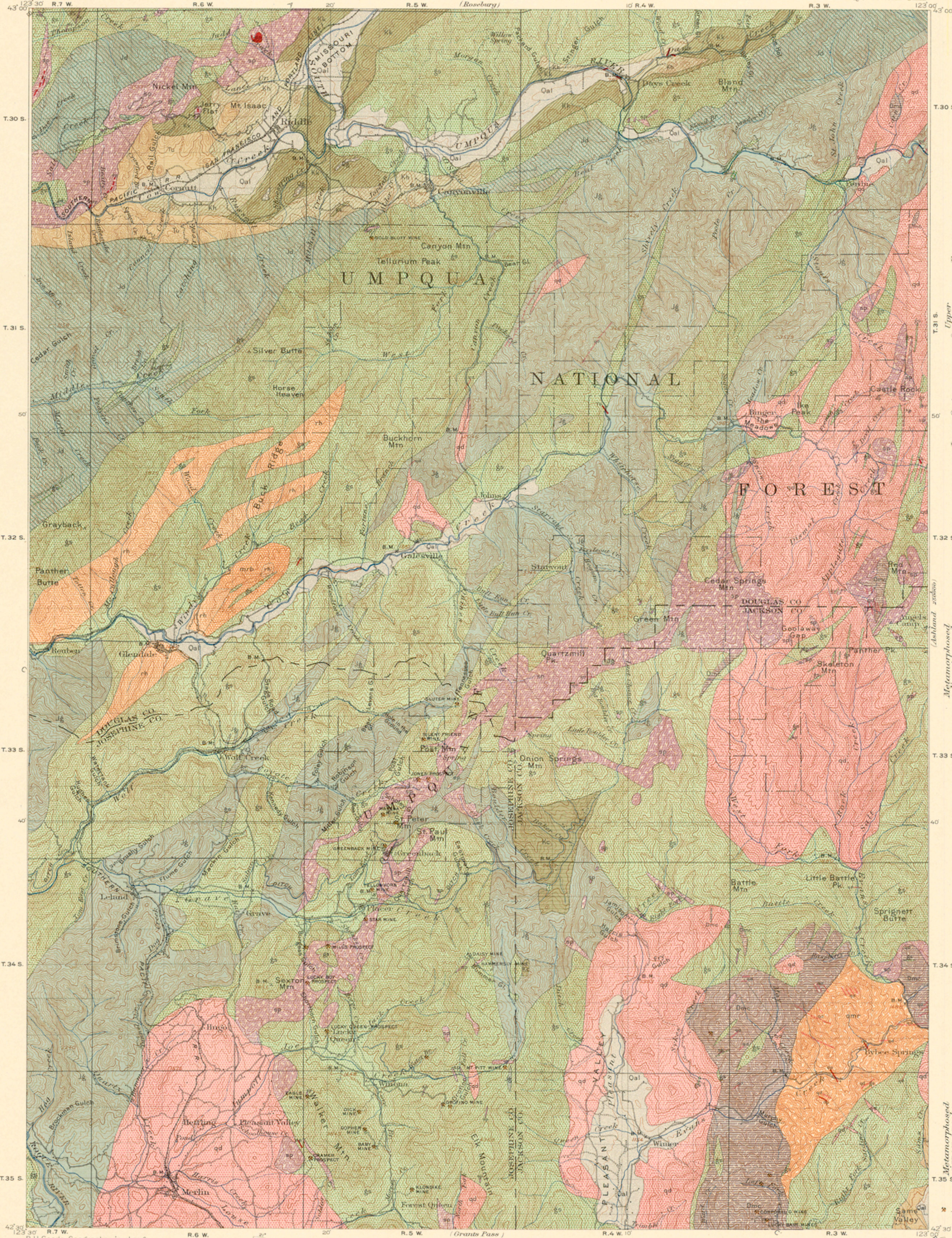


DIAGRAM OF TOWNSHIP

1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12
1	2	3	4	5	6	7	8	9	10	11	12

Edition of April 1904, reprinted 1923.

Contour interval 100 feet.
Datum is 20 feet below mean sea level.
(The elevations on this map were derived from railroad levels and originally referred to mean sea level. Subsequent accurate leveling by the U.S. Geological Survey shows these to have been 20 feet too high.)



EXPLANATION

SEDIMENTARY ROCKS

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

- QUATERNARY**
 - Qal Alluvium (in flood plains of present streams)
 - Hg High terrace gravels (remnants of old stream gravels on high terraces and benches)
- TERTIARY**
 - Evocene**
 - Tu Umpqua Formation (chiefly thin bedded sandstone and shale, with some conglomerates)
 - Upper Cretaceous**
 - Kc Chico Formation (chiefly sandstone with conglomerate and shale)
 - Lower Cretaceous**
 - Kh Horseshoe formation (chiefly gray shale and thin gray sandstones)
 - kk Knoxville Formation (chiefly sandstone and shaly sandstone conglomerate at base)
- JURASSIC**
 - Jd Dothan formation (chiefly hard sandstone containing a little conglomerate and some gray shale)
 - Jg Galice formation (chiefly fine grained dark shale with some sandstone and conglomerate)
- DEVONIAN ?**
 - Dmc Metamorphosed sedimentary rocks (micaceous shale and slate)
- TERTIARY**
 - Tb Basalt (dikes)
 - dp Dacite porphyry and related rocks (lavas, tuffs and dikes)
- LATE JURASSIC OR EARLY CRETACEOUS**
 - qd Quartz diorite, quartz-mica diorite, and related rocks (large intrusive masses and dikes; quartz diorite in the greenstone north of South Umpqua River not separately mapped)
 - sp Serpentine derived from and including some peridotite and saxonite (intrusive masses)
- CHIEFLY LATE JURASSIC (possibly in part Paleozoic)**
 - gs Greenstone, gabbro, and related rocks (lavas and intrusive rocks; greenstone north of South Umpqua River includes quartz diorite not separately mapped)
- DEVONIAN ?**
 - rh Rhyolite (includes some meta-rhyolite, mch, lava flows)
 - omr Older meta-rhyolite (lava flows associated with May Creek formation)

R.U. Goode, Geographer in charge.
Triangulation by W.T. Griswold.
Topography by A.B. Searle and J.G. Hefty.
Surveyed in 1901-1902.

Scale 1:25000
Miles
Kilometers

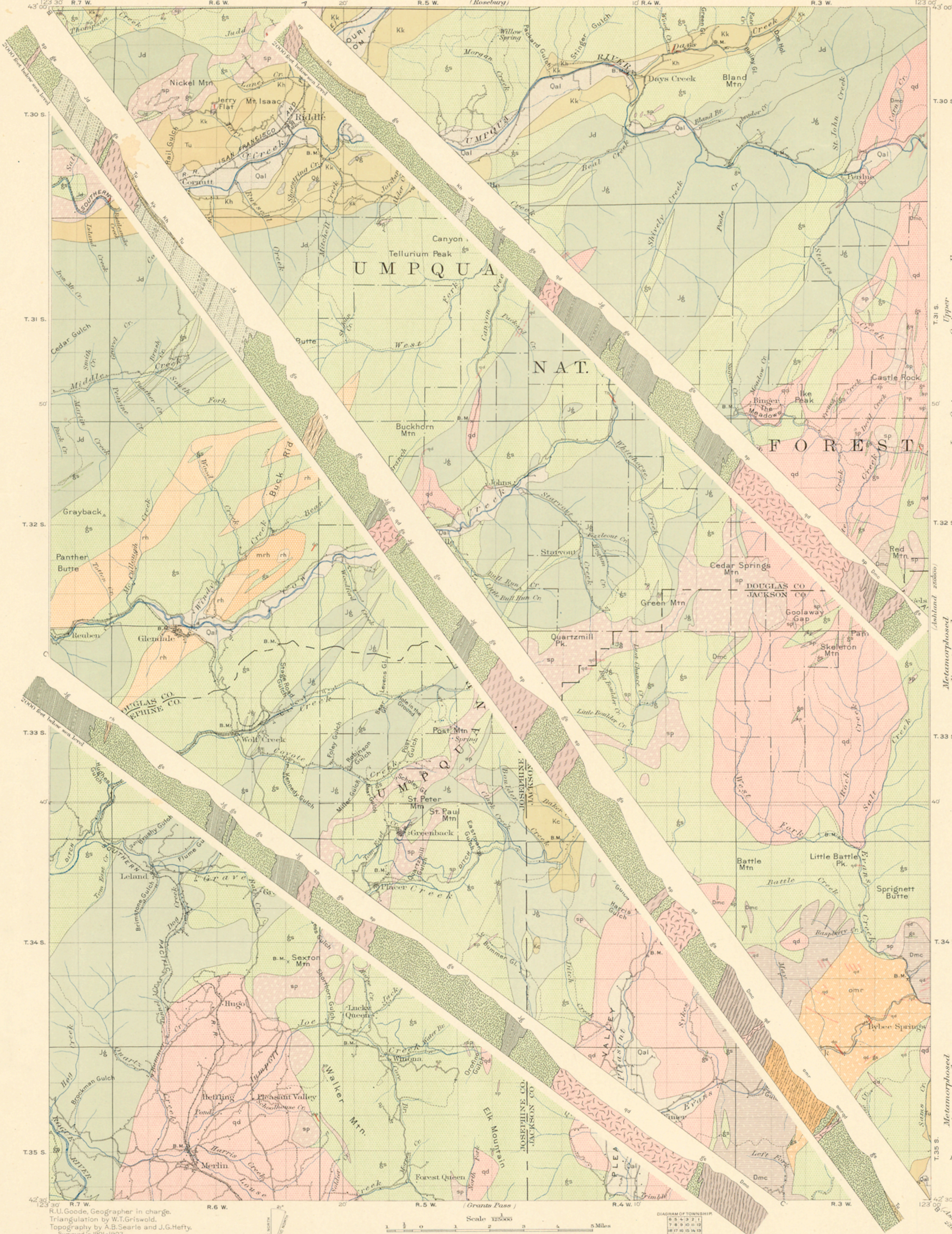
DIAGRAM OF TOWNSHIP

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

Geology by J.S. Diller and G.F. Kay.
Surveyed in 1905-1907.

Contour interval 100 feet.
Datum is 20 feet below mean sea level.
(The elevations on this map were derived from railroad levels and originally referred to mean sea level. Subsequent accurate leveling by the U.S. Geological Survey shows these to have been 20 feet too high.)
Edition of Aug. 1923.

* Principal gold-lode mines and prospects in 1907.
Endite not shown on map.



EXPLANATION

SEDIMENTARY ROCKS

SHEET SYMBOL SECTION SYMBOL

Qal Alluvium
(in flood plains of present streams)

Og High terrace gravels
(remnants of old stream gravels on high terraces and benches)

UNCONFORMITY

Tu Unupqua formation
(chiefly thin bedded sandstone and shales with some conglomerate)

UNCONFORMITY

Kc Chico formation
(chiefly sandstone with conglomerate and shales)

UNCONFORMITY

Kh Horsetown formation
(chiefly gray shale and thin gray sandstone)

UNCONFORMITY

Kk Knoxville formation
(chiefly sandstone and shales massive conglomerate with shales)

UNCONFORMITY

Jd Dothan formation
(chiefly hard sandstone containing a little conglomerate and some gray shales)

UNCONFORMITY?

Jg Galice formation
(chiefly fine grained dark slate with some sandstone and conglomerate)

UNCONFORMITY

Dmc May Creek formation
(massive shales and slate)

IGNEOUS ROCKS

Tb Basalt
(thick)

dp Dacite porphyry and related rocks
(possibly massive and thin)

qd Quartz diorite, quartz-mica diorite, and related rocks
(large intrusive masses and thin quartz diorite in the greenstone north of South Oregon River and separate masses)

sp Serpentine derived from and including some peridotite and saxonite
(intrusive masses)

gs Greenstone, gabbro, and related rocks
(massive and intrusive rocks greenstone north of South Oregon River includes quartz diorite not separately mapped)

rh Rhyolite
(includes some metarhyolite, lava flows)

omr Older metarhyolite
(lava flows associated with May Creek formation)

Faults not shown on map or sections.

QUATERNARY

TERTIARY

CRETACEOUS

JURASSIC

DEVONIAN?

TERTIARY

LATE JURASSIC OR EARLY CRETACEOUS

CHIEFLY LATE JURASSIC
(possibly in part Paleozoic)

DEVONIAN?

R. U. Goode, Geographer in charge.
Triangulation by W. T. Griswold.
Topography by A. B. Searle and J. G. Hefty.
Surveyed in 1901-1902.

Scale 1:25000
0 1 2 3 4 5 Miles
0 1 2 3 4 5 Kilometers

DIAGRAM OF TOWNSHIPSHIP

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

Geologic time.—The larger divisions of geologic time are called *periods*. Smaller divisions are called *epochs*, and still smaller ones are called *stages*. The age of a rock is expressed by the name of the time division in which it was formed.

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

As sedimentary deposits accumulate successively the younger rest on the older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or their relations to adjacent beds have been changed by faulting, so that it may be difficult to determine their relative ages from their present positions at the surface.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them or were buried in surficial deposits on the land. Such rocks are said to be fossiliferous. A study of these fossils has shown that the forms of life at each period of the earth's history were to a great extent different from the forms at other periods. Only the simpler kinds of marine plants and animals lived 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 forms that 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. If two sedimentary formations are geographically so far apart that it is impossible to determine their relative positions the characteristic fossils found in them may determine which was deposited first. Fossils are also of value in determining the age of formations in the regions of intense disturbance mentioned above. The fossils found in the strata of different areas, provinces, and continents afford the most effective means of combining local histories into a general earth history.

It is in many places, difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or lies upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

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

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations that are known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. The colors in which the patterns of parallel lines are printed indicate age, a particular color being assigned to each system.

Each symbol consists of two or more letters. The symbol for a formation whose age is known includes the system symbol, which is a capital letter or monogram; the symbols for other formations are composed of small letters.

The names of the geologic time divisions, arranged in order from youngest to oldest, and the color and symbol assigned to each system are given in the subjoined table.

Geologic time divisions and symbols and colors assigned to the rock systems.

Era.	Period or system.	Epoch or series.	Sym- bol.	Color for sedi- mentary rocks.
Cenozoic	Quaternary	Recent	Q	Brownish yellow.
		Pleistocene		
		Holocene		
Tertiary		Miocene	T	Yellow ochre.
		Oligocene		
		Eocene		
Mesozoic	Cretaceous		K	Olive green.
			J	Blue-green.
			W	Peacock-blue.
Triassic				
Paleozoic	Carboniferous	Permian	P	Blue.
		Pennsylvanian		
		Mississippian		
Proterozoic	Devonian		D	Blue-gray.
			S	Blue-purple.
			O	Red-purple.
			C	Brick-red.
Cambrian			A	Brownish red.
			A	Gray-brown.

DEVELOPMENT AND SIGNIFICANCE OF SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. Most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains that border many streams were built up by the streams; waves cut sea cliffs, and waves and currents build up sand spits and bars. Surface forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth

oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is built and afterward partly eroded away. The shaping of a plain along a shore is usually a double process, hills being worn away (*degraded*) and valleys filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wears them down, producing material that is carried by streams toward the sea. As this wearing down depends on the flow of water to the sea it can not be carried below sea level, which is therefore called the *base-level* of erosion. Lakes or large rivers may determine base-levels for certain regions. A large tract that is long undisturbed by uplift or subsidence is worn down nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted it becomes a record of its former close relation to base-level.

THE GEOLOGIC MAPS AND SHEETS IN THE FOLIO.

Areal-geology map.—The map showing the surface areas occupied by the several formations is called an *areal-geology map*. On the margin is an explanation, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the explanation, where he will find the name and description of the formation. If he desires to find any particular formation he should examine the explanation and find its name, color, and pattern and then trace out the areas on the map corresponding in color and pattern. The explanation shows also parts of the geologic history. The names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and those within each group are placed in the order of age, the youngest at the top.

Economic-geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic-geology map*. Most of the formations indicated on the areal-geology map are shown on the economic-geology map by patterns in fainter colors, but the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral product mined or quarried. If there are important mining industries or artesian basins in the area the folio includes special maps showing these additional economic features.

Structure-section sheet.—The relations of different beds to one another may be seen in cliffs, canyons, shafts, and other natural and artificial cuttings. Any cutting that exhibits these relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of the beds or masses of rock in the earth is called *structure*, and a section showing this arrangement is called a *structure section*.

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, after tracing out the relations of the beds on the surface he can infer their relative positions beneath the surface and can draw sections representing the probable structure to a considerable depth. Such a section is illustrated in figure 2.

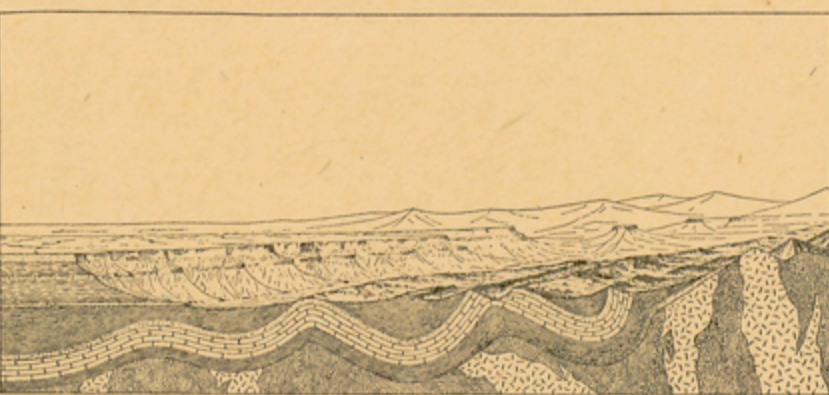


FIGURE 2.—Sketch showing a vertical section below the surface at the front and a view beyond.

The figure represents a landscape that is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated

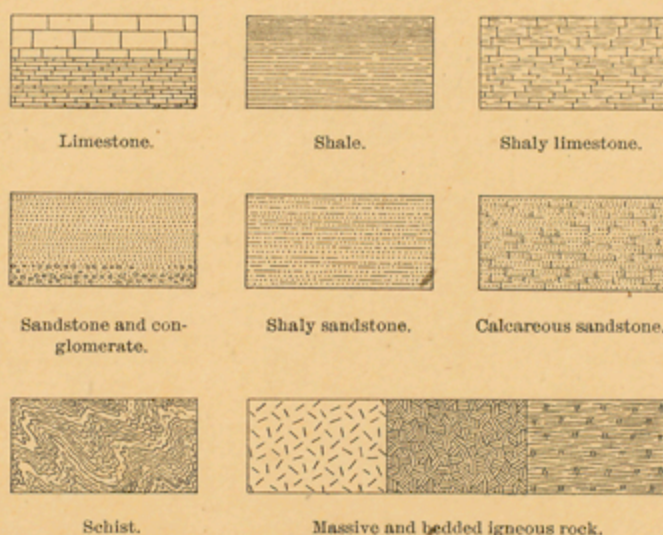


FIGURE 3.—Symbols used in sections to represent different kinds of rock.

by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

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

Where the edges of the beds appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed, and by means of these observations their positions underground are inferred. The direction of the intersection of the surface of a dipping bed with a horizontal plane is called its *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called its *dip*.

In many regions the beds are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the materials that formed the sandstone, shale, and limestone were deposited beneath the sea in nearly flat layers the fact that the beds are now bent and folded shows that forces have from time to time caused the earth's crust to wrinkle along certain zones. In places the beds are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in figure 4.

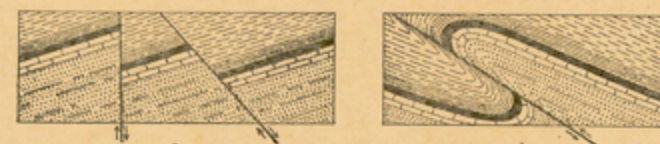


FIGURE 4.—Ideal sections of broken and bent strata, showing (a) normal faults and (b) a thrust or reverse fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted, and the form or arrangement of their masses underground can not be inferred. Hence that part of the section shows only what is probable, not what is known by observation.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of beds of sandstone and shale, which lie in a horizontal position. These beds were laid down under water but are now high above the sea, forming a plateau, and their change of altitude shows that this part of the earth's surface has been uplifted. The beds of this set are *conformable*—that is, they are parallel and show no break in sedimentation.

The next lower set of formations consists of beds that are folded into arches and troughs. The beds were once continuous, but the crests of the arches have been removed by erosion. These beds, like those of the upper set, are conformable.

The horizontal beds of the plateau rest upon the upturned, eroded edges of the beds of the middle set, as shown at the left of the section. The beds of the upper set are evidently younger than those of the middle set, which must have been folded and eroded between the time of their deposition and that of the deposition of the upper beds. The upper beds are *unconformable* to the middle beds, and the surface of contact is an *unconformity*.

The lowest set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and intruded by masses of molten rock. The overlying beds of the middle set have not been traversed by these intrusive rocks nor have they been affected by the pressure of the intrusion. It is evident that considerable time elapsed between the formation of the schists and the beginning of the deposition of the beds of the middle set, and during this time the schists were metamorphosed, disturbed by the intrusion of igneous masses, and deeply eroded. The contact between the middle and lowest sets is another unconformity; it marks a period of erosion between two periods of deposition.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps in much the same way that the section in the figure is related to the landscape. The profile of the surface in each structure section corresponds to the actual slopes of the ground along the section line, and the depth to any mineral-producing or water-bearing bed shown may be measured by using the scale given on the map.

Columnar section.—Many folios include a *columnar section*, which contains brief descriptions of the sedimentary formations in the quadrangle. It shows the character of the rocks as well as the thickness of the formations and the order of their accumulation, the oldest at the bottom, the youngest at the top. It also indicates intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition.

THE TEXT OF THE FOLIO.

The text of the folio states briefly the relation of the area mapped to the general region in which it is situated; points out the salient natural features of the geography of the area and indicates their significance and their history; considers the cities, towns, roads, railroads, and other human features; describes the geology and the geologic history; and shows the character and the location of the valuable mineral deposits.

GEORGE OTIS SMITH,

January, 1922.

Director.

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