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GEOLOGY AND MINERAL RESOURCES

OF THE

BAKER QUADRANGLE, OREGON

BY

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GEOLOGY AND MINERAL RESOURCES OF THE BAKER QUADRANGLE, OREGON

By James Gilluly

ABSTRACT

This report presents the results of a rather complete reconnaissance of the Baker quadrangle, Oregon, carried out during brief studies of some mining districts in and near the area.

The Baker quadrangle is for the most part mountainous but contains two considerable intermontane basins of low relief, Baker and Lower Powder Valleys. The relief is about 4,000 feet, altitudes ranging from a little more than 6,600 to a little less than 2,600 feet above the sea.

The climate is semiarid, and only the Powder and Burnt Rivers, the master streams, are perennial throughout their courses. These streams are tributary to the Snake River. Their courses are conspicuously tortuous, and they offer interesting problems in drainage adjustment, which this report discusses only in general terms.

The rocks of the quadrangle may be divided into two groups—(*a*) pre-Tertiary and (*b*) Tertiary and Quaternary. The pre-Tertiary rocks consist of highly deformed and more or less metamorphosed sedimentary and volcanic rocks, intruded by many plutonic igneous bodies. The sedimentary and volcanic rocks comprise three formations, of which two are Carboniferous and the third is of unknown, possibly pre-Carboniferous age. The older formation of the Carboniferous system is represented by possibly 5,000 feet of argillite, chert, tuffaceous argillite, limestone, and other rocks; and the younger Carboniferous formation, which is of Permian age, by fully 4,000 feet of greenstone with subordinate limestone. The formation of unknown age comprises fully 5,000 feet of greenstone schist, quartz schist, and phyllite with some limestone. The pre-Tertiary plutonic rocks intruding these formations embrace two structural variants, one more or less gneissic and cataclastic, the other generally undeformed. The gneissic rocks include a great variety, of which gabbro, metagabbro, diorite, trondhjemite (soda-rich quartz diorite), and albite granite are most abundant, although serpentine, peridotite, and other subsilicic rocks are represented. The relatively undeformed plutonic rocks are all biotite-quartz diorite. Two plutonic cycles are believed to be represented, the earlier probably of post-Carboniferous, possibly Triassic age and the later probably post-Jurassic. The folding and metamorphism of the pre-Tertiary rocks was essentially complete before the irruption of the biotite-quartz diorite masses. The quartz lodes and replacement bodies worked for gold and copper in the region are related to these latest pre-Tertiary intrusions.

A profound unconformity of considerable local relief divides the pre-Tertiary from the later rocks. The Tertiary rocks were deposited upon the irregular

surface of the eroded older rocks, building up the hollows, and the higher members of the sequence eventually covered nearly if not quite all the area. Practically complete structural independence exists between the two groups separated by this unconformity.

The Tertiary rocks are dominantly volcanic, comprising local accumulations of rhyolite breccia, flow-banded andesite, and andesitic tuff-breccia. Basalt probably belonging to the Columbia River lava overlies these local deposits and probably once covered most of the area. Its eruptions led to disturbance and finally destruction of the earlier drainage, the formation of lakes, and consequent fluviatile and lacustrine deposition. Plant remains found in these rocks suggest a Miocene age. A few dacite sills and basaltic dikes intrude the earlier Tertiary formations.

The Pleistocene sediments include alluvial deposits in the down-faulted basin of Baker Valley and terrace gravel in the areas of Tertiary sediments. The Recent sediments are similar but include also a little volcanic ash.

The pre-Tertiary structural features are closely compressed, probably isoclinal folds trending generally east. The mutual contacts of the supracrustal rocks were largely destroyed by plutonic intrusions or covered by Tertiary rocks, so that the major structural features have not been further deciphered.

The Tertiary structural features include broad open folds, trending somewhat north of west, cut by many normal faults, largely with displacement in a direction that has increased the structural relief due to folding. As a rule the faults have a somewhat more northerly trend than the folds. Many horsts and grabens are also present, and the faulting that has brought them about is still going on in a few places. One of the largest faults is that bounding Baker Valley on the southwest.

Since Miocene time the history of the area has been dominantly one of erosion. No early Tertiary erosion surfaces have been recognized other than the one of considerable relief which was buried by the Miocene lava. Two doubtful partial cycles of post-Miocene age have been distinguished, but the only clearly established pause in the degradation of the region is marked by the Pleistocene terrace developed on the soft Tertiary sediments. This terrace is marked on the harder lava and pre-Tertiary rocks only near the major streams. In Recent time this terrace has been generally dissected to depths ranging from 200 to 500 feet.

The mineral resources of the area include deposits of gold and silver, copper, manganese, tungsten, asbestos, coal, diatomite, and building stone, but the only considerable production has consisted of gold, chiefly from placers and the Virtue mine, granite from Haines, and volcanic tuff from Pleasant Valley.

INTRODUCTION

FIELD WORK AND ACKNOWLEDGMENTS

The field work upon which this report is based was done during parts of the field seasons of 1929 and 1930 in connection with a general reconnaissance of many of the mining districts of eastern Oregon,[1] carried on as a cooperative project between the Oregon State Mining Board and the United States Geological Survey. During

[1] Gilluly, James, The copper deposits near Keating, Oreg.: U. S. Geol. Survey Bull. 830, pp. 1–32, 1932. Gilluly, James, Reed, J. C., and Park, C. F., Jr., Some mining districts of eastern Oregon: U. S. Geol. Survey Bull. 846–A, pp. 1–140, 1933.

the study of the mining districts many questions arose whose solution was dependent upon knowledge of the regional geology, and, as opportunity offered, an attempt was made to contribute to this knowledge by a study of the Baker quadrangle. The time devoted to the work was limited by the more immediate interest in the mining districts, so that many questions that are doubtless capable of solution within the quadrangle had to be left unsolved. The time devoted to the Baker quadrangle was about equivalent to that of one man for 9 months, although five men participated in it at one time or another. The study may perhaps be characterized as a detailed reconnaissance.

The writer was fortunate in having the able and energetic assistance of R. B. Stewart in 1929 and of J. C. Reed, C. F. Park, Jr., and H. G. Mitchell in 1930. W. C. Mendenhall, G. F. Loughlin, and D. F. Hewett visited the parties in the field and contributed useful suggestions, and R. W. Brown assisted in collecting plant remains from some Tertiary rocks.

Previous work in the Baker quadrangle has been limited to general reconnaissances by Lindgren, Washburne, Swartley, and Buwalda and detailed studies of small areas by Grant, Cady, and Moore. The following bibliography notes the publications based on these earlier examinations. The Sumpter quadrangle, adjoining the Baker quadrangle on the west, has been described by Pardee and Hewett,[2] and their report has been of great value in interpreting the geology of this area.

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1914. Grant, U. S., and Cady, G. H., Preliminary report on the general and economic geology of the Baker district of eastern Oregon: Mineral Resources of Oregon, vol. 1, no. 6, pp. 129–161, Oregon Bur. Mines and Geology. Gives a brief discussion of the geology near Haines, Magpie Peak, Baker, and Virtue Flat, with descriptions of some of the mines.

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[2] Pardee, J. T., and Hewett, D. F., Geology and mineral resources of the Sumpter quadrangle, Oreg.: Mineral Resources of Oregon, vol. 1, no. 6, pp. 3–128, Oregon Bur. Mines and Geology, 1914.

1932. Gilluly, James, The copper deposits near Keating, Oregon: U. S. Geol. Survey Bull. 830, pp. 1–32. Describes the geology of an area in the northeastern part of the quadrangle and extending into the adjoining Pine quadrangle, to the east.

1933. Gilluly, James, Reed, J. C., and Park, C. F., Jr., Some ore deposits of eastern Oregon: U. S. Geol. Survey Bull. 846–A, pp. 1–140. Describes the geology of several mines and prospects near Baker, Pleasant Valley, and Virtue Flat.

Moore, B. N., The nonmetallic mineral resources of Oregon: U. S. Geol. Survey Bull. 875 (in press).

GEOGRAPHY

LOCATION AND GENERAL FEATURES OF THE REGION

The Baker quadrangle, in eastern Oregon, is an area of about 840 square miles bounded by the meridians of longitude 117°30′ and 118° W. and the parallels of latitude 44°30′ and 45° N. (See fig. 1.)

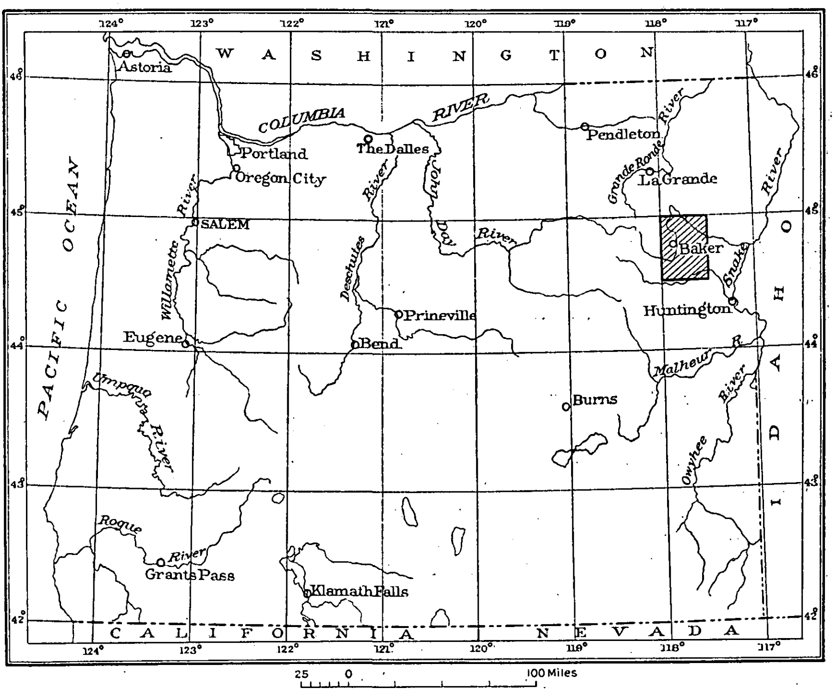

FIGURE 1.—Index map showing location of Baker quadrangle, Oregon.

The quadrangle lies near the east end of the straggling mountain group to which the name "Blue Mountains" is loosely given. The southern part of the quadrangle is mountainous; the northern part is much less so and includes the large flat-floored Baker Valley and the wide Lower Powder Valley.

The quadrangle is traversed by the Oregon-Washington Railway & Navigation Co.'s line, a part of the Union Pacific System, and also by the narrow-gage Sumpter Valley Railroad, which extends from

Baker to Prairie City, 80 miles to the southwest. The old Oregon Trail crossed the region, and its former route is now followed in general by a modern macadam State highway, which crosses the quadrangle diagonally from southeast to northwest. Other excellent highways radiate from Baker, one north and then northeast to Medical Springs, which lies just north of the quadrangle boundary; another northeast by way of Virtue Flat and the Lower Powder Valley to Richland, in the adjoining Pine quadrangle; another south over Dooley Mountain to Unity, where it connects with the John Day Highway; and another southwest up the upper Powder River to Sumpter.

The settlement of the country was largely induced by the discovery of gold near Auburn in 1862. Considerable wealth has since been won from the placer deposits in the Elkhorn Ridge, in Virtue Flat, and along the Burnt River. Lode mining, except in a few places, has not yet been highly productive, although there are potential mines in the quadrangle. At present the principal resources of the region are agricultural, and Baker is a conspicuous center of cattle breeding and sheep grazing. There are still considerable areas of merchantable yellow-pine timber in the southern and northeastern parts of the quadrangle, though many of the formerly timber-clad slopes have been cleared.

The only large town is Baker, the seat of Baker County, with a population of 7,858 in 1930. Haines is a village of a few hundred persons, Pleasant Valley of a few dozens, and the other settlements consist of only a house or two each.

TOPOGRAPHY

Southeast of Baker the transcontinental railroad follows the valleys of Sutton and Alder Creeks, which can conveniently be regarded as dividing the area of the quadrangle into topographically contrasting districts, the one to the southwest embracing chiefly mountainous country, and the one to the northeast, though hilly, much less precipitous and containing wide flat areas. Southwest of this line is the east end of the Elkhorn Ridge, separated from the eastward-trending highland of Dooley Mountain by the upper Powder River Valley and bounded on the north by the Baker Valley. In the southeast corner of the quadrangle the Burnt River cuts a deep canyon through Dooley Mountain.

Northeast of Sutton and Alder Creeks is a line of rolling hills that extend from Baker to a point just beyond the eastern border of the quadrangle. A wide, gently sloping depression embracing Virtue Flat and Pritchard Flat parallels these hills on the north and is separated by another lower ridge, extending from the Farley Hills southeastward across the quadrangle, from the wide, gently sloping

Lower Powder Valley. Northeast of the Lower Powder Valley, in the corner of the quadrangle, are the lowermost southerly foothills of the Wallowa Mountains, which rise to heights of nearly 10,000 feet just northeast of the mapped area.

The Farley Hills separate the Lower Powder Valley from the broad intermontane depression of Baker Valley, which, although its flat floor is interrupted by the low hills east of Haines and east of Hutchinson, embraces nearly 100 square miles of the quadrangle north and northeast of Baker.

The relief between the highest summits on Bald Mountain (6,667 feet) and the east end of Elkhorn Ridge and the point where the Powder River leaves the quadrangle (about 2,600 feet) is over 4,000 feet.

CLIMATE

The climate of the Baker quadrangle is semiarid, with an average annual precipitation of less than 15 inches, although the highest summits doubtless receive several inches more. The summers are hot and dry, with a rather short growing season, and the winters are rather cold, with temperatures frequently well below zero Fahrenheit.

Owing to the climate, only a few perennial streams are found in the area. Even the Powder and Burnt Rivers are practically dry in the late summer, though the diversion of water for irrigation probably accounts largely for this. Deer Creek, Dark Canyon, and Auburn Creek, tributaries of the Burnt River, are perennial through parts of their courses, but the other streams are intermittent.

DRAINAGE

All the country included in the Baker quadrangle drains to the Snake River, chiefly through the Powder River but in part also through the Burnt River and its tributaries. A glance at the map of the general region of which this area is a part (fig. 1) suffices to show the remarkably tortuous courses of the principal streams. The development of these courses is discussed in the section of this report dealing with the geomorphology. It will suffice here, therefore, to call attention to the remarkable S-shaped curve in the course of the Powder River, which, after flowing southeastward across much of the Sumpter quadrangle, to the west, and for 6 miles into the Baker quadrangle, turns abruptly north to Baker, then north and northwest through the Baker Valley, only to cut across the north end of the Farley Hills just north of the quadrangle boundary and then flow southeast again for nearly 40 miles to the Snake River. Within this S-shaped part of its course it receives tributaries which together drain more than two-thirds of the quadrangle. The southern and southeastern parts of the quadrangle drain to the Burnt River.

GEOLOGY

GENERAL FEATURES

The rocks of the Baker quadrangle may conveniently be considered in two categories—the pre-Tertiary rocks and those of Tertiary and Quaternary age. The pre-Tertiary rocks are more or less metamorphosed sedimentary and volcanic rocks into which numerous igneous masses have been intruded. The Tertiary and Quaternary rocks include much less deformed and practically unaltered lavas and soft sediments. (See pl. 1, in pocket.)

The pre-Tertiary supracrustal rocks are known to embrace two representatives of the Carboniferous system and a formation (the Burnt River schist, defined on p. 9) of unknown, possibly pre-Carboniferous age. The older Carboniferous formation, which may be of Pennsylvanian age, includes possibly 5,000 feet of argillite, chert, and tuffaceous argillite with minor amounts of limestone and other rocks; the younger Carboniferous formation, which is of Permian age, consists of 4,000 feet or more of greenstone with small lenses of intercalated limestone. The Burnt River schist is made up largely of greenstone schist, quartz schist, and phyllite, with a little limestone. It aggregates at least 5,000 feet in thickness. It has not yielded fossils.

The pre-Tertiary plutonic rocks include, in addition to many subordinate varieties, gabbro, metagabbro, diorite, trondhjemite (soda-rich quartz diorite), and albite granite, all more or less metamorphosed, and practically unaltered biotite-quartz diorite. At least two periods of intrusive activity are represented, the earlier of unknown but probably post-Carboniferous age and the later of probable post-Jurassic age.

A profound unconformity separates the Tertiary from the pre-Tertiary rocks. The Tertiary rocks include rhyolite breccia, flow-banded andesite, andesitic tuff-breccia, and much basalt, with interbedded and overlying lacustrine and fluviatile deposits. Dacite and a few basaltic dikes are intrusive into the earlier Tertiary rocks. Fossil leaves from lake beds intercalated with the basalt indicate a Miocene age for these deposits, but no direct evidence has been obtained to date the older formations, whose assignment to the Tertiary is based in part upon their unconformable relation to the metamorphosed older sediments and in part upon their relations elsewhere in the general region.

The Quaternary deposits include terrace gravel, alluvial-fan deposits, volcanic ash, landslide material, and alluvium.

The following generalized section presents the sequence and thickness of the supracrustal rocks as far as they have been worked out in the Baker quadrangle:

Generalized section of the supracrustal rocks of the Baker quadrangle

Period	Epoch	Formation	Lithology	Thickness (feet)
Quaternary.	Recent.	Alluvial and colluvial deposits and volcanic ash.	Unconsolidated gravel along the present streams and in alluvial cones. Landslide material and a little volcanic ash, now much reworked.	0-50±
		-Unconformity		
	Pleistocene.	Alluvial deposits.	Terrace gravel, bench gravel, and unconsolidated deposits in Baker Valley.	0-600+?
		-Unconformity		
Tertiary.	Miocene.	Lacustrine and fluviatile deposits.	Gravel, sand, volcanic mud flows, silt, clay, and diatomaceous earth. Contain much volcanic material and grade into tuffs and breccias. Mostly overlie but in part interfinger with the Columbia River lava.	0-1,000+
		-Partial interfingering		
		Columbia River lava and interbedded sediments.	Chiefly basalt, both olivine-free and olivine-bearing, hypersthene-augite andesite, and hypersthene andesite, in part interbedded with lacustrine and fluviatile deposits.	0-2,500
		-Unconformity		
	Miocene (?)	Andesite tuff-breccia.	Coarse water-laid breccia with andesite boulders as much as 10 feet in diameter in a finer andesitic matrix.	0-1,200±
		-Unconformity		
		Andesite.	Conspicuously flow-stretched porphyritic andesite.	0-300
		-Probable conformity		
		Dooley rhyolite breccia.	Rhyolitic and subordinate andesitic breccias and flows.	0-1,500+
		-Probable conformity		
		Gravel.	Poorly consolidated gravel consisting chiefly of local rocks but containing locally numerous well-rounded quartzite cobbles of foreign source.	0-100.
		-Major unconformity		
Carboniferous.	Permian.	Clover Creek greenstone.	Altered volcanic flows and pyroclastic rocks, with subordinate conglomerate, limestone, and chert. Possibly some sills.	4,000+
		-Relation unknown		
	Pennsylvanian. (?)	Elkhorn Ridge argillite.	Argillite, tuff, and chert, with subordinate limestone and greenstone masses.	5,000+
		-Relation unknown		
Pre-Carboniferous (?).	(?)	Burnt River schist.	Various greenstone schists, quartz schist, conglomeratic schist, and some interbedded limestone, slate, and quartzite.	5,000+

The pre-Tertiary rocks are strongly folded and strike west. The mutual relations of the supracrustal formations are obscure, so that the structure has not been deciphered. These rocks are all closely, probably isoclinally folded and more or less schistose. The Tertiary rocks have been only gently warped and are cut by numerous normal faults. Although the trend lines of both folds and faults in the Tertiary rocks are westerly to west-northwesterly in the southern part of the quadrangle, in the northern part they are northwesterly, thus cutting the strike of the pre-Tertiary rocks at a notable angle.

The higher country, broadly considered, is composed of pre-Tertiary rocks, and the lower country of Tertiary rocks, although there are numerous exceptions to this generalization. The present "grain" of the topography is parallel to the Tertiary trend lines, compelling the conclusion that the erosion which produced the present topography was controlled chiefly by the Tertiary (post-Miocene) structure.

PRE-TERTIARY ROCKS

SUPRACRUSTAL ROCKS

BURNT RIVER SCHIST

Distribution and topographic expression.—The Burnt River schist (here named from its exposures in the canyon of the Burnt River in Tps. 11 and 12 S., R. 41 E.) consists of a considerable thickness of greenstone schist, phyllite, quartz schist, quartzite, and limestone. It crops out over large areas in a belt extending across the south side of the Baker quadrangle from a point south of Black Mountain to the eastern edge of the area. There is little doubt that, were the locally overlying Tertiary rocks removed, this outcrop would be continuous except, possibly, for some intrusive igneous masses.

The areas underlain by the Burnt River schist are characterized by rather more jagged topography than that developed upon most of the other pre-Tertiary rocks of the quadrangle. This is due not merely to the fortuitous exposure of the formation in the district of greatest local relief, but more directly to the prominent intersecting structural features within the formation. Although planar schistosity is only locally developed, the Burnt River schist is characterized by a remarkable linear schistosity, which gives the rocks a pencil structure. This structure is in general oriented nearly east-west and plunges at low angles either east or west. Almost normal to this pencil structure, the schist is cut by prominent cross joints at intervals ranging from a few inches to several feet. Erosion controlled by these well-marked cross joints and the slightly less prominent linear schistosity results in a topography that is notably jagged on a small scale.

Thickness.—Although the Burnt River schist is excellently exposed, the metamorphism that it has undergone has so masked the original sedimentary features that very detailed observations, far more numerous than could be made during this survey, would be required to work out the details of structure and stratigraphy necessary to a close estimate of thickness. Most exposures that reveal evidence of bedding show that the schistosity lies nearly or quite parallel to the bedding, but that is not invariable. The observed dips are mostly steep, so that, if no repetition of beds is assumed, the estimated thickness of the formation would exceed 4 miles. However, it is far more likely that there has been duplication of beds—

in fact, there is some suggestion that anticlinal folding has duplicated the thick limestone section in T. 12 S., Rs. 41 and 42 E., so that the true thickness is probably much smaller than 4 miles. Still it is difficult to believe, even if isoclinal folding has occurred, that the lithologic variety in the formation and the thicknesses transverse to the strike can represent an original thickness less than 5,000 feet. However, this is hardly better than a mere guess: the true thickness may be much greater.

Lithology.—The rock varieties represented in the Burnt River schist, named in the estimated order of their abundance, include greenstone schist, quartz schist, conglomeratic schist, limestone, slate, and quartzite.

Probably at least half of the formation and possibly as much as three-fourths of it is composed of various greenstone schists. These include many varieties, ranging from somewhat schistose tuffs, whose pyroclastic origin is obvious in hand specimens, through more schistose mottled green and gray rocks to aphanitic phyllites and chlorite schists.

The less schistose tuffs are coarsely granular rocks, some of which are conglomeratic, with grains ranging from those measuring 3 centimeters or more to the finest particles. They are commonly mottled green and gray and weather brown. Under the microscope they are recognized as lithic tuffs, with some probably meta-andesite fragments composed of quartz, albite, chlorite, and epidote in a fine chloritic base. Conglomerate facies contain rolled chert pebbles and angular argillite fragments, all readily recognizable, with little crystalloblastic material evident.

These lithic tuffs grade through somewhat more schistose mottled greenstones to pencil chlorite schists which are aphanitic but reveal, under the microscope, chlorite and muscovite leaves dividing lenses of quartz, plagioclase, and epidote. The plagioclase is commonly albite or oligoclase, but andesine also occurs in some less epidotic specimens. Locally a little biotite occurs, but more common is a micaceous mineral with properties resembling those of nontronite. This may, indeed, be nontronite, but possibly it is merely chlorite rendered more pleochroic and highly birefringent by iron adsorbed during weathering. Actinolite is common, especially in the more schistose rocks. Many of these schists contain black carbonaceous material. Calcite is common.

Other dark carbonaceous chloritic schists, some of which are marked by planar rather than linear schistosity and resemble imperfectly cleaved slates, are present in subordinate amount through the formation. Their green color on transverse fracture betrays their chloritic character, which is confirmed by the microscope. The quantity of chlorite present indicates an igneous contribution to the deposit, which otherwise would have been a normal argillaceous sediment.

In addition to these schists derived from tuffs or admixed volcanic and detrital material, there are green schists, as a rule somewhat less well cleaved, which reveal, by their relict structure, their derivation from andesitic lavas.

The rocks next most abundant after the chlorite schists are the quartz phyllites. Most of these are dark bluish-gray or greenish-gray, buff-weathering rocks with pencil structure, but others have planar schistosity. Most of these rocks are aphanitic, but a few are sufficiently coarse to display recognizable mica flakes on cleavage surfaces. Under the microscope most of these rocks show flattened lenses of very fine grained mosaic-textured quartz with a little oligoclase-andesine feldspar cut by wavy surfaces marked by muscovite flakes. A little biotite occurs in some specimens; chlorite, actinolite, clinozoisite, and epidote are also distributed locally. Carbonaceous material is widespread. The grain of some of these rocks is so fine as to suggest that some of them may be sheared cherts, but others suggest sheared sandstones.

Quartzites, varying from coarse arkosic grit through sugary-textured varieties to dense "stretched" quartz schists, make up a very subordinate part of the formation. Some are rocks severely sheared by rotational movements into cigar-shaped pseudopebbles; less common facies show slight shear effects. The microscope shows that the composition of the quartzites is essentially that of the quartz phyllites except that they contain very much less muscovite and chlorite. Thus shear movements, which in the impure quartzites induced sufficient recrystallization of the micas to coat the shear surfaces and warrant the use of the term "phyllite", were unable to produce similar results in the purer quartzites.

Limestone makes up only a small part of the formation, probably less than 3 percent. In the western part of the quadrangle, near Bald Mountain, the limestones have been broken and squeezed into small isolated lenses, like those in the Elkhorn Ridge argillite and Clover Creek greenstone, but in the southeastern part of the quadrangle, on both sides of the Burnt River, the limestone beds are much more persistent and, although interrupted by faulting and contorted by folding, form fairly continuous bands. Although the widths of the thinner limestones have been slightly exaggerated on plate 1 (in pocket), several beds as much as 200 feet thick occur on the south wall of the Burnt River Canyon in T. 12 S., R. 41 E., and a few can be traced for 2 or 3 miles. Their junctions and commonly abrupt terminations are presumably due to faults, but no attempt has been made to map such faults, on account of a lack of

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conspicuous marker beds other than the limestones. Accordingly the reader who consults the map should not interpret the jointing and parting of limestone beds as evidence of lensing but as more likely due to obscure faults.

Large masses of limestone whose apparent thickness approaches or exceeds 1,000 feet occur in sec. 17, T. 12 S., R. 41 E., and secs. 1, 2, and 3, T. 12 S., R. 42 E., but these thicknesses probably result from repetition of beds by faulting. The limestone constituting these masses is light blue-gray and massive, with some irregular magnesian layers. The rock shows contamination by pyroclastic material in some places. Inclusions as much as 2 inches in diameter of chloritic volcanic material are found in some of the limestone in the Burnt River Canyon below Dark Canyon, in sec. 3, T. 12 S., R. 41 E. Locally the limestone has been altered to marble, and bedding within the individual masses is only exceptionally discernible.

Conditions of sedimentation.—Although the rock varieties just described have been discussed as if they were entirely distinct in origin, it should be emphasized that there are practically complete gradations from quartzite through quartz schist and quartz phyllite to chlorite-muscovite schist and chlorite schist, just as there are gradations from carbonaceous slate through chloritic slate to chlorite schist. The impression received in the field, which is supported by microscopic studies, is that pyroclastic material was added in amounts varying from time to time to a basin of sedimentation to which at some times sand and at others clay, with some carbonates, were being supplied. When volcanic contributions were small the deposits were such as have yielded the quartzites and carbonaceous slates now found, but when the volcanic material increased relative to the normal terrigenous sediment the deposits were such as have yielded the intermediate rocks described. At times such floods of volcanic material were contributed that practically unmixed tuff was formed.

Stratigraphic relations and age.—No systematic variations in the lithology of the Burnt River schist which might throw light on the depositional sequence within it or on the question as to which is the top and which the bottom of the formation have been found during this survey. The areal distribution and some structural details of the thicker limestone beds along the canyon and south of the Burnt River suggest that these beds may be exposed in the core of an anticline. If so, they are, of course, in the lowest exposed part of the formation. This conclusion must be considered only tentative, however.

The only pre-Tertiary rocks with which the Burnt River schist comes into visible contact within the Baker quadrangle are intrusive igneous masses. Inasmuch as no fossils have been found in the formation, it is thus far impossible to establish its age either indirectly or directly. It may be older than the Elkhorn Ridge argillite or younger than the Clover Creek greenstone—possibilities which will doubtless be readily disposed of when the adjoining Pine quadrangle is mapped. It is even conceivable that the Burnt River schist is in part contemporaneous with and equivalent to the Elkhorn Ridge argillite, as it was regarded by Lindgren[3] in his reconnaissance work. This suggestion is supported by the fact that it is possible to match, except for differences explicable by differences in degree of metamorphism, practically every lithologic variant except the chert of the Elkhorn Ridge argillite with some variety of the Burnt River schist. In fact, some of the finer quartz phyllite in the Burnt River schist may represent sheared chert. Nevertheless, on the whole, the Burnt River schist appears much less siliceous than the Elkhorn Ridge argillite, and its quartzose members appear to be chiefly of clastic origin, whereas those of the argillite are probably chemical deposits. Perhaps these grounds are insufficient to justify the conclusion that two formations are represented here, but when to these general features the differences in metamorphism of the rocks are added, the evidence seems to justify, at least provisionally, the cartographic distinction made in this report.

For the purpose of systematic discussion, it is assumed that the Burnt River schist is older than the Elkhorn Ridge argillite and probably of pre-Carboniferous age. This assumption is based chiefly on the fact that the metamorphism of the Burnt River schist probably exceeds in intensity that of the Elkhorn Ridge argillite, which is closely adjacent. This is no more than a suggestive criterion, however, and there is some lithologic resemblance between this formation and one in the Wallowa Mountains which appears stratigraphically equivalent to the Martin Bridge formation, of known Triassic age.[4]

The known Triassic rocks of the Wallowa Mountains, though having locally undergone severe igneous metamorphism, have undergone in general relatively less dynamic metamorphism than the Burnt River schist, but this difference may be of little significance, for the Burnt River schist is about 30 miles across the strike from the Triassic of the Wallowa Mountains and may well be in a different orogenic zone.

Thus it may be that the Burnt River schist is younger than the Elkhorn Ridge argillite and possibly Triassic or younger. Rocks resembling it in some respects and indeed probably belonging to the formation itself are represented in the Mormon Basin, where

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[3] Lindgren, Waldemar, op. cit., pl. 64.

[4] Ross, C. P., Geology and ore deposits of the southern Wallowa Mountains, Oreg.: U. S. Geol. Survey manuscript report.

they were assigned to the Triassic by Lindgren, although without direct evidence.

Future more detailed work—especially, it is thought, in the Pine quadrangle—may solve these questions; at present no adequate evidence is available.

ELKHORN RIDGE ARGILLITE

General features.—The most widespread formation of pre-Tertiary rocks in the Baker quadrangle is the Elkhorn Ridge argillite, a thick series of argillite, tuff, and chert with subordinate limestone and greenstone masses, here named from its exposures on Elkhorn Ridge in the Sumpter quadrangle.

The Elkhorn Ridge argillite is widely exposed in the Sumpter quadrangle, west of the Baker quadrangle, and extends in a broad eastward-trending belt—interrupted, it is true, by overlapping Tertiary rocks and by considerable intrusive bodies—across the middle third of the Baker quadrangle and beyond its eastern limits into the Pine quadrangle.

The topography developed on the formation is rather smoothly rounded as a rule, presumably because of the nearly uniform durability of the rocks in all directions and the absence of well-marked bedding or schistosity. The country where the formation crops out is mantled over wide areas by residual chert debris, which, by its tendency to accumulate on belts of less resistance than the adjoining ones, presumably is an important factor in producing rounded topographic forms.

Thickness.—The thickness of the Elkhorn Ridge argillite is not determinable with accuracy in the Baker quadrangle. From its areal distribution and observed attitude and the relief of the country it is obviously many hundred feet, probably several thousand feet, in thickness. The much better exposures in the Sumpter quadrangle furnished Pardee [5] a basis for estimating the thickness of a partial section of the formation as 3,000 feet. The siliceous argillite, limestone, and interbedded lava omitted from the section estimated by Pardee must increase this total considerably. Even making allowance for probable isoclinal folding and duplication by faulting a provisional estimate of 5,000 feet for the whole of the formation seems not excessive.

Lithology.—The Elkhorn Ridge argillite is composed of argillite, tuffaceous argillite, tuff, conglomerate, chert, and limestone, as well as thin beds of altered lava. The most abundant of these varieties are tuffaceous argillite, argillite, and tuff. Chert is widespread and locally the dominant rock through considerable thicknesses, but prob-

[5] Pardee, J. T., and Hewett, D. F., op. cit., p. 32.

ably its greater resistance to erosion leads to an exaggerated impression of the quantity present.

The argillite members of the formation are dark-gray, almost black rocks, with obscure or no bedding. They break into blocky fragments and only rarely along bedding surfaces. As a rule, they are very fine grained, though they grade into tuffs and conglomerates. Other specimens show a gradation into chert. Microscopic examination reveals the fact that most of these rocks have been sheared by rotatory movements into torpedo-shaped masses set in a matrix of similar material that shows shear lines. In some places this structure is visible in outcrops, and the rock has been called by Pardee [c] "pseudoconglomerate." It is not, however, to be confused with the true conglomerates described below. Systematic parting, sufficiently pronounced to be classed as cleavage, occurs only exceptionally.

The component grains of the argillite include quartz, andesine, nontronite (?), subordinate muscovite, and chlorite, together with considerable black carbonaceous material. Locally this carbonaceous material appears graphitic along shear surfaces. The average grain of these rocks is very fine, probably less than 0.005 millimeter, and many have no grains as large as 0.01 millimeter. Almost all the grains are angular, although a few are slightly rounded. In some specimens a crude "aggregate polarization" effect testifies to a common orientation of the micaceous minerals, but in many others no bedding or schistosity is evident in the argillite, even under the microscope.

The tuffaceous argillites, which seem even more widespread than the nontuffaceous varieties, resemble the rock just described both in color and in structure. On weathering, however, they commonly show pitted surfaces and even slight mottling. Microscopic study shows these features to be due to small fragments of dense andesitic lava or pumice, which disintegrate more readily than the fine matrix. Many specimens of dense dark-gray to black rock, which are quite aphanitic in hand specimens, are shown by the microscope to be tuffaceous with splintery crystals of andesine feldspar, with or without accompanying quartz, set in a matrix of finer feldspar fragments, chlorite, nontronite (?), and carbonaceous material.

By increase in the content of igneous material the rocks assume a more greenish color and become clearly recognizable tuffs. However, many specimens of tuff, even those with fairly coarse grains as large as 0.1 millimeter, contain enough carbonaceous matter to mask the chlorite which forms most of the matrix, so that they appear, in hand specimens, as dark as the argillites whose origin was not definitely pyroclastic.

[c] Pardee, J. T., and Hewett, D. F., op. cit., p. 34.

Cherts make up a very large part of the formation, even if allowance is made for the disproportionate prominence of outcrops of so hard a rock. The cherts vary from black through red, pink, and yellow to practically white. All are aphanitic. The microscope shows that the component quartz grains have the usual mosaic texture and that the dark cherts owe their color to carbonaceous matter. Carbonate rhombs are common in the chert, and muscovite flakes with no common orientation are also present.

All the rocks so far described as components of the formation occur in considerable quantity. Any single variety may form massive members scores of feet thick, but interbedding is common also. Chert, for instance, occurs almost to the exclusion of other rock varieties south of Pritchard Flat, in the southeast corner of T. 9 S., R. 42 E., but more commonly it occurs in layers ranging from a fraction of an inch to 3 inches in thickness, separated by thin partings of argillite. The boundaries between the two rocks are commonly wavy, and the wavy-surfaced chert layers seem to grade into chert lenses and nodules set in an argillite matrix. This is probably in part an original sedimentary feature, but some specimens of smaller chert lenses show shear phenomena, so that at least some of them probably resulted from shearing out by orogenic movements of a thin, once continuous chert layer in an argillite matrix, thus producing pseudoconglomeratic rocks. Examples of these pseudoconglomerates are well seen on Elkhorn Ridge in Five Bit Gulch, about half a mile north of the junction with Elk Creek.

True conglomerate beds are not conspicuous in the formation but have been observed in Blue Canyon near the site of Auburn, on the hill south of Pritchard Creek in sec. 24, T. 10 S., R. 42 E., and southeast of Virtue Flat in sec. 30, T. 9 S., R. 42 E. These conglomerate beds are made up of rounded and subangular pebbles of chert, argillite, limestone, and tuff as much as 3 inches across, set in a finer matrix of similar composition They are distinguished from the pseudoconglomerates by the diverse lithology of their component pebbles and the fact that the pebbles are not all bounded by shear surfaces, as they are in the pseudoconglomerates. The rocks composing the pebbles were already indurated, fractured, and the fractures filled with quartz before they were supplied to the conglomerate, so that, although consisting of materials such as the Elkhorn Ridge argillite is itself capable of having furnished, they suggest not intraformational deposition but either a remarkable fortuitous supply of sediment similar to the rest of the formation or a deposit younger than the older part of the argillite formation and unconformable upon it. The second of these possibilities seems much more likely than the first, so that it is probable that more detailed work than could be done on the scale of the present map will show that the Elkhorn Ridge argillite, as here mapped, is composed of two or possibly more formations rather than being a single depositional unit. This probability is strengthened by Pardee and Hewett's observation of a conglomerate containing transported Carboniferous fossils in the argillite south of Sumpter Valley in the Sumpter quadrangle.[7]

Limestone is present as a very subordinate but highly interesting constituent of the Elkhorn Ridge argillite. It occurs as lenses or podlike bodies, some with rectilinear boundaries, clearly resultant from stretching out and breaking up of a once continuous bed or beds. The masses range in size from those measured in fractions of an inch to those exceeding 1,500 feet in length (west of Washington Gulch, in sec. 15, T. 9 S., R. 39 E.) and 300 or 400 feet in width. Most of the masses are less than 300 by 100 feet in area of outcrop, some much less, so that many of those shown on the map have been slightly exaggerated. Many of the smallest bodies were not mapped. In the Sumpter quadrangle the detailed work of F. J. Katz demonstrated sufficient continuity of these small bodies to postulate a plunging fold involving a torn limestone bed.[8] In the Baker quadrangle such continuity is hardly to be seen except possibly north of the Powder River west of California Gulch, but there is a rough alinement of the limestone bodies in T. 10 S., R. 42 E., into belts converging southeastward and joining near the southeast corner of the township. It is doubtful whether this arrangement is to be interpreted as a stretched and broken limestone bed closely folded about a pitching axis, but the probability is enhanced by the more suggestive arrangement in the Sumpter quadrangle. The limestone is commonly bluish gray, highly jointed, and locally altered to marble. Consequently, although organic traces are common in these bodies, they have yielded very few determinable fossils. As the bedding of the limestone is nowhere satisfactorily preserved, determination of structure within these bodies is impossible.

Many of the limestone bodies are obviously impure, containing many small fragments, the largest 3 inches across, of greenish-gray, brown-weathering aphanitic material which are etched in relief on weathered surfaces. Under the microscope these fragments are identifiable as andesitic fragments grading from lapilli down to fine crystal splinters. Even some limestones that are apparently only silty prove in thin section to contain broken feldspar crystals and chlorite in a calcite base.

[7] Pardee, J. T., and Hewett, D. F., op. cit., p. 35.
[8] Idem, geologic map.

A minor but significant component of the Elkhorn Ridge argillite is andesite, some of which is altered to greenstone. No single layers of these volcanic flow rocks more than 20 feet thick have been found, but thinner flows were seen in many places. Locally, as in Blue Canyon at Auburn, well-exposed lenses of andesite occur in a linear arrangement suggesting a flow, sheared out by orogenic movements into lenses, in a pyroclastic argillite matrix. The andesite lenses attain dimensions of 20 by 5 feet, which may not exclude the possibility of their being huge breccia fragments, but their interpretation as representatives of a sheared flow seems more reasonable, especially in view of their lenslike shapes and alinement in bands.

Associated with these sheared flows are argillites containing sheared-out fragments of andesite tuff and limestone in a dense but highly sheared matrix. Representatives of this peculiar band are illustrated in figure 2.

In the absence of continuous good exposures it is difficult to estimate quantitatively the proportions of the several rock varieties just described in the formation. Nevertheless it seems warrantable to record the subjoined estimates, with the caution that they record only impressions—not results of measurements.

Estimated proportions of rock varieties composing the Elkhorn Ridge argillite in the Baker quadrangle

	Percent
Argillite, not cherty or definitely tuffaceous	10
Tuffaceous argillite	20
Tuff	15
Cherty argillite	40
Chert	10
Conglomerate	2
Limestone	<1
Andesite flows	3

Nonfissility of the argillite.—The factors which determine that, of two sediments composed of silt and clay-sized particles, one shall become a shale with well-marked fissility and the other an argillite without notable directional properties are not clearly recognized. Doubtless many factors may enter into the problem, either on the hypothesis that shale fissility is an original sedimentary feature due to flat-lying flakes of micaceous minerals or on the hypothesis that it is a derived feature consequent upon burial and deformation resulting in the rotation of micaceous constituents into approximate parallelism with the original bedding or recrystallization favoring mineral grains of this orientation. Whichever theory is correct, it is probably justifiable to assume that shale fissility is enhanced by predominance of flaky particles in the rock. This would be an effective factor, whether or not the classification of the grains by shape and size led to a classification by minerals.[9] The problem is

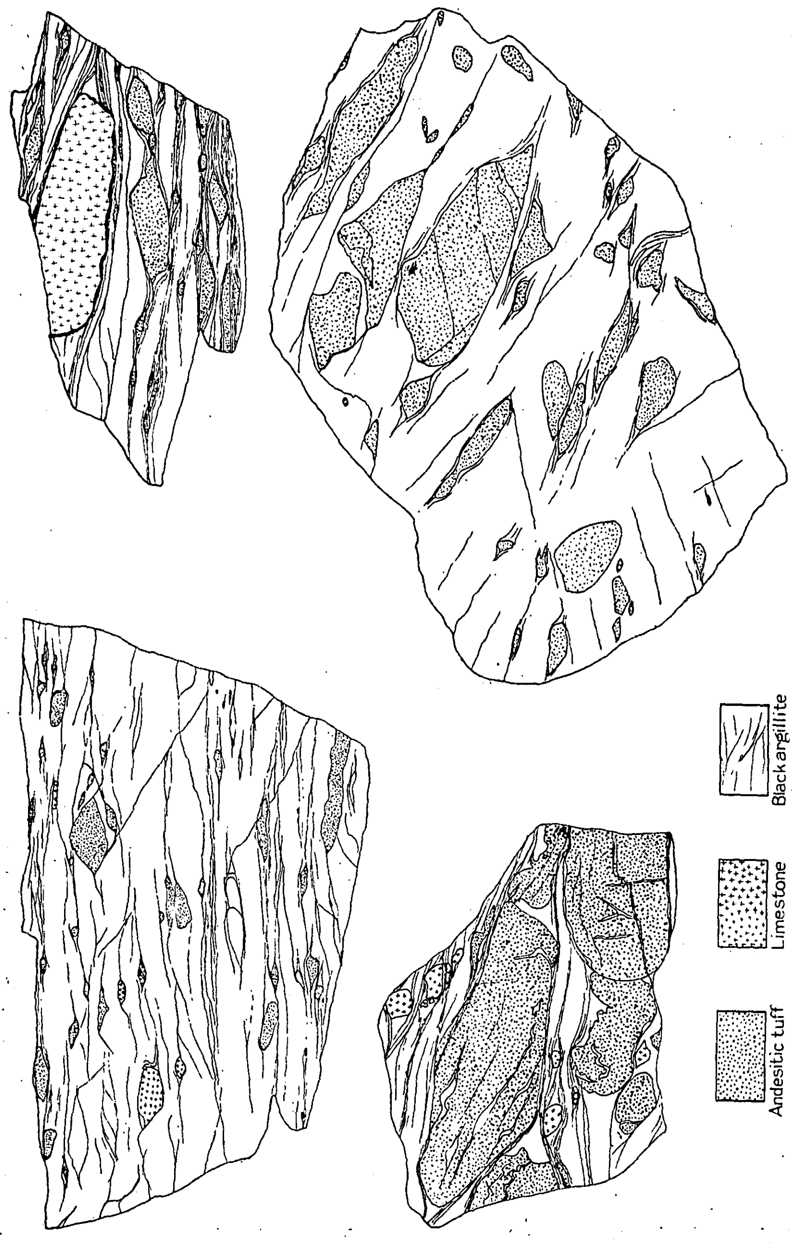

FIGURE 2.—Argillite containing sheared-out layers of andesitic tuff and limestone in a dense carbonaceous but much-sheared matrix, in Blue Canyon, near Auburn.

far too involved for dogmatic pronouncement, but if fissility tends to be inhibited by poor sorting, then the considerable contributions

[9] Bradley, W. H., Origin and microfossils of the oil shale of the Green River formation of Colorado and Utah: U. S. Geol. Survey Prof. Paper 168, p. 7, 1931.

of pyroclastic material in the Elkhorn Ridge argillite furnish a reasonable explanation for the almost entire absence of shaly parting in these rocks, for the particles in these contributions would obviously have little relation in size or shape to those sorted by normal waves and currents. The equidimensional grains interrupt the surfaces determined by the micaceous minerals, and parting along bedding planes is suppressed. Whether this explanation is generally applicable would require much work to decide, but it conforms to the observed features in these rocks.

Conditions of deposition.—The conditions under which the Elkhorn Ridge argillite was deposited are obscure, because of the deformation it has undergone and the relatively few continuously exposed sections of the formation. The limestone lenses are definitely of marine origin, as is demonstrated by their fossils, but the limestone is quantitatively a very minor part of the formation. Nevertheless, the cherty argillites and interbedded chert and argillite resemble known marine deposits elsewhere, and the absence of thick conglomerates also conforms with the interpretation as marine. Provisionally then, the formation is regarded as wholly marine, though it may include portions of continental origin.

The most striking feature is the marked proportion of pyroclastic material. The tuffaceous argillite, the tuff, and the tuffaceous limestone all clearly attest notable pyroclastic contributions to the formation, and it is highly probable that cherts so numerous and thick as those in this formation may be considered evidence of igneous contribution.[10] Only the noncherty argillite is free from definite pyroclastic material, and although absence of rounding in the constituent particles is to be expected even in normal detrital material of rocks so fine-grained, the large proportion of feldspar is ground for some suggestion of igneous contribution to these noncherty argillites, as well as to the others.

The association of the limestone with the volcanic materials may have no genetic significance, but it may be dependent upon the influence of volcanism in raising the temperature of the sea and hence decreasing the solubility of the lime, as has been suggested by Kania.[11]

Age and relations to other formations.—Nothing is known of the relations of the formation to other pre-Tertiary supracrustal rocks in the region, as the critical areas are masked by the overlapping

[10] Davis, E. F., The radiolarian cherts of the Franciscan group: California Univ. Dept. Geology Bull. 11, pp. 235–432, 1918. Sampson, Edward, The ferruginous chert formations of Notre Dame Bay, Newfoundland: Jour. Geology, vol. 31, pp. 571–598, 1923. Rubey, W. W., Origin of the siliceous Mowry shale of the Black Hills region: U. S. Geol. Survey Prof. Paper 154, pp. 153–170, 1929.

[11] Kania, J. E. A., Precipitation of limestone by submarine vents, fumaroles, and lava flows: Am. Jour. Sci., 5th ser., vol. 18, pp. 347–359, 1929.

Tertiary and Quaternary rocks or invaded by large intrusive bodies which effectually prevent the recognition of the contacts.

The Elkhorn Ridge argillite is referred to the Carboniferous period on the basis of small and fragmentary fossil collections from Winterville,[12] from a point 3 miles due south of Sumpter,[13] and from north of Pleasant Valley (obtained during the survey of the Baker quadrangle). The collections were all derived from limestones. The only generically determinable fossils represented were *Fusulina* from the locality near Sumpter, where a few brachiopods were also found. The other localities have yielded only large crinoid stems, some of which are over an inch in diameter, and indeterminable bryozoans. These collections suggest a Carboniferous age but contain nothing diagnostic of that period except the *Fusulina*, which is definitely upper Carboniferous (Pennsylvanian). The possibility that younger beds have been included in the formation as mapped in the Baker and Sumpter quadrangles has been pointed out on page 16 and by Pardee.[13]

Without more diagnostic fossils it is fruitless to attempt any regional correlation of the Elkhorn Ridge argillite. It is perhaps pertinent, however, to mention the occurrence of Carboniferous cherts, limestones, and chert breccias in the southwestern part of the Blue Mountains near Supplee.[14]

CLOVER CREEK GREENSTONE

General features.—The Clover Creek greenstone (here named from its exposures along Clover Creek in secs. 24, 25, 26, and 35, T. 7 S., R. 42 E.) consists of altered volcanic flows and pyroclastic rocks, with subordinate conglomerate, limestone, and chert. The formation is widely exposed in the northern third of the Baker quadrangle and is known to extend far into the adjacent Pine quadrangle on the east. It is also present still farther east, at Homestead, in the Snake River Canyon.

The Clover Creek greenstone is generally exposed in low, rolling hills, from which sharp, jutting crags project here and there a few feet above the general surface.

Thickness.—The thickness of the formation is not accurately known. Neither the bottom nor the top has been recognized in the Baker quadrangle, nor has the stratigraphic sequence within the formation been ascertained. The exposures are not continuous enough to permit working out the structure in detail; wherever the

[12] Lindgren, Waldemar, op. cit., p. 578.

[13] Pardee, J. T., and Hewett, D. F., op. cit., p. 35.

[14] Washburne, C. W., Notes on the marine sediments of Oregon: Jour. Geology, vol. 11, pp. 225–226, 1903. Packard, E. L., A new section of Paleozoic and Mesozoic rocks in central Oregon: Am. Jour. Sci., 5th ser., vol. 15, p. 222, 1928.

attitude of the greenstone could be determined on the interbedded tuff layers, it was seen to strike westerly and dip steeply either north or south. As the formation is exposed over a width of about 4 miles across the strike, it is highly probable that the great apparent thickness is due to close or isoclinal folding. It is thought likely, however, that the thickness of the Clover Creek greenstone is at least 4,000 feet, and it may be very much more.

Lithology.—Although many specimens from the Clover Creek greenstone are readily recognizable as altered volcanic rocks, most are highly sheared, chloritized, and silicified and are even somewhat schistose. The rocks are divided into lozenge-shaped blocks by seams of chlorite, so that they are aptly termed "greenstones."

The rocks composing the Clover Creek greenstone include quartz keratophyre,[15] keratophyre, spilite, albite diabase, keratophyre and quartz keratophyre tuff and breccia, meta-andesite, chert, conglomerate, argillite, and limestone. The most abundant varieties are the quartz keratophyres, probably followed by quartz keratophyre tuffs, keratophyre flows, meta-andesites, and keratophyre tuffs. The other rock varieties are subordinate.

The quartz keratophyres are commonly greenish rocks with sporadic phenocrysts of plagioclase and rounded quartz set in an aphanitic groundmass. The phenocrysts range in size from less than 0.5 millimeter to 1 centimeter and probably average about 1 millimeter. The groundmass is in some specimens porcelaneous and dense; in others, finely crystalline.

Under the microscope the rocks are seen to consist of quartz and cloudy albite or other triclinic alkaline feldspar set in a groundmass composed of quartz, albite, and chlorite. Epidote, calcite, green hornblende, sericite, and biotite, either one or all, are commonly present in small amounts, and sphene, magnetite, ilmenite, and apatite are accessory. Orthoclase may be present in some specimens, but it was not demonstrated and if present is rare. One specimen of the several scores studied contained a little augite in the groundmass, but chlorite is by far the most prominent dark mineral. The groundmass textures range from andesitic and trachytic through microspherulitic and micrograniitic (devitrified?) to granophyric. Shearing is evident in nearly every thin section, and some of the rocks are practically reduced to mylonite.

The feldspars are albitic and range from nearly pure albite to sodic oligoclase. Most have all indices well below 1.54, which corresponds to compositions more sodic than Ab_{95}. Chemical analysis confirms this—in fact, one analyzed specimen, no. 1 in the table on page 25, contains only enough CaO to satisfy the P_2O_5 present for apatite. However, all specimens carry apparently only one

[15] The term "keratophyre" has been used in two senses in petrography—(1) as a name for a lava bearing primary (magmatic) albite; (2) as a name for lava whose original more calcic feldspars have been later albitized. Published descriptions of most spilitic associations suggest the second mode of origin. It may be that rocks of both varieties are included under the name in this report, although it is believed that most of their contained albite is of postmagmatic origin. The name does not necessarily imply such an origin, however, and as here used connotes merely a felsic effusive rock with highly albitic feldspars.

feldspar, and as considerable K_2O is present in this specimen, there may be a little orthoclase in the microcrystalline groundmass, although the albitic feldspar may have some potash feldspar in solid solution. Symmetrical extinction angles of 16° normal to 010 and extinction angles of 18° to 20° between α and 001 on sections normal to γ correspond, however, to accepted values for nearly pure albite, so that if the potash is present in solid solution it does not seem to affect the optical properties of the feldspar appreciably. Some specimens clearly carry only albite, as their K_2O content is very slight. The feldspars are all cloudy and commonly contain very minute inclusions of chlorite. Inasmuch as epidote is very sparingly present and zoisite is practically absent from these rocks, their albite is clearly not due to saussuritic alteration, as might be expected from the shearing they have undergone. However, the mottled appearance and inclusions of the feldspars suggest a secondary origin, and they are believed to be albitization products, resembling strongly the feldspars described by Dewey and Flett[16] as characteristic of their "spilitic suite."

Keratophyres are widespread in the Clover Creek greenstone. Most of them are finely porphyritic rocks with phenocrysts of plagioclase and, in some, of hornblende set in a dense greenish-gray groundmass. The rocks are very similar, except for the absence of quartz, to the quartz keratophyres.

The microscope reveals albite and, in some specimens, oligoclase albite, green and brown hornblende, chlorite, epidote, zoisite, calcite, secondary quartz, and "ores", with accessory sphene and apatite. The texture is typically andesitic (pilotaxitic), but a few specimens are felsitic. The hornblende is largely altered to chlorite and epidote; some of the rocks show chlorite pseudomorphic after augite. The feldspars contain a little zoisite and epidote, suggesting a saussuritic origin, but the quantity of these two minerals is so small that it is unlikely that their solution in the plagioclase would yield a feldspar more calcic than oligoclase. Like the feldspars of the quartz keratophyres, these are cloudy and have chloritic inclusions. The evidence that their composition is due to albitization of originally more calcic feldspars is, however, much stronger than in the quartz keratophyres, for the textures of these rocks are those of typical andesites, and partly albitized andesites are found as gradational steps in their development.

The meta-andesites are dark-green rocks, some porphyritic and some nonporphyritic. The phenocrysts, where present, are nearly all feldspar with a little chlorite pseudomorphic after hornblende.

The microscope shows typical andesitic textures and the minerals labradorite-andesine, albite, chlorite, green hornblende, augite, zoisite, epidote, sericite, calcite, secondary quartz, apatite, and ilmenite. The augite and hornblende are in part altered to epidote and chlorite. Some specimens retain completely unaltered feldspars; in others slight saussuritization has occurred; and in still others the original labradorite or andesine feldspars are embayed and partly replaced by cloudy albite. In a few specimens this replacement has proceeded to the extent that only cores of the original more calcic feldspars remain, but in others it is only incipient or even absent. These partly albitized feldspars strongly suggest that the albite feldspars of the associated keratophyres are

[16] Dewey, H., and Flett, J. S., On some British pillow lavas and the rocks associated with them: Geol. Mag., dec. 5, vol. 8, pp. 204, 205, 1911.

secondary, for the rock textures are identical, and the mineralogic differences between the two rocks are only in the feldspar composition and in the considerably greater proportion of chlorite than pyroxene and amphibole in the keratophyres as contrasted with the meta-andesites.

Albite diabase is locally present in the Clover Creek greenstone, probably as sills of essentially the same age as the mass of the formation. It is a finely crystalline dark greenish-gray rock and shows feldspar and chlorite in hand specimens.

Under the microscope the rock shows a diabasic texture, with the original pyroxene altered to hornblende and chlorite; albite is the only feldspar. Ilmenite and magnetite also occur. The feldspar composition is here again supposed to be due to albitization, chiefly on the grounds of demonstrable albitization in the associated meta-andesites and the fact that the diabasic texture in fresh rocks is practically confined to rocks whose feldspars are labradorite or more calcic.

A few specimens best described as spilite were also collected from the formation. These are superficially like the dense meta-andesites but under the microscope show divergent granular textures, chlorite pseudomorphs after olivine, and other suggestions of an originally basaltic character.

The quartz keratophyre tuffs include dense porcelaneous rocks whose pyroclastic origin is revealed only by the microscope, somewhat gritty greenstones, and coarser mottled rocks whose fragmental origin is emphasized by weathering. Although the dense porcelaneous rocks are largely devitrified glassy tuffs, as is evident from the ghosts of shards which they contain, most of the tuffs are composed of rock fragments, ranging in size from 1 millimeter or so up to 10 centimeters or more. A few coarse breccia beds containing boulders as much as 3 or 4 feet in diameter also occur, but most of the pyroclastic rocks are to be classed as tuffs rather than breccias. The lithic tuffs contain fragments of quartz keratophyre and nonquartzose keratophyre similar to the flow rocks of these varieties. The keratophyre tuffs are like those of the quartz keratophyre except that they are essentially quartz-free.

Representative specimens of the rocks of the formation were selected and analyzed chemically, with the results shown in the subjoined table. For comparison some analyses regarded by Dewey and Flett[17] as typical of their "spilitic suite" are included.

[17] Dewey, H., and Flett, J. S., op. cit., pp. 206, 208, 209.

Analyses of rocks from the Clover Creek greenstone and other "spilitic" associations

	1	2	3	4	5	6	7	8	9
SiO_2	72.31	75.04	81.33	66.05	79.64	53.30	59.84	53.15	51.31
Al_2O_3	12.76	13.39	9.21	13.29	11.44	15.16	15.71	14.39	12.67
Fe_2O_3	1.94	1.61	1.09	3.22	.11	2.54	1.68	1.28	.54
FeO	1.26	.37	.74	5.07	.30	8.71	7.03	9.33	7.99
MgO	1.32	.18	.40	1.36	.15	4.14	1.37	4.74	2.19
CaO	.10	.40	.25	.50	.71	2.97	3.71	7.04	8.17
Na_2O	3.75	6.36	3.25	6.67	6.40	5.55	6.52	4.58	5.21
K_2O	3.61	.83	1.66	.87	.38	.32	2.76	1.01	.54
H_2O-	.26	.24	.15	.96	.16	.18	.14	.19	.04
H_2O+	1.48	1.07	1.12	1.88	.30	3.14	.31	2.02	2.31
TiO_2	.40	.10	.25	.49	.50	2.41	.64	1.50	1.92
CO_2	Tr.	.10	.10	--------	.02	None	--------	.10	6.15
P_2O_5	.15	.08	.04	.09	.08	.51	.20	.19	.90
MnO	.08	.05	.05	--------	.08	.28	.12	.14	.46
BaO	.09	None	Tr.(?)	--------	--------	None	--------	None	Not found
FeS_2	None	None	None	--------	--------	.40	[1].10	Tr.(?)	.30
Fe_7S_8	--------	--------	--------	--------	--------	--------	--------	--------	.17
Total	99.51	99.82	99.64	100.45	100.27	99.61	100.13	99.66	100.86

[1] S, not FeS_2.

1. Quartz keratophyre, west of Balm Creek, NW¼ sec. 29, T. 7 S., R. 43 E.; J. G. Fairchild, analyst.
2. Quartz keratophyre, SW¼ sec. 21, T. 7 S., R. 41 E.; J. G. Fairchild, analyst.
3. Quartz keratophyre, silicified, SW¼ sec. 23, T. 7 S., R. 41 E.; J. G. Fairchild, analyst.
4. Keratophyre, Trevennen, Great Britain (Dewey H., and Flett, J. S., op. cit., p. 209, no. II); W. Pollard, analyst.
5. Soda rhyolite, west side of Skomer Island, Wales (idem, no. III); E. G. Radley, analyst.
6. Albite diabase, level 2, Poorman mine, sec. 32, T. 7 S., R. 43 E., in Pine quadrangle, Oreg.; J. G. Fairchild, analyst.
7. Albite diabase, Newlyn, Cornwall (Dewey, H., and Flett, J. S., op. cit, p. 208, no. I); W. Pollard, analyst.
8. Spilite, NE¼ sec. 35, T. 7 S., R. 42 E., Baker quadrangle; J. G. Fairchild, analyst.
9. Spilite, Tayvallich Peninsula, Argyllshire (Dewey, H., and Fleet, J. S., op. cit., p. 206, no. I); E. G. Radley, analyst.

The marked similarity of most of the eastern Oregon rocks to the representative spilitic rocks of Dewey and Flett is obvious. The only exception is no. 1 of the table, which has nearly as much potassa as soda by weight. However, even in this rock the molecular ratio of soda to potassa is 3:2, and the others are all much higher in soda than this ratio.

It has been pointed out on page 22 that there is only enough CaO in rock no. 1 to satisfy the P_2O_5 present for apatite, so that the feldspar contains no lime whatever. Similarly rocks nos. 2 and 3 carry less than 1 percent of normative anorthite.

Chert and argillite beds are local and not abundant. The conglomerate members of the formation are few and apparently discontinuous, although this may be due to later deformation as well as to original deposition. The conglomerate consists of fairly well rounded pebbles of volcanic rock in a chloritic matrix. It is possibly intraformational and may have little historical significance.

Limestone and limestone breccia make up a small part, probably less than 0.5 percent, of the formation. The limestone occurs in disconnected lenses or pod-shaped bodies from a few feet to about 2,000 feet long and a few inches to about 400 feet wide. The largest limestone masses seen in this formation were found west and northwest of Table Mountain, in T. 7 S., R. 42 E. Some of the limestone is impure, with fragments of volcanic rock interspersed through it, suggesting a pyroclastic contribution to the sea in which the limestone was being deposited, but most of the limestone is rather pure. It is blue-gray, but some parts have been recrystallized to coarse white marble. Presumably the lens form of the limestone bodies is due to later shearing and squeezing, not to original deposition, for several of them show clear signs of flow at the edges. Furthermore, the limestones are marine, as is proved by fossils found in them, and it is the habit of marine limestones to form extensive beds without the abrupt terminations shown by these bodies.

Conditions of origin.—The marine limestone and associated fossiliferous tuffs demonstrate that parts of this formation are of submarine origin. The bulk of the formation consists of volcanic rocks not directly demonstrable as laid down on the sea bottom. The type of albitization which the volcanic rocks have undergone is, however, common in demonstrably submarine volcanic rocks. Most known bodies of spilitic volcanic rocks were erupted in submarine environments, and, although similar rocks are known to have been erupted under nonmarine conditions, the association here with marine limestone suggests rather strongly that the Clover Creek greenstone is in large part of submarine origin.

The classification and magmatic evolution of these albitic lavas have been discussed by the writer elsewhere.[18]

Age and correlation.—Small fossil collections have been made from the formation and submitted to G. H. Girty, of the Geological Survey, for examination. Mr. Girty's report is as follows:

Lot 6761, SE¼ sec. 11, T. 7 S., R. 41 E., Baker quadrangle; R. B. Stewart, collector:

- Stenopora sp.
- Productus aff. P. gruenewaldti.
- Productus aff. P. aagardi.
- Productus aff. P. aagardi var.
- Productus sp.
- Marginifera aff. M. typica var. septentrionalis.
- Pustula? sp.
- Camarophoria aff. C. margaritovi.
- Spirifer sp.
- Spirifer? sp.

[18] Gilluly, James, Keratophyres of eastern Oregon and the spilite problem: Am. Jour. Sci., 5th ser., vol. 29, pp. 225–252, 336–352, 1935.

Lot 6763, northeast corner sec. 21, T. 7 S., R. 41 E., Baker quadrangle; R. B. Stewart, collector:

Batostomella sp.
Derbya? sp.
Productus aff. P. aagardi var.
Marginifera aff. M. typica var. septentrionalis.
Spirifer, 3 sp.
Ambocoelia? sp.

These collections are noteworthy in several respects. The faunal lists rather misrepresent than conceal the fact that the fauna consists almost entirely of productoid shells, which are exceedingly abundant, other forms being equally scarce. Furthermore, with very few exceptions the Producti are represented by pedicle valves, only two or three brachial valves having been recognized as such. In point of preservation these fossils leave much to be desired, and that fact accounts for my inability to identify, except generically, the rarer forms, or even to suggest probable relations for them. The two collections contain essentially the same fauna, which appears to be more nearly allied to the Permian faunas of Alaska than to any that have come under my observation from the United States, and I have employed in identifying these species the same formulae that I have employed for species found in Alaska. Because of the poor preservation of the fossils from Oregon and the wide stretch of territory that intervenes between them and the Alaskan faunas, I cannot be sure that the names are employed in exactly the same way. The facts just recited will explain such differences in nomenclature as may be found between lists prepared now and lists prepared many years ago dealing with a fauna essentially the same. The age of the fauna, however, was at that time also determined tentatively as Permian, an opinion which is sustained by the present collections.

It is known that the Clover Creek greenstone extends at least a few miles west of the west edge of the Baker quadrangle, and it also extends eastward, cropping out at Homestead, in the Snake River Canyon, and in the southern part of the Seven Devils Mountains of Idaho. However, too little is known of the geology of eastern Oregon to permit extensive correlations of the formation on the basis of lithology, and the small fauna known from it is hardly distinctive enough to warrant widespread regional correlations.

INTRUSIVE ROCKS

GENERAL FEATURES

Nearly a sixth of the surface of the Baker quadrangle is occupied by outcrops of plutonic rocks. They are widely distributed through the quadrangle and exhibit no pronounced trends, although there is probably a slight tendency toward a westerly alinement, agreeing with that of the other pre-Tertiary geologic bodies.

These bodies occupy large areas on Elkhorn Ridge, on and south of Black Mountain, in the southeast corner of the quadrangle, on the divide between the Burnt River and Alder Creek, north of Virtue

Flat, in the hills near Hutchinson, and on Magpie Peak. Smaller masses are numerous elsewhere.

The plutonic rocks may be divided, on the basis of their degree of deformation and metamorphism, into two groups, one showing notable cataclastic and metasomatic metamorphism and another in which these features are negligible. The sheared plutonic rocks exhibit a wide range of composition, from ultrabasic to siliceous, but on the whole are chiefly gabbroic. The nondeformed plutonic rocks are all biotite-quartz diorites.

It is inferred that the differences in postmagmatic deformation that these two groups exhibit is a reflection of an age difference, because the wide distribution of both types, not only in the Baker quadrangle but throughout the Blue Mountain region, seems to exclude the alternative possibility that local structural features may have operated to bring about the contrast by permitting the protection of the biotite-quartz diorite bodies from a later orogenic pressure. Whether this age difference is slight and the groups are comagmatic, or great, so that they represent distinct magmatic cycles, is problematic. The writer is inclined to regard the agê difference as considerable. There are consistent slight differences in the accessory "heavy mineral" suites of the rocks of the two groups: the zircon and apatite crystals of the biotite-quartz diorite are sharply euhedral, while those of the other suite are notably corroded; pyrrhotite is almost lacking in the quartz diorite and relatively abundant in the other siliceous rocks. Other differences in the accessory minerals of the two groups lend some support to the idea that the rocks belong to distinct suites, but the evidence is not conclusive.[19] More persuasive is the fact that Lupher [20] has discovered evidence in the region south of Canyon City, toward the west end of the Blue Mountains, that some of the pyroxenite there present is of Lower or Middle Triassic age, while a gabbro intruding it is probably late Jurassic. In the Sumpter quadrangle, adjoining the Baker quadrangle on the west, a metagabbro sill is involved in folding earlier than the intrusion of "granodiorite" [biotite-quartz diorite] at Bald Mountain.[21]

The occurrence of volcanic rocks in the deposits of Carboniferous and Triassic age in the general region gives evidence of a corresponding series of plutonic intrusions, while the Idaho batholith, some 80 miles to the east, whose rocks compare closely with the "granodiorite"

[19] Reed, J. C., and Gilluly, James, Heavy mineral assemblages of some of the plutonic rocks of eastern Oregon: Am. Mineralogist, vol. 17, pp. 201–220, 1932.

[20] Lupher, R. L., personal communication, April 1930.

[21] Pardee, J. T., and Hewett, D. F., op. cit., pp. 34, 36–38.

of Lindgren, here called biotite-quartz diorite, has been regarded as late Jurassic.[22]

Accordingly the more or less metamorphosed plutonic rocks are here classed, with some reservations, as post-Carboniferous (?), while the biotite-quartz diorite is considered doubtfully post-Jurassic. It is entirely possible, however, that some of the so-called "post-Carboniferous (?) rocks" are really Permian.

GABBRO AND RELATED ROCKS

RANGE IN COMPOSITION

The most widespread intrusive rocks of the Baker quadrangle are gabbros or closely related basic rocks. Rocks of considerable range in composition, from serpentine, peridotite, and hornblendite, through hyperite (augite-hypersthene gabbro), hornblende-rich gabbro, bytownite gabbro (eucrite), and labradorite gabbro, to hornblende-quartz diorite are doubtless differentiates of a common magma, while trondhjemite (oligoclase-albite-quartz diorite) and albite granite are more siliceous but probably related rocks. Most of the gabbro has undergone metamorphism to lower-grade facies and is shown on the accompanying geologic map as "metagabbro." By far the most of this metamorphism has proceeded without notable change in bulk composition of the rocks involved, but locally there has been much silicification, and, in fact, there is considerable evidence that the albite granite has resulted from additive low-grade metamorphism of the hornblende-quartz diorite or even of the gabbro itself. These features are discussed in the descriptions of the individual rock varieties.

PERIDOTITE

The only considerable body of peridotite observed in the Baker quadrangle is just north of Ruckles Creek in the NE¼ sec. 13, T. 9 S., R. 41 E. The rock is clearly a facies of the gabbro mass extending west along the north side of Virtue Flat, and it is not shown separately on the geologic map because only a small area is occupied by the outcrop. Another even smaller mass occurs in the gabbro in the NW¼ sec. 34, T. 7 S., R. 40 E., about 2 miles south of Magpie Peak.

The peridotite north of Ruckles Creek is very dark gray, almost black, with lighter-gray mottling due to interstitial feldspar. The dark minerals observable in the hand specimen are amphibole, serpentine, and magnetite. The average grain of the amphibole is perhaps 2 millimeters long; the feldspar granules are chiefly less than 0.5 millimeter long.

[22] Ross, C. P., Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geology, vol. 36, pp. 673–693, 1928.

The microscope shows that the rock is composed of about 50 percent serpentine and residual olivine, 20 percent pale-green and yellow-brown amphibole, 10 percent slightly saussuritic calcic plagioclase, 15 percent diallage, and 5 percent magnetite, with trifling amounts of prehnite. The rock thus falls into the cortlandite subdivision of the peridotites. The olivine and its alteration product, serpentine, commonly form rounded grains, poikilitically enclosed by amphibole. Some of the amphibole is in parallel intergrowth with augite. It is probably actinolitic. The plagioclase is clearly interstitial. The mass south of Magpie Peak is similar in many respects but carries less plagioclase than the other and also has a little green spinel.

SERPENTINE

Small bodies of serpentine are widely distributed in intimate association with the more basic facies of the gabbro intrusions. Very few are large enough to be shown on a map of the scale of plate 1. The largest serpentine mass seen, about 2,000 by 500 feet, is in sec. 30, T. 10 S., R. 42 E., about 2 miles southeast of Pleasant Valley. Smaller bodies of mappable dimensions occur near and on Bald Mountain, in T. 11 S., R. 39 E.; in secs. 14 and 15, T. 12 S., R. 40 E.; in sec. 9, T. 11 S., R. 42 E.; and in sec. 4, T. 9 S., R. 41 E.

All the masses except a few of those near Bald Mountain are gradational facies of the basic intrusions; the few near Bald Mountain form isolated plugs in the Burnt River schist. It is probable that the serpentine is all or nearly all intrusive and of common origin with the gabbro.

Some of the serpentine masses appear to be localized along shear zones in the gabbro, but others show no such evident relation.

The serpentine varies in color from light green to almost black. Some is massive and aphanitic, some is much slickensided, and some contains metacrysts of antigorite in a dense base. Locally chrysotile seams cut through the masses. Green opal and magnesite veinlets are common. The bodies west of Auburn Creek in T. 12 S., R. 40 E., have borders of talc schist.

Under the microscope most of the serpentine is seen to be antigorite, with subordinate chrysotile and impurities such as ferriferous and aluminous chlorites, talc, anthophyllite, and locally a little residual olivine, pyroxene, or amphibole. Opal, chalcedony, quartz, and magnesite are weathering products. Relict structures were not observed, but the residual olivine and pyroxene locally present in the serpentine masses seem clearly to corroborate the field evidence of their derivation from basic differentiates of the gabbroic magma.

HYPERITE

Hyperite (diallage-hypersthene-plagioclase rock) has been found in only one area in the Baker quadrangle, in secs. 2, 3, and 11, T. 9 S., R. 41 E., north of Virtue Flat. The outcrop area is one of poor exposures, and at the time of mapping the rock was believed to be a part of the normal gabbro mass that extends for several miles along the north side of Virtue Flat. Only when examined under the microscope was it seen to be distinct from the normal gneissic gabbro. Accordingly, without additional field work, it cannot be stated whether this body forms merely a facies of the gabbro or is a separate intrusion.

The rock is dark gray, slightly gneissic, and fairly coarse grained, with average grain about 1 millimeter in some specimens and as much as 3 millimeters in others. All the specimens are fresh, with plagioclase and well-cleaved dark minerals apparent in hand specimens. The dark minerals are not notably bronze-colored in cleavage fragments.

In thin section the rock shows a faint gneissic texture, with no evidence of severe deformation. There is a slight suggestion of protoclastic texture.

Plagioclase in one specimen is about An_{60} in composition; in others it is An_{65}, very much more calcic. It is uniformly fresh and only slightly zoned. It makes up more than half the rock in all the specimens examined. Hypersthene, strongly pleochroic in green and red, forms subhedral crystals, a few of which show rounded forms. Diallage is a minor constituent, rarely exceeding 5 percent of the rock. Brown amphibole has replaced part of the hypersthene and augite but is a minor constituent. Iron "ores" and apatite are accessory minerals, and prehnite and chlorite occur as vein-forming secondary minerals.

It is possible that these rocks represent gabbro contaminated by admixed sediments. Such contamination has resulted in hypersthene-bearing rocks at the contact of the biotite-quartz diorite mass of Black Mountain. No sign of inclusions was seen here, however, and as the rocks are fully as coarse as the gabbros and no contacts with sediments are very near, there is no field evidence to support the idea. It is perhaps equally probable that the hypersthenic magma was intruded as such, but lack of field observations directed toward ascertaining the relations of the hyperite to the neighboring gabbro renders speculation on this point fruitless.

HORNBLENDITE

Hornblendite occurs as a minor facies of the gabbro at several places in the quadrangle, notably along a nearly east-west line through T. 9 S. Such masses are found on the lower north slopes of Elkhorn Ridge near the head of Washington Gulch; in the Flagstaff mine; east of Palmer; and southwest of Palmer just north of Virtue Flat. In none of these localities do the hornblendites form large masses.

The hornblendites in Washington Gulch, in the NE¼ sec. 28, T. 9 S., R. 39 E., are coarse porphyries with phenocrysts of hornblende commonly as much as an inch in diameter in a groundmass of hornblende and bytownite feldspar. Fully 80 percent of the rock is hornblende.

The hornblendite in the Flagstaff mine is also coarsely crystalline but in hand specimens is apparently equigranular, with crystals about 1 centimeter in diameter. Under the microscope the rock shows considerable diallage and olivine, a small amount of interstitial bytownite, and a little green spinel. Some shearing has occurred, with the production of actinolite after hornblende and of serpentine after olivine. The rock is intermediate between peridotite and hornblende gabbro.

The rocks near Palmer, in the NE¼ sec. 13, T. 9 S., R. 41 E., and the NE¼ sec. 8, T. 9 S., R. 42 E., are pseudoporphyritic, with poikilitic hornblende crystals 1 centimeter or more across, enclosing small amounts of altered plagioclase. Small amounts of sulphides occur as accessories with these rocks.

GABBRO AND METAGABBRO

General features.—By far the most abundant intrusive rocks of the Baker quadrangle are gabbro and metagabbro. They are distributed widely throughout the quadrangle and are exposed over areas measured in square miles near Magpie Peak, in Elkhorn Ridge, on the ridge north of Virtue Flat, and on the divide between Alder Creek and the Burnt River. The last-mentioned body is the largest single mass of gabbroic rock in the quadrangle, but small masses are to be found in nearly every considerable exposure of pre-Tertiary rocks. Roughly 7 or 8 percent of the quadrangle area is occupied by outcrops of gabbro and metagabbro.

These rocks are intrusive into all the supracrustal rocks of pre-Tertiary age. They are older than the albite granites and are either contemporaneous with or older than the hornblende-quartz diorite. They are clearly older than the biotite-quartz diorite, as is shown by the alteration of the gabbro to gneissic amphibolite along the contacts with the biotite-quartz diorite in the Dixie Creek Canyon and in general by the much-brecciated condition of the gabbroic rocks in contrast with the fresh, almost undeformed biotite-quartz diorite.

The complex structure of the intruded rocks, together with the strong deformation which both gabbro and country rock have subsequently undergone, has not permitted the working out of detailed relations between the shape of the gabbro masses and the structure of the adjacent country rock. In the large, the country rock seems to have exerted but little influence upon the emplacement of the gabbro, although there is some suggestion of a sill-like form of some of the gabbro masses on Elkhorn Ridge. In the Sumpter quadrangle, next to the west, gabbro sills have been recognized,[23] although this is not the only form taken by the intrusions. It is thought that in the Baker quadrangle most of the gabbro masses are crosscutting. One may hazard the speculation that the huge gabbro mass on the Alder Creek-Burnt River divide, separating, as it does, the Elkhorn Ridge argillite from the Burnt River schist, has been intruded along a major east-west fault. No direct evidence, beyond the suggestive outcrop relations, was found to support this speculation, however.

The gabbros and metagabbros are almost all gneissic, and in the few localities where the rocks yield hand specimens that show no shear banding it is generally possible to find evidences of crushing on a larger scale. There is no doubt that the entire region has undergone severe compression subsequent to the intrusion of the gabbro.

Petrography.—On plate 1 the attempt has been made to differentiate between gabbro, which has suffered little or no mineralogic change since consolidation, and metagabbro, in which alterations have proceeded to a considerable extent. The distinction is naturally an arbitrary one but conceivably of value as showing the regions of more and of less severe postgabbro deformation. The criterion used in the subdivision has been the degree of saussuritization of the feldspar. Where the feldspar retains sufficient clarity for determination the rock has been mapped as gabbro; where saussuritization has gone on to such an extent that the original feldspar is no longer recognizable and is now represented by a mass of zoisite and epidote in an albitic base the rocks are shown as metagabbro. The distinction made by some authors between gabbro and metagabbro, based upon the occurrence in the gabbro of augite rather than hornblende, has been rejected, because alteration of augite to hornblende is a common magmatic reaction and is clearly not suitable as a measure, however crude, of postmagmatic alteration.

The least-altered gabbros are found near Magpie Peak, southeast of Haines, and in the ridge north of Virtue Flat and are sparingly present in Elkhorn Ridge. Those in the southeast quarter of the quadrangle have undergone such severe metamorphism that they have been mapped as metagabbro.

The gabbros are chiefly dark-gray coarsely crystalline rocks, with feldspars, commonly from 2 millimeters to 1 centimeter in diameter, averaging about 3 millimeters, and augite or hornblende, in grains of comparable dimensions, as the only minerals determinable in hand

[23] Pardee, J. T., and Hewett, D. F., op. cit., p. 33.

specimens. Commonly they show a crude gneissic banding, but this is not invariable.

Under the microscope the gabbros show calcic plagioclase, augite or hornblende, locally a little actinolite, biotite, chlorite, rare quartz, and the accessories ilmenite, titanite, apatite, and locally pyrrhotite. Epidote and zoisite occur in small amounts, but any considerable amount of them suffices to class the rock with the metagabbro.

The plagioclase is in some specimens as calcic as An_{85}, in other specimens it approaches An_{50} in composition, but most is about An_{70}. Zoning of a wide range is not common; in most specimens it is practically absent. The augite commonly has diallage parting. Hornblende is in some specimens clearly secondary after augite; in others there is no trace of the former presence of any augite. The hornblende is ordinarily pleochroic in brownish-green to yellowish-green tones, but some specimens show two amphiboles, the second being actinolite. Biotite is present in but few specimens, and in them only in small amounts. Quartz occurs to the extent of 2 or 3 percent in a few specimens.

In some specimens the texture is hypidiomorphic granular. In others this texture shows cataclastic modifications, and in still others is crystalloblastic. Most of the gabbro is more or less cataclastic. Locally it has been altered to crystalloblastic amphibolite along the contact of the biotite-quartz diorite body in the southeast corner of the quadrangle.

Nearly all the gabbroic rocks of the southeast corner of the quadrangle are to be classed as metagabbro, as are those on Dooley Mountain, on much of Elkhorn Ridge, and at many other localities in the quadrangle. As noted on page 33, the metagabbros are arbitrarily separated from the gabbros on the basis of the saussuritization that their feldspars have undergone. Most of these rocks are readily distinguished in hand specimens from the gabbros, which are less altered, by the cloudy appearance of the feldspar and by the indistinct boundaries of the dark minerals, which feather out and penetrate the adjacent light minerals. Commonly also, shearing is much more conspicuous in the metagabbro than in the gabbro.

The minerals of the metagabbro are much the same as those of the gabbro except that a cloudy mass of zoisite or epidote in an albitic base takes the place of the clear feldspar. In addition to this change in the feldspars, there is characteristically much more secondary epidote, actinolite, and chlorite than there is in the gabbro. Augite is practically absent, though a few remnants were observed. Calcite is also commonly found in small amounts in the metagabbro. A little sericite is also present, and quartz is common, though usually in small amounts. In general, it may be said that the minerals of the metagabbro are those characteristic of low-grade metamorphism of the gabbro. They are those characteristic of the "green schist facies" of Eskola,[24] although the rocks by no means reached equilibrium.

[24] Eskola, Pentti, The mineral facies of rocks: Norsk geol. tidsskr., vol. 6, pp. 143–194, 1920.

Doubtless a more detailed study would permit subdivision of the metagabbros into more restricted mineralogic facies.

Texturally the metagabbros differ from the gabbros in having obviously undergone much more severe cataclastic deformation. There is also much more crystalloblastic texture and a nearly but not quite complete absence of the hypidiomorphic granular texture.

SILICIFIED GABBRO

Rocks whose derivation from gabbro can be demonstrated but which have been richly impregnated and partly replaced by silica are widespread in the Baker quadrangle. It is believed that the albite granite of the region has a comparable origin but differs by having received albite impregnations as well. In this section only those rocks that retain indisputable evidence of original gabbroic character are described.

The largest areas of outcrop of such silicified gabbros are (1) on the south slope of the hill southwest of the Flagstaff mine, in sec. 7, T. 9 S., R. 41 E.; (2) about the common corner of Tps. 9 and 10 S., Rs. 38 and 39 E., in Elkhorn Ridge; (3) on California Gulch in sec. 7, T. 10 S., R. 39 E., and neighboring areas. Smaller zones of sheared and silicified gabbro are common in the large gabbro mass on the divide between Alder Creek and the Burnt River. Most of these smaller zones consist chiefly of breccia of gabbro, the interstices of which are filled with dark quartz and epidote. Examination of the gabbro fragments in the breccia shows, however, that they have all been severely altered, the plagioclase saussuritized, and the dark minerals chloritized.

Silicification has occurred, commonly proceeding to the formation of an epidote-quartz-chlorite rock with little albite except in veinlets. In some specimens the dark minerals have altered to actinolite. These epidosite and chlorite-epidosite rocks are clearly due to mild hydrothermal alterations and silicification of fault zones.

The large mass south of the Flagstaff mine, however, is not so simply explicable. This rock appears like a normal diorite, except for a slightly blue color of the quartz. The rock is moderately coarse grained, with feldspars 1 or 2 millimeters across and a little hornblende. It appears to be equigranular in hand specimens. Under the microscope, however, the rock shows saussuritic calcic feldspars and actinolitic or chloritic alterations of earlier augite, in a micrographic groundmass of quartz and albite. The relations are such as would exist if the residual magma liquor in a normally crystallizing gabbro were removed and its place taken by quartz and albite. The plagioclase is not zoned in the usual sense. Rather, the broken-up saussurite has been flooded by albite-quartz intergrowth.

Replacement is suggested in some places but not so clearly as in the albite granites. Rocks such as these have been described from Ardnamurchan, Scotland.[25] Their relation to the albite granites seems very close, both in Scotland and here. (See pp. 39–40.)

The silicified bodies on Elkhorn Ridge are less thoroughly impregnated than those south of the Flagstaff mine. They are similar in general features, however.

HORNBLENDE-QUARTZ DIORITE

The only large body of hornblende-quartz diorite in the Baker quadrangle crops out in an irregular area of about 1 square mile just north of the divide between Virtue Flat and the Lower Powder Valley in sec. 35, T. 8 S., R. 41 E., and sec. 2, T. 9 S., R. 41 E. Small bodies occur in the SE¼ sec. 13, T. 9 S., R. 38 E., on Elkhorn Ridge, in the Flagstaff mine; a mile south of Palmer, near the northwest corner of sec. 17, T. 9 S., R. 42 E.; and in Ruckles Creek Canyon about a mile below Palmer. Other small bodies doubtless occur in association with the gabbroid rocks of the quadrangle, but many of the quartzose and hornblendic rocks which at first glance would be classed as hornblende-quartz diorite prove, on microscopic study, to be silicified gabbro rather than true diorites of igneous origin.

The hornblende-quartz diorite mass north of Virtue Flat is not well exposed, most outcrops being confined to stream beds. Accordingly little can be stated about its relations to the gabbro mass that bounds it on the south. It is clearly intrusive into the greenstone bounding it on the north. It may be a facies of the gabbro or, more probably, a separate intrusion.

In hand specimens the rock is light gray, millimeter-grained, and has a faint gneissic banding.

The microscope shows that it is composed chiefly of oligoclase-andesine feldspar, augite, quartz, a little green hornblende, and a small percentage of orthoclase. Sphene is an abundant accessory, and apatite and magnetite are less abundant. The plagioclase is slightly saussuritic, and the augite is partly converted to hornblende, both probably owing to mild cataclastic deformation to which the rock has been subjected. A few veinlets of prehnite penetrate the rock. Although in some specimens from this body there is more augite than hornblende, so that the rock is better called "augite-quartz diorite" than "hornblende-quartz diorite", this is not true in general, nor of the smaller scattered masses mentioned.

Because of the close association with gabbro in the field and because of local variations of other gabbro masses of the quadrangle toward similar composition, these quartz diorite intrusions are

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[25] Thomas, H. H., in Richey, J. E., Thomas, H. H., and others, The geology of Ardnamurchan, Northwest Mull and Coll: Scotland Geol. Survey Mem., pp. 147, 227, 325, and elsewhere, 1930.

regarded as probably comagmatic with the gabbro. The mild cataclastic deformation the quartz diorite has undergone is comparable to that which has affected the gabbro.

TRONDHJEMITE

Several small bodies of trondhjemite (soda-rich quartz diorite) are found in the Baker quadrangle. The rock is not present in large amount but is of considerable theoretical interest. The largest mass seen is just southeast of Palmer, where Ruckles Creek leaves Virtue Flat, in secs. 8, 17, and 16, T. 9 S., R. 42 E. About half a square mile is occupied by the trondhjemite outcrop, and its limits are masked by overlying Tertiary deposits. A smaller body of trondhjemite occurs about a mile northeast of the Flagstaff mine, north of Virtue Flat. Other bodies, too small to be shown on the accompanying map, are found near Magpie Peak, associated with gabbro and albite granite; between Rouen and Dutch Gulches in the north foothills of Elkhorn Ridge in an area surrounded by Tertiary sediments; in association with the gabbro mass north of Alder Creek in T. 10 S., R. 42 E.; and in a few other localities, associated with gabbro or albite granite.

The contacts of these bodies are not sufficiently exposed to show definitely whether or not they are intrusive into the associated gabbro masses. From analogy with the albite granites, it is considered possible that the trondhjemites grade into the more basic intrusives, but more probably they represent distinct masses.

The trondhjemites are light-colored, coarsely crystalline rocks, commonly massive but with local tendencies toward gneissic banding. Minerals recognizable in hand specimens include plagioclase, quartz of a notably dark-blue hue, hornblende, and epidote.

Thin sections show that these rocks are partly crystalloblastic and partly cataclastic. They consist of sodic oligoclase and quartz as major constituents, with less amounts of augite, hornblende, and epidote. In some specimens a more calcic, now saussuritic core of plagioclase is surrounded and embayed by oligoclase, but most specimens are not saussuritic. The textures suggest a little replacement of feldspar by quartz, but the evidence is far from conclusive. Cataclastic deformation has been rather severe in most specimens, even in one which showed an earlier crystalloblastic texture. The epidote and blue quartz seem to point toward a genetic connection between these rocks and the albite granite. The inconclusive field and microscopic evidence, however, is insufficient to warrant ascribing a similar origin to the trondhjemite.

ALBITE GRANITE

Major features.—Albite granite is widespread in the Baker quadrangle and adjacent territory to the east. Commonly it crops out in areas of a few acres only, closely associated with gabbro or diorite.

The largest body in the quadrangle, however, cropping out on and near Magpie Peak, occupies between 2 and 3 square miles. Smaller masses occur east of Hutchinson; near the north boundary of the quadrangle in R. 40 E.; near the head of Elk Creek in Elkhorn Ridge; in the northeast and southwest corners of T. 8 S., R. 42 E.; just northwest of Palmer; and at several localities in T. 11 S., R. 42 E. Outcrops too small to appear without unwarranted exaggeration on a geologic map of the scale of plate 1 are widely scattered, everywhere in close connection with gabbro or diorite.

As shown on the geologic map, nearly all these masses of albite granite are closely associated with gabbro or diorite intrusions. This association is so intimate, in fact, that the albite granites seem to form parts of the same intrusive masses with the gabbro and diorite. The body at Magpie Peak grades into the gabbro bounding it on the south. The same relation was observed just north of the Burnt River in sec. 29, T. 11 S., R. 42 E. Critical areas are more clearly exposed in the valley of Goose Creek and at the mouth of Maiden Gulch, in the Pine quadrangle to the east, and the writer believes that gradation between the two rocks can there be clearly demonstrated.[26] Evidence for this gradation is reviewed briefly on page 39 and more fully in the paper cited.

The albite granites, as modified portions of the gabbroic intrusions, penetrate all the pre-Tertiary formations of the quadrangle in a similar way to the gabbro. Their relations to or effects upon the preexisting structure of the intruded rocks are very obscure, owing both to later deformation and to the difficulty of deciphering the structure of the country rocks.

Practically all the albite granite is much crushed and brecciated, and much of it shows a vague gneissic banding—nowhere, however, sufficiently well marked to warrant classing the rock as a gneiss. Although hardly subject to quantitative measurement, it seems that, as a rule, the albite granite has undergone more severe deformation than the gabbro.

Petrography.—Most specimens of the albite granite are light gray or nearly white, with more or less marked banding. A few specimens are dark gray or greenish gray, owing to the dark-blue color of the quartz they contain, or to impregnation with epidote. As a rule the rocks are very poor in dark minerals, but a few, near Magpie Peak and elsewhere, carry as much as 20 percent of hornblende and biotite. Minerals identifiable in hand specimens are plagioclase, quartz, chlorite, and epidote in nearly all specimens; hornblende, biotite, and muscovite in a few. The average grain of the

[26] Gilluly, James, Replacement origin of the albite granite near Sparta, Oreg.: U. S. Geol. Survey Prof. Paper 175–C, pp. 69–70, 1933.

rocks is about 2 to 4 millimeters, but some are nearly aphanitic, with only sporadic crystals reaching this size.

Under the microscope the rocks show cataclastic textures as a rule, but a few are crystalloblastic. In some a granophyric intergrowth forms a matrix for irregular broken and corroded grains of feldspar, chlorite, and amphiboles. A few specimens have nearly normal granitic textures. Myrmekitelike intergrowths are common.

Minerals in the albite granite include plagioclase, quartz, amphibole, biotite, sericite, chlorite, epidote, clinozoisite, sphene, zircon, apatite, rutile, and magnetite.

Some of the plagioclase consists of clear albite with saussurite cores, usually not bounded by crystal forms. In other specimens all the feldspar is water-clear albite, but in most it is slightly cloudy though not saussuritic albite. In a very few specimens two varieties of plagioclase are found—a central core of andesine or even labradorite, surrounded by a wide rim of partly clear, partly cloudy albite. Tongues and vermicular and scalloped masses of albite anastomose through the central cores in a complex manner. Certainly the relations are not normal zoning. In the graphic varieties the albite is cloudy but not saussuritic. A little albite commonly fills veins through the rock. The optical properties of the plagioclase show that most of it is as sodic as Ab_{95}, and some is nearly pure albite, with all indices lower than 1.54.

The quartz has diverse habits. Some is merely interstitial, as in normal granites, but most has lobed edges against the feldspar and appears to have replaced it. In some specimens with as much as 50 percent of quartz it has clearly replaced plagioclase. It is notably bluish in color, with minute inclusions, probably of rutile.

Amphiboles of two varieties are sparsely represented. One is apparently common hornblende; the other corresponds optically to hastingsite. In some specimens this sodic amphibole is clearly secondary after the green hornblende. Biotite and sericite are present in a few specimens, but chlorite and epidote are the commonest dark minerals. Both have replaced earlier dark minerals, and epidote likewise occurs in minor bodies of saussurite and as veinlets through the rock. Titanite, magnetite, pyrrhotite, apatite, zircon, and rutile are accessories. Only 2 specimens, of more than 30 examined, carry orthoclase, and these in small amount.

The features that are found in the zones transitional to the quartz diorite (with which the albite granite is associated near Sparta) and that appear, but not so clearly, in the zones transitional to gabbro in the Baker quadrangle are, in passing from the host rock toward the albite granite, increasing quartz, commonly appearing along breccia zones; increasing quantities of biotite and chlorite relative to hornblende, though the total content of dark minerals is decreasing; the appearance of first sporadic and then concentrated grains of bluish quartz in the mass of the rock; and finally a marked diminution of dark minerals and a corresponding increase of light minerals throughout the rock.

In the Sparta district such transitions can be followed in the field, verified by the microscope, and confirmed by chemical analyses of the series of rocks involved. The ultimate product—that is, the most siliceous albite granite analyzed—has the following composition:

Analysis of albite granite, sec. 13, T. 8 S., R. 43 E., Pine quadrangle

[J. G. Fairchild, analyst]

SiO_2	77.04	H_2O-	0.00
Al_2O_3	11.88	H_2O+	.54
Fe_2O_3	1.05	TiO_2	.37
FeO	1.32	CO_2	.14
MgO	.04	P_2O_5	.04
CaO	1.28		
Na_2O	4.45		99.79
K_2O	1.64		

Similar rocks are widespread in the Baker quadrangle, and their relations to the associated more basic intrusions appear identical.

From the relations near Sparta the conclusion was drawn [27] that the rocks grade into each other, that the differences between them arose in place and do not directly result from differentiation at depth. The correlation between intensity of crushing and the quantity of the characteristic minerals of the albite granite—namely, quartz, albite, and hastingsite—is further evidence in favor of the derivation of the albitic rock in place and, with the direct evidence of replacement cited above and other features, suggests that the albite granite resulted from the albitization and silicification of the more calcic rock, in zones localized by brecciation. Through these zones siliceous and sodic solutions gained ready access to large volumes of rock and, by impregnation and reaction with some parts and complete replacement of others, brought about the formation of the albite granite. Details of the evidence supporting this hypothesis are given in the paper cited.

MAGMATIC RELATIONS OF THE EARLIER INTRUSIVES

The intimate association of gabbro, peridotite, hyperite, hornblende-quartz diorite, trondhjemite, and albite granite and the modifications suggesting gradation between them indicate, though lacking much of proof, that all are comagmatic. Pardee and Hewett [28] have reported that in the Sumpter quadrangle the peridotite is intrusive into the gabbro, but the writer, while unable to deny the possibility of similar relations in the Baker area, believes that the peridotite here represents a locally differentiated facies of the gabbro. According to either interpretation the genetic relation of the two rocks is probably intimate. It is clear that the gradations shown by the gabbro toward quartz diorite (near Magpie Peak, near the Flagstaff

[27] Gilluly, James, op. cit., pp. 69–70.
[28] Pardee, J. T., and Hewett, D. F., op. cit., p. 33.

mine, and elsewhere) are indicative of a close connection between them. The relations of the albite granite to the gabbro and quartz diorite are summarized on page 39. All these rocks have been deformed comparably. Tentatively it seems reasonable to regard them all as products of a single magmatic cycle.

Nevertheless, in the mountains south of Canyon City, toward the west end of the Blue Mountains, Lupher[29] has found definite evidence of two distinct intrusions—a pyroxenite of Middle or Lower Triassic age and a gabbro of Upper Jurassic age. It may well be that more detailed work will show that several cycles are represented among the intrusions older than the biotite-quartz diorite of the Baker quadrangle.

BIOTITE-QUARTZ DIORITE

Geologic relations.—The youngest of the large intrusive masses of the Baker quadrangle are quartz diorites in which the dominant dark mineral is biotite, although hornblendic varieties are found. Four rather large bodies of this rock occur in the quadrangle. Near Haines, where it has been quarried for many years, this rock crops out over an area of nearly 4 square miles and doubtless forms the bedrock beneath the alluvium in a considerable additional area. On the south flank of the hill spur projecting into Baker Valley southwest of the Flagstaff mine about one-third of a square mile of this rock is exposed. Here, again, alluvium prevents the complete delimitation of the mass. Black Mountain, at the west edge of the quadrangle, is largely made up of another mass of this rock, which underlies about 2 square miles in the Baker quadrangle and a similar area in the Sumpter quadrangle.[30] In the extreme southeast corner of the quadrangle an area of about 3 square miles is underlain by biotite-quartz diorite. This is part of the intrusive body about 6 miles in diameter that makes up Pedro Mountain. Another small body is exposed in an upthrown fault block a mile to the northwest of Lost Basin. Although only about 10 square miles of the area of the Baker quadrangle is underlain by biotite-quartz diorite, it is both widespread and in large volume in the Blue Mountains as a whole. It has been found at many places in a belt more than 100 miles long and 40 miles wide. It occurs in the Wallowa Mountains, to the northeast, and great masses are exposed in Elkhorn Ridge and the Greenhorn Mountains, to the west of the Baker quadrangle, and it has been recognized even as far west as Susanville, 50 miles west of Baker.

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[29] Lupher, R. L., personal communication, Apr. 21, 1931.
[30] Pardee, J. T., and Hewett, D. F., op. cit., geologic map.

Within this belt the individual masses of the rock range in size from small dikes to bodies with a surface exposure measured in tens of square miles, and from the uniformity of the rocks over this area it seems reasonable to conclude that all are cupolas on a much larger deep-seated mass, comparable in size perhaps to the Boulder batholith of Montana.

The biotite-quartz diorite is, at one place or another, intrusive into all the pre-Tertiary supracrustal formations of the Baker quadrangle. The structure of the pre-Tertiary formations is not sufficiently well known to permit confident assertion, but there is little obvious relation between the preexisting structure and the intrusive masses. In the larger sense they are probably crosscutting. Nevertheless, secondary structures have been locally impressed upon the wall rocks by the intrusive masses, testifying to the powerful intrusive pressures under which they were emplaced. Examples of such structures are found southeast of Hutchinson, where the Permian greenstones along the northwest border of the quartz diorite mass have been altered to biotite gneiss that shows strong vertical stretching. Other examples appear along the south side of the Black Mountain intrusion and almost entirely around the border of the Pedro Mountain intrusion. On the north wall of Dixie Creek Canyon, at the north contact of the quartz diorite of Pedro Mountain, the gabbro mass into which it has been intruded has been altered to a biotitic amphibolite with very steeply pitching linear features.

The testimony of the wall rocks is corroborated by the internal structure of the intrusive bodies themselves. These bodies appear at first glance to be essentially massive near the centers, but toward their contacts more and more marked schlieren are found. Immediately at the contact these schlieren are locally very pronounced, and observation on large rock surfaces of sufficient irregularity shows that faint banding persists even into the apparently massive central portions. The clearest exposures of these features are found on the north flank of Dixie Creek Canyon, in the southeast corner of the quadrangle, but they are also present on Black Mountain and near Haines and Hutchinson. Linear stretching is not so marked within the masses, but where found it dips steeply in the plane of the schlieren. Such meager observations of the schlieren as were made show conformity amounting almost to parallelism of the strike of the schlieren and that of the nearest contact. Dips of the schlieren are characteristically steep near the contact and more gentle at a distance from it.

The parallelism in strike between schlieren and contacts of course suggests similar parallelism in dip. On this assumption, the suggestion is advanced that the contact of the mass in the southeast corner of the quadrangle plunges steeply north and northwest. The Black Mountain mass appears to have the form of a bulbous sill, or dike, dipping about 60°–70° N. This conclusion is based on the prevalence of northward-dipping schlieren throughout the mass except immediately at the southern contact, where nearly vertical and southward-dipping schlieren are alone found. The exposures of the body near Haines are not favorable to structural observations, but those that were made strongly suggest that this mass widens downward on the northwest, south, and southeast. The west, north, and northeast contacts are concealed by alluvium. No observations were made on the internal structure of the small mass southwest of the Flagstaff mine.

The internal structure of these quartz diorite masses and the local structure imposed upon the country rocks strongly suggest that the masses were injected under powerful pressure. No cataclastic or even protoclastic textures have been found in the rocks under microscopic examination, and one is forced to conclude that the observed structures record magmatic movements just prior to complete consolidation.

However, suggestive as this evidence is, it hardly warrants a statement that the entire volumes now occupied by quartz diorite have been displaced by "shouldering" action of the magma. It is possible that at earlier stages stoping has been effective. It must be confessed, however, that no direct evidence, either structural or petrographic, has been found to suggest stoping in this area, and the direct evidence of shouldering must be considered, tentatively, as outweighing the possibilities of stoping.

The downward widening of the Bald Mountain batholith in the Sumpter quadrangle,[31] together with the suggestive evidence of the schlieren that the masses at Haines and Pedro Mountain similarly widen downward, must be considered as strengthening the probability, suggested by their petrography, that all are comagmatic and derived from a single large deeper-seated mass, upon which they are cupolas.

Petrography.—The most abundant facies of these intrusive bodies is a handsome light- to medium-gray equigranular rock whose average grain size is between 1 and 3 millimeters. Plagioclase, quartz, hornblende, and biotite are conspicuous in hand specimens. There are evident variations both in the total proportion of dark minerals and in the ratio of biotite to hornblende. As in the Sumpter quad-

[31] Pardee, J. T., and Hewett, D. F., Geology and mineral resources of the Sumpter quadrangle: Mineral Resources of Oregon, vol. 1, no. 6, p. 36, Oregon Bur. Mines and Geology, 1914.

rangle,[32] the border facies of the larger masses and the smaller masses as a whole are characterized by the preponderance of hornblende over biotite, a relation reversed in the central parts of the larger masses. Biotite is invariably present in considerable amount, however, so that these rocks are readily distinguished from the older hornblende-quartz diorites, from which biotite is absent.

An interesting and apparently characteristic feature of the rock is the presence of numerous rounded dark inclusions, rich in biotite and hornblende, in the otherwise light rock. Such dark clots range from less than an inch to more than a foot in diameter, but most of them are 1 to 3 inches in length. Probably they average one or two to every cubic yard of the rock. The problem of origin of the inclusions has not been attacked, and whether they are xenolithic or autolithic is unknown. Although quantitative studies were not made, they appear somewhat more abundant near contacts. The occurrence of these inclusions is unfortunate so far as building or monumental use of the rock is concerned, as they detract from the appearance and lead to many rejects in partly worked up stone.

The characteristic minerals of the quartz diorite identified under the microscope include plagioclase, quartz, biotite, and hornblende, with locally a little orthoclase, elsewhere a little augite, and the accessories apatite, titanite, zircon, and magnetite, with less ilmenite and pyrrhotite. The principal plagioclase is andesine, commonly strongly zoned as widely as from Ab_{40-45} to Ab_{70}. Locally, small apophyses from the larger intrusions show only labradorite feldspar and are strictly speaking quartz gabbro, but as a rule the average plagioclase composition, even where labradorite cores occur, is about Ab_{60}. Orthoclase is absent from many specimens, but in a few it makes up about 20 percent of the total rock. Such specimens are granodiorites, but they are so subordinate that they must be regarded as only minor facies. A few aplitic dikes contain even more orthoclase and are quartz monzonite. Despite these minor variant phases the rock as a whole is clearly a quartz diorite. This agrees with the conclusion of Hewett[33] respecting the Bald Mountain intrusive mass. Quartz constitutes on the average between one-fourth and one-fifth of the rock. The hornblende is mostly of the common green variety, locally with cores of residual augite in reaction relation. In turn the hornblende is in reaction relation with biotite, although much of the biotite is apparently independent of the hornblende. Secondary chlorite, sericite, and epidote are common but only in very small amount.

Specimens from the immediate contact of the Black Mountain mass are contaminated by reaction with the wall rock, with the production of considerable granulitic augite, hypersthene, and sillimanite (?) and suppression of quartz.

The texture is granitic except where granulitic texture has developed as a result of contamination. A very little myrmekite is present in some of the facies richer in orthoclase. Protoclastic and cataclastic structures are absent.

[32] Hewett, D. F., Zonal relations of the lodes of the Sumpter quadrangle, Oregon: Am. Inst. Min. Met. Eng. preprint, 1931, p. 6; Trans., 1931, p. 310.
[33] Idem (preprint), p. 5.

Estimated mode of the average biotite-quartz diorite

	Percent		Percent
Quartz	23	Hornblende	5
Andesine (Ab_{60})	55	Augite	<1
Orthoclase	5	Magnetite	1
Biotite	8	Other accessories	2

DIKES

Dikes are numerous in the vicinity of the intrusive stocks and rare elsewhere in the quadrangle. Most are siliceous and clearly to be referred to a pre-Tertiary date, but a few andesite and diabase dikes are probably representative of Tertiary volcanism. In this section only the pre-Tertiary dikes are described; the others are referred to in connection with the Tertiary rocks.

The scale of the mapping and time available for it did not permit showing the dikes on the geologic map. Most of them are between 10 and 50 feet wide, and although a few north of Auburn were traced as much as a mile, this is an unusual length. No rigorously systematic arrangement of the dikes is discernible, but there appears to be a tendency for them to trend slightly east of north and to dip steeply. It is probable that this reflects some control by the numerous joints normal to the regional strike, which are oriented in this direction generally throughout the quadrangle. (See p. 9.)

Some of the dikes appear to be related to the gabbro and hornblende diorite intrusions, but most of them are presumably connected with the quartz diorites. Those which are believed to be affiliated with the gabbros are commonly dark hornblendic porphyries, somewhat sheared and chloritic; those related to the quartz diorites are undeformed feldspathic porphyries, alaskites, and aplites. That they are younger than the gabbros is demonstrated by the presence of sheared gneissic gabbro inclusions in an undeformed porphyry dike in Blue Canyon west of Auburn. (See fig. 3.)

The dikes of gabbroic affinities are chiefly sheared porphyries containing feldspar and hornblende in a chloritic groundmass. The microscope shows cataclastic texture, with saussuritic feldspars, in both groundmass and phenocrysts, and highly chloritized dark minerals. Original feldspars have not been found in these rocks.

The younger dikes are mostly porphyritic granophyres with feldspars as much as 2 millimeters long and hornblende crystals somewhat smaller as a rule, set in a dense groundmass.

The microscope shows the feldspar phenocrysts to be andesine in most specimens, although slight albitization is apparent, and in some the feldspars are oligoclase.

These rocks have a little augite and considerable green and brown hornblende and andesine, commonly in a granophyric groundmass. Nongranophyric andesites also occur among these rocks. Most of the feldspar of the groundmass is sodic oligoclase or albite, but some orthoclase is also present. Quartz is confined to the groundmass. Many of these rocks show considerable hydrothermal alteration, with partial albitization of the feldspar phenocrysts and chloritization of the dark minerals. Calcite is common, and sericite is present in some specimens.

A few aplites, with the composition of biotite-quartz monzonites, occur in the biotite-quartz diorite mass in the southeast corner of the quadrangle, and dikes of alaskite and malchite (microdiorite) are found in the mass near Haines. Similar dikes in the gabbro and greenstone south of Magpie Peak may be referred to an origin in the younger quartz diorite.

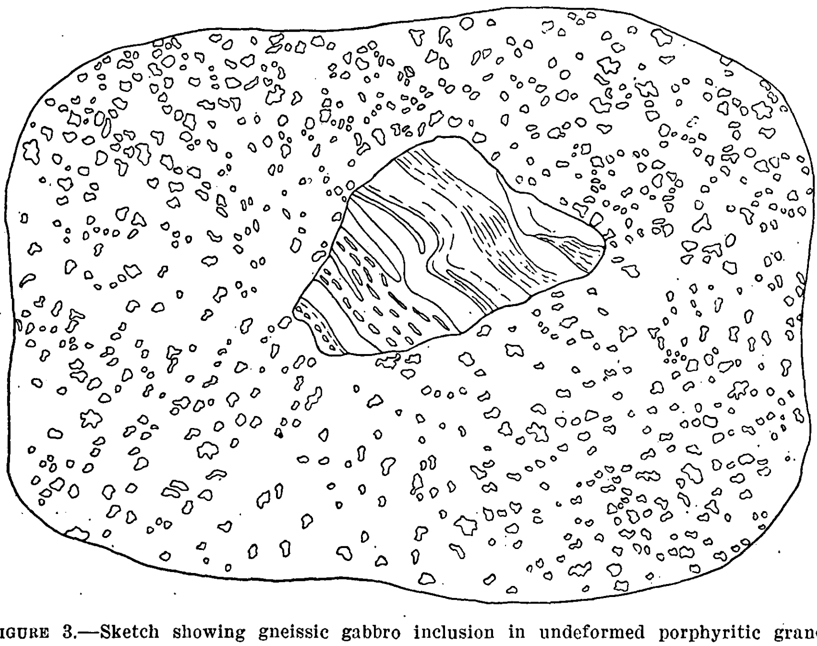

FIGURE 3.—Sketch showing gneissic gabbro inclusion in undeformed porphyritic granophyre dike in Blue Canyon, near Auburn.

GREENSTONE OF UNKNOWN AGE AND ORIGIN

A large proportion of the pre-Tertiary terrane of the quadrangle is composed of greenstone of one variety or another. Most of the masses of such rock have been classified as of intrusive origin (metagabbros) or of extrusive origin (volcanic flows and tuffs in the several supracrustal formations) and mapped accordingly. The rocks of definitely surficial origin have not been distinguished in mapping from their associated sediments.

In addition to these bodies of greenstone, there are considerable masses, largely on the divide between Alder Creek and the Burnt River, whose origin and relations, whether intrusive or extrusive, were not ascertained. No doubt more detailed study would readily permit classification of these rocks, but the reconnaissance was not sufficient to do so. These rocks are sheared but only moderately schistose, are thoroughly chloritic, and may represent metagabbros or massive volcanic rocks.

PRE-TERTIARY UNCONFORMITY

A profound unconformity separates the Tertiary from the pre-Tertiary rocks. A considerable lapse of time is represented by this unconformity, for the older rocks had been thrown into steep or isoclinal folds, intruded by a considerable range of plutonic rocks, and then eroded deeply enough to expose these plutonic bodies over wide areas before the Tertiary rocks were laid down upon them. The angular discordance between the rocks above and below this unconformity is as great as can well be imagined.

The surface upon which the Tertiary formations were deposited was one of considerable irregularity. Local relief of at least 600 feet in a horizontal distance of 1,500 feet was found in the quadrangle, though this is probably unusual. More subdued but still notable slopes are demonstrable in many localities. Such relief has been noted beneath each of the more widespread Tertiary formations where they rest on the pre-Tertiary rocks.

The interpretation of the contact relations of the Tertiary formations to the pre-Tertiary basement is greatly complicated by the existence of late Tertiary and Quaternary faults in the area. As a result, in any locality where the Tertiary formations rest with steep contact against the pre-Tertiary, the possibility that the relations may be due to tilting or faulting, and not to unconformity, must be considered. The question as to tilting is usually easily answered, but the decision between the other two possibilities is not everywhere apparent. However, beneath the Dooley rhyolite breccia in the valley of Cornet Creek, in the northwest corner of T. 12 S., R. 40 E.; in the valley of the westerly tributary of Auburn Creek in sec. 11, T. 12 S., R. 40 E.; and on the north slopes of Burnt River Canyon in secs. 19 and 20, T. 12 S., R. 41 E., marked relief, clearly not referable to faulting, is to be seen. The relations on the north slope of Dooley Mountain, a mile east of Bald Mountain, where the contact between Tertiary and pre-Tertiary descends 1,200 feet in about three-quarters of a mile, may be in part due to faulting.

One of the best localities in which to observe the rugged topography of the surface of unconformity is at the mouth of Big Creek, near the lower end of the Powder River Canyon, in T. 7 S., R. 41 E. Here a hill of Clover Creek greenstone only a few hundred feet wide rises nearly 400 feet through the lower lava flows. A similarly steep contact occurs a mile up Big Creek from this locality. Other localities in which this hilly topography can be demonstrated are (1) northeast of Magpie Peak, in sec. 14, T. 7 S., R. 40 E.; (2) in Washington Gulch, in sec. 14, T. 9 S., R. 39 E.; (3) in the canyon of Clover Creek, in sec. 18, T. 7 S., R. 42 E.; (4) due south of the Virtue mine; (5) in sec. 15, T. 11 S., R. 42 E.; (6) 3 miles east-southeast of Pleasant Valley; and (7) in the N½ sec. 31, T. 8 S., R. 41 E. Numerous other but less striking examples were found in the area.

The conclusion that these areas of local relief in the pre-Tertiary surface are representative and hence that the surface was one of steep hills, if not, indeed, of mountains, is at variance with that of Pardee and Hewett,[34] who state that the surface was "practically a plain", although granting that some hills rose above the general surface in the neighborhood of Elkhorn Ridge. Not only do the widely scattered examples of considerable local relief in this surface testify against this conclusion, but the irregular Tertiary overlaps seem also to indicate relief in the pre-Tertiary surface. In the Sumpter quadrangle the thickness of "andesitic tuff-breccia" which underlies the "early basic lavas" of Pardee and Hewett ranges from a knife-edge to 2,000 feet in about 6 miles, northeast of Kings Mountain. In the Baker quadrangle the overlap of the basalt on the Dooley rhyolite breccia is comparable, whereas the irregularities toward the north end of the quadrangle are commonly measured in hundreds of feet in less than a mile. Lindgren's conclusion [35] that the prevolcanic surface was one of considerable relief which finally became subdued by filling the depressions with flows and sediments appears more in keeping with the evidence in the Baker and Sumpter quadrangles than the conclusion that the prevolcanic surface was of gentle contour. There appears to be no convincing evidence of peneplanation before these Tertiary rocks were deposited.

TERTIARY ROCKS

SUPRACRUSTAL ROCKS

GRAVEL OLDER THAN THE DOOLEY RHYOLITE BRECCIA

The oldest of the Tertiary formations of the Baker quadrangle are scattered patches of gravel, locally underlying all the other Tertiary rocks. Such gravel beds are especially common in the more easterly areas, near Pleasant Valley and near the east edge of the quadrangle. On the map they are included with the Miocene lacustrine and fluvial deposits.

Most of these gravel beds are composed of material of local origin, but in the valley of Alder Creek and at nearby localities they com-

[34] Pardee, J. T., and Hewett, D. F., op. cit., pp. 21, 23–24, 29.

[35] Lindgren, Waldemar, The gold belt of the Blue Mountains of Oregon: U. S. Geol. Survey 22d Ann. Rept., pt. 2, pp. 596–597, 1901.

monly contain considerable quantities of well-rounded quartzite pebbles and boulders as much as a foot in diameter which are clearly foreign to the region. Rhyolitic tuff and obsidian, resembling the Dooley rhyolite breccia and shown on the map as part of it, are interbedded in or overlie these gravel deposits near Alder Creek, and possibly they are in part contemporaneous with the breccia. However, most of the sediments overlying the rhyolite breccia throughout the quadrangle are considerably younger than the breccia (see pp. 59–61), so that it is possible that there are two groups of sediments represented, one older and the other distinctly younger than the breccia, rather than one group of sediments in which intercalations of rhyolite breccia were deposited. The present study was not sufficiently detailed to prove this, however, and the gravel deposits, both older and younger, are shown on the geologic map with the same symbol.

It is likely that not all the gravel patches underlying the rhyolitic breccia are of the same age, but those containing the quartzite boulders of extraneous source probably are. What the age is remains unknown beyond the fact that it is probably earlier than Miocene and later than Cretaceous. (See pp. 61–63.)

DOOLEY RHYOLITE BRECCIA

The Dooley rhyolite breccia, here named from its excellent exposures on Dooley Mountain, consists of rhyolitic and subordinate andesitic breccias and flows. Although locally underlain by thin patches of gravel, the formation is regarded as the earliest one of appreciable extent in the Tertiary section. This interpretation is consistent with the mapped relations over most of the quadrangle, but as mapped the breccia rests on Columbia River lava in the valley of Lake Creek and nearby places and on some fairly thick fluviatile deposits near and south of Pleasant Valley. These features are most probably due to misidentification of the rocks and not to structural complexities, so that the reader should bear in mind the possibilities, first, that the Dooley rhyolite breccia is in part contemporaneous with the Columbia River lava of this quadrangle; second, that rhyolitic rocks of two ages, one earlier than the Columbia River lava, the other younger than the lava or contemporaneous with it, have been erroneously mapped as a single formation. The second of these possibilities seems much the more likely, but the problem must be solved in the field. In this connection the intercalation of rhyolitic flows and breccias between andesitic and basalt flows in the adjacent Sumpter quadrangle[36] is of interest. The lower

[36] Pardee, J. T., and Hewett, D. F., op. cit., pp. 42–45.

basic flows are correlated by Pardee and Hewett with the Columbia River lava, but it is possible that both overlying and underlying basic flows should be so correlated. (See pp. 61–62.) Along Sutton Creek and just east of Baker rhyolite tuffs, distinguished in mapping from the associated fluviatile deposits, occur interbedded with the basalt. These tuffs are possibly to be correlated with the Dooley rhyolite breccia and if so would fix its age as contemporary with the basalt.

The Dooley rhyolite breccia is thickest and most clearly exposed on Dooley Mountain, in canyons of Stices Gulch and Mill Creek, but thins rapidly in all directions away from this locality. To the west it barely extends to the edge of the quadrangle except at the divide between Whipple Gulch and Lake Creek, south of Black Mountain, and in the Powder River Valley. It has been doubtfully identified near Auburn, to the northwest, and in sporadic residual patches as far as the hills north of Virtue Flat, to the northeast. Southeastward small outliers correlated with the formation are found north of Lost Basin, near the quadrangle boundary. In all these extreme localities the residua of the formation are small and thin, and it is doubtful whether the formation ever extended more than a very few miles farther from the present center, near Dooley Mountain.

For the most part the formation is soft and readily eroded, but it contains enough inhomogeneities, such as obsidian flows and large boulders, to form a somewhat irregular topography in detail.

The stratigraphy of the formation is obscure, owing both to original complexities and to poor exposures brought about by the ready disintegration of the rocks composing it. The chief components appear to be light-buff to almost white glassy rocks, in huge bouldery masses set in a whitish matrix. Locally black or green obsidian, spherulitic rhyolite flows, pumice, or glassy flow breccias are dominant in the formation, but on the whole such flow rocks are probably subordinate to the breccias.

Among the commonest rocks in the breccia are light-buff glassy rocks with sporadic crystals of plagioclase about 2 millimeters in maximum size. Light-gray pumiceous-appearing flow breccias are also common, especially among the outlying representatives of the formation such as those near Pleasant Valley. Finely banded light-gray to green-gray obsidian is common. A few outcrops of resplendent black obsidian are exposed in the highway cuts in Mill Canyon and elsewhere.

The only crystals identifiable in hand specimens are a few of plagioclase and still fewer of sanidine; for the most part the rocks are aphanitic. The microscope shows a considerable range in the composition of the plagioclase, different specimens containing labradorite, andesine, and even oligoclase feldspars. Quartz was rarely found in phenocrysts and, indeed, was determined in the finely crystalline groundmass of only a relatively few specimens. By far the majority of the specimens examined consist of more than 80 percent glass, and many are almost entirely glassy.

From the mineralogy alone the rocks would nearly all be classed as andesite vitrophyres, but partial chemical analyses of representative specimens so classed prove that the rocks are better regarded as rhyolite or quartz latite.

Partial chemical analyses of Dooley rhyolite breccia

[J. G. Fairchild, analyst]

	1	2
SiO_2	73.49	78.31
CaO	.22	.05
Na_2O	2.55	3.86
K_2O	5.48	3.81

1. Pumiceous flow breccia, from mesa top in NE¼ sec. 8, T. 9 S., R. 42 E.
2. Vitrophyre, NE¼ sec. 35, T. 11 S., R. 41 E.

Nevertheless, there are a good many breccia fragments of true andesite, with hornblende, augite, and andesine arranged in flow textures in a glassy groundmass.

The formation embraces so many rock varieties that it is highly probable that detailed study would result in its subdivision, yet at least the main body, centering on Dooley Mountain, is believed to be a unit in its geologic relations. It seems to represent the coarsely fragmental and subordinate fluid ejecta of a volcanic center located somewhere near Mill Creek or Stices Gulch. Although the country in this vicinity was fairly well covered by traverses, no volcanic neck was recognized; possibly it lies concealed beneath the basalt flows or fluviatile deposits just north or south of Dooley Mountain, or it may be filled with obsidian like that in Mill Creek.

The thickness of the formation, as shown in the canyons of Mill Creek and Stices Gulch, cannot be less than 1,500 feet and probably exceeds 2,000 feet. Near the outer margins the thickness is less than 100 feet and commonly less than 20 feet. Although it is conceivable that these differences in thickness might arise from subsequent erosion of an originally less variable formation, whose source was at a greater distance, the thinning away from the Mill Creek locality in all directions in which observations were made is considered strong evidence that the volcanic center from which the materials of the formation were erupted lay close by.

The Dooley rhyolite breccia is locally underlain by small patches of gravel, but over most of its area it rests with marked unconformity on the pre-Tertiary rocks. The unconformity is angular and erosional, with steeply tilted or nearly vertical schist or argillite overlain by moderately dipping breccia. Although the attitude of the breccia is commonly obscure, it is believed to dip only locally at angles steeper than 30°. These dips have no relation, either in direction or in steepness, to those of the pre-Tertiary rocks. The relief of the surface upon which the breccia was deposited was considerable, as is clear from the attitudes of the contacts with the older rocks near Cornet Creek, near Auburn Canyon, and to the east, where hills of pre-Tertiary rock project several hundred feet into the overlying breccia, with relations not explicable except by original deposition on an irregular surface.

The upper contact of the formation is probably conformable, in the Dooley Mountain area, with flow-banded andesite and rhyolite resting on the breccia. In the outlying areas the formation is in some places directly overlain by fluviatile deposits and in others by Columbia River lava, but these differences are probably due less to angular discordance than to postbreccia erosion and irregularities in the surface on which it lies.

FLOW-BANDED ANDESITE

On both the north and south slopes of Dooley Mountain the Dooley rhyolite breccia is overlain, probably conformably, by a conspicuously flow-banded series of red porphyritic andesites with subordinate rhyolite. On both sides of Mill Creek just above the mouth of the canyon, and extending in a band both east and west of this place, these rocks are well exposed just beneath the overlying basalt. Similarly, they are exposed on Stices Gulch about 3 miles south of Bennett, and 2 miles east of this point, northwest and northeast of Rogers. Although the formation is relatively conspicuous, owing to its prominent flow stretching and porphyritic character, study of several specimens from Cornet Creek and between Cornet and Indian Creeks has shown that certain porphyritic flows mapped with this formation should probably have been mapped with the overlying Columbia River lava, instead. The doubtful contact has been indicated as uncertain on the map, although exposures here are good, and the uncertainty is due merely to misinterpretation of the relations of certain flows. Elsewhere the microscopic studies confirm the field discrimination of these rocks.

Inasmuch as this lava formation rests upon the relatively much softer Dooley rhyolite breccia it is a fairly prominent ledge-former. It is also the oldest Tertiary formation that can be used as a marker bed on both slopes of Dooley Mountain, as the underlying rocks are so variable as to be useless for this purpose, at least until they are studied more minutely.

The most striking lithologic feature of the andesite is its marked flow stretching, which is so pronounced that a pseudofibrous structure is produced, and in the field the name "woody andesite" was adopted for the rock. This flow banding is less prominent in the higher beds than in the lower. The rocks are all reddish-brown porphyries, with phenocrysts of plagioclase in an aphanitic stony or glassy groundmass. Some of the higher flows contain olivine phenocrysts as well as feldspar. The microscope shows that the lower flows consist of andesine phenocrysts in a glassy base or of andesine phenocrysts in a groundmass of quartz, orthoclase, and andesine. Higher beds contain olivine and andesine but no quartz, have andesitic texture, and are best called "olivine andesites." They resemble some of the porphyritic andesites that are interbedded with the basalts of the Columbia River lava in the bend of the Powder Valley northwest of Bennett, and it is probable that in places the formation has not been consistently distinguished from porphyritic basalts of this overlying formation.

The formation varies in thickness from about 300 feet, west of Cornet Creek, to a knife edge, and it disappears entirely near Auburn Creek, on the south flank of Dooley Mountain, and near Beaver Creek and west of Rancheria Creek, on the north flank. The basal contact may be conformable, but the indistinct attitude of the Dooley rhyolite breccia renders this uncertain. On the north flank of Dooley Mountain the upper contact is clearly an unconformity, because the formation is overlain at different places by Columbia River lava and by fluviatile deposits interbedded with it, which elsewhere rest directly on the Dooley; on the south slope of the mountain the succeeding deposits likewise differ in different places, but between Indian Creek and Mill Creek the basalts seem conformable on the andesite. Presumably detailed study would reveal an unconformity here, also.

ANDESITE TUFF-BRECCIA

Rocks widely exposed in the adjacent Sumpter quadrangle have been referred to by Pardee and Hewett [37] as "andesite tuff-breccia." As the name implies, the formation consists of andesite boulders set in a tuffaceous matrix. Although rather thick in the canyon of the Burnt River through Kings Mountain, a few miles west of the boundary of the quadrangle, the formation extends only about 3 miles into the Baker quadrangle, near its southwest corner.

Owing to the soft matrix in which the boulders are set, the formation is relatively easily eroded but yields in places a "hoodoo"

[37] Pardee, J. T., and Hewett, D. F., op. cit., pp. 40–42.

topography studded with pedestal rocks. More commonly it forms smooth slopes strewn with boulders.

The andesite tuff-breccia consists almost wholly of water-laid materials, which are rather poorly sorted. Angular boulders and blocks as much as 10 feet in diameter are present, but most of the boulders measure only a foot or two. From these the material grades down through all sizes to that of fine silt, and it is not uncommon to find large boulders set in a fine silty matrix. The boulders consist of dark-gray, light-gray, or red porphyritic andesite, with phenocrysts of hornblende and plagioclase in a dense felsitic or glassy groundmass. A considerable variety of texture is found, but the rocks are clearly all andesites. The matrix is chiefly volcanic ash, with naturally some debris derived from abrasion of the boulders.

Although the materials are poorly sorted, the irregular bedding of lenses of sand and silt or fine grit testifies to the action of water in the deposition of the breccia. The materials can hardly have been transported for more than a few miles, and the source is probably not far distant.

The andesite tuff-breccia is reported by Pardee and Hewett [38] to be about 1,800 feet thick on Kings Mountain, 8 miles west of the edge of the Baker quadrangle. Accurate measurement in the Baker quadrangle is impossible, because of poor exposures and the probability of unseen faults, but the exposures west of Cow Creek, in secs. 4 and 5, T. 12 S., R. 39 E., seem to indicate a local thickness of about 600 feet. The breccia is eroded east of Cow Creek and cannot be traced farther in this direction.

In the Sumpter quadrangle the formation rests directly on the pre-Tertiary basement, and this relation also exists for about 2 miles within the Baker quadrangle. The andesite tuff-breccia east of the divide between Cow Creek and Big Creek is interpreted as overlying the Dooley rhyolite breccia, perhaps on an erosion surface developed on the rhyolite breccia. This interpretation may demand revision, however, as the possibility that faults have caused the present relations, though remote, cannot be entirely rejected.

On the hypothesis that the andesite tuff-breccia overlies the Dooley rhyolite breccia, the relief developed on the surface of the rhyolite breccia before the andesitic rocks were laid down was of the order of 300 feet in half a mile—a moderate amount that might be accounted for by very slight erosion of the variable rhyolite breccia, which doubtless had an originally irregular surface, and would clearly not demand either a long time interval or structural disturbance of a volcanic formation so local in occurrence as the Dooley rhyolite breccia.

[38] Pardee, J. T., and Hewett, D. F., op. cit., p. 41.

COLUMBIA RIVER LAVA

Distribution and topographic expression.—The most widespread geologic formation in eastern Oregon is the Columbia River lava. In the Baker quadrangle this lava, together with the intimately associated and interfingering sediments, occupies about a third of the area. The lava alone covers about a fifth of the quadrangle.

The Columbia River lava makes a gently southward-tilted plateau about 20 square miles in area in the extreme northeast corner of the quadrangle. Another large belt extends from the north edge of the quadrangle northeast of Magpie Peak slightly east of south to Virtue Flat. Other moderately large exposures are found east of Baker and in the curve of the Powder River northwest of Bennett. Although these are the only large areas of outcrop, the lava is represented by scores of small outliers scattered from the northwest corner of the quadrangle to the valley of the Burnt River, on the southwest, and even to the valley north of Lost Basin, near the southeast corner.

The Columbia River lava is more resistant to erosion than any other formation in the area and exerts a striking influence on the topography. Where the lava is flat-lying it produces a benchland topography, but where it is tilted it forms hogback ridges and cuestas.

Petrography.—The Columbia River lava is composed of many flows, ranging from about 20 to 80 feet in thickness, the average being perhaps 40 feet. As a rule, the flows are separated by scoriaceous zones at the top and bottom. These zones are commonly but by no means invariably bright red.

There are three principal varieties of lava in the series—olivine basalt, hypersthene-augite andesite, and hypersthene andesite. A minor variety, found chiefly in the southwestern areas, is augite andesite.

The olivine basalt, which constitutes probably two-thirds of the flows, is a dark-gray dense rock, with or without phenocrysts of olivine as much as 1 millimeter in diameter, in an aphanitic, finely vesicular to dense groundmass. A few flows are coarse enough to be classed as diabase.

In thin section they commonly show ophitic to divergent granular textures; a few are intersertal or approach a fluidal andesitic texture. Tabular crystals of calcic labradorite, about An_{70} make up 40 to 45 percent of the rock; olivine, chiefly in microphenocrysts, 8 to 10 percent; pyroxenes, which range from normal augite to a variety of pigeonite, 30 percent; and magnetite, apatite, and glass the remainder.

Hypersthene-augite andesite makes up many flows in the more northerly exposures of the lava but is subordinate toward the south. It is light to medium gray and characteristically platy, with the platy structure commonly subparallel to the base of the flow but locally at any angle, even normal to the base. Wavy streaks of minute vesicles bring out the flow structure.

In thin section the rock shows a felted texture, with local tendencies to fluidal arrangement of crystals in a glassy groundmass. Feldspar of a composition close to An_{45} occurs in minute laths not more than 0.1 millimeter long and makes up about 50 to 60 percent of the rock. Augite is present in granules averaging about 0.03 millimeter in length and constituting 25 percent. Hypersthene, in microphenocrysts as much as 0.2 millimeter long, makes up about 5 percent. Minor amounts of magnetite and apatite are present, and the rest is glass.

The hypersthene andesite is much less abundant than the two lavas just described and, like the hypersthene-augite andesite, is widespread in the more northerly localities. None was found south of Baker. It is a very dark gray, almost black rock, dense and glassy, and breaks with a glistening conchoidal fracture. No minerals are identifiable in hand specimens.

Under the microscope the rock shows a felted texture, with flow structure, in a glassy groundmass. The rock is about 45 percent andesine-labradorite, in minute laths rarely exceeding 0.1 millimeter in length. Columnar microphenocrysts of hypersthene 0.5 millimeter in maximum length make up about 3 percent; magnetite is present as accessory, and glass makes up about half the rock. Some specimens carry a little augite as well as the hypersthene.

The augite andesites resemble the basalts except for the sparing amount or absence of olivine and the somewhat greater quantities of plagioclase they contain. They also have textures in which flow effects are more prominently preserved.

Relations to older rocks.—The surface upon which the Columbia River lava rests is one of the profound unconformity, at least in most parts of the quadrangle. Angular discordance with the older Tertiary beds, though probable in places, has not been proved; angular discordance with the pre-Tertiary rocks is obvious on the most cursory view.

The Columbia River lava rests, at one place or another, upon every pre-Tertiary formation in the quadrangle, in utter disregard of their attitude. The structural discordance between them is as profound as could be imagined. In addition to this structural discordance, a markedly irregular topography had been developed upon the pre-Tertiary rocks before the extrusion of the basalts. The evidence for this statement is briefly outlined in the section dealing with the pre-Tertiary unconformity (pp. 47–48).

The unconformity between the Columbia River lava and the earlier Tertiary formations, although not demonstrably angular and hence not so striking as that on the pre-Tertiary formations, is well brought out by the relations in the southern part of the quadrangle. Here, just east of the head of the Burnt River Canyon, in T. 12 S., R. 41 E., the basalt rests on the Dooley rhyolite breccia. Just east of Auburn Creek it lies directly on the Burnt River schist, overlapping from the Dooley, and from Mill Creek west it is separated from the Dooley by the flow-banded andesite. West of Cow Creek it rests on the andesite tuff-breccia and on fluviatile sediments, which also seem to dip at slightly steeper angles than the basalt; and on the south slopes of Dooley Mountain, in T. 11 S., R. 39 E., the basalt overlaps all the earlier Tertiary rocks and rests directly on the Burnt River schist. In the valley at the head of Lake Creek, south of Black Mountain, the Columbia River lava rests upon Dooley rhyolite breccia and locally on fluviatile deposits, but on top of Black Mountain it rests directly upon the biotite-quartz diorite. Similar variation in the underlying rocks is common throughout the area of earlier Tertiary sediments.

These overlaps of the Columbia River lava from one earlier Tertiary formation to another and from the Tertiary onto the pre-Tertiary do not in themselves prove a period of erosion immediately antedating the Columbia River lava extrusions, because in part they may simply be due to the earlier Tertiary formations having filled part of the hollows in a hilly surface comparable to that now seen where the lava rests directly on the pre-Tertiary rocks. Nevertheless, erosion intervals are probable in a volcanic sequence so diverse as that of the Baker quadrangle. If the interpretation of the dacite body near Cow Creek, in the southwest corner of the quadrangle, as a sill is correct, there is evidence of considerable erosion before the deposition of the Columbia River lava in that area, for obviously younger fluviatile deposits rest directly on the dacite and are themselves interbedded with the Columbia River lava. If the dacite body is a flow, however, the irregular surfaces of contact with the overlying fluviatile deposits may not have required much time for its production and indeed may be constructional. There is definite local evidence of aggradation just before certain flows locally at the base were poured out, but this may have occurred even though erosion was the dominant process in the area at the time.

These relations, together with those outlined in the section dealing with the pre-Tertiary unconformity, indicate that the surface upon which the Columbia River lava was extruded was one of considerable relief. The eventual extent of the lava over most if not all of the quadrangle is thus not indicative of low relief of the prevolcanic surface but merely of continued construction of the land surface by the long succession of flows and intercalated sediments.

Relations to fluviatile and lacustrine deposits.—Fluviatile deposits locally underlying the basalt are common and are well seen northwest of Magpie Peak; in the valley of Big Creek; in the north half of T. 7 S., R. 41 E. (in part lacustrine); just north of the Powder River in secs. 21 and 28, T. 7 S., R. 41 E.; in sec. 32, T. 8 S., R. 41 E.; along Griffin Creek southwest of Baker; southwest of the Virtue mine; in Sheep Flat; in the valley of Lake Creek; in the valley of Pine Creek; and in many other localities.

The most significant exposures of the relations between the Columbia River lava and the fluviatile deposits are probably those in that part of the Farley Hills extending from the north side of Virtue Flat to Magpie Peak. Here tuff beds and fluviatile deposits are clearly seen to interfinger with the basalt flows, the sedimentary members thickening rapidly to the southeast while the basalt flows thin in the same direction, with the result that in Tps. 8 and 9 S., R. 42 E., only a little lava is present in the section. Several hundred feet of tuff, diatomite, and fluviatile beds are here uninterrupted by lavas, although 10 miles to the northwest the lava is practically uninterrupted by sediments. Similar relations of interbedding between lava and sediments are seen, though less clearly, in Tps. 10 and 11 S., R. 39 E., and in the Burnt River Valley in T. 12 S., R. 39 E.

In view of the irregular topography upon which the lavas were extruded, such variations from place to place are to be expected. The huge lava floods must surely have destroyed the drainage of the country when they were erupted. In the lakes and in the overflattened stream courses thus produced sediments were deposited, only to be later buried by further lava flows. The relief of the country, the positions of the volcanic vents, the size and tributary drainage of the various basins, and many other factors affected the rate of deposition and the location of such sediments, and as these factors varied from place to place, the resulting distribution of the sediments was variable.

Thickness.—It follows both from later erosion and from the irregularities of the surface upon which the Columbia River lava was extruded that the thickness of the formation varies widely from place to place. In the section exposed between the head of Lower Powder Valley, in sec. 34, T. 7 S., R. 41 E., and Baker Valley northeast of Baldock Slough, in sec. 1, T. 8 S., R. 40 E., probably 2,500 feet of lava, with minor interbeds of sediments, makes up the formation. Three or four miles northwest of this section there is about 800 to 1,000 feet of lava exposed in the Powder River Canyon, with a few feet of sediments at the base but no considerable interbeds. In the canyon of the Powder River a mile south of Baker apparently about 2,000 feet of lava is exposed, but there is some possibility of duplication here. Five miles farther south 700 or 800 feet of lava is present, affected by normal faulting which makes the apparent thickness much greater. West of Bennett probably 1,000 feet is present. Elsewhere the exposed thicknesses appear less than these amounts, but erosion has reduced the formation greatly, and it is not possible to state with any confidence the original thickness in different parts of the quadrangle. In some places it may have been only a few score feet thick, but in others it may have been several thousand feet. The probability is great that at one time it extended over nearly if not quite the entire area of the quadrangle.

LACUSTRINE AND FLUVIATILE DEPOSITS ASSOCIATED WITH COLUMBIA RIVER LAVA

Water-laid tuffs occur both beneath the Columbia River lava and interbedded with the lava; in places they overlie the lava extensively and possibly are in part younger than all the volcanic flows, although the assumption of general contemporaneity seems more reasonable. The definite interbeds are for the most part clearly lenticular, possessing but slight continuity, especially toward the mountains. They are almost surely local deposits due to accumulation by streams of volcanic ashes and debris from exposed older rocks during pauses in the extravasation of the lava flows.

All the sediments associated with the Columbia River lava are soft, so that they are readily eroded, producing valleys along the strike. Over large areas their ready erosion, compared with other rocks, has led to beautiful terrace development across their outcrops, notably in Lower Powder Valley, south of Sutton Creek, and along the upper Burnt River.

About 200 feet of tuff is found beneath the Columbia River lava in the canyon of the Powder River. In Big Creek a smaller thickness of chiefly diatomaceous lake sediment is seen, and along Table Mountain about 80 feet, chiefly tuffaceous, is locally exposed (not shown on pl. 1.) In the areas between Baker Valley and Lower Powder Valley a series of strike valleys indicate the presence of at least three sedimentary layers interbedded in the Columbia River lava. All three of these layers narrow in outcrop and thin out toward the northwest, disappearing before the Powder River Canyon is reached, whereas southeastward they thicken and apparently coalesce in the wholly sedimentary section of Lower Powder Valley. Along Clover Creek and Ruckles Creek these beds are largely lacustrine; on Ritter Creek they include volcanic mud breccias.

The Tertiary sediments along the Sutton Creek-Alder Creek trench are dominantly fluviatile or fanglomerate material, consisting chiefly of debris of the Elkhorn Ridge argillite and other pre-Tertiary rocks, though with considerable admixtures of rhyolite. The rhyolitic tuffs interbedded with the fluviatile deposits near Baker may belong to the Dooley rhyolite breccia (p. 50). Toward the base, along Alder Creek, rounded quartzite boulders whose source is outside the quadrangle are contained in the gravel. (See p. 49.) Along this creek and, indeed, in much of the southeast quarter of the quadrangle these gravel beds are the earliest Tertiary deposits preserved, resting directly on the pre-Tertiary basement, but locally they are underlain by rhyolite breccia mapped as part of the Dooley. The earliest basalts in this part of the quadrangle generally lie on these gravel deposits, though in places they overlap directly on the pre-Tertiary.

In the area underlain by these fluviatile deposits between Baker Valley and Sutton Creek and the north flank of Dooley Mountain the fluviatile deposits commonly underlie the basalt flows, but at some places, as along Griffin and Elk Creeks and southeast of Denny Creek, they are interbedded with the Columbia River basalts. Probably this area was a site of fluviatile deposition for some time before it was flooded by the basalts, and the alternation of stream deposits and lava flows continued for some time afterward. The correlation with the Dooley rhyolite breccia of the rhyolite obsidian shown as interbedded with these sediments on Lake Creek (p. 49) is possibly erroneous. Along Rancheria Creek, Stices Gulch, and the East Fork of Sutton Creek the sediments overlie the Dooley rhyolite breccia, as do similar deposits on the south side of Dooley Mountain.

West of Cow Creek, near the southwest corner of the quadrangle, the sediments rest on an erosion surface carved on the dacite sill, whereas east of Cow Creek they rest on the Dooley rhyolite breccia and are interbedded with the Columbia River basalt. The gravel in this locality contains cobbles and pebbles of all the pre-Tertiary beds, as well as of the rhyolites, andesite, and basalt of the Tertiary.

In the southeast corner of the quadrangle, southeast of the Burnt River Canyon, the Tertiary sediments are chiefly gravel composed in large part of detritus derived from the Mormon Basin district, to the southeast. Characteristic carbonaceous hornfels, quartz-biotite schist, and other metamorphic rocks (not exposed north of Pedro Mountain, just southeast of the Baker quadrangle, but well developed in the Mormon Basin, just to the south) are numerous in these deposits, to the practical exclusion of locally derived material.

The lithology of these sediments is extremely variable. Locally they are very tuffaceous, as in the Powder River Canyon in T. 7 S.,

R. 41 E., along Ritter Creek in T. 9 S., R. 42 E., and in the hills east of Baker. Elsewhere, and most commonly, the sediments consist of loosely coherent sand, silt, and gravel, with lenticular bedding, poor sorting, and other features common in stream-laid material. Most of the pebbles are subangular, but rounding is not unusual.

Less abundant but fairly widespread true lake beds occur in the hills east of Big Creek, in secs. 11 and 12, T. 7 S., R. 41 E., and in the hills north and south of the Powder River in T. 8 S., R. 42 E. They also occur at Encina and to the west along Sutton Creek. These beds are well sorted, with even bedding, and in the more northerly localities include considerable thicknesses of diatomite, commonly nearly pure or with a few pumiceous interbeds and rare lapilli. These diatomite beds are as much as 40 feet thick in sec. 10, T. 8 S., R. 42 E. They contain leaf casts in profusion and a few snail shells. Similar material is also present in sec. 36, T. 8 S., R. 41 E.

Lignite occurs in the fluviatile deposits near Auburn and just east of the quadrangle boundary in the Lower Powder Valley. The lignite, which is of a poor grade, forms beds as much as 2 feet in thickness.

The thickness of these sediments is variable and nearly everywhere difficult to measure with any confidence, because the loosely consolidated material rarely gives exposures adequate to demonstrate continuity of the beds over any considerable distance. The possibilities of omission or duplication of beds by faulting are correspondingly great. However, estimates of minimum thicknesses have been made as follows: Along Ritter Creek not less than 800 feet and possibly 2,000 feet of sediments are exposed; along Beaver Creek, about 500 feet; north of Alder Creek, a mile north of Unity, about 400 feet; in the Burnt River Valley along Brannan Gulch, about 800 feet. In all these localities erosion has removed higher beds, so that it is safe to say that in several places the deposits were originally more than 1,000 feet thick. In Durkee Valley, just east of the quadrangle boundary, the sediments continuous with those along Alder Creek attain thicknesses to be measured in thousands of feet.

CORRELATION AND REGIONAL RELATIONS OF THE TERTIARY SUPRACRUSTAL ROCKS

The only fossil collections made from the Tertiary rocks of the Baker quadrangle consisted of leaves and associated vegetable remains from diatomaceous beds in sec. 25, T. 8 S., R. 41 E., and the NE¼ sec. 10, T. 8 S., R. 42 E. These sediments are known to interfinger, in part, with the Columbia River lava.

The collections were made with the assistance of R. W. Brown and have been studied by him. Mr. Brown's report is as follows:

Localities 1 (S½ sec. 25, T. 8 S., R. 41 E.) and 2 (NE¼ sec. 10, T. 8 S., R. 42 E.), plants in diatomaceous matrix:

Sequoia langsdorfii.
Salix inquirenda.
Hicoria juglandiformis.
Betula largei.
Carpinus grandis.
Quercus consimilis.
Quercus sp.
Ulmus fernquisti.
Liquidambar pachyphyllum.
Prunus sp.
Celastrus confluens.
Acer bendirei.
Acer osmonti.
Acer oregonianum.
Ceanothus sp.
Nyssa knowltoni.

This aggregation shows clearly a relationship with the Latah and Mascall floras. A few elements like *Sequoia langsdorfii*, *Quercus consimilis*, *Carpinus grandis*, and *Acer osmonti* range backward into the Oligocene, but I should regard the whole collection as of Miocene age.

Pardee and Hewett [39] reported collections of Miocene age from similar deposits at several localities in the Sumpter quadrangle, at one of which the sediments are overlain by a basaltic flow.

The difficulties in precise correlation of these beds are illustrated by the marked lensing they exhibit in the Lower Powder Valley. There is considerable uncertainty in the correlation of the fluviatile sediments in Virtue Flat, in Sutton Creek Valley, and in the Burnt River Valley with each other or with the fossiliferous beds of the Lower Powder Valley, although there is little doubt that they were roughly contemporaneous.

The assignment of the unaltered volcanic rocks to the Tertiary is based upon their similarity in attitude to these known Miocene rocks, their positions beneath these rocks, and their marked unconformable relations to the early Mesozoic rocks of the general region. The assumption of a Tertiary age is thoroughly justified, but more precise assignments must, in view of rapid lateral variations, await more detailed tracing and more successful search for fossils.

The tentative correlation of the Tertiary rocks of the Sumpter quadrangle with those in the John Day Valley offered by Pardee and Hewett [40] seems sound, insofar as they correlate their "lake beds" with the Mascall and the underlying "older basic flows" with the Columbia River lava. They recognize, of course, that their "lake beds" were never continuous with the Mascall. The writer accepts these correlations and also correlates the basaltic lavas interbedded with the lacustrine and fluviatile beds of the Baker quadrangle with the Columbia River lava. Probably the "younger basic lavas" of Pardee and Hewett should also be so correlated. Correlations of the

[39] Pardee, J. T., and Hewett, D. F., op. cit., p. 44.
[40] Idem, p. 47.

"andesitic tuff-breccia" with the John Day and of the "pre-tuff-breccia gravels" with the Clarno(?), as suggested by Pardee and Hewett, appear much more dubious, as there is little lithologic similarity between the rocks of these groups in the Sumpter quadrangle and the rocks of the John Day region, and there is evidence that these formations, at least in the Baker quadrangle, were never widespread.

Of course, the lake and river deposits of the Baker quadrangle were also of local origin and were never continuous with the type Mascall. Plateau eruptions such as produced the Columbia River lavas must have disrupted the existent drainage. Where this terrane was irregular, as in the Baker quadrangle, in the Snake River Canyon below Homestead,[41] and at more distant points, such as Steptoe Butte[42] and Spokane,[43] such underlying and intercalated sediments are irregular and lenticular. This idea was long ago advanced by Russell[44] and has been elaborated by Pardee and Bryan[45] and by Kirkham and Johnson[46] to explain the deposition of sediments at the margins of and interfingering with the Columbia River basalt. All these sediments intercalated with the basalt have yielded a flora of supposed Miocene age, but it seems to the writer very doubtful whether the beds were all contemporaneous. The fact that beds with this same flora, itself none too precisely dated, occur below, interbedded with, and above rocks correlated with the Columbia River lava at different points between the Picture Gorge of the John Day and Boise does not necessarily mean different ages of the basalts in these different places. These relations may well have been brought about by topographic conditions at each locality. Neither does it seem valid to extend formation names resting upon such slight foundations too widely. The writer therefore refrains from extending the name "Payette" or the name "Mascall" to the local development of these sediments, although recognizing the probability that the beds here developed are roughly equivalent in age to both these formations but most probably were never connected with those of the type locality of either.

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[41] Lindgren, Waldemar, The gold belt of the Blue Mountains of eastern Oregon: U. S. Geol. Survey 22d Ann. Rept., pt. 2, pp. 596–597, 1901; A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: U. S. Geol. Survey Prof. Paper 27, p. 79, 1904.

[42] Russell, I. C., A reconnaissance in southeastern Washington: U. S. Geol. Survey Water-Supply Paper 4, pp. 18, 30–33, 35–39, 1897.

[43] Pardee, J. T., and Bryan, Kirk, Geology of the Latah formation in relation to the lavas of the Columbia Plateau near Spokane, Wash.: U. S. Geol. Survey Prof. Paper 140, pp. 1–16, 1926.

[44] Russell, I. C., op. cit., p. 55.

[45] Pardee, J. T., and Bryan, Kirk, op. cit., p. 8.

[46] Kirkham, V. R. D., and Johnson, M. M., The Latah formation in Idaho: Jour. Geology, vol. 37, pp. 483–504, 1929. Kirkham, V. R. D., Revision of the Payette and Idaho formations: Jour. Geology, vol. 39, p. 234, 1931.

INTRUSIVE ROCKS

DACITE

About 4 or 5 square miles near the southwest corner of the quadrangle is occupied by a body of coarsely porphyritic dacite, forming part of a larger mass in the adjoining Sumpter quadrangle. The rock is somewhat more resistant to erosion than the associated formations and makes rather conspicuous hills with steep cliffs. Lindgren [47] regarded the mass as a flow, and, indeed, nothing was seen in this area to refute this interpretation. It is here considered a sill, however, because it is intercalated in the andesitic tuff-breccia in the Sumpter quadrangle.[48] In the Baker quadrangle it rests locally upon Dooley rhyolite breccia and elsewhere on the andesitic tuff-breccia. No flows could be distinguished in it, although a thickness of fully 800 feet is exposed, so that this interpretation that it is a sill is more likely than that it is a surface flow, but locally the only overlying rocks are Columbia River lava and fluviatile deposits, both clearly unconformable upon it.

The rock forming this mass is a light-gray porphyry containing phenocrysts of plagioclase and hornblende, which are commonly as much as 1 centimeter long but probably average about 1 millimeter, in a finely crystalline groundmass. The microscope permits recognition of the plagioclase as sodic andesine; the hornblende is brown-green, with a small extinction angle; and quartz is present in the groundmass, along with the usual accessories.

DIKES

Dikes of probable Tertiary age are not common or at least not prominent in the Baker quadrangle. A few were seen in the eastern slopes of Elkhorn Ridge, both north and west of Auburn, and one was observed in the Burnt River Canyon. Some of these are hornblende andesites which seem to have no analogs among the Tertiary extrusive rocks, but several narrow basalt dikes, possibly related to the Columbia River lava, occur on Elkhorn Ridge north of Griffin Creek. None of those seen were more than 20 feet wide, and hence no attempt was made to show them on plate 1.

No dike swarms comparable to those at Cornucopia described by Lindgren [49] as probable important sources of the Columbia River lava were found in the Baker quadrangle.

The dikes observed seem commonly to trend a few degrees east of north and stand at steep angles, presumably having been controlled by the older joint system in the pre-Tertiary basement.

[47] Lindgren, Waldemar, op. cit. (Blue Mountains), p. 591.
[48] Pardee, J. T., and Hewett, D. F., op. cit., p. 42.
[49] Lindgren, Waldemar, op. cit., pp. 741–742.

QUATERNARY ROCKS

Quaternary rocks in the quadrangle embrace four principal varieties—terrace gravel, slide rock, flood-plain and alluvial fan deposits, and volcanic ash.

The terrace gravel is especially plentiful in the Lower Powder Valley and Virtue Flat; remnants are widespread but mappable deposits few in the area underlain by Tertiary sediments between Encina and Bennett; a few minor deposits, not mapped, occur near Haines. These gravel deposits are unconsolidated and consist of boulders, pebbles, and sand of the varieties being carried by the present streams. Except locally on the walls of the Burnt River Canyon they are found only on flat surfaces developed across the softer sediments and doubtless represent relatively slight still-stands of degradation. They range from a few score to 500 feet above the present streams; few exceed 50 feet in thickness.

In the Burnt River Canyon most of these gravel deposits extend to heights of about 300 feet above the river. These are commonly gold-bearing. From their apparent relations to the present drainage they are referred to a partial filling of the canyon in Pleistocene time. In the Snake River Canyon, 20 miles to the east of the Baker quadrangle, similar relations exist.[50]

Slide rock is found in most parts of the quadrangle; it is shown on the accompanying map only where it is too thick to permit any confident inference as to the bedrock. Such localities are northeast of Black Mountain, east of Auburn, and west of Baker. On a more detailed map much larger areas would necessarily be represented in this classification.

Alluvial fans are present along the south side of Baker Valley, west of Baker, where the streams debouch from Elkhorn Ridge into the valley. The older part of these deposits may be Tertiary; but the greater part is probably Pleistocene and some is Recent. At their extremities the fans merge with the alluvial deposits of the Powder River in Baker Valley. The wide alluvial flat of Baker Valley is probably now being slightly degraded at the north end, but the sediments at the surface are probably all Quaternary, although Tertiary rocks may be buried in places. Lower Powder Valley and the valley south of Baker, as well as the Sutton Creek, Burnt River, and Alder Creek Valleys, all contain stream deposits of this sort.

Lindgren[50] reports that wells have been drilled through sediments to a depth of 600 feet at Baker. Although these sediments may be Pleistocene throughout, as assumed by Lindgren, the possibility that some may be of Tertiary age must be considered, especially as their

[50] Lindgren, Waldemar, op. cit., p. 585.

discrimination in drill cuttings is difficult or impossible. Accordingly, Lindgren's conclusion that the Pleistocene of Baker Valley rests in a closed basin, although probable, cannot be considered established on this basis only.

Volcanic ash is widespread in the area but is preserved only on flat undrained places or concentrated in alluvial cones where the minor streams enter the main valleys. A thin bed is well exposed in the gravel at the mouth of Salmon Creek, west of Baker. Other notable accumulations are on Ruckles Creek just above its canyon, where the road from Baker to Medical Springs crosses Salt Creek, and in Stices Gulch above Bennett. From observations made by Pardee, this ash is known to be postglacial, as it overlies moraines in the higher part of Elkhorn Ridge.[51] Its accumulations become thicker westward, at least as far as Prairie City, and presumably it was derived from an eruption in the Cascade Range. Microscopic examination shows that it consists entirely of glass shards.

STRUCTURE

GENERAL FEATURES

The structural features of the rocks of the Baker quadrangle are the results of deformation during at least two widely separated periods. Although there is some possibility of a diastrophic period in pre-Permian time, the earliest period for which there is definite local evidence and which on detailed study might be further subdivided occurred in post-Permian time. This diastrophism was clearly complete long before the Tertiary volcanism in the region. The later diastrophic period, which is likewise doubtless susceptible of division, began in late Miocene or Pliocene time and is still continuing. The pre-Tertiary deformation, so far as known, was chiefly compressional, resulting in close folding and overturning of the rocks about axes trending in general east. Presumably some faulting accompanied this folding, but its record is not clear. The later deformation, which is still going on, is broadly due to differential vertical movements, although some warping, perhaps referable to compressive forces, has also occurred. The trend lines of the later deformation are generally west-northwest, but there are some more northerly and more westerly faults and even a few northeasterly faults that are to be referred to this period. The present topography of the region is in a large way, but by no means rigorously, governed by the trend lines of this later period.

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[51] Pardee, J. T., personal communication.

STRUCTURAL FEATURES REFERABLE TO PRE-TERTIARY DEFORMATION

MAJOR FEATURES

The obvious westerly trends, steep dips, and metamorphic character of the pre-Tertiary rocks testify to their deformation by compressive forces acting in a north-south direction. Unfortunately the critical lines of contact between the several formations are obliterated by igneous intrusions or masked by overlying Tertiary rocks; and as one of the major elements in the geology, the Burnt River schist, is of uncertain age, it is impossible to work out satisfactorily the structural relations of the formations.

The assumption is here made that the Clover Creek greenstone overlies the Elkhorn Ridge argillite. Several possibilities, among which it is at present impossible to decide, present themselves as interpretations of the major structure, dependent in large part upon the age of the Burnt River schist.

If the Burnt River schist is Triassic, as was thought by Lindgren,[52] it may rest normally upon the Clover Creek greenstone. The absence of the Clover Creek greenstone between the Burnt River schist and the Elkhorn Ridge argillite would in this case be explicable by faulting, along the line now followed by the large gabbro intrusions on Dooley Mountain. If the schist is unconformable upon the greenstone and argillite, the absence of the greenstone between it and the argillite would be explicable by post-Permian, pre-Triassic deformation, and erosion.

Should the Burnt River schist, on the contrary, prove to be pre-Carboniferous, as is here assumed, the structure in the quadrangle may be that of the north limb of a large anticlinorium, or, possibly, the schist may be overthrust on the argillite. It is also possible, in view of the notable shearing that all the rocks have undergone, that the Elkhorn Ridge argillite is overthrust northward on the Clover Creek greenstone.

So many possibilities arise, in view of the scant information at hand, that it is obviously not worth while to develop them at length until more work is done, both here and in neighboring quadrangles.

STRUCTURE OF THE BURNT RIVER SCHIST

The structure of the Burnt River schist is obscure but is dominated by a westerly strike and steep dips. The formation has undergone intense compression operating in a meridional direction. Presumably its folds are closed, nearly isoclinal, but it has not been feasible to work out the anticlinal or synclinal axes.

[52] Lindgren, Waldemar, op. cit., pl. 64.

There are few marker beds in the Burnt River schist, although the larger limestone beds may prove to be valuable as markers. The time available for the mapping reproduced on plate 1 did not suffice to establish whether or not the limestones there shown have been duplicated, but there is a suggestion of anticlinal structure in the 2 or 3 square miles just east of the mouth of Dark Canyon. Original stratification can be determined only in a few places, as the prominent structural features in the formation are metamorphic. Where clearly exposed it is common to find the schistosity nearly or quite parallel to the bedding, but there are evident exceptions, and too much reliance should not be placed upon this feature.

The most striking structural features of the Burnt River schist are the strongly marked linear schistosity, which is apparent on nearly every outcrop, and the still more conspicuous jointing. The linear schistosity in some exposures is clearly due to intersecting surfaces of parting, which divide the rock into torpedo or pencil shapes; in other exposures it is due to nearly parallel crumples of schistosity, and in still others it seems to be the reflection of a fibrous arrangement of the minerals. Locally only a planar schistosity is apparent, but this is unusual.

The jointing is oriented practically normal to the linear schistosity and is remarkably regular. In many places the joints are coated with quartz. On many cliff exposures the rocks resemble huge split logs regularly piled and sawn at right angles.

Observations made on the linear and platy schistosity of the schists are shown on plate 1 (in pocket). It is apparent that the pitch of the linear schistosity is remarkably regular over considerable areas, although the platy schistosity is rather variable in dip. For the most part the linear schistosity pitches down toward the west, although there are places where it pitches eastward.

The linear schistosity and its complementary jointing seem susceptible of only one mechanical interpretation. This is that the lines mark axes along which tension operated during a late stage of the deformation of the rock. This is equivalent to saying that these lines represent the axes of least compression during their production, hence the rocks yielded more readily in this direction than in the others. As the linear schistosity commonly pitches at low angles, the depth at which it was formed was sufficient, probably owing to packing of folds, to necessitate elongation at low angles to the present surface. Structurally, unless there has subsequently been great downward tilting to the west, the more easterly areas were higher than the more westerly. Nevertheless, it does not follow that lower horizons of the formation are brought to the surface toward the east, unless it is granted that the linear elements were formed in the same epoch as the folding. This is, however, regarded as highly probable, because the schistosity lies dominantly in the plane of the bedding where that can be recognized. Accordingly it is believed that the formation as a whole plunges westward, but more detailed studies would be necessary to establish this beyond debate.

STRUCTURE OF THE ELKHORN RIDGE ARGILLITE

The structure impressed upon the Elkhorn Ridge argillite is so intricate that it has thus far proved fruitless to attempt to work out major axes of folding or lines of faulting. In many places the beds involved have such faint contrasts in lithology and their bedding is so obscure that it is impossible to read a strike or dip with any confidence. Elsewhere, in the thinner-bedded, cherty portions, it is easy to determine the attitude of the bedding, but a few square feet of outcrop is sufficient to show complicated swirling folds which attest the intense crumpling the rocks have undergone but do not yield any satisfactory clue to the major folding. Elsewhere the rock is highly sheared to a pseudoconglomerate (see fig. 2), as has been described by Pardee [53] from work in the adjoining Sumpter quadrangle. This shearing is so pervasive and has affected so large a part of the formation that it probably represents a "penetrative movement" or distributive overthrusting. The folding has obviously been induced by intense compression, and these closely spaced shears are almost certainly surfaces of overthrusting, the cumulative displacement of which must be considerable.

Where observed the dips are most commonly steeper than 45°, especially where the strikes are nearly west, but where the strikes diverge toward the north the dips are generally less steep. This is of course to be expected when the general area of exposure of the formation is considered and does little more than confirm the westerly trend that is already clear from the areal map (pl. 1).

There is some slight suggestion in the arrangement of the discrete blocks of limestone east of Pleasant Valley that they outline a plunging fold, much sliced with faults, so that a once continuous limestone bed is now represented by these blocks, but the suggestion is not obviously supported by the strike and dip readings obtained in that area. In the adjoining Sumpter quadrangle [54] the arrangement of similar limestone blocks is yet more suggestive of plunging folds. Presumably, then, the major westward-trending folds of the Elkhorn Ridge argillite are interrupted by plunging. This is probable and is suggested by similar features of the Burnt River schists.

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[53] Pardee, J. T., and Hewett, D. F., op. cit., p. 34.
[54] Idem, map.

STRUCTURE OF THE CLOVER CREEK GREENSTONE

The structure of the Clover Creek greenstone is obscure, owing to poor exposures and more especially to the massiveness of the lava flows that make up much of the formation. Where structure readings can be made with confidence on interbedded tuff members the strikes are westerly and the dips steep on either side of the vertical. The general westerly strike of the formation is clear from its areal distribution. It has been impossible to work out structural axes, but it seems highly probable that some of the folds are isoclinal. Shearing exhibited in practically every outcrop, as well as on a microscopic scale in thin sections, gives evidence of gliding movements in the formation whose cumulative displacement must be very considerable, though probably less than those of the Elkhorn Ridge argillite and Burnt River schist. The widely scattered separate lenses and blocks of limestone in the formation doubtless owe their distribution to these movements, modified, of course, by the folding that affected the rocks at the same time.

METAMORPHISM

By far the greater part of the metamorphism that the rocks of the quadrangle have undergone has been of dynamic origin. The metamorphism induced by the igneous intrusions has been slight. Where the Permian greenstones have been invaded they have been altered to hornfels or, immediately at the contact, to garnet gneiss, but only small volumes have been so affected. The Elkhorn Ridge argillite has been locally altered to spotted andalusite hornfels, and its chert members have been coarsely recrystallized. The Burnt River schist has been altered, near igneous contacts, to amphibolite, but on the whole all these changes have been limited to narrow zones.

The metagabbro intruded by the biotite-quartz diorite in the southeast corner of the quadrangle has been altered to biotite amphibolite. Other evidence of igneous metamorphism is shown in the slight serpentinization and presumably some albitization and the silicification of some of the earlier intrusive rocks, as described on pages 35–40.

However, all the pre-Tertiary rocks of the quadrangle except the biotite-quartz diorite have been subjected to thorough dynamic metamorphism. All have undergone shearing of the most pervasive sort, with the production in many places of pseudoconglomerates and mylonites. Concomitant with these mechanical changes, the rocks have undergone mineralogic transformations, the most prominent of which were the saussuritization of feldspars and the alteration of clays to sericite, of mica and other ferromagnesian minerals to chlorite and epidote, and of augite and hornblende to actinolite.

These changes are all characteristic of metamorphism in the upper zone ("epizone") of Grubenmann and Niggli,[55] and the mineral associations tend toward those of the "green schist" facies of Eskola.[56] It is perhaps worth noting that the emphasis placed by Grubenmann and Niggli on the depth factor in metamorphism is here, as in many other places, shown to be unfortunate, because the amphibolites and garnet schists found near Haines and in Dixie Creek Canyon are typical "mesozone" rocks but were not more deep-seated at the time of the metamorphism than the nearby "epizone" chlorite schists. They were at higher temperature, however, owing to contact metamorphism, an inconsistency in the depth-zone classification which is overcome by the "facies" concept of Eskola.

STRUCTURE REFERABLE TO LATE TERTIARY AND QUATERNARY DEFORMATION

GENERAL FEATURES

Tertiary deformation in the Baker quadrangle has taken place by both folding and faulting, chiefly along trends ranging from N. 45° W. to N. 80° W. It is difficult to evaluate the relative importance of the folding and faulting, but it seems likely that folding has been the larger factor in producing the structural relief, although in view of the fact that faults can rarely be traced for any considerable distance except where they cut the contacts between Tertiary formations or between the Tertiary and the pre-Tertiary, it is possible that they have contributed more to the structural relief than would appear from either the map or the structure sections. The relative scarcity of mapped faults in the areas wholly underlain by one formation, whether pre-Tertiary or Tertiary, is almost surely due to lack of distinct marker beds and not to the absence of the faults.

MAJOR STRUCTURAL UNITS

Dooley Mountain anticline.—The most prominent of the Tertiary folds is one which trends a little south of east from Black Mountain to a place near the southeast corner of the quadrangle. It extends beyond the quadrangle borders in both directions. For much of its length in the quadrangle its axis roughly follows the ridge of Dooley Mountain, and it is conveniently referred to as the "Dooley Mountain anticline." Its southern limb forms part of a large syncline extending along the upper course of the Burnt River and, south of the quadrangle, along Clark Creek. An eastward-plunging branch of the Dooley Mountain anticline passes under the west side of the Durkee Basin just at the east edge of the quadrangle in T. 11 S.

[55] Grubenmann, Ulrich, and Niggli, Paul, Die Gesteinsmetamorphose, pp. 397–413, 1924.
[56] Eskola, Pentti, The mineral facies of rocks: Norsk geol. tidsskr., vol. 6, p. 143, 1921.

The northern limb of the anticline dips down toward a synclinal area extending from the west edge of the quadrangle along the upper course of the Powder River as far as Bennett, thence bounding the Tertiary sediments on the south as far as Pleasant Valley, where it becomes a part of the south wall of the Alder Creek-Sutton Creek trough.

This fold is not smooth but is cut by many faults and has reversed dips on both limbs at places. In the large, however, the divergent dips on the two limbs may average 15°, though locally rising to as much as 30° or even steeper.

Elkhorn Ridge anticline.—The Elkhorn Ridge anticline enters the quadrangle from the west, where it is a major feature,[57] but plunges rapidly eastward and dies out in the basin southwest of Bowen. Possibly the hills composed partly of argillite west of Baker may be considered a broken part of the north limb of this fold. Dips on the south flank of this plunging fold are about 5° and on the east about 6°, but those on the north, owing to faulting (see p. 74), are of unknown amount, although along Rouen Gulch dips of 33° N. have been measured. There is little doubt that the fold is slightly asymmetric, with the north limb the steeper.

Alder Creek-Sutton Creek trough.—The courses of Sutton and Alder Creeks follow a depression formed by warping and faulting. Although the more striking portions of the trough east of Pleasant Valley are conspicuously faulted, even there the depression is in large part formed by warping, and to the northwest, nearly to Baker, the faulting is clearly subordinate to the folding. West of Encina the depressed area widens southwestward to Bennett, where it connects with the syncline extending along the upper Powder River to the western edge of the quadrangle. This widening of the depressed area owes its existence to the fact that the plunge of the Elkhorn Ridge anticline permits the junction of the upper Powder syncline with the more northerly trough.

Dips on the flanks of the syncline are moderate, rarely exceeding 10°. The trough is highly complicated by faults and cross folds, as is evident, for instance, in the railroad cut at Encina, where northward-trending faults are to be seen and the beds strike nearly north and dip 14° E. It is practically certain that numerous unmapped faults are present in the Tertiary sediments in the basins of Beaver Creek and the West and East Forks of Sutton Creek, for such faults occur on the strike both east and west, but exposures in the soft sediments are insufficient to permit tracing them.

[57] Pardee, J. T., and Hewett, D. F., op. cit., p. 45.

Virtue Hills upwarp.—The Alder Creek-Sutton Creek trough is bounded on the north by an upwarp extending east-southeastward from the vicinity of Lone Pine Mountain to and beyond the eastern edge of the quadrangle. The range of hills in this locality is commonly called the "Virtue Hills," so that the name "Virtue Hills upwarp" is appropriate for the fold. Along the southern flank this upwarp is bounded by a fault zone for its entire length. These faults only accentuate the warping effects, as their downthrows are on the south, toward the synclinal area of Alder Creek.

The upwarp has a complex structure in detail, with many faults and minor folds indicated by the Tertiary rocks and by the topography. On the west end it passes into a faulted southwestward-dipping monocline. In general the local structural features are irregular and cannot be followed far, even where considerable areas of Tertiary rocks are preserved; where these are absent the topographic unconformities give local evidence of deformation, but such features are not readily traced with confidence.

On the north flank of the Virtue Hills the sparse remnants of Tertiary rocks mostly dip northward toward the depression occupied by Virtue Flat and Pritchard Flat.

Virtue Flat depression.—Virtue Flat is underlain by Tertiary sediments with dominantly low dips to the north. These beds occupy a depression formed by faulting and folding, on the north flank chiefly by faulting. Toward the east the fault bounding the depression on the north dies out, and the monocline north of it swings into a plunging anticline, so that it has disappeared in the country near Ritter Creek, where the Virtue Flat depression becomes part of the south limb of the Lower Powder syncline. Toward the west, the downwarp of Virtue Flat narrows considerably, and it apparently becomes a narrow syncline south of the Flagstaff mine.

North dips of 5° to 20° are common along the south flank of the downwarp; locally, along faults, the dips exceed 30°. It is probable that faults are present in Virtue Flat, but the exposures in the soft sediments are inadequate to permit tracing them.

Ruckles Creek-Magpie Peak monocline.—The Farley Hills between the canyon of Ruckles Creek north of Virtue Flat and Magpie Peak are largely formed of Columbia River lava. These hills mark the course of a gentle northeastward-dipping monocline with an average dip of about 8°. On the south the monocline is cut off by the faults bounding Virtue Flat on the north. At the southeast end the monocline becomes a plunging fold and disappears. To the southwest it is bounded by Baker Valley, from which it is probably separated by a fault. At the northwest end, at and north of Magpie Peak, the fold becomes anticlinal, although broken by irregularities. Northeast of Magpie Peak the monocline flattens out, is cut by faults, and is finally succeeded by a flat or nearly flat structural bench, in the angle between Big Creek and the Powder River Canyon.

Lower Powder syncline.—The monocline just described forms part of the southwest limb of a major syncline, the axis of which is roughly marked by the course of the river through the Lower Powder Valley. The axis plunges southeastward, probably to a point east of the quadrangle, although possibly the structural low is near the mouth of Ritter Creek.

The south flank dips on an average about 8° or 10° NNE. and NE. East of Ruckles Creek the attitude of the rocks is less uniform, but the general northward dip prevails to the border of the quadrangle. North of Pritchard Flat there are minor reversals of dip. The northeast limb of the syncline rises at angles of 4° or 5° to form a gently inclined plateau on the southwest flank of the Wallowa Mountains.

Baker Valley.—Baker Valley is both a topographic and a structural depression. On the south it is bounded in large part by faults, although there is evidence that these faults only accentuate, by their northward downthrows, a fold that would alone suffice to produce a considerable structural relief.[58] (See pl. 1.) On the southeast the evidence of faulting is less complete, although the abrupt terminations of the spurs west of the Flagstaff mine are suggestive. At the northeast border of the valley, west and south of Magpie Peak, there is evidence of faulting, both in the linear truncation of basalt and greenstone and in a line of springs. There is little direct evidence of this fault either northwest or southeast of this group of springs, but its presence is suggested by the absence of a westward-dipping limb on the fold extending from Ruckles Creek to Magpie Peak. The probability is that Baker Valley is almost entirely bounded by faults.

One of the clearest exposures of a fault bounding the valley on the southwest side is to be seen in the old Nelson placer, at the mouth of the Salmon Creek Canyon. This locality has been diagrammatically illustrated and described by Lindgren,[59] whose drawing is here reproduced as figure 6 (p. 104). The placer diggings have been made in a gravel deposit where Salmon Creek emerges from the mountains into Baker Valley and expose about 100 feet of the gravel, for nearly half a mile along the mountain front. A shaft 90 feet deep dug beneath the large excavation disclosed only gravel, showing a minimum depth of nearly 200 feet of this deposit. Toward the

[58] Pardee, J. T., and Hewett, D. F., op. cit., pp. 45–46.
[59] Lindgren, Waldemar, op. cit. (Blue Mountains), pp. 652–653.

mountains this pit in the gravel is bounded by a smooth wall of bedrock, which locally shows slickensides and a clay gouge veneer and is obviously a fault wall. This wall can be traced for about half a mile west-northwest of Salmon Creek and about the same distance to the east. A short distance east of Washington Gulch the fault is clearly present and has had recent downthrow on the north, as is shown by the scarp north and northeast of the spur in sec. 11, T. 9 S., R. 39 E., and the presence of a line of springs and a marsh directly against the scarp. If no downfaulting of the valley block had occurred, a depression or marsh would be found not against the mountain, from which sediments are continually being furnished to the valleys, but at a distance from the mountains bounding the valley.

Durkee Basin.—Durkee Basin is almost wholly in the adjoining Pine quadrangle, on the east, but a few square miles of its southwest corner, at the mouth of the Burnt River Canyon, lies in the Baker quadrangle. The south side of this basin, like Baker Valley, is down-faulted with respect to the adjoining pre-Tertiary hills, as is shown by recent landslides of pre-Tertiary rocks, the fineness and even bedding of the Tertiary sediments directly adjoining the steep slopes of older rocks, the high dip angles of the Tertiary sediments (as much as 70°), and the fact that the springs on the contact of the Tertiary rocks with the older terrane are as commonly on the divides as in the valleys. All these features show that this scarp is a result of young faults and is not a fault-line scarp.

MINOR STRUCTURAL FEATURES

Many structural complexities and details must be left untouched in a summary report on so complex an area as the Baker quadrangle. Among the minor features, however, are several that appear worthy of some discussion, notably the faulted areas along Denny and Lake Creeks, in T. 11 S., R. 39 E.; near Sheep Flat, in T. 11 S., R. 41 E.; southeast of Pleasant Valley, to the edge of the quadrangle; and northwest of Lost Basin, in T. 12 S., R. 42 E.

The faulted area along Lake and Denny Creeks is one of extreme complexity. The faults mapped on plate 1 can represent only a part, perhaps only a small part, of those that are present. In this region there is considerable local irregularity in the Tertiary stratigraphy, with basalt, rhyolite breccia, and fluviatile sediments each at the base of the section at different places. This irregularity, explicable by reason of the irregular pre-Tertiary surface, renders it difficult to use the stratigraphic sequence in determining the throw of faults. The interpretation put upon the relations is that there is a rough trough bounded on the south by a fault just south of Lake Creek, whereas its northern boundary is surely in part but may not be en-

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tirely faulted. This depressed block trends roughly southwest and has been sliced by many northwestward-trending faults. Most if not all of the faults are normal, and by far the greater number have their downthrows on the northeast. Movement on these faults has continued until very recent geologic time, as is shown by the numerous undrained ponds and marshes which have given the name to Lake Creek. The topography is similar, in distant view, to that of moraine regions, but the glaciation of Elkhorn Ridge never extended to altitudes as low as 4,500 feet, except on major streams heading at 8,000 feet or higher, and the facts that most of the hills are composed of rock, not till, and that no roche moutonnée forms or other signs of glacial action are present toward the heads of these streams seem to eliminate any possibility that the topography is of glacial origin. Enough faults can be demonstrated by stratigraphic methods to show that faulting is the dominant cause of the anomalous topography.

The area near Sheep Flat, in the northwest corner of T. 11 S., R. 41 E., contains a graben and a horst, both bounded by northwesterly faults. The fault that cuts off Dooley Mountain on the north from a place near Bennett to the canyon of the East Fork of Sutton Creek there turns sharply southeast and dies out in about half a mile. Just northeast of this is a pair of northwestward-trending faults, with downthrow on the northeast, which bring the Tertiary sediments down opposite lower basalt flows in secs. 16 and 17, T. 11 S., R. 41 E. In going northeast from this block, two faults with downthrow on the southwest are crossed, and the axis of a northwestward-trending horst is reached in secs. 4 and 5. To the northeast this block, in which metagabbro is the surface rock, is bounded by a strong fault with downthrow on the northeast. This fault extends northwestward across the East Fork of Sutton Creek but is lost where it has Tertiary sediments on both walls. It can be traced about 3 miles southeast of the East Fork, where it seems to die out and its structural effect is produced by an échelon zone a mile to the east.

In the country between the horst just described and Encina at least two horsts of pre-Tertiary rock project through the Tertiary beds.

The fault zone southeast of Pleasant Valley is dominated by northwest trends. The faults seem to be all normal. The most prominent include two groups outlining the trench that is followed by Alder Creek—one group of two or three faults with a combined northeasterly downthrow of probably 1,000 to 1,500 feet and a second group of two or three with a somewhat smaller southwesterly downthrow. Southwest of this large graben there are many subparallel faults, slicing the country into many smaller grabens and horsts, which in turn are complicated by a few northeastward-trending faults.

Several grabens, cut by recent cross faults, are to be seen in T. 12 S., R. 42 E. In this locality, as in that along Lake Creek, the faulting has been so recent that the drainage has been disrupted, and several ponds and lakes are present. The details of the structure are obscure because of slope wash and a few landslides, but the essential structure seems to be much like that near Lake Creek. The general trend of the faults bounding the grabens is more nearly westerly than anywhere else in the quadrangle.

STRUCTURAL RELIEF DUE TO TERTIARY AND QUATERNARY DEFORMATION

Owing to the irregularities of the pre-Tertiary surface and consequent stratigraphic variations in the Tertiary rocks, there are many uncertainties in estimating the amount of late Tertiary or post-Tertiary deformation. There is no key bed whose altitude can be used over the entire quadrangle as a structural datum. The most widespread formation, the Columbia River lava, is thick, is known to have buried an uneven topography, and has been eroded different amounts in different places, so that a considerable stratigraphic interval is covered by it. For all these reasons it is not feasible to make any precise measurement of the structural relief due to the Tertiary diastrophism.

Broadly, however, estimates of 4,000 feet as the relief of the Dooley Mountain anticline, 2,500 feet as that of the Virtue Hills upwarp, and 3,000 feet as that of the Lower Powder syncline seem not unreasonable: surely they are not more than 50 percent in error. Baker Valley has perhaps been depressed about 5,000 feet relative to Elkhorn Ridge and about 2,000 feet relative to Magpie Peak, at least in the region of Coyote Point. It is impossible to state how great the depression has been where only Quaternary deposits are exposed.

ORIGIN OF THE TERTIARY STRUCTURE

The dominant west-northwesterly trend of the Tertiary structure, not only in the Baker quadrangle but in the entire region of which it is a part, seems to indicate a regional control during the deformation. The broad folds suggest a slight compression normal to this trend, but the prevalence of parallel normal faults seems to indicate that compression was not great at levels now exposed. It may be that these features are best explained by vertical adjustments of the crust, consequent on the great extrusions of the Columbia River basalt, which must have upset the subcrustal equilibrium. Differential vertical movements, acting under compression sufficient only to control the trend of the resulting wrinkles and breaks, seem competent to have produced the existing Tertiary structural features. Their general independence of pre-Tertiary trend lines seems to suggest a deep-seated source of the movements.

GEOMORPHOLOGY

In this section the attempt is made to interpret the geomorphic history of the Baker quadrangle as revealed by its topographic forms and the relations of these forms to the structure of the rocks. Although in a sense the development of the present topography is dependent upon the entire geologic history of the quadrangle, the land forms have been, in all major features and many minor ones, so dominantly controlled by late Tertiary events that it is justifiable to begin their discussion with a summary of the probable conditions in Miocene time, after the eruptions of the Columbia River lava.

THE LATE MIOCENE SURFACE

In the Miocene epoch, at the end of the extrusion of the Columbia River lava, the general region of the Baker quadrangle may have presented a fairly smooth surface, with chiefly constructional lava slopes rising toward the fissures that had been the local sources of the lava. Analogy with present basaltic volcanoes suggests that these surfaces may have sloped at considerable angles, perhaps as great as 10°, although this is probably much higher than the average.

The depressions between these slopes were largely occupied by lakes and marshes, through which the streams were slowly endeavoring to integrate their systems. There is, of course, no connection between the drainage pattern as it was then formed and the pre-Miocene drainage pattern, for the lava floods had effectively destroyed all of the older system. It is thus fruitless to discuss such questions as the pre-basalt course of even the master streams of the general region, until the pre-Miocene topography and post-Miocene displacements have been much more fully studied. It is very probable that no streams closely comparable to the recent ones existed.

Probably some of the folding and faulting of the Tertiary rocks went on during the extrusion of the Columbia River lava; certainly these structural movements were in operation soon afterward. It is possible that some synclinal areas in which Tertiary sediments are now found were made the sites of stream and lake deposition by such movements, though some of these areas of sedimentary accumulation were determined by their greater distances from the fissures feeding the basaltic flows, as is shown by the interfingering of lava and water-laid sediments on the southwest flank of Lower Powder Valley and near Elk Creek. If this is true in general, there is a strong probability that the sediments at one time were continuous from the Lower Powder Valley to the upper valley of the Burnt River, over the entire southeastern third of the quadrangle, as is suggested by remnants at considerable altitudes on many of the pre-Tertiary hills now separating the more continuous areas of these deposits and by the course of the Burnt River across the hard rocks of Dooley Mountain. If so, this area was probably a rather even plain, with some lakes, while the east end of Elkhorn Ridge may have stood slightly above the constructional surface of the volcanic and associated water-laid deposits.

EFFECTS OF DEFORMATION

Had no erosion occurred, the deformation of the late Miocene surface would have produced a rolling topography (modified by some steep fault scarps and troughs) whose high and low points would have more or less closely corresponded to those of the present surface. It is, however, almost certain that such folds and faults were not formed so rapidly that erosion was unable to modify the topography during their formation. Some of the faults at least, are very recent (see pp. 75–77), and probably the movements have been in progress since Miocene time, with the structural relief constantly subjected to erosional modifications.

DEVELOPMENT OF DRAINAGE

At least two fundamentally distinct theories may be entertained to account for the origin of the present master streams.

One theory would attribute the dominantly synclinal courses to the direct effect of the warping of the late Miocene surface, whereby the drainage would be concentrated in the structurally low places. The places where deviations from this arrangement occur—for example, where the Powder River cuts through the basalt between Bennett and Baker and the canyon of the Burnt River—may represent low places between the structural basins. According to this theory the major streams are dominantly consequent upon the warping of the late Miocene surface, and their tortuous courses represent the linking of structural basins by more or less haphazard channels owing their locations to structural and topographic lows.

The other theory would explain the stream courses by adjustment to the soft beds—the Tertiary sediments. The synclines are sites of streams merely because in these troughs the slightly resistant rocks extend to lower altitudes and have accordingly been cut down lower than the more resistant rocks of the interstream anticlines. Locally the streams are guided by fault lines, as in the Powder River Canyon near Magpie Peak and along Alder Creek. The streams are chiefly subsequent, although certain minor portions, such as the canyons of the Burnt River and Ruckles Creek, are due to superposition.

The choice between these two theories is not clear-cut, as the local geology is such that the arrangements to be expected under the two are similar, but a few considerations suggest that the second is the more probable. Among these is the very marked contrast between the lavas and the intercalated sediments in hardness and, what is perhaps even more important, in permeability to ground water. The lavas are relatively very hard rocks, not readily broken into small fragments; but their common coarse jointing renders them highly permeable to ground water. On the other hand, the sediments are largely unconsolidated or only slightly consolidated and are readily disintegrated into fragments capable of stream transportation. At the same time the sediments, owing to their large content of fine volcanic debris, are relatively impermeable to ground water. Hence, in any hillside exposures where Tertiary sediments are overlain by lavas the contact is marked by springs. The undermining of the lavas by creep of the sediments near these springs leads to the recession of the resistant lava beds. This process is well seen in the valley of Big Creek near the north edge of the quadrangle, as well as in many smaller stream valleys. It results in a very marked control of drainage by the belts of soft sediments and has led to streams being rapidly adjusted. Throughout eastern Oregon the soft sediments, even where they had been covered by now flat-lying later lava flows, are selected by the superposed streams when, in downcutting, they expose the sedimentary belts to erosion, as shown in Rye Valley and the upper John Day Valley.

Another feature opposed to the interpretation of the course of the rivers as consequent upon the warping is the probability that the Burnt River in the southeastern part of the quadrangle does not occupy the structural saddle of the anticlinal ridge through which its canyon is cut, as it would if it were consequent: it therefore suggests a superposed course in this portion. Other arguments in favor of the interpretation that the master streams are chiefly subsequent are (1) the scarcity of demonstrably consequent master streams in other regions that have undergone deformation; (2) the improbability that slight tilting of such soft rocks as the Tertiary sediments could directly displace large streams flowing on their surface, though the streams would be expected to shift in response to ground-water control by structure and to differences in erodibility of different beds; (3) the long persistence of deformation, probably from late Miocene to Recent time, suggesting that the deformation occurred in small increments, which would have had but slight direct effects on drainage courses, although fault lines and depressed areas of soft rocks would still be favored by erosion. For these reasons, the master streams are regarded as dominantly subsequent.

A third theory, that the streams of the region are in any considerable part antecedent to the structure and have maintained preexisting courses despite the folds and faults, seems untenable for several reasons. (1) The contrast in erodibility of the several formations is extreme, so that there is a strong tendency for rock character to influence drainage. (2) The synclinal courses of the Powder River and Burnt River both within and near the quadrangle would not be expected under this theory. These courses can hardly be fortuitous: they must reflect either direct (consequent) or indirect (subsequent) drainage control by structure. (3) In the sections of the streams between these synclines there is, locally at least, control by other structural features, such as the faults northeast of Magpie Peak. While it is perhaps impossible to disprove an antecedent origin for the section of the Burnt River across Dooley Mountain or for the sections of the Powder River in the Telocaset quadrangle (north of this area) and between Bowen and Baker, all these sections are at least as well or better referred to structural modifications of a now lost drainage system.

The present course of the Powder River from Baker to Haines is being aggraded, as is shown by the division of the stream into several widely meandering shallow channels. This aggradation is doubtless a result of recent faulting along the southwest flank of Baker Valley (see pp. 74–75), which depressed the valley block below stream grade. The throw of this fault is considerable, several hundred feet being a minimum estimate. That it has affected the recent drainage history seems clear. (See pp. 85–86.) It is natural to assume that relative depression of a block, either by long-continued small increments or by a few large movements, must empower the streams draining into this block to incise their courses. It is indeed possible that at earlier stages in the depression of the Baker Valley block a stream so empowered extended southward and captured a stream at Bennett which had formerly flowed eastward in the soft sediments of the syncline extending toward Encina and possibly even to Durkee. (See fig. 4.) The sharp turn in the Powder River at Bennett may be a somewhat modified elbow of capture.

Should this interpretation, admittedly hypothetical, be true, the capture must have occurred at a considerably higher altitude. As the stream cut lower it became entrenched in the basalt ridges between Bowen and Baker and again just north of Bennett, being in these sections almost surely superposed from well-developed terraces, which are still readily reconstructed. At present levels the drainage of this trough is being more and more diverted to Alder Creek and away from Sutton Creek and the Powder River drainage basin.

The headward advance of Alder Creek at the expense of Sutton Creek is apparent near Pleasant Valley, where at least three and possibly four of the southerly tributaries of Alder Creek present barbed patterns with respect to it and were almost surely feeders of Sutton Creek until recently.

As the Burnt River at Durkee, 2 miles east of the quadrangle, is flowing at about the same altitude as the Powder River at the mouth

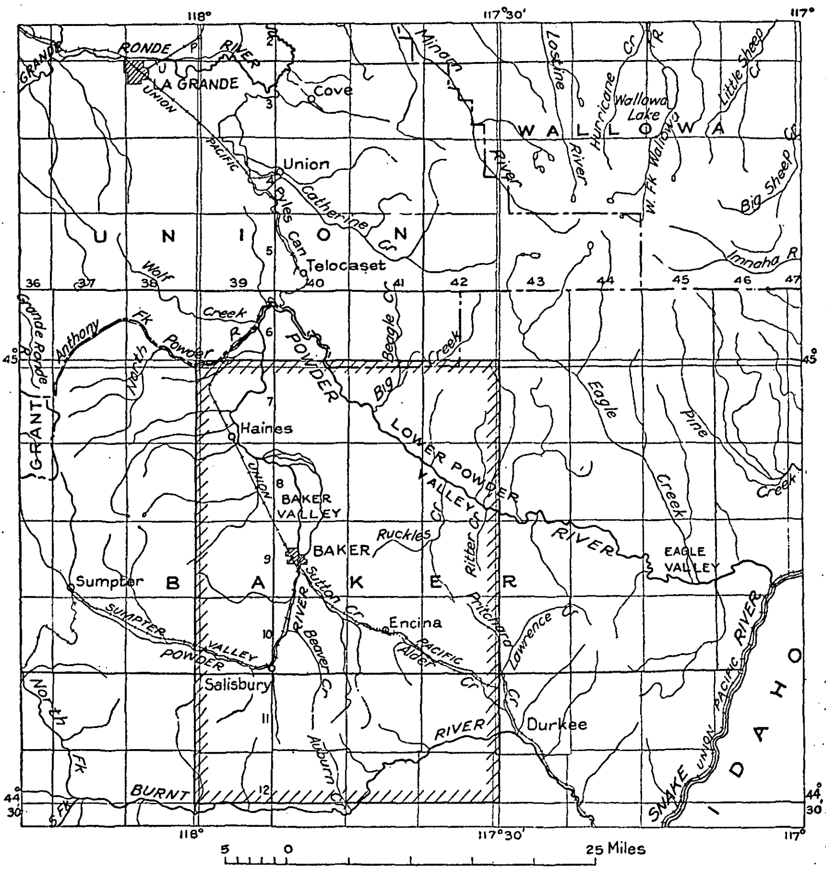

FIGURE 4.—Principal drainage of Baker quadrangle and adjacent areas.

of Ritter Creek, and the course from Baker by way of Sutton and Alder Creeks is less than half as long as the great bend of the present Powder River, it seems that the capture of the Powder by Alder Creek is a matter of but a short time geologically, unless it is interfered with by more crustal movements.

The course of the Powder River just north of the quadrangle, where it changes from north to southeast, has been interpreted as due to obstruction of a formerly continuous course to the Grande Ronde by a northwestward-trending fault block[60] uplifted across its path. There is no doubt of a partial but slight fault control (rather subsequent than consequent, however) of the Powder River Canyon near Magpie Creek, nor is there any doubt of the origin of the Grande Ronde Valley by down-faulting and the control of many of its tributaries, notably Pyles and Catherine Creeks, by fault lines. Nevertheless, the capture of Powder River tributaries by the Grande Ronde[61] seems to indicate a recent addition to, rather than subtraction from, the power of the Grande Ronde drainage, and the course of the Powder may not represent a recent diversion but a long established course. Certainly there is no evidence of fault control of the Powder from the mouth of Big Creek to Eagle Valley, 15 miles east of the Baker quadrangle, though its valley is clearly synclinal throughout this distance.

The part of the course of the Burnt River in the southeast corner of the quadrangle, where it is cut into the pre-Tertiary rocks in a sharp canyon between the mouth of Auburn Creek and Durkee Valley, suggests superposition, especially because the presence of considerable areas of Tertiary sediments far above the stream level on both sides demonstrates the earlier continuity of these deposits over this part of the quadrangle.

In view of the persistence of diastrophic movements in the area until very recent time, it is impossible to refer the topographic features to a common datum applicable to Miocene time. Hence present altitudes of particular topographic features are merely convenient means of reference and cannot be regarded as measures of their respective altitudes in the late Tertiary. So qualified, the Burnt River was probably superposed on the Dooley Mountain ridge from a course developed on Tertiary sediments, at an altitude now represented by points somewhat above 5,600 feet, probably 6,000 feet.

EARLIER EROSION CYCLES

The early Tertiary topography can no longer be recognized in the present land forms, owing to the Tertiary deposits mantling it and to later deformation. The differing interpretations of this surface as hilly and in places mountainous, by Lindgren and the writer, on the one hand, and as an old peneplain, by Pardee and Hewett, on the other, are discussed on pages 47–48. In this section only those older erosion cycles that are suggested by or can be recognized in the present topography are considered. All are post-Miocene.

The recent faulting and possible folding of the rocks in the quadrangle may have obscured a former widespread surface of low re-

[60] Livingston, D. C., Certain topographic features of northeastern Oregon and their relation to faulting: Jour. Geology, vol. 36, p. 703, 1928.
[61] Idem, p. 704.

lief. At present there is a fairly even sky line on the Dooley Mountain ridge, extending nearly across the quadrangle at an altitude of about 6,000 feet. It may represent a postmature erosion surface from which the superposition of the Burnt River occurred. These summit altitudes rise slightly westward (see fig. 5) and in the Sumpter quadrangle are more than 9,000 feet, but this may represent either later tilting or, as the Tertiary folds rise in that direction also, an original slope due to a greater proportion of resistant pre-Tertiary rocks in these areas. However, the narrowness of the Dooley Mountain ridge and the absence or at least the nonrecognition of a widespread concordance of summits in the general region make it doubtful whether any such surface existed. Future work in the region should nevertheless consider the possibility of such an erosion surface.

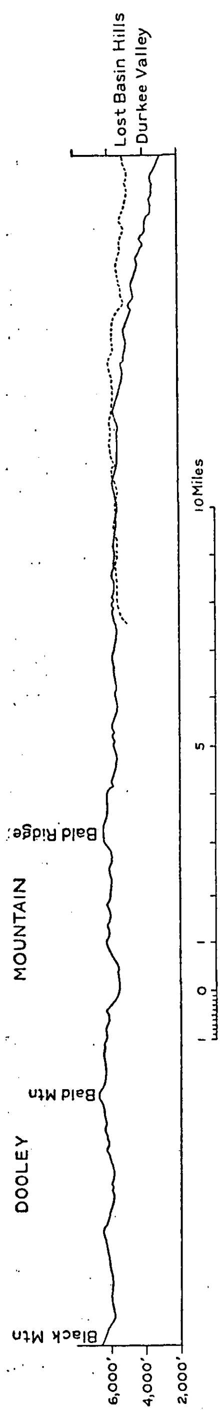

FIGURE 5.—Longitudinal profile of Dooley Mountain sky line and of the Lost Basin Hills, in the southern part of the Baker quadrangle.

If it existed and has not been obscured by deformation, it has all but disappeared from the area of the Baker quadrangle, for the Virtue Hills and Farley Hills are all much lower. Inasmuch as these topographic highs rise little above 4,500 feet and residuals of Tertiary rocks are even now widespread on them, it is likely that even a maturely developed surface concordant with the Dooley Mountain sky line would have been largely destroyed by later erosion of the softer rocks upon which it was carved, though its preservation where cut on the Columbia River lava would be expected. It is possible that the bench at 5,000 to 5,200 feet near Tamarack Flat, in the northeast corner of the quadrangle, represents this surface, but work in neighboring areas would be needed to settle the matter.

The next lower widespread areas of accordant altitude range from about 4,300 to 4,800 feet in the Virtue Hills and the hills south and southeast of Pleasant Valley. If these areas indeed represent a postmature erosion surface it falls off to the north and ranges from about 3,500 to 4,200 feet in the Farley

Hills and from 3,200 to 3,700 feet on the north side of the Lower Powder Valley. However, much of the area of the Virtue Hills shows remnants of the Tertiary cover, and the approximate accordance of level may represent only the partly stripped surface of earlier Tertiary time, given a deceptive regularity by the Tertiary filling remaining in its hollows.

The ridge extending from Magpie Peak to the Flagstaff mine is, however, made of Columbia River lava and is roughly accordant with the basaltic plateau between Big Creek and the Powder River Canyon in T. 7 S., R. 41 E. The suggestion is reasonable that this surface represents a relatively long erosion interval, during which the land near the master streams was reduced to fairly low relief, though there is no evidence of the development of this surface in the larger mountain masses nearby. It is perhaps significant that the general level of the basalt surface (the old valley?) above the sharply incised Powder River Canyon northeast of Magpie Peak is at about 3,700–3,800 feet, whereas the divide southeast of Magpie Peak is about 100 feet lower, but possibly the surface sloped this much when it was formed. The possibility also exists that part of this surface, north of Magpie Peak, is a bench formed by stripping of the soft Tertiary tuffs from the basalt, but this cannot be true of all parts.

The oldest clearly recognized and widely developed erosion surfaces now prominent in the topography are the terraces so well represented on all the larger areas of Tertiary sediments. In the Lower Powder Valley they are beautifully developed at 200 to 400 feet above the present tributaries of the Powder. Comparable terraces in Virtue Flat are less deeply dissected, for the streams there have been delayed in lowering their beds by the hard-rock sill in Ruckles Creek. In the valleys of Sutton Creek and the Powder River above Baker these terraces are 300 to 500 feet above the present streams. The greater depth to which the terraces south of Baker have been dissected is probably due largely to the recent relative (and, in part, absolute) downthrow of Baker Valley, because the Powder River is aggrading rather than degrading the Baker Valley for at least 6 miles north of Baker. Thus the dissection of these terraces south of Baker cannot be due to headward advance of a new subcycle of degradation; indeed, the subcycle represented by the dissection of the Lower Powder terraces seems to have extended headward only to the neighborhood of Haines. That the Powder was graded at the time the terraces were formed seems clear, hence a climatic change to which the incision of the present streams in the older terraces is probably due should expectably bring about roughly uniform dissection throughout the course of the river, or at least a gradual change from degraded areas to aggraded areas. Instead, we have evidence of excessive degradation above Baker and aggradation below Baker, the boundary between being, as shown by other evidence, one of recent faulting in the sense required to bring about these relations. Accordingly it is probable that these abrupt differences in the amount of dissection of the terraces are due to faulting just south of Baker.

Comparable terraces occur in the Burnt River Valley along Pine and Cow Creeks, where they are dissected to depths of 300 to 400 feet. All these terraces are attributed to the Pleistocene on the basis of their close parallelism to the present valley bottoms and the roughly similar degradation they have undergone.

MINOR GEOMORPHIC FEATURES

Certain fragmentary records of stages in the development of the present land forms remain to be discussed. One of these is furnished by a high valley, about 1,000 to 1,500 feet above the present stream, along the canyon of the Burnt River in the southeast corner of the quadrangle. The existence of this older gently sloping valley in which the present steep-walled canyon is abruptly incised seems clear, but the ridge crests outlining it are too short to permit anything like a complete reconstruction of it. This surface cannot be correlated with any of the tentatively recognized surfaces already discussed.

A second stage in the history of the Burnt River Canyon is recorded by the remnants of gravel up to 300 feet above the present stream, both in the main canyon and in its tributaries, and also by the cut-off meanders about 200 feet above the stream just below Dark Canyon. No level-topped benches of gravel or rock-cut terraces (except in the cut-off meanders) can be recognized in the canyon, and the gravel is all about uniform in degree of weathering, so that probably the gravel represents a single filling of an earlier canyon cut within 50 feet or so of the depth of the present one. As no considerable widening of the bedrock walls is to be seen at the level of the tops of these gravel remnants, no long period during which the stream flowed at this height can have ensued. This dissected filling may be correlative with the 300-foot filling of the Snake River Canyon attributed to the Pleistocene by Lindgren,[62] as similar gravel deposits occur on the lower course of the Burnt River in the adjacent Pine quadrangle.

A minor drainage modification is indicated on the north side of Virtue Flat. Here the saddle through which the old road to the Lower Powder Valley passes out of Virtue Flat suggests that the stream now heading west of the 3,672-foot hill in sec. 35, T. 8 S., R.

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[62] Lindgren, Waldemar, op. cit. (Blue Mountains), p. 585.

41 E., at an earlier period included much of the west end of Virtue Flat in its drainage basin. The stream encountered hard pre-Tertiary rocks at a higher altitude than Ruckles Creek did, farther east, so that it was unable to cut down as rapidly and was beheaded by a westward-growing tributary of Ruckles Creek. Now that Ruckles Creek is itself engaged in carving a course through the hard rocks north of Palmer, it is likely to be beheaded in turn by a more easterly stream, possibly Ritter Creek.

The history of Big Creek, near the north side of the quadrangle, has been discussed by Livingston,[63] who concludes that it formerly carried, through Beagle Creek, the waters now going to the Grande Ronde Valley through Catherine Creek but has been beheaded by fault valleys or diverted by fault blocks uplifted in its path. This diversion occurred in the Telocaset quadrangle, to the north, and the writer has made no attempt to study the question on the ground. It may be significant, however, that the wide valley of Big Creek in secs. 2 and 11, T. 7 S., R. 41 E., is at least in large part due to erosion of soft lacustrine sediments which here form the basal members of the Tertiary. Their impounding of ground water beneath the Columbia River lava must conduce to rapid retreat of the overlying rocks, so that the valley width may not necessarily imply a formerly greater discharge from the basin. Nevertheless, Livingston's interpretation seems not inconsistent with the topographic relations in the Baker quadrangle.

In a few small areas (see pp. 75–77) the present topography reflects the recent faulting directly. This is an evanescent phase in the topographic development, however, and must soon give place to erosional control, though of course the indirect structural effects in changing the vertical relations of rocks of differing erodibility are persistent.

HISTORICAL GEOLOGY

The geologic history of the Baker quadrangle, so far as it is revealed by the features discussed in preceding sections of this report, is here summarized. Much of that history is lost to view, and it is reasonable to suppose that events quite as important as any whose record is still legible have occurred and left no clear traces. The present summary must be considered provisional in many features and definitely established in but few. For the purpose of this treatment the uncertainties discussed in earlier sections will here be neglected, and the assumptions there made will be regarded as established.

The geologic record in the Baker quadrangle begins in probable pre-Carboniferous time, with the area depressed beneath the sea and

[63] Livingston, D. C., op. cit., pp. 703–704.

receiving deposits of siliceous coarse and fine clastic material, with varying amounts of volcanic ash, breccias, and some limestone, now represented by the Burnt River schist. The great variety of rocks composing the Burnt River schist seems to have been brought about, in large part, by changes in the amount of pyroclastic debris supplied to the region along with a relatively constant supply of normal quartzose sediments, indicating an expectable variation in the volcanic activity with time.

Possibly the sedimentation continued without notable pause into the Carboniferous period, or there may have ensued a period of mountain-making and erosion before the Carboniferous. At any rate, in Carboniferous time the region was again depressed beneath the sea and became the site of deposition of the silt and mud, with some limestone, represented today by the Elkhorn Ridge argillite. From time to time volcanic-ash falls occurred, and their aggregate amount was very large. Some lava was also erupted. The conglomeratic members of the formation may indicate that the region was at times elevated above the sea, but they may merely testify to a local shoaling of the sea with consequent advance of near-shore sediments into the areas formerly receiving only offshore facies. Most of the formation, however, seems to have originated under fairly deep water, for most of the component materials are of very fine grain.

As no evidence was discovered bearing upon the conditions that immediately followed the deposition of the Elkhorn Ridge argillite, it is impossible to state whether the area was emergent or whether the thick series of lavas and tuffs of the Clover Creek greenstone were poured out in conformable succession upon the sea floor without an interval of uplift. At any rate, this huge volcanic accumulation was in part, at least, submarine, as is shown by its included limestone beds and some fossiliferous tuffs, although it is possible that some of the pyroclastic members were of subaerial origin. Pillow lavas, which are commonly regarded as characteristic of submarine eruptions, were not observed in the greenstone, but the deformation it has undergone and its relatively poor exposures may account for this lack. It is probable that the widespread albitization of the lavas occurred at the time of their solidification.

No direct information is available as to the history of the area immediately after these eruptions, which occurred in Permian time. There is some suggestion that a period of strong folding, perhaps of mountain building and igneous intrusion, occurred after these eruptions and before the Upper Triassic sedimentation. At least there is rather definite lack of sediments of Lower and Middle Triassic age in the nearby Wallowa Mountains, and the Upper Triassic conglomerate beds there contain many granitoid pebbles not seen in the older rocks.[64] The greater dynamic metamorphism of the known Permian as compared to the known Triassic in the Wallowa Mountains also leads to the same conclusion.

In the western part of the Blue Mountains intrusive rocks, according to Lupher,[65] were emplaced in Lower or Middle Triassic time, suggesting more directly an orogenic period at that time. None of the intrusive masses of the Baker quadrangle have been shown to belong to this period, however, and albite granites regarded as possibly belonging to the earlier of the two provisionally recognized magmatic cycles of this region have been found intruding known Triassic rocks near the Eagle River, in the Wallowa Mountains.[66]

The early Triassic was probably a time of erosion in the quadrangle, but the erosion was probably succeeded by renewed submergence and the deposition of fine silty material, now represented in the shales that crop out just north of the quadrangle, in the Wallowa foothills.[67] Whether these shales were deposited over the Baker quadrangle or not is quite uncertain, as none have been found within the area. They may have been entirely removed by erosion.

The Upper Triassic was followed by a period whose events are very obscure. In the western part of the Blue Mountains Lupher[68] has found a considerable unconformity between Triassic and Jurassic rocks, indicating some folding and erosion after the Triassic period. He has also found in the Silvies River region a thick series of deposits representing most of Jurassic time, testifying to quiescent sedimentation there. No Jurassic beds have been recognized in the eastern part of the Blue Mountains, however. If they are truly absent from this area and not merely unrecognized, it may indicate either epeirogenic uplift and erosion at this time, deposition and later complete erosion of rocks of this age, or a period of folding in this area earlier than that farther west. If the earlier plutonic rocks of the Baker quadrangle are entirely post-Triassic, it is possible that their emplacement occurred at this time. Post-Jurassic folding and intrusion have been demonstrated by Lupher in the Silvies River country. The time between the late Jurassic and the early Cretaceous is regarded as the date of intrusion of the Sierra Nevada batholith and of the Idaho batholith. It is therefore likely that some of the plutonic rocks of the Baker quadrangle were emplaced at this time. Thus the area of this quadrangle was probably exposed to erosion from the end of the Triassic period until

[64] Ross, C. P., Geology and ore deposits of the southern Wallowa Mountains, Oreg.: U. S. Geol. Survey manuscript report.

[65] Lupher, R. L., personal communication, 1931.

[66] Ross, C. P., op. cit.

[67] Idem.

[68] Lupher, R. L., personal communication, 1929.

it was overwhelmed in Tertiary time by the eruptions of volcanic material.

No record of the early part of the Tertiary period has been recognized here. It is possible that the Dooley rhyolite breccia and the earlier gravel deposits may date back to Eocene time, but it is perhaps more probable that they are Oligocene or even early Miocene. The available record is interpreted as indicating an early Tertiary uplift and accompanying erosion, which ultimately produced a rather hilly or even mountainous topography, perhaps comparable to that of the present day. Possibly several cycles of uplift and degradation, extending even to peneplanation, had ensued in the area, but the land surface as preserved by the Tertiary deposits records only a moderately advanced cycle, with a hilly topography and rather coarse gravel along the streams.

The degradation of the area was interrupted by voluminous eruptions of rhyolitic lava, breccia, and pumice, probably from vents near the present site of Dooley Mountain. These volcanic products reached a thickness of more than 1,500 feet near their presumed source but thinned away from it. They are here grouped as the Dooley rhyolite breccia. The latest recorded phase in the volcanic activity associated with them is represented in the conspicuously flow-stretched porphyritic andesite locally overlying the breccia on both slopes of Dooley Mountain.

The next episode in the geologic history was the eruption of huge volumes of coarse andesitic breccia near the southwest corner of the area. The source of this material must have been close at hand, as the huge boulders cannot have traveled very far, but it has not been recognized in the Baker quadrangle. Probably soon after the formation of this breccia it was locally intruded by a large dacite sill.

During all this earlier phase of the volcanism the accumulation of stream-laid and lacustrine deposits consequent upon the disruption of the drainage by eruptions must have continued, but it is probable that there were intervening periods when the drainage became reestablished and possibly eliminated all lakes. No record of peneplanation during the Tertiary volcanism has been recognized, however. It is probable that a fairly long period of erosion intervened between the accumulation of the andesite tuff-breccia and the eruption, in Miocene time, of the Columbia River lava, but there is nothing to prove that the period began before the Miocene and hence that the earlier volcanic rocks are Oligocene.

The Columbia River lava records a long series of eruptions, presumably of the fissure type. Again the drainage was disorganized, and stream and lake sediments were deposited. Eventually, probably after several long periods of quiescence, the Columbia River lava flooded nearly if not quite all of the Baker quadrangle. The topography must then have presented a monotonous series of ridges near the fissures that furnished the lava, sloping down to valleys at the distal parts of the flows. In these valleys lakes continued to exist for some time, and in the lakes diatoms, stimulated perhaps by the large silica content of the waters, flourished in myriads, their tests accumulating to form thick beds. The leaves associated with these sediments indicate an age and a floral assemblage like that of the Latah formation, which has been said to suggest that the region was one of moderate, equally distributed rainfall, perhaps 30 to 40 inches annually, supporting a vegetation comparable to that of present-day Maryland.[69]

It is probable that earth movements accompanied the extravasation of the Columbia River lava, as its huge volume must have demanded crustal readjustments when displaced. Whether these movements were considerable at the actual time of eruption is uncertain, but their continuation afterward has left a strong impress on the present topography of the region. Gentle swells and downwarps were formed, accentuated locally by faults.

Upon the land surface so produced the streams resumed their work of degradation. In this they were interrupted locally by structural movements, such as the dropping of the Baker Valley, which made it the site of deposition rather than erosion, and the faults of the Lake Creek and other areas, which have disorganized the drainage, but on the whole the history of the quadrangle since Miocene time has been one of erosion.

There is doubtful evidence of two advanced cycles of post-Miocene erosion, but the only clear record of a pause in the degradation is given by the widespread terraces developed on the Tertiary sediments. These are attributed to Pleistocene time. In Recent time the only interruption to continued erosion has been a light fall of volcanic ash, which mantled the entire area but has now been washed from most of the steeper slopes and concentrated along the present streams and in alluvial cones.

ECONOMIC GEOLOGY

MINERAL RESOURCES

The mineral resources of proved or potential value in the Baker quadrangle include gold and silver, copper, manganese, tungsten, antimony, coal, asbestos, limestone, building stone, and diatomite.

[69] Berry, E. W., A revision of the flora of the Latah formation: U. S. Geol. Survey Prof. Paper 154, pp. 233–234, 1929.

Although all these except the asbestos and diatomite have been commercially produced, the only product of considerable value has been gold.

The gold deposits are of two types—fissure and replacement veins in the pre-Tertiary rocks and placer deposits in the Recent and earlier gravel. The quartz veins are commonly small and nonpersistent, though a few strong and continuous veins are known. They are all mineralogically simple, with gold, pyrite, chalcopyrite, sphalerite, and locally stibnite and galena in a gangue of quartz, sericite, and carbonate, with locally clay and scheelite. Silver is present in small amounts in all the veins. The veins are believed to be genetically related to the intrusions of biotite-quartz diorite so widespread in the general region. Probably the placers have yielded considerably more than half the total output. Locally, the relation of the placers to the veins is direct and obvious, but in other places the gold has traveled considerably from its primary source. The exploitation of the placers has been going on more or less continuously since 1862 but has shrunk to very small proportions in recent years with the working out of the higher-grade gravel.

The copper deposits of the quadrangle are all in the northern quarter, in the area occupied by the Clover Creek greenstone. The deposits are replacement veins and irregular masses in the greenstone and consist of pyrite, chalcopyrite, and sphalerite in a gangue of quartz, epidote, chlorite, and ankerite, with locally barite and zeolites. Near the surface there is in places considerable chalcocite, with native copper, cuprite, malachite, and other oxidation products forming at the surface. Only a small production of copper has been won from the deposits in the quadrangle.

Tungsten, in the form of scheelite, has been found associated with gold in quartz veins. One mine, the Cliff, has been unsuccessfully worked especially for the scheelite.

Manganese has been found in the Elkhorn Ridge argillite near Pleasant Valley and in the Burnt River schist east of Cave Creek, associated with gold quartz veins. It has doubtless been concentrated by the oxidation of manganiferous silicates and carbonates. These deposits were worked in 1917, in response to the demands for manganese during the World War, but have since been inactive.

Antimony, in the form of stibnite, has been mined from a gold quartz vein near Baker. This operation also was limited to the war years.

Asbestos of the anthophyllite variety is found as veins in metagabbro and on contacts with schist south of Bald Mountain. Although some experimental work has been done with this fiber, no production on a commercial scale has yet been attempted.

Lignitic coal, very impure and of low quality, occurs in the Tertiary sediments near Auburn. It has been mined in a small way for local use but offers no hope of commercial exploitation on a large scale.

Limestone occurs in irregular podlike masses in the Clover Creek greenstone and the Elkhorn Ridge argillite and as more continuous beds in the Burnt River schist. It has been exploited as a source of lime only in small pits near Pleasant Valley. These pits are now inactive.

Volcanic tuff has been quarried for building stone in the hills east of Baker and north and south of Pleasant Valley. It is durable and relatively attractive, but no quarries have been active for several years, possibly because of competition with concrete.

Granite, technically biotite-quartz diorite, has been quarried near Haines for many years. It is light gray, even-textured, and fresh but is principally useful for monumental work, as the dark clots of inclusions are so closely spaced that large dimension stone free from them is very difficultly obtainable.

Diatomite occurs in beds at least 20 feet thick in the Tertiary sediments of the Lower Powder Valley. The deposits, though probably extensive, have not yet been exploited or indeed even developed to the point where the amount available can be estimated with confidence.

The general features of the mineral deposits of the region of which the Baker quadrangle is a part have been recently summarized.[70] The present section is accordingly confined to simple descriptions of the deposits occurring within the quadrangle. These will be taken up under the head of the principal products.

GOLD DEPOSITS

Although the principal gold production of the quadrangle has doubtless been obtained from placers, there are two areas where lode mines have been operated with more or less success. These are the Virtue district, embracing the area from the Flagstaff mine and Lone Pine Mountain on the west to Pleasant Valley on the east, and the Baker district, which includes most of the east end of the Elkhorn Ridge.

VIRTUE DISTRICT

ORE DEPOSITS

The ore deposits of the Virtue district are quartz veins in the pre-Tertiary rocks. They are probably due to emanations from the

[70] Hewett, D. F., Zonal relations of the lodes of the Sumpter quadrangle: Am. Inst. Min. and Met. Eng. preprint, 1931; Trans., 1931, pp. 305–346. Gilluly, James, The copper deposits near Keating, Oreg.: U. S. Geol. Survey Bull. 830, pp. 22–24, 1932. Gilluly, James, Reed, J. C., and Park, C. F., Jr., Some mining districts of eastern Oregon: U. S. Geol. Survey Bull. 846–A, pp. 24–31, 1933.

biotite-quartz diorite exposed south of the Flagstaff mine, or from related masses at greater depth.

The veins consist of quartz, calcite, and scheelite, with a little sericite, and contain small amounts of pyrite and chalcopyrite and free gold. They are commonly brecciated, and the breccia zones are favored sites for the sulphides.

THE MINES

VIRTUE MINE

Location.—The Virtue mine, which has given its name to the district and has hitherto been the greatest producer in it, is situated in sec. 21, T. 9 S., R. 41 E., at the foot of the hills bounding Virtue Flat on the south. It is about 3 miles south of the Baker-Richland highway and about 12 miles by road from Baker.

History and production.—The veins worked in the Virtue mine, according to Lindgren,[71] were discovered in 1862 by tracing up the rich placers in the gulch below. For the next 10 years the mine was known as the Rucker or Union mine and was very actively worked. Between 1871 and 1878 it was worked almost continuously, largely by Brown & Virtue. In 1878 it was sold to Grayson & Co., of San Francisco, who worked it in a more or less satisfactory way till 1884. It was then idle until 1893, when work was resumed and continued until 1898 with excellent results. After a short period of idleness the mine was sold to the Consolidated Virtue Mine Co., of Montreal, Canada, which also owned the adjoining Collateral mine. The upper parts of the mine were worked for a short time, and the mine was again closed August 1, 1899. The property has not since been worked except for a brief interval in 1906–7, when a little ore was extracted above the drainage level and about $1,500 was obtained from ore on the dump.[72] The total production has been about $2,200,000.

At the time of this survey the mine was almost entirely inaccessible except for a mill-tunnel level and a few stopes above it, so that little can be added to the description of Lindgren. A sketch map of this level is given in plate 2.

Development.—The mine is developed by three tunnels, the lowest, or mill level, about 300 feet below the outcrop. From the lowest tunnel a vertical shaft was sunk 800 feet and crosscuts were made to the vein every 100 feet. The levels extend 200 to 400 feet north of the shaft and 800 to 900 feet south of it. Development work aggregates not less than 10,000 feet.

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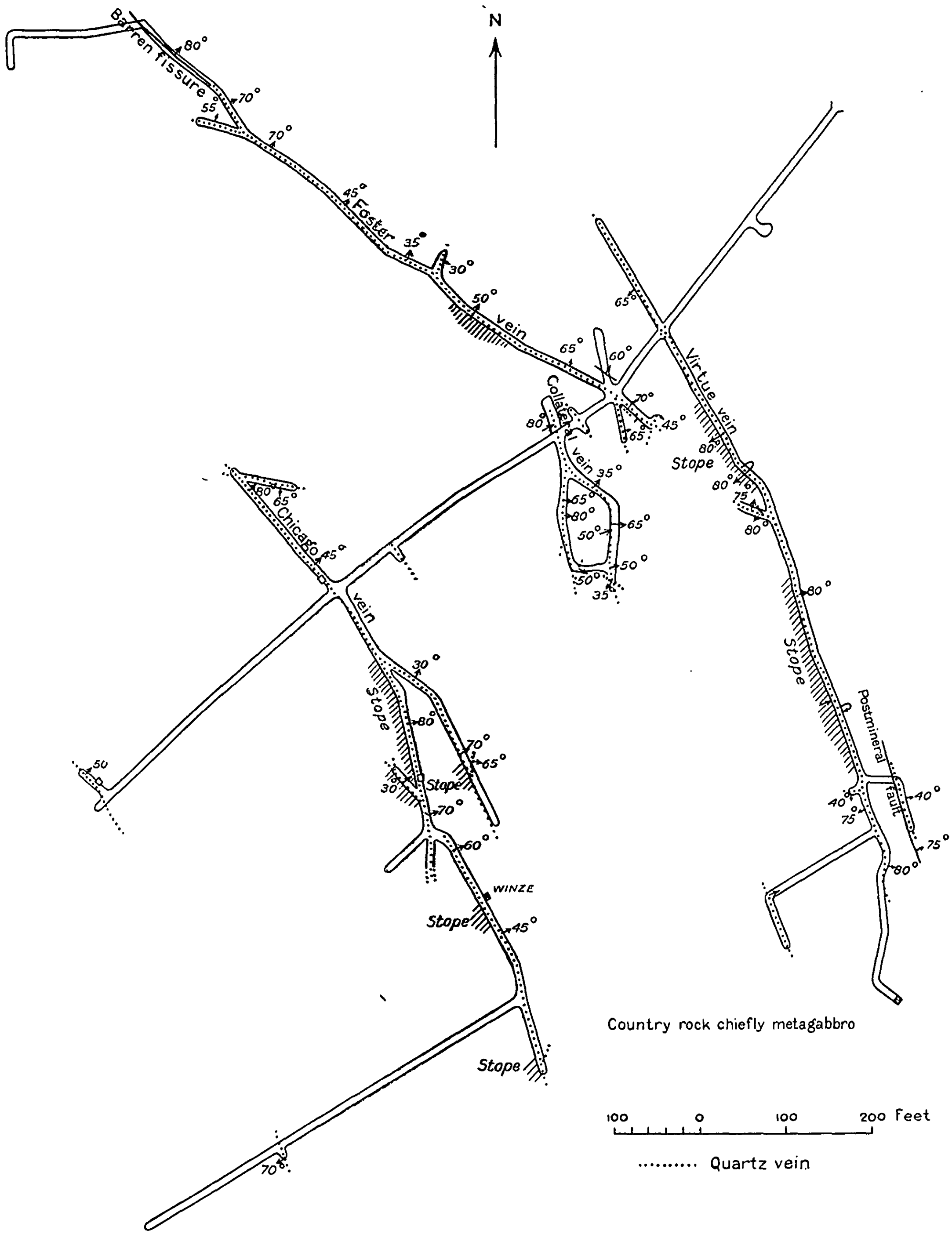
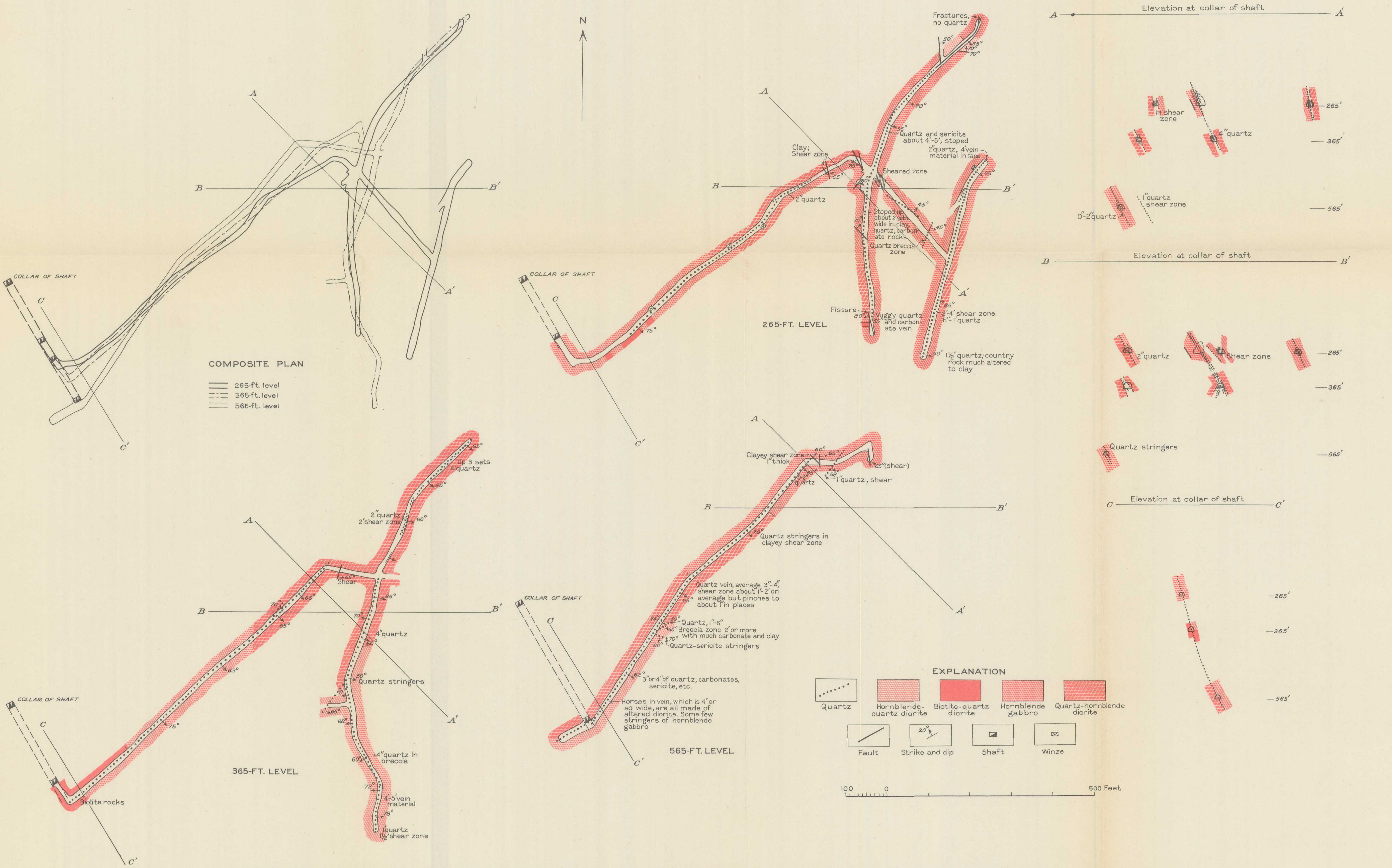
[71] Lindgren, Waldemar, op. cit. (Blue Mountains), pp. 722–723.

[72] Parks, H. M., and Swartley, A. M., Handbook of the mining industry of Oregon: Mineral Resources of Oregon, vol. 2, no. 4, pp. 229–230, Oregon Bur. Mines and Geology, 1916,



SKETCH MAP OF THE MILL TUNNEL LEVEL OF THE VIRTUE MINE, VIRTUE DISTRICT.



COMPOSITE PLAN AND SECTIONS OF FLAGSTAFF MINE, VIRTUE DISTRICT, OREGON

Geology.—The country rock is strongly sheared greenstone, highly chloritic and somewhat serpentinous. It was regarded by Lindgren as an altered volcanic tuff or breccia, and some of it may be of this origin, but most of it is believed to be a strongly sheared gabbro. Specimens collected in the crosscut on the mill level show all gradations between a chloritic schist whose origin it would be impossible to determine from the specimen itself and a brecciated and chloritized rock that is clearly derived from the brecciation of a gabbro. Accordingly it is considered likely that other rocks in the mine whose mottled schistose character at first suggests their origin as tuffs are also sheared gabbro. It is clear that sheared gabbro forms most of the rounded hill south of the mine.

Eight veins, of which the Virtue, Collateral, and Chicago have been the most productive, have been cut in the mine workings. The Chicago and Collateral were formerly the bases for independent mines, but all are now owned by one company. They are subparallel and strike N. 20°–45° W. They dip northeast above the mill level but steepen downward and dip southwest in the lower workings of the mine.

The veins range in thickness from 6 inches to 12 feet and average about 14 inches. They are filled with white coarsely crystalline quartz and subordinate calcite. Vugs are common. Free gold, coarse and partly crystalline, with the unusual fineness of 0.940, is reported by Lindgren.[73] The only sulphides observed were pyrite and chalcopyrite, both of which are sparingly present. The veins are locally brecciated and banded parallel to the walls, and these places are reported to have been richest. Veinlets of calcite, quartz, and pyrite occur in the country rock bordering the veins. Lindgren reports that the richest ore occurred near the surface. Average returns of $20 to the ton were obtained in 1870, of $40 in 1873, of $24 in 1875, and from $15 to $16 between 1893 and 1898.

The pay shoot is said to have been cut off between the seventh and eighth levels at a brecciated zone below which the vein was of very low grade. Warm water was encountered in the lower levels and stands in the shaft to a point a short distance below the mill level, considerably above the valley. This was interpreted by Lindgren, doubtless correctly, as an ascending column of underground circulation. A fault separates the Tertiary beds of Virtue Flat from the pre-Tertiary rocks to the southwest, and it seems that this fault may well have afforded a channel for the warm water from the deeper levels. Gouge, sealing the fault above, may account for the height of the water level in the mine.

[73] Lindgren, Waldemar, op. cit., p. 724.

FLAGSTAFF MINE

Location.—The Flagstaff mine, owned by J. L. Layden, is in sec. 5, T. 9 S., R. 41 E., on the crest of the divide between Virtue Flat and Baker Valley, at an altitude of 3,900 feet. It is less than half a mile from the Baker-Richland highway and about 7 miles from Baker.

Development and production.—The mine was actively worked in the years preceding 1898 and has been developed by an inclined shaft 760 feet deep, with levels at 265, 365, and 565 feet. The workings aggregate about 6,000 feet. The only reported production since 1898 was in 1923, when a small output was made incidental to development. The total production of the mine is probably not more than $100,000.

Geology.—The country rock of the mine consists chiefly of coarse sheared gabbro and quartz-bearing hornblende diorite, both containing much actinolite and some epidote, cut by dikes of biotite-quartz diorite and hornblende-quartz diorite. The two principal rock varieties appear to grade into each other, but in view of their petrographic differences, this is probably due to later metamorphism rather than to an original heterogeneity of a single intrusive mass.

The biotite-quartz diorite and hornblende-quartz diorite dikes have been recognized only in the mine workings, where exposures are insufficient to demonstrate their attitudes. They are cut by and are clearly older than the mineralized shear zones of the mine.

The ore deposit consists of several sheared and brecciated zones and veins. They range in strike from N. 45° E. to north and dip steeply, averaging 65°, either east or west.

The faults and veins are arranged in a twisted pattern. The main vein, in whose footwall the incline is sunk, flattens from a dip of about 75° in the upper workings to about 55° on the 565-foot level. The drifts on the three levels from this shaft trend successively more northerly on the lower levels, although they start on what is almost certainly the same vein at the shaft. Inasmuch as the dips of these principal veins are all southeastward, the necessary conclusion from this arrangement is that a number of branch veins must join the main vein from the north. The raises and manways of the mine were all inaccessible, owing to defective timbers, so that it was impossible to pass from one level to another except at the main shaft. The "horsetail" arrangement of the veins suggests torsion about a steeply inclined axis. A map and sections of the mine are shown on plate 3.

The faults through the gabbro and diorite are all accompanied by great masses of clay gouge. Some of this gouge is probably due to comminution of the country rock by friction, but much of it is hydrothermal rather than mechanical in origin, as is shown by the association of zeolites with the clays.

Within these masses of gouge are extremely irregular brecciated lenses of quartz. These masses locally range from a knife edge to more than a foot in thickness in a few feet of strike length. The maximum thickness of quartz observed in any one stringer was 1½ feet, although in one place, where the shear zone is over 20 feet wide, several lenses whose aggregate thickness is about 4 feet are present. The shear zones themselves are irregular; they probably average about 3 feet in thickness.

In some places the quartz is massive and coarsely crystalline, in others vuggy, and in still others sheeted and brecciated. Gold is present in the quartz but according to Mr. Layden occurs also in the gouge, though in less amount. No sulphides were observed during this survey, but tetrahedrite, stibnite, and scheelite have been recorded from the mine by Lindgren.[74]

The principal minerals of the altered rock are a clay mineral of low refringence and birefringence, sericite, calcite, serpentine, and a zeolite related to chabazite. Locally the wall rock is silicified, but more commonly it is altered to clay.

No assay samples were collected, but Lindgren reports average values of $16 to the ton in the quartz. According to Mr. Layden, large quantities of the gougelike material will assay $5 to the ton, on the basis of gold at $20.67 an ounce. The largest stopes in the mine occur at the junctions of fissures. Here the shear zones are wider and commonly have more quartz, with higher gold assays.

The lowest accessible level, the 560-foot, is seemingly less well mineralized than the higher levels. The exposed shear zones are narrower and carry less quartz. Mr. Layden believes that the future of the property is dependent on large-scale mining of the gougelike material with its relatively low gold tenor of $5 to the ton. Large quantities of this material are available.

The water level in the mine is just below the 560-foot level, about 420 feet vertically below the outcrop and not far above the level of Baker Valley.

KOEHLER MINE

The Koehler mine is on the west slope of the range of hills lying south of the Flagstaff mine. The workings were inaccessible at the time of this survey. According to Parks and Swartley[75] the mine yielded antimony and gold beginning late in 1915. The vein is reported to be well defined, with a maximum width of about 10 feet.

[74] Lindgren, Waldemar, op. cit., p. 725.
[75] Parks, H. M., and Swartley, A. M., op. cit., p. 137.

Stibnite is distributed through the whole width of the vein, but massive stibnite occurred near the hanging wall in lenses that were 2 feet thick. Some of these lenses yielded ore that was shipped direct; other ore was brought up to grade by sorting. Several carloads carrying over 50 percent of antimony were shipped, and the receipts from these sales are reported to have been about $15,000.

NORWOOD MINE

The Norwood mine, in sec. 8, T. 9 S., R. 41 E., about 2 miles north of the Virtue, was caved and inaccessible in 1930. The property has been described [76] as embracing two lode claims. The country rock is greenstone cut by several quartz and calcite veins, mostly rather small, and shows considerable postmineral brecciation. The largest vein dips steeply, strikes west, and consists of quartz gouge and country rock. Along 450 feet of strike the vein averages about 2 feet in width. A small mill was installed in 1913, but no production has been reported. Little or no work has been done for many years at this property.

CLIFF MINE

The Cliff mine is about three-quarters of a mile north of the Flagstaff, on the north side of a small gulch draining into Baker Valley. In 1930 the mine had been long abandoned, and the shaft was inaccessible. The following account is summarized from the reports by Lindgren[77] and by Parks and Swartley,[78] with some observations of surface geology by the writer.

The country rock of the mine is sheared gabbro. The vein strikes north and consists of 1 to 3 feet of quartz with a little calcite in altered gabbro. Scheelite was identified in the quartz 30 years ago by C. L. King, of Baker. The property is developed by a 300-foot vertical shaft. In 1916 the war prices of tungsten induced F. S. Baillie and later W. E. King to reopen the long-abandoned mine in the endeavor to exploit the scheelite, but nothing came of the attempt.

WHITE SWAN MINE

The White Swan mine is situated at the foot of the hills south of Virtue Flat, in sec. 25, T. 9 S., R. 41 E. It is about 5 miles from the Baker-Richland highway and about 14 miles from Baker by road.

According to Lindgren,[77] the White Swan deposit was discovered in the early days by following up the rich placers of the gulch

[76] Parks, H. M., and Swartley, A. M., op. cit., p. 174.
[77] Lindgren, Waldemar, op. cit., p. 725.
[78] Parks, H. M., and Swartley, A. M., op. cit., p. 56.

below. The mine was vigorously operated about 1890 but was closed in 1897. It was reopened about 1900 and operated by Letson Balliet until 1903, when it was again closed.[79] Lindgren estimated the total production at not less than $200,000, on the basis of Mint reports of output in 1891 as $72,000 and in 1892 as $72,642.

In 1930 the mine was being reopened by a Washington syndicate, with E. McNaughton as manager, but at the time of visit very little of the old workings was accessible.

The mine was developed by a nearly vertical shaft 300 feet deep, from which four levels were turned. About 2,000 feet of development work has been done.

The country rock is Elkhorn Ridge argillite, consisting of dark carbonaceous argillite with interbedded layers of chert and greenstone. The greenstone represents altered volcanic sediments. Intrusive into this argillite formation are several narrow dikes of diorite porphyry. The general strike of the formation is westward.

Several narrow veins are exposed in the vicinity of the mine. All trend generally west, but there is no consistent parallelism observable, although most dip steeply south. The exposed veins reach thicknesses of 1 to 1½ feet, but more common widths are a few inches. No information is available regarding the thickness of the White Swan vein in the old workings.

The only minerals observed in the veins were quartz, sericite, and calcite, with a little limonite to attest the former presence of sulphides, which, however, must have been sparse.

CHICAGO-VIRTUE PROSPECT

The Chicago-Virtue prospect, locally called the "Barry property", is in sec. 35, T. 9 S., R. 41 E., just south of Virtue Flat. The property was idle in 1930, and apparently little work had been done there for many years.

The property has been developed by a steeply inclined shaft 86 feet deep, from which a short drift has been run 30 feet below the collar and a crosscut and drift aggregating 250 feet at the bottom of the shaft. No production has been reported.

The country rock is cherty argillite belonging to the Elkhorn Ridge argillite. The work has been directed to the development of a vein that strikes east and dips 65° S. The vein contains quartz, locally vuggy, elsewhere brecciated, which ranges in thickness from a knife edge to almost a foot. The vein follows a slickensided surface. Nothing is known of the assay value of this quartz.

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[79] Swartley, A. M., Ore deposits of northeastern Oregon: Mineral Resources of Oregon, vol. 1, no. 8, p. 131, Oregon Bur. Mines and Geology, 1914.

CARROLL B. PROSPECT

The Carroll B. prospect consists of 10 claims in the SE¼ sec. 3, T. 10 S., R. 41 E., which are controlled by S. J. Niblack. The developments consist of a shaft, from which at least one drift, which is partly accessible, has been turned, and two adits, each several hundred feet long, on other parts of the property. The predominant country rock is greenstone and cherty argillite of the Elkhorn Ridge argillite, with some gabbro. The quartz vein on which most of the work has been done is 1 to 2 feet thick where exposed in the drift near the shaft. In the other two adits nothing was observed but the greenstone country rock.

BRAZOS MINE

The Brazos mine, in sec. 11, T. 10 S., R. 41 E., was inaccessible in 1930. It has been described by Lindgren.[80] Since his visit considerable work has been done on the property, including the sinking of a 600-foot shaft and driving several drifts,[81] but for many years prior to 1930 the mine had been inactive.

The mine is developed in black argillite of the Elkhorn Ridge argillite, most of it considerably crushed. The vein, whose outcrops are obscure, strikes northwest and dips southwest at flat angles. The hanging wall is a clay seam; the footwall is also definite. The vein averages from 3 to 4 feet in thickness and is composed of soft black argillite containing little nodules of quartz, which rarely constitute continuous veins. Lindgren believed the discontinuity of the quartz to be due to movements on the vein. All the quartz seams and nodules contain gold, some of it coarse. The pay shoot was said to extend for 400 feet along the vein. The ore was of low grade.

OTHER PROSPECTS

The hills on all sides of Virtue Flat are studded with dumps of prospect pits, attesting the widespread mineralization of the area. Most of these workings date back many years, and none have been productive.

North of Virtue Flat the Columbia-Friday vein has been developed in several shallow inclined shafts. The vein follows the fault contact between Tertiary sediments and argillite for a short distance. All the workings were inaccessible in 1930.

A great many prospects have been worked on the hill south of the Flagstaff mine. The country rock is chiefly argillite, but some work has been done in the gabbro and quartz diorite also.

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[80] Lindgren, Waldemar, op. cit., p. 726.
[81] Parks, H. M., and Swartley, A. M., op. cit., p. 43.

There are many small prospect adits and pits on the southern slope of the ridge that lies between Virtue Flat and the Sutton Creek-Alder Creek trench. Most of the underground work is inaccessible.

Three adits, each several hundred feet long, are in the SW¼ sec. 2, T. 10 S., R. 41 E. The country rock is Elkhorn Ridge argillite, here cherty, striking about N. 75° E. and dipping 75° SE. A few thin irregular quartz veins, striking east and dipping 45° S., are encountered by the adits. The maximum thickness of the veins observed was 2 feet. In many places the argillite is sheared, and considerable thicknesses of clay gouge are developed.

BAKER DISTRICT

ORE DEPOSITS

The Baker district has been practically inactive for many years, and most of the old mines and prospects were inaccessible at the time of this survey. Much of the following information has therefore been taken from the earlier reports of Lindgren, Swartley, and Parks and Swartley. Lindgren [82] says:

> Though nearly every creek and gulch heading in this part of the range has carried more or less placer gold and a few have been enormously rich, there is throughout a very marked absence of important vein systems to which the origin of these placers could be attributed. In part this may be due to insufficient prospecting, but in most cases I believe that the placer gold was here rather derived from small seams and veinlets than from prominent fissure veins.

This conclusion seems to be supported by the mining history of the district since Lindgren's visit and is probably sound, although the possibility that deposits large and rich enough to be profitably mined is not excluded.

THE MINES

TOM PAINE MINE

The Tom Paine mine is in McCord Gulch, the first gulch west of Salmon Creek, in sec. 7, T. 9 S., R. 39 E. The property consists of one patented claim and is developed by several adits, all of which are caved and inaccessible except one, about 55 feet below the main level. A raise to the surface is open for about 30 feet above the lower adit. It is reported that the Tom Paine vein produced $70,000 worth of coarse gold from a small pocket about 1884. The country rock is limestone and argillite of the Elkhorn Ridge argillite. Swartley [83] speaks of the company as the Yellowstone Mining Co.

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[82] Lindgren, Waldemar, The gold belt of the Blue Mountains of Oregon: U. S. Geol. Survey 22d Ann. Rept., pt. 2, p. 650, 1901.

[83] Swartley, A. M., Mineral Resources of Oregon, vol. 1, no. 8, p. 162, 1914.

and mentions two veins on the property—the Tom Paine and the Old Soldier. He reports the Tom Paine vein to range in width from several inches to several feet and the Old Soldier to be 3 feet wide. The only observation that could be made on the vein in 1930 was in the 30-foot raise from the lower level just mentioned, where it consists of 18 inches of quartz and sericite with 2 or 3 inches of gouge on both hanging and foot walls. The vein strikes N. 20° E. and dips 40° W. The hanging wall is limestone that contains numerous small cubes of pyrite partly altered to limonite. The limestone strikes N. 55° E. and dips 60° SE.

A short distance west of the Tom Paine mine and a little farther upstream Mr. Lilley and one other man have recently exposed in a 30-foot adit a small 6-inch vein of quartz and sericite. The country rock is crushed argillite.

OLD SOLDIER CLAIM

The Old Soldier claim lies east of the Tom Paine and a short distance downstream from it. The workings are all inaccessible.

MARBLE CREEK MINING & MILLING CO.

The claims of the Marble Creek Mining & Milling Co. lie between McCord Gulch and Marble Creek. The property is opened by several thousand feet of drifts, most of which were inaccessible. No production has been reported.

The country rock is crushed and altered gabbro in which the workings expose an irregular shear zone. A few irregular patches of quartz and some specks of bornite with a little copper stain were seen.

YELLOW BOY MINE

The Yellow Boy Mining Co. controls nine claims, three of which are patented, just south of the Nelson placer, in sec. 8, T. 9 S., R. 39 E. The president of the company is N. A. Muegge, and the secretary is F. C. McColloch, both of Baker. The property is developed by two adits—the older, upper one several hundred feet long, including a 50-foot incline, and the lower one about 450 feet long.

The country rock is greenstone, belonging to the Elkhorn Ridge argillite. At the face the upper adit cuts a dike, probably one of the granophyre dikes so common in the region. A few quartz stringers show in the adits.

STUB MINE

The Stub or Kent mine of George and Chester Gardener lies in sec. 20, T. 9 S., R. 39 E., near the head of Washington Gulch. The property is opened by an adit which is now caved about 150 feet from the portal but which, according to Swartley,[84] is several hundred feet long and has a short winze and some raises turned from it. Swartley states that a test run made in 1914 is reported to have returned $1,140 from 140 tons of ore. No other production has been reported.

The country rock is siliceous argillite of the Elkhorn Ridge argillite. The adit encounters a shear zone, striking N. 65° W. and dipping steeply southwest, about 100 feet from the portal. According to William Dale, who controls several claims in this township, this is not the main Stub vein, and Swartley [85] says: "The vein has a north-northeast strike and a nearly vertical dip, with but a few inches of quartz to several feet of broken rock."

SORBECK PROSPECT

The Sorbeck brothers, of Baker, own 170 acres of patented land in sec. 27, T. 9 S., R. 39 E., on which adits several thousand feet in total length have been driven. The predominant country rock is greenstone, but some gabbro and a little limestone also occur. No veins have been found in any of these adits.

DALE PROSPECT

William Dale controls several claims in sec. 22, T. 9 S., R. 39 E., which are opened by several small adits and numerous prospect pits. The predominant country rock is gabbro. One of the pits exposed a 3-inch quartz seam in which a few flakes of native gold were seen.

PLACER MINES

At the time of this survey all the placers in the Baker district were inactive. The following report on the placer mines is quoted from Lindgren: [86]

> Nearly every gulch of the south end of Elkhorn Range has been worked on a more or less extensive scale for placer gold, though few localities have been exceedingly rich. Though the bulk of the gold was extracted shortly after the discovery in 1862, some work is yet going on at several of the old diggings, showing that the gravels are not yet exhausted.
>
> At the northern end of the eastern slope small placers have been worked on Marble Creek, near the limekiln. On Salmon Creek the placers are of much greater importance. This creek was worked with success for about 1 mile upward from the mouth of the canyon. The gravels were 4 to 10 feet deep and covered by 10 to 15 feet of an exceedingly fine, brilliantly white kaolinic material.[87] The bottom of the canyon was originally filled with deposits to a

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[84] Swartley, A. M., op. cit., p. 163.
[85] Idem, p. 162.
[86] Lindgren, Waldemar, op. cit., pp. 652–654.
[87] Microscopic examination of this "white kaolinic material" shows that it is not clay but fine volcanic ash, similar to that in the Sumpter quadrangle described by Pardee and Hewett.—J. G.

width of 100 or 200 feet. Working downstream, the placer miners at the mouth of the canyon gradually discovered a very remarkable deposit, called the "Nelson placers." These have been worked successfully for 30 years by the hydraulic process and are by no means yet exhausted. The working season extends from April to September, 1,000 miner's inches of water being used. The yearly production has generally been from $20,000 to $30,000. In the Mint reports for 1889 the production is given as $77,000; in 1890, $19,000. The total production is believed to be over $400,000. For one period of 6 years the production is said to have reached $214,000. As the available grade is small, it is proposed to use a hydraulic elevator for mining below the level of the permanent sluice.

The mouth of Salmon Creek Canyon is marked by a low-spreading debris fan. The Nelson placers are working the gravels of this fan in a pit covering 40 to 50 acres and from 20 to 100 feet deep. At the top of the bank the elevation is 3,750 feet. The gravel is subangular, many fragments reaching 1 foot in diameter, and consists of argillite and diorite, very little quartz being present. There are two layers. The upper stratum has a bluish-gray color, is 10 to 20 feet thick, and contains, evenly distributed, most of the gold.

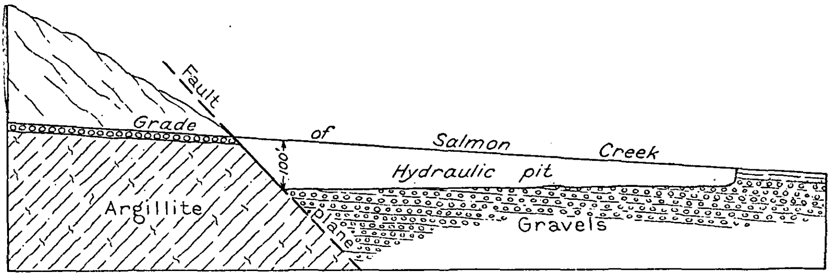

FIGURE 6.—Section of Nelson placer mine showing faults at the base of Elkhorn Ridge. After Lindgren, Waldemar, op. cit., fig. 80, p. 653.

The lower stratum is yellowish brown, and its rocks are more decomposed. This also contains gold, though in lesser amount, and its bottom has never been reached. Covering the top layer, near the mouth of the canyon, is the same white kaolin which covers the gravels of the creek. The gold, which is worth only $14 to $16 per ounce, is ordinarily fine, though nuggets up to $10 in value occur. To the rough pieces quartz sometimes adheres.

Most interesting are the relations immediately at the mouth of the canyon, for here the hydraulic work has disclosed the presence of a continuous fault scarp 100 feet high and dipping 40° E. It is smooth now, but when first exposed it is said to have been almost polished and in places covered with a clayey gouge. The direction is northwesterly, but with occasional bends and bulges. The exposed fault line extends completely across Salmon Creek for a distance of 1,500 feet, and the same line, less well exposed, is seen in the Baisley diggings, one-fourth of a mile northward, and in the Carpenter placers, half a mile southeasterly.

A shaft has been sunk in the bottom of the hydraulic pit near the foot of the scarp, but no bedrock was found at a depth of 90 feet. A minimum vertical throw of 200 feet is here shown, the valley side having sunk relatively to the mountains (fig. 6). The upper blue gravel probably was accumulated during the glacial epoch, while the lower dark-brown gravel is more likely to antedate that time; whether any very recent movement has taken place could not be decided.

Small placers have been worked in Washington Gulch, and the same applies to Griffin Creek and Elk Creek. The Griffin Creek placers are the oldest in eastern Oregon, having been discovered in the fall of 1861. The workings are 6 miles southwest of Baker City and at an elevation of 4,750 feet above where the creek enters the lava hills. Some work was in progress in 1900. On the divide between Griffin and Washington Creeks is a small area of high gravels which is said to contain gold in paying amount.

Most important were the placers of Auburn, in Blue Canyon, a tributary of Powder River. The diggings were discovered in 1862, and in a short time a town of several thousand inhabitants had grown up. For many years Auburn was the most prominent place in eastern Oregon; but the gold yield gradually diminished, and the camp was given over to the Chinese. At the present time hydraulic mining is carried on by two or three white companies. The total production of Auburn is difficult to determine, but it did not nearly reach that of Canyon, and the richest placers were soon exhausted. A small and rather steady production is maintained. The Mint reports give $12,000 for 1889, $2,600 for 1890, $8,900 for 1891, $3,000 for 1892. The important Auburn Ditch was completed in 1863. It takes water from the head of Pine Creek and other watercourses and carries it down to Auburn, a distance of over 30 miles; its capacity is 1,000 miner's inches. [This ditch is now used for the municipal water supply of Baker, but no longer for mining.]

Auburn is located in a wide basinlike valley at an elevation of about 4,000 feet. The argillites of the mountains here dip below the lava floods of the foothills. On both sides of the town the lava reaches up to elevations of 4,500 feet. The lavas cover soft clayey and loamy lake beds containing some coaly layers and impressions of deciduous leaves. On top of the eroded lake beds in the wide gulch rest subangular gravels 8 to 15 feet thick; the latter have been washed both in the gulches and on the flats. Near the town the depth to bedrock is not great; but farther down the valley the thickness of the sediments increases rapidly. The gravels are thus later than the lavas and have accumulated during the erosion of the present valley.

West of Auburn, on the road to Sumpter, several gulches with old placers are passed, Poker Gulch and California Gulch being next to Blue Canyon.

RECENT GRAVEL OF POWDER RIVER

During 1930 numerous test pits and churn drill holes were sunk in the flood plain of the Powder River near Bennett and south of Bowen, with the object of ascertaining the feasibility of dredging operations in the Recent gravel there. The results of these tests are not known.

PINE CREEK PLACERS

Placer gravel along Pine Creek is still being worked in a small way. The deposits include not only the Recent gravel along the present stream, which is now practically exhausted, but the Pleistocene bench gravel capping the Tertiary sediments, and in places, as near the mouth of the creek, just outside the quadrangle, the Tertiary conglomeratic sediments themselves. Dry washing of the Pleistocene bench gravel has been attempted on a rather large scale on the west side of Pine Creek in sec. 15, T. 12 S., R. 39 E. A large drag-line scraper and gasoline jigs were installed here but apparently proved unprofitable, as only small amounts of gravel were worked. The property was inactive and apparently abandoned when it was visited in 1930. The Tertiary gravel just outside the quadrangle was being worked when water was available during the early summers of 1929 and 1930. It is possible that this gravel, which is unconsolidated, may also prove profitable in a small way, within the quadrangle. The small amount of water available, however, seems to limit rather sharply the volume that may prove workable.

BURNT RIVER PLACERS

Placer mining has been carried on since the early days in the Burnt River Canyon and in Clark Creek, just above the canyon. In the canyon the deposits worked include not only the Recent gravel in the beds of the present river, but also the bench gravel, of probable Pleistocene age, at considerable heights up to 300 feet above the stream. Occasionally rich potholes are still found in the river bed, though they are usually small. The bench gravel contains sporadic nuggets but for the most part is difficult to work profitably because of shortage of water. Dredging has been carried on at the head of the canyon, where Clark Creek enters the Burnt River, but was inactive in 1930. The unworked gravel available for dredging lies outside the quadrangle limits: the bedrock is too shallow to permit dredging in the canyon itself.

TERTIARY GRAVEL

The Tertiary gravel found high on the hills south of the Burnt River in T. 12 S., R. 42 E., has been worked in a small way from time to time. One or two prospectors were working it with dry washers in 1930. A few nuggets worth $3 or $4 rewarded their efforts, but the small scale and inefficiency of their operations made the average return very small, perhaps $1 a day. Shortage of water seems to put this gravel out of consideration as an important gold reserve, although its tenor is such that it would otherwise be worth working.

COPPER DEPOSITS

GENERAL FEATURES

Copper deposits in the Baker quadrangle are numerous but, so far as known, all small. They are found in the Farley Hills near Magpie Peak, along Tucker Creek, and along Clover Creek. The only recorded production has been from the old Copper Queen mine, near the west edge of sec. 24, T. 7 S., R. 42 E.

In all these localities the deposits are crudely tabular quartzose replacement bodies in the Clover Creek greenstone, of Permian age. Although these copper deposits form part of a belt over 70 miles long extending from the vicinity of North Powder, just north of the Baker quadrangle, at least to Homestead, on the Snake River, all in the same greenstone series, there is no doubt that they are all epigenetic. It is thought that they are probably genetically related to the Mesozoic intrusive rocks.

THE MINES

BUCKEYE MINE

The Buckeye mine is in the NW¼ sec. 6, T. 7 S., R. 40 E. There are many test pits and tunnels on the property and at least three shafts, all abandoned and now inaccessible. The mine has not been worked for many years and was reported by Grant and Cady[88] to have been long abandoned at the time of their visit in 1914.

To judge from specimens on the dumps, the ore consists of silicified greenstone, veined with narrow stringers of quartz and sulphides. The sulphides present include pyrite, sphalerite, and chalcopyrite, of which pyrite is much the most abundant. Nothing is known of the tenor of the rock nor of the underground extent of the mineralization.

CLOVER CREEK COPPER CO.

The property of the Clover Creek Copper Co. is on Clover Creek in sec. 35, T. 7 S., R. 42 E., and comprises a large block of claims.

Prospecting for copper has been carried on for several years in the valley of Clover Creek in the west-central part of sec. 35. For some years the claims were held, together with those of the present Oregon Copper Co., in the adjacent Pine quadrangle, by the Mother Lode Copper Co. In 1928 they were taken over by the Clover Creek Copper Co.

The developments in the west-central part of sec. 35 at the time of this survey included several shallow trenches and a caved tunnel reported to be 400 feet long. A head frame had been erected, and preparations were being made for a shaft on the west side of Clover Creek near this old prospect tunnel. Another tunnel half a mile to the south, near the south line of the section, was being driven northeastward and was about 1,300 feet long in August 1929. A sketch map of this tunnel is shown in figure 7.

All the claims of the Clover Creek Copper Co. are in the Clover Creek greenstone. At the south end of the property the attitude

[88] Grant, U. S., and Cady, G. H., Mineral Resources of Oregon, vol. 1, no. 6, pp. 155–156, 1914.

of the rocks is uncertain, but just north of the old caved tunnel on Clover Creek tuffaceous members strike eastward and dip steeply to each side of the vertical. The rocks appear to form an isoclinally folded series.

The rock is cut by innumerable fractures and shear surfaces, characteristically coated by chlorite. In the new tunnel the most prom-

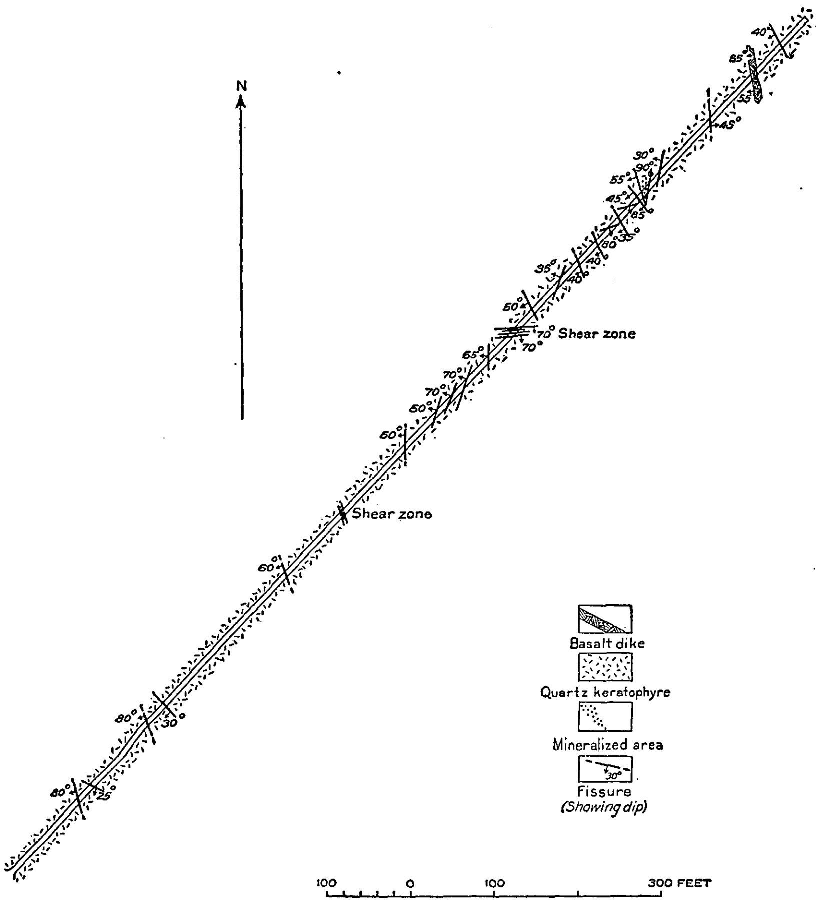

FIGURE 7.—Map of the Clover Creek Copper Co.'s prospect tunnel.

inent shear planes strike generally within 30° of north, chiefly N. 10°–30° W. Most of them dip west at rather steep angles, but many have easterly dips. Some very prominent shear zones trend about east. This seems to be the dominant trend at the northern prospects.

The new prospect tunnel was being driven to cut beneath oxidized bodies of gossan which contain barite, malachite, jarosite, limonite, and casts of sulphides. At the time of this survey a few narrow stringers of quartz and manganiferous ankerite, with associated pyrite and small amounts of chalcopyrite, had been intersected, but the tunnel had not reached a point below the most prominent gossans.

Near the old caved tunnel there is considerable evidence of mineralization. A 4-foot vein of barite crops out just east of Clover Creek opposite the new head frame, and much barite is disseminated through the gossan outcrops on both sides of the creek. The gossans extend in two subparallel zones about 200 feet apart in a general easterly direction. They range from a few feet to about 20 feet in width. They appear to be of low grade.

Little can be determined from the surface exposures as to the shapes of the mineralized bodies of which these are outcrops, but from analogy with the bodies exposed in the Oregon Copper Co.'s property, a few miles to the east, they are probably also replacement bodies of irregular but roughly tabular form.

The presence of considerable pyrite and a little chalcopyrite in fragments of fresh rock on the dump of the caved tunnel implies that the oxidized zone is shallow. A grab sample of highly pyritic rock from this dump, collected by the writer, showed 0.40 percent of copper and 40 cents in gold to the ton (gold at $20.67 an ounce).

COPPER QUEEN MINE

The old Copper Queen mine, sometimes called the "Copper Butte", is just southwest of Crane's mill, near the west edge of sec. 24, T. 7 S., R. 42 E. It is on a good road about 8 miles from Keating post office and 28 miles from Baker.

The copper deposits at this place have been known for over 60 years, for Raymond's report for 1873 [89] states that "W. B. Crane & Co. sold their copper mine [at Copper Butte] to Messrs. Carson, Williams & Co., of Detroit, Mich." A furnace was erected, and 4½ tons of copper was produced. For a long time after this the workings were idle. Up to 1900 about 100 tons of 12-percent copper ore was reported to have been shipped. No report of further activity was received until 1923, when, according to Hill,[90] the property was reopened "with a view to supplying the Sumpter Valley smelter with fluxing ore." Since that time no activity has been reported at the property. The early production and the test lots for the Sumpter smelter from this property and the Poorman group (now owned by the Oregon Copper Co.) constitute the only reported copper production from the Keating district. The mine was dismantled at the time of this survey in 1929.

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[89] Quoted by Lindgren, Waldemar, op. cit., p. 731.

[90] Hill, J. M., Gold, silver, copper, and lead in Oregon: Mineral Resources U. S., 1923, pt. 1, p. 370, 1925.

The workings consist almost wholly of shallow surface cuts, but there are also a few short tunnels and shafts. None of them were accessible in 1929.

The country rocks include amygdaloidal and tuffaceous members of the Clover Creek greenstone. Their structure is obscure, but they are cut by many fractures, the most prominent of which strike northwest and have steep dips. Along these fractures the rock is coated with oxidation minerals—malachite, azurite, chrysocolla, and cuprite—which also permeate the greenstone along the joints. A very little bornite was seen in one or two of the joints. A specimen of cupritic material from this locality assayed 20 percent of copper and 40 cents in gold to the ton. The ore body is probably due to the oxidation of chalcopyrite originally disseminated through the greenstone along the fractures and replacing the body of the rock. Mining below the shallow oxidized zone was evidently not profitable.

PROSPECTS NEAR TUCKER CREEK

Considerable prospecting for copper has been done in secs. 28 and 33, T. 7 S., R. 42 E., near the deserted camp of Burkemont, but most of this work is old and now inaccessible. The deposits have been briefly described by Lindgren [91] as follows:

The claims of the North American Copper Co. are located 1 mile southeast of Table Mountain, at an elevation of 3,300 feet and a short distance below the basalt bluffs. The country rock is here an amygdaloid metabasalt [Clover Creek greenstone of this report], with small veinlets of natrolite or similar zeolites. Prehnite was not observed. Much of the rock contains chalcocite in fine distribution, associated with epidote. Near the surface the rock also contained finely divided native copper throughout its mass, and especially in the little white zeolitic seams. * * * Of well-defined fissures or veins there is no indication. A shaft 120 feet deep has been sunk in this copper-bearing rock, and crosscuts extend for 80 feet. It is claimed that a large mass of this rock contains enough copper to be profitably mined, milled, and smelted.

Lindgren described the ore in more detail as follows [92]:

With the naked eye may be seen irregular grains of chalcocite and a little metallic copper, the latter mostly contained in the white veinlets traversing the slide. Under the microscope the basaltic character of the rock is apparent. Phenocrysts of labradorite are contained in a dark groundmass full of prisms of the same mineral. Chlorite is very abundant in the feldspars as well as in small vesicles throughout the mass. The augite has disappeared completely. Along lines of pressure and deformation small replacement veins of chalcocite enclosed in epidote are noted; no other mineral accompanies the chalcocite. Throughout the section very finely divided metallic copper is distributed; especially abundant is it in little veins filled with zeolite, which corresponds well with natrolite and occurs in fibrous masses with radial structure. Much

[91] Lindgren, Waldemar, op. cit. (Blue Mountains), pp. 731–732.
[92] Idem, pp. 630–631.

copper is also contained in the groundmass and in the feldspar of the rock, but it replaces the minerals in which it occurs and is accompanied by chlorite, a little quartz, and a considerable amount of reddish or brownish limonite or hematite, which seems to surround the aggregates of chlorite near the copper.

Neither chalcocite nor copper in their present form is a primary constituent of the rock. The chalcocite has been introduced first, and the native metal seems a secondary product derived from the sulphide. While a secondary process, the formation of native copper cannot justly be said to be due to surface decomposition, for it is clearly connected with the chlorite and the zeolites, which may form at great depth. While there is thus no reason why the metallic copper could not occur throughout larger masses of rocks and on a larger scale, the fact seems to be that its occurrence is of subordinate importance to that of the chalcocite. The latter certainly has formed along cracks and joints but is, nevertheless, not concentrated in well-defined fissure veins.

MANGANESE DEPOSITS

The manganese deposits of the Baker quadrangle were not given particular attention during this survey, as there was no activity at any of them nor did their production records and the economic outlook for manganese lend any hope of successful operations in the near future. They have been described by Pardee[93] as follows:

PLEASANT VALLEY AREA

Location and accessibility.—Manganiferous deposits are found at several places near Pleasant Valley station on the Oregon-Washington Railroad & Navigation Co.'s line, in an area that lies from 12 to 20 miles southeast of Baker and can be easily reached from that place by automobile. From Pleasant Valley the Stephens and Capitola groups of claims are respectively 2 miles and 3 miles north, the Black Prince group and the Black Nigger claims respectively 2 miles and 5 miles northeast, and other claims from 4 to 7 miles east. The Stephens and Black Prince groups and several of the other claims are distributed along a belt that trends about N. 60° W. This belt is approximately parallel to the valley of Alder Creek, through which the railroad goes, and from 1 to 2 miles northeast of it.

Production.—Most of the claims were located prior to 1917 for gold and silver, though very little development work was done on them. In 1917, according to reports, 450 tons of manganiferous material was produced from the Utah claim of the Stephens group. Most of this material was shipped to Tacoma and after being reassorted yielded about 300 tons of 40 percent manganese ore that was used in making ferroalloys. The Utah and other claims in the Stephens group were idle when visited by the writer, September 4, 1917. Development workings on the Utah had reached a depth of 45 feet; elsewhere they consisted of shallow pits. No production was reported in 1918.

Occurrence of tungsten.—One feature of the Pleasant Valley deposits of more than ordinary interest is the association of tungsten with manganese, as reported by Emil Melzer, of Baker, Oreg., who acquired control of the claims late in 1917. According to Mr. Melzer, a sample composed of material from four different bodies was tested for concentration by the Hendrie-Bolthoff

[93] Pardee, J. T., Deposits of manganese ore in Montana, Utah, Oregon, and Washington: U. S. Geol. Survey Bull. 725, pp. 224–228, 1921.

Co., of Denver, Colo., the assays being made by E. E. Burlingame & Co. Of several different concentrates produced, one that represented the final product and amounted to 3.69 percent of the composite sample carried 23.62 percent of tungstic acid (WO_3). This is equivalent to about 0.75 percent of tungstic acid in the crude ore. Whether the tungsten came from one or all of the four different deposits represented by the sample or in which proportion from each was not determined, and the tungsten-bearing mineral was not identified.

Ore bodies.—The ore bodies are of moderate to small size and irregular form. Most of them are found near the surface along bedding planes or joints in the argillite and are associated with tabular or lenslike masses of fine-grained quartz. Ore obtained from them, even by careful mining, runs high in silica. The sample of crude ore reported by Mr. Melzer assayed 36.06 percent of manganese, and the concentrate produced by reducing it about one-half contained 48.28 percent of manganese, 13.40 percent of silica, and 0.124 percent of phosphorus. The largest body found on the Utah claim is in general terms a flat lens 20 feet wide (stope length), 30 feet long (pitch length), and 5 feet thick in the middle. It extends from a point near the surface downward along a wavy gouge-lined bedding plane or seam that has an average dip of 20° E. Several smaller lenses are found below it to a depth of 60 feet on the slope, which is the limit of exploratory work. The ore is rather soft and cavernous and is composed chiefly of manganese oxides, clay, and quartz. The oxides are apparently an intimate mixture of pyrolusite, psilomelane, and wad.

About 200 feet east of the deposit just described other bodies are developed by a 25-foot shaft, from which a drift runs east 63 feet and ends in a winze inclined southwestward 30 feet deep. Water stands in the bottom of the winze, at a level estimated to be about 45 feet below the surface. The shaft penetrates an irregular cylindrical body about 10 feet in diameter and 15 feet long, composed chiefly of quartzose or silicified argillite. A small part of it is made up of indistinct veinlets and bunches of manganese oxides, among which pyrolusite and manganite were identified. The body is cut by a few stringers of a coarser-textured quartz with manganese oxides, and from its lower end several seams filled with manganese oxides and clay lead off along bedding planes. The drift follows a seam that is normally 2 or 3 inches wide but swells here and there into bunches or pockets, the largest of which is 5 feet in diameter. Another seam with several small pockets is developed by the winze. Ore from these pockets is said to carry from 35 to 45 percent of manganese and 20 to 30 percent of silica and to be practically free from iron. A shallow cut 20 feet west of the shaft exposes an 18-inch vein of flinty-textured quartz and manganese oxides that dips 50° NE.

On the Black Joe claim, about half a mile southeast of the Utah, a body of flinty-textured quartz with manganese oxides is exposed by shallow workings for a distance of 50 feet. This deposit is of tabular or vein form, is 4 feet wide, and strikes about east. Seams and small cavities in it are filled with the softer manganese oxides.

Outcrops of many bodies similar to those in the Utah and Black Joe are reported in an area that extends from the vicinity of these claims southeastward for 6 or 8 miles. None are extensively developed. Several in the Capitola group of claims are said to occur in the limestone and to be high in iron. A body of manganiferous quartz 10 feet wide is said to form a prominent outcrop on the Black Prince claim.

The manganese oxides were probably derived from rhodonite and rhodochrosite. Oxidation of the rhodochrosite was accompanied by shrinkage that gave the ore its cavernous texture. The distribution of the siliceous manganiferous bodies for several miles along a course that coincides with the general strike of the bedded rocks suggests that they are of sedimentary origin. On the other hand, the presence of vein quartz and the reported occurrence of small amounts of gold, silver, and tungsten indicate that they are similar in origin to the metalliferous quartz lodes of the surrounding region, which are believed to have been deposited by solutions ascending from some deep-seated intrusive rock.

No good basis exists for making an estimate of ore in reserve. Probably, however, small amounts that contain 35 percent or more of manganese are to be found, together with a comparatively large amount of highly siliceous material which is rather poor in manganese but which may possibly be capable of beneficiation.

SHEEP MOUNTAIN

An undeveloped lode showing considerable manganese at the surface crops out in the claims located by John Arthur and others near the summit of Sheep Mountain, 7 miles west of Durkee. Sheep Mountain is a massive rounded knob on the ridge south of Burnt River that reaches an altitude of 5,325 feet, or about 2,300 feet above the stream. The prevailing rock is schistose argillite, presumably to be correlated with the argillite at Pleasant Valley.[94] The outcrop, which is not conspicuous, ranges from 2 to 10 feet in width and extends from a point near the summit S. 50° W. at least 4,000 feet down the slope. It consists chiefly of siliceous argillite traversed by small quartz veins, the whole fractured and partly replaced by manganese oxides. Irregular masses of manganiferous material as much as 3 feet wide and 6 feet long appear here and there. These are composed of streaks, nodules, and irregular bodies of psilomelane, pyrolusite, manganite, and wad bound together with a lattice of quartz seams. The body is cavernous, and the quartzose portions show some flattened cavities whose forms suggest they were molded around crystals of a carbonate such as calcite or rhodochrosite. An average sample of the material selected in mining is reported to carry 27.62 percent of manganese and 42.48 percent of silica. Possibly it can be beneficiated by ordinary methods of concentration. According to Mr. Arthur, a panning test yielded a concentrate containing 39.68 percent of manganese, 24.60 percent of silica, and 0.052 percent of phosphorus. A small amount of ore is found that runs as much as 48 percent of manganese, with 8 percent or less of silica.

The general features of this deposit suggest that it is to be classified with the metalliferous quartz lodes that are abundant in the surrounding region and like them was probably formed by solutions ascending from some cooling, deeply buried igneous rock.

TUNGSTEN

No ores primarily valuable for their tungsten content are known in the quadrangle, but the attempt has been made to utilize the gold ores of the Cliff mine and the manganese ores of the Stephens group (see p. 111) for tungsten. The Cliff ore and that of the nearby Flagstaff mine contain scheelite. The mineral occurrence of the tungsten

[94] According to the interpretations offered in this report, this correlation should not be made, the Pleasant Valley argillite belonging to the Elkhorn Ridge argillite, and the rocks on Sheep Mountain to the Burnt River schist.—J. G.

in the manganese ores is unknown. It is unlikely that any commercially valuable deposit of tungsten ore is to be found in this quadrangle.

ANTIMONY

The antimonial (stibnite) ore of the Koehler mine has been described in the section dealing with gold deposits (p. 97).

LIGNITE

The only coal known in the Baker quadrangle is the lignite that occurs in the Tertiary sediments near and north of Auburn. The lignite is present in relatively thin seams and is dirty and of low grade. It is hardly more consolidated than peat. Although doubtless of use locally in a small way, it offers slight hope of commercial exploitation.

ASBESTOS

Asbestos deposits occur at several localities in the Baker quadrangle, notably near Pine Creek, in secs. 34 and 35, T. 11 S., R. 39 E.; in sec. 30, T. 10 S., R. 42 E.; and in sec. 15, T. 12 S., R. 40 E. Of these the deposit near Pine Creek has been best explored. All are associated with serpentinous alteration of basic rocks.

The deposits along Pine Creek and the next divide to the west have been described by Moore,[95] from whom the following information has been obtained. The deposits are found in greenstone (metagabbro of the present report) and in argillite (Burnt River schist), associated with greenstone. They are definitely associated with shear zones. There is much talc, serpentine, magnesite, and calcite in these rocks. The asbestos has been shown to be anthophyllite, low in iron, and occurs both as cross-fiber and slip-fiber varieties. The length of the fiber ranges from 1 inch to 16 inches, with an average of 4 to 10 inches. The fiber is harsh, brittle, and rather weak compared to that of chrysotile. No production has been made in the district except a few tons for use in testing.

Anthophyllite asbestos occurs also on the northeast flank of Bald Mountain and in sec. 15, T. 12 S., R. 40 E. Chrysotile asbestos occurs in small amounts in the NW¼ sec. 30, T. 10 S., R. 41 E. None of these occurrences seem to encourage commercial exploitation.

[95] Moore, B. N., Nonmetallic mineral resources of Oregon: U. S. Geol. Survey Bull. 875 (in press).

BUILDING STONE

"GRANITE"

The only "granite" quarried on a commercial scale in the Baker quadrangle is that east of Haines. Here hornblende-biotite-quartz diorite belonging to the younger of the plutonic groups (pp. 41–45) has been quarried for many years.

The quarries are about a mile east of Haines, low on the west flank of the hills culminating in Coyote Point, in the E½ sec. 27, T. 7 S., R. 39 E. The quarries have been opened to a depth of about 50 feet. They furnish a medium-textured dark-gray rock, jointed rather sparsely, so that single blocks as large as 20 by 4 by 3 feet are obtainable, and cubes 6 feet on a side could be had.[96]

The rock is handsome and durable and has had a considerable market for monumental purposes. For building, however, it is less suitable, owing to the large number of dark clots of ferromagnesian minerals scattered through it. These can be avoided in small pieces for monuments but are a serious drawback to the use of the rock for dimension stone. Although these clots characterize the biotite-quartz diorite masses of the entire region and hence can hardly be expected to be absent at greater depth, there is a chance that a local band in which they are less prevalent may be discovered and successfully exploited.

VOLCANIC TUFF

Volcanic tuff has been quarried for use in building at three localities in the Baker quadrangle. In the hills about a mile southeast of Baker (mapped as Tertiary sediment on pl. 1) a small quarry has been operated but not in recent years. Two larger quarries are situated near Pleasant Valley—the Ideal quarry, north of the station, and the quarry of the Oregon Lava Stone Co., south of the station.

The stone obtained from these quarries is vitric rhyolitic tuff, mapped as part of the Dooley rhyolite breccia. It is light gray, very porous, light in weight, and resistant to weathering. It presents a mottled appearance and is highly absorbent, so that it is considerably darker when moist and is readily soiled by soot. On the other hand, it is an excellent insulator of heat. Many of the larger buildings of Baker have been built of this stone and have resisted weathering successfully for many years.

The quarries near Pleasant Valley have large reserves of the stone available. It can be obtained in cubes as much as 8 feet on a side.[97]

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[96] Parks, H. M., The building stones of Oregon: Mineral Resources of Oregon, vol. 1, no. 2, p. 19, 1914.

[97] Idem, pp. 38–39.

Stratification is not distinct in these rocks, although noted on the larger blocks. The north dip of the beds at the Ideal quarry requires the handling of an increasing proportion of overburden in this quarry, but the large available reserves nearby seem to make this factor irrelevant to the immediate future of the industry. Despite the ease with which it can be sawed and handled, the stone is not so attractive or so economically produced that it may expect to invade successfully other than local markets. Here, however, it seems destined to continue as an important factor in the building industry.

DIATOMITE

So far as known, diatomite has not been exploited commercially in the Baker quadrangle. Considerable beds of rather pure diatomite, at least 40 feet in maximum thickness, occur in sec. 10, T. 8 S., R. 42 E., on the north flank of the Lower Powder Valley, and smaller and less promising deposits occur in the valley of Big Creek in T. 7 S., R. 41 E., but in neither locality has enough work been done to make it possible to estimate the resources available.

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