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GEOLOGY

OF THE

BERNERS BAY REGION

ALASKA

BY

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By Alfred H. Brooks.

The general plan for the Alaskan work provides first for reconnaissance surveys which it is intended eventually to extend over the entire Territory. These reconnaissance surveys are followed by the detailed mapping of the most important mining district.

The first investigation of the mineral resources of southeastern Alaska by the Geological Survey was made by Becker[a] in 1895. More systematic surveys of Alaska were begun in 1898, but for several years the demands of the unexplored regions of the interior prevented any attention being given to the coastal provinces. In 1901 a hasty examination of the Ketchikan district[b] was undertaken, and in 1903 and 1904 reconnaissance surveys of the Juneau and Porcupine districts[c] were completed. Reconnaissance surveys have been continued in southeastern Alaska up to the present time. With the publication of the report on the Wrangell and Ketchikan districts[d] in 1908 all the most important mining regions were covered. There still remain, however, extensive areas in southeastern Alaska of which the geology is but little known.

Meanwhile some detailed geologic studies have been made. In 1902 and 1903 the detailed geologic[e] and topographic[f] mapping of the most productive part of the Juneau district was completed. Between 1906 and 1908 detailed topographic surveys of the Kasaan Peninsula, Karta Bay, and Hetta Inlet copper-bearing areas were completed. Owing to circumstances beyond the control of the writer, the results of these surveys have not been published, but it is hoped that they may be issued during 1911. Plans for detailed studies of the Berners Bay region were formulated in 1906, when a topographic survey of the district[g] was made. Owing to the litigation in which several of

[a] Becker, G. F., Reconnaissance of the gold fields of southern Alaska, with some notes on the general geology: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1897, pp. 1-86.

[b] Brooks, A. H., Preliminary report on the Ketchikan mining district, with an introductory sketch of the geology of southeastern Alaska: Prof. Paper U. S. Geol. Survey No. 1, 1902.

[c] Spencer, A. C., The Juneau gold belt; Wright, C. W., A reconnaissance of Admiralty Island: Bull. U. S. Geol. Survey No. 287, 1906. Wright, C. W., The Porcupine placer district: Bull. U. S. Geol. Survey No. 236, 1905.

[d] Wright, C. W. and F. E., The Ketchikan and Wrangell mining districts, Alaska: Bull. U. S. Geol. Survey No. 347, 1908.

[e] Spencer, A. C., Bull. U. S. Geol. Survey No. 287, 1906.

[f] Juneau special map, U. S. Geol. Survey, 1904.

[g] Berners Bay special map, No. 581B, U. S. Geol. Survey, 1908.

the largest mining properties of the district have been involved, the geologic work was postponed until last year (1909), when the settlement of one of the important lawsuits gave promise that the district would soon become an important gold producer.

The heavy growth of timber, the thick underbrush, and the mat of moss mantle the bed rock of much of this region to such an extent as to make detailed geologic surveys almost hopeless. It is for this reason that but few cartographic units have been used in representing the geology. It is believed, however, that the subdivisions made are sufficiently detailed so that the geologic map may serve the purpose of the prospector as well as outline the important features of the geology.

Mr. Knopf's studies show that the ore bodies occur in intrusive rocks which are partly of post-Jurassic or post-Lower Cretaceous age. This is confirmative of the views previously held, of which definite proof was lacking. It affords additional evidence of the synchroneity of the mineralization of south-central Alaska with that of the Mother Lode district of California. This work also proves that the sediments and associated greenstones of the Juneau gold belt previously assigned to the Carboniferous are in part at least Mesozoic.

This report is based on studies made in such detail as the physical conditions permitted. The fact that none of the mines were in operation hampered to a large degree the investigations of the ore bodies. If mining develops in this field to the extent which seems warranted by the knowledge of its auriferous deposits, the time will come when a more exhaustive study of the ore bodies should be undertaken.

THE BERNERS BAY REGION, ALASKA.

By Adolph Knopf.

INTRODUCTION.

The Berners Bay region forms the northwestern extremity of the long zone of auriferous mineralization on the mainland of southeastern Alaska known as the Juneau gold belt. This belt has a total length of 100 miles and extends southeastward to Windham Bay, 60 miles southeast of Juneau. A large number of prospects are scattered along the gold belt, but at two localities, Juneau and Berners Bay, there is a marked clustering of producing mines or of potentially productive ore bodies.

The famous Treadwell group of mines, the Perseverance mine, and other properties of great possibilities are located in the Juneau region; a large number of auriferous lodes, although none are comparable in magnitude with those of the better-known properties of the Juneau region, are massed in the Berners Bay region—a comparatively small area—and on account of the favorable topographic conditions make that region an attractive mining field.

The general geologic features of the Juneau gold belt as a whole have been described by Spencer.[a] During his reconnaissance of the gold belt in 1903 only two or three days could be devoted to the Berners Bay region, but that brief study sufficed to bring out the broader facts concerning the ore bodies. In the same year he completed a detailed geologic investigation of the environs of Juneau and was able to publish a geologic map on the scale of 1 mile to the inch to accompany his report. The present study, undertaken in the year 1909, is part of the plan that contemplates a detailed investigation of the northern portion of the Juneau gold belt, to connect with the earlier detailed work of Spencer in the vicinity of Juneau.

Field work on the Berners Bay region was commenced by the writer on May 25, 1909, and completed July 6, 1909. The conditions under which it was carried on were not of the most auspicious character. On account of the unusually late season snow lay on the mountains above an altitude of 1,000 feet during the greater

[a] Spencer, A. C., The Juneau gold belt, Alaska: Bull. U. S. Geol. Survey No. 287, 1906.

part of the time. The rocks are obscured as a rule by a dense growth of moss and other vegetation, and exposures are rare between the shore and the timber line. Nevertheless it is believed that the broader distribution of the rock types is indicated with sufficient accuracy on the geologic map accompanying this report (Pl. II). The general cessation of all mining activity in the region, the absence of everyone familiar with the underground development, and the inaccessible condition of many of the mines precluded as complete a study of the economic geology as might otherwise have been possible.

HISTORY.

Gold ore lodes were first discovered in the Berners Bay region in 1886 or 1887.[a] According to local report float was found by prospectors at the mouth of Sherman Creek, and this led to the discovery of ore bodies outcropping in the upper portion of the drainage area of this stream. In 1890 a settlement known as Seward City was started on the shore of Lynn Canal at the mouth of Sherman Creek,[b] and enjoyed an ephemeral prosperity during the middle of the last decade of the nineteenth century. The settlement, now nearly deserted, is known as Comet, the name Seward having been adopted by an important town on Resurrection Bay on Kenai Peninsula.

Between 1890 and 1900 five stamp mills aggregating 80 stamps were erected in the region. Owing to a variety of causes, they are now all idle. In 1905 the Berners Bay Mining and Milling Company, which controlled one of the most productive mines in the region and which held other valuable properties, became involved in financial and legal difficulties. A protracted litigation ensued which extended through a number of years, and final adjudication was not rendered until near the close of 1909. It was reported in March, 1910, in current numbers of the mining periodicals that the property had been sold at marshal's sale for $800,000 to the International Trust Company, of Boston. Development of the ore bodies and rehabilitation of the plant and tramways will undoubtedly soon be undertaken and a period of increasing production may be anticipated.

PRODUCTION.

The total production of the Berners Bay region up to the close of 1909 has been approximately $1,100,000. Two mines, the Comet and the Jualin, have furnished almost the entire output. The largest output for any single year was that of the year preceding June, 1895, when the Comet mine is reported to have yielded over $200,000.[c]

[a] Garside, G. W., Trans. Am. Inst. Min. Eng., vol. 21, 1893, p. 822.
[b] Alaska: Eleventh Census, 1893, p. 234.
[c] Becker, G. F., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1897, p. 77.

GEOGRAPHY.

SITUATION OF THE REGION.

The Berners Bay region, which takes its name from a sheet of water 4 miles wide indenting the northeast side of Lynn Canal, is situated 45 miles northwest of Juneau, the capital of Alaska. The term "Berners Bay region" would naturally include all territory contiguous to the bay, but for the purposes of this report, as in popular usage, the name is applied to the long, tapering peninsula and its mountainous background that lie between Berners Bay and Lynn Canal (fig. 1). The areal extent is approximately 50 square miles.

The region is easily reached by water from Juneau. Local steamers plying on a weekly schedule between Juneau and Skagway call

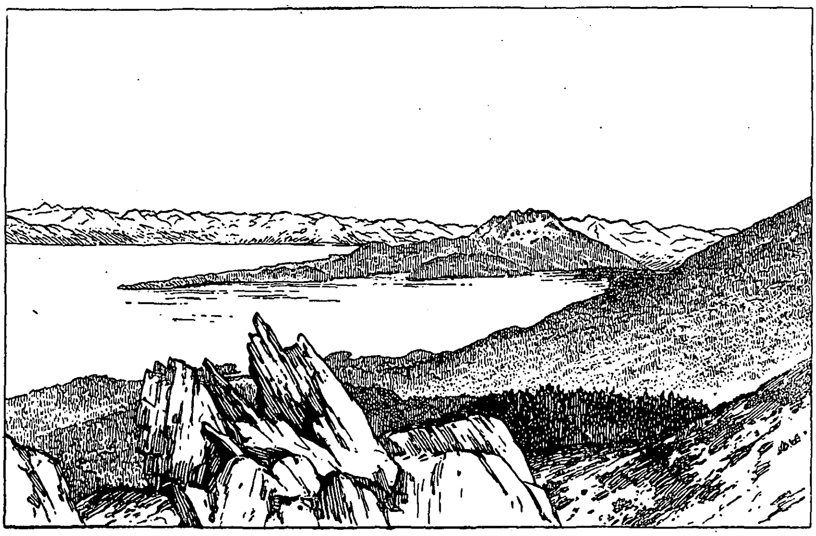

FIGURE 1.—Sketch of Berners Bay region.

regularly at Comet, on Lynn Canal, which is the only settlement in the district. Although no post-office is maintained at Comet, a weekly mail service is furnished by the Post-Office Department.

PHYSICAL FEATURES.

Berners Bay, which was named by Vancouver in 1794, is a broad and deep indentation from Lynn Canal, in latitude 58° 42′ north and longitude 135° west, and lies between Point St. Mary on the north and Point Bridget on the south. The head of the bay is marked by extensive tidal flats formed by the distributaries of Berners River, which enter from the north, and by other large streams of glacial origin, which enter from the east and northeast. Harbors are not common in the bay, but a bight known locally as the Jualin cove affords safe anchorage for large craft.

Lynn Canal, or Lynn Channel, as it was named by Vancouver, flanks the region on the west. Although deep water can be found near shore, there are no harbors affording protection from storms. Lynn Canal is a magnificent fiord, 6 miles wide here, and is the highway of all commerce entering Alaska and the Yukon by way of Skagway.

The Berners Bay region is characterized by abrupt topographic relief (Pl. I). The northern part consists of a rugged assemblage of precipitous peaks which rise steeply from the shore of Lynn Canal to heights of 5,000 feet. The most notable of these form a group known as Lions Head Mountain, whose serrate profile is said to show, when seen from Chatham Strait, a resemblance to a couchant lion. Toward the south the altitudes become lower and the profiles of the mountains become smoother and rounder, until near the tip of the peninsula the low hills scarcely attain an altitude of 500 feet.

The streams on the peninsula are short, but on account of the heavy rainfall they carry relatively large volumes of water. Johnson and Sherman creeks are the largest, and they are also the most important because of the fact that most of the properties are located in their drainage areas.

Johnson Creek heads in an amphitheater of ideal symmetry lying under the shadow of Lions Head Mountain and flows southeastward through a U-shaped valley, emptying into Berners River near the head of the tidal flats of the bay. Its total length is only 4 miles. The lower course is broken by a waterfall 75 feet high and affords a favorable site for the development of hydroelectric power.

Sherman Creek is a short stream heading opposite Johnson Creek and flows northwestward into Lynn Canal. It is fed by numerous small tributaries cascading from the high mountains that flank the stream on its north side. Below an altitude of 500 feet Sherman Creek is intrenched in a narrow gorge.

CLIMATE AND VEGETATION.

No climatologic data concerning the Berners Bay region are available, but the records for Juneau and Skagway will serve to give a general idea of the climatic conditions. As shown by the subjoined table, which was furnished by the courtesy of the Weather Bureau, the total precipitation is considerably less at Skagway than at Juneau. Although Berners Bay is approximately midway between these two cities, the climatic conditions seem to be closely similar to those obtaining at Juneau.

Climatologic data for Juneau and Skagway, Alaska.

Mean maximum temperature.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Juneau	32.9	34.3	39.8	47.6	55.9	62.7	64.6	61.4	55.6	48.3	40.5	35.9	48.3
Skagway	24.9	27.6	35.8	47.9	60.7	66.7	68.5	64.1	56.5	46.1	36.7	31.3	47.2
Mean minimum temperature.													
Juneau	24.2	24.2	28.7	34.8	40.8	46.3	49.6	48.2	44.0	38.1	30.3	27.2	36.4
Skagway	15.9	18.1	22.2	32.4	39.2	46.3	48.2	47.3	42.0	35.8	28.5	23.3	33.3
Mean temperature.													
Juneau	28.5	29.3	34.3	41.2	48.4	54.5	57.4	54.8	49.8	43.2	35.5	31.9	42.4
Skagway	20.5	22.9	29.0	40.1	49.9	56.5	58.7	55.7	49.3	40.9	32.6	27.3	40.3
Maximum temperature.													
Juneau	50	51	61	63	80	84	88	82	74	68	60	60	88
Skagway	47	49	63	62	94	90	92	89	76	63	56	57	94
Minimum temperature.													
Juneau	−10	−4	−5	13	24	31	38	36	31	20	−1	1	−10
Skagway	−21	−9	−10	9	25	33	37	31	26	12	4	−4	−21
Mean precipitation (inches).													
Juneau	7.87	4.75	4.86	5.58	5.40	3.97	4.53	7.08	11.16	10.14	8.54	7.24	81.12
Skagway	1.20	1.43	.56	1.78	.68	.90	1.13	1.45	2.65	4.76	3.50	2.76	22.80
Mean snowfall (inches).													
Juneau	32.9	23.1	11.7	4.8	0	0	0	0	0	1.3	6.6	30.1	110.5
Skagway	11.0	3.6	1.2	.9	0	0	0	0	0	2.8	10.4	12.2	42.1
Average number of days with precipitation.													
Juneau	17	12	14	18	16	13	14	17	20	21	19	19	200
Skagway	6	4	4	7	4	5	5	7	10	14	10	9	85

Period of climatologic records, Alaska stations.

	Years.
Juneau:	
1890–1891	2
1899–1908	10
Total	12
Skagway: 1899–1908 (record missing from September, 1900, to April, 1902)	8

The region is well forested with spruce and hemlock. The timber line (the limit of erect tree growth) reaches 2,500 feet above sea level along Lynn Canal, but stands several hundred feet lower on the mountains flanking Berners River on the west. In most places a growth of low contorted forest extends a few hundred feet above timber line. As a rule, the timber forms open stands, and the largest and finest trees, many of which attain a diameter of several feet, are found in the alluvial bottoms bordering Berners River. The undergrowth is rank and luxuriant and in many places forms impenetrable thickets. Alder and devil's club are particularly common, but many other kinds of shrubby growth occur.

GLACIATION.

A few small glaciers are left in the region and their distribution is indicated on the map (Pl. I). On the Lynn Canal side they have nearly disappeared, lying only in the amphitheaters at the heads of the high hanging valleys. On the Berners River side they are much larger and descend considerably farther from the gathering grounds—a difference that seems to be due to the diminished insolation on the north side of the range.

The only moraine in the region is found at 3,300 feet elevation in the cirque above the Ivanhoe mine. It consists of blocks of amygdaloid, and is 20 or 30 feet high, but the glacier which deposited it has retreated from it, so that it is no longer in process of accumulation.

During the recent geologic past great ice streams flowed down the troughs of Lynn Canal and Berners River and covered the larger part of the region under ice. Along Lynn Canal diorite erratics up to 6 feet in diameter were found east of Point Sherman at an altitude of 1,000 feet, and evidence of powerful glacial abrasion occurs up to 2,550 feet above sea level. Along Berners River roche moutonnée surfaces persist up to 2,500 feet.

In general, evidence is abundant as to the former glacial occupation of the region, but observations bearing on the maximum thickness of the trunk glacier that formerly occupied Lynn Canal are not so readily obtained. The data at hand indicate that the minimum thickness, measured from present sea level, was 2,600 feet; from data procured south of Berners Bay, 3,400 feet appears to be a maximum measure of the thickness of the former ice mass.

OUTLINE OF GEOLOGY AND ORE DEPOSITS.

The sedimentary rocks of the Berners Bay area consist of an interstratified series of slates and graywackes, named the Berners formation because it is well exposed across the strike on both shores of Berners Bay. The formation occupies the larger part of the area and lies between the high mountains and Lynn Canal. The strata have been intensely folded, but as a rule strike northwest and southeast and dip steeply northeast. Fossil plants, consisting chiefly of ferns, were found in the rocks on the east side of Berners Bay and indicate that the formation is of Jurassic or Lower Cretaceous age.

A belt of much altered basic lavas, which forms Lions Head Mountain and the high peaks north of Independence Creek, extends northwestward from Berners River to Lynn Canal. The ancient volcanic rocks are commonly amygdaloidal and contain numerous amygdules of epidote. During the time that has elapsed since the lavas were erupted they have undergone many vicissitudes; some which originally were diabase porphyries now resemble fine granular diorites, owing to the fact that the pyrogenic augite has been converted to fibrous hornblende; others have been rendered partly schistose, forming hornblende schists, and subsequently they have been recrystallized around the borders of an intrusive mass of diorite. In consequence of the various kinds of metamorphism to which they have been subjected their originally volcanic character is in many places highly obscure.

Some felsitic or rhyolitic dikes and sills occur with the amygdaloids, in places cutting across the bedding and in places lying between the volcanic sheets. They are light-colored rocks of dense, flintlike texture, and weather white on exposed surfaces. They range in thickness from a few feet to about 100 feet.

The northeastern part of the region is underlain by quartz diorite gneiss, a part of the granitoid core making up the axial mass of the Coast Range. On the west side of Berners Bay the gneiss lies in contact with the amygdaloids; on the east side it intrudes the rocks of the Berners formation. At some time after its intrusion the quartz diorite was rendered coarsely schistose by the action of powerful stresses, as is shown by the partly crushed character of its component minerals when viewed under the microscope.

A mass of diorite, named the Jualin diorite because it is well displayed at the Jualin mine, occupies the basin of Johnson Creek and the upper portion of that of Sherman Creek. It is a grayish rock, composed essentially of plagioclase feldspar, hornblende, and biotite, and ranges in texture from rather fine granular to coarse granular. A small area of heavy black rock composed mainly of hornblende—a coarse hornblendite—is associated with this variety of diorite near Berners River.

The Jualin diorite is undoubtedly of younger age than the quartz diorite gneiss and has escaped the widespread crushing to which the older rock was subjected. It is intrusive into the slates and graywackes of the Berners formation and into the series of basic amygdaloids. It has produced some contact alteration of the sedimentary rocks, but has effected more profound changes in the volcanic rocks, so that their original characteristics are locally obliterated.

The general geologic history of southeastern Alaska suggests that the irruption of the quartz diorite and the Jualin diorite took place during one broad epoch of intrusion, which so far as now known extended through the greater part of the Jurassic period. At Berners Bay powerful deformational forces have been operative between successive intrusions.

The Jualin diorite is the most important rock in the region from an economic point of view. The main ore bodies, in both point of size and of content, lie within the area underlain by it.

The ore bodies are auriferous deposits, of which the larger number are either well-defined fissure veins or irregular stockwork deposits. The fissure veins range up to 15 feet in thickness, but the average vein is 5 feet thick; the stockworks range up to 80 feet in thickness. The mineralogy of the ores is exceedingly simple; the gangue material is quartz with subordinate calcite, and the principal metallic sulphide is pyrite with which are minor amounts of chalcopyrite, galena, and sphalerite. Gold is rarely seen.

The wall rock of the ore bodies has been affected by a locally intense hydrothermal metamorphism, the characteristic feature of which is the production of albite, especially in the small veinlets that penetrate the altered wall rock. This metamorphism is similar to that in the Juneau region, notably like that which has transformed the Treadwell albite-diorite dike into an auriferous lode. The ore bodies are therefore of deep-seated origin, and a magmatic source for the vein-forming solutions is regarded as probable. General considerations indicate that the deposits are likely to extend downward to the limits of profitable mining.

During the recent geologic past the region was affected by a powerful glacial erosion, so that the ores now exposed at the surface are of primary origin.

GENERAL GEOLOGY.

BERNERS FORMATION (JURASSIC-CRETACEOUS).

GENERAL CHARACTER AND DISTRIBUTION.

A sedimentary formation consisting predominantly of slates and graywackes occupies the largest part of the Berners Bay area. Some basaltic greenstones and quartz porphyry schists are associated with it, but are of small importance. The slates comprise in the main highly cleaved black clay slates, but include some of green and to a less extent some of red color. The graywackes are intimately interstratified with the slates in beds ranging from a few inches to 8 feet or more in thickness, and are commonly of a gray or greenish-gray color. They are roughly schistose and in the thicker beds nearly massive.

In places the graywackes constitute the bulk of the formation and comprise a thick succession of heavy beds separated only by thin beds of slate. This massive development of graywacke is particularly well shown toward the south end of the peninsula.

The general strike of the rocks is northwest and southeast, and the dip is steep to the northeast, averaging 70°. Locally high dips to the southwest occur.

The rocks of this formation are splendidly displayed along the west shore of Berners Bay and along Lynn Canal from Point St. Mary to the mouth of Independence Creek. Topographically they form the lower-lying parts of the region, and the boundary between the sedimentary slate and graywacke formation and the igneous rocks also separates the area of the bold craggy peaks from the lesser mountains and hills that make up the southern part of the peninsula.

The formation is also finely exposed on the east shore of Berners Bay, where it includes, however, an important series of augite melaphyres[a] and related pyroclastic rocks. The volcanic member attains its main development as a narrow belt fringing the shore of Lynn Canal from Auke Bay to Point Bridget on the east side of Berners Bay. The nonappearance of this belt on the west side of Berners Bay is probably due to the fact that the strike carries it to the west of Point St. Mary.

On account of the thick carpet of moss that is everywhere prevalent below timber line the sedimentary rocks are poorly exposed inland, and the internal structure of the formation can not be unraveled. In the shore cliffs, however, it can be seen that the rocks have been profoundly folded and closely compressed, and that the axes of folding have also been acutely folded, and that in places they pitch vertically. In consequence of this severe folding of the axes it happens that at many places closely adjacent strata show an angular discordance of strikes. Ordinarily this would be taken to indicate faults of some magnitude, but along the beach, where the geologic relations are perfectly exposed, it can be seen that this feature is due to the vertical attitude of nearly appressed folds.

Subsequent to the complex folding of the rocks a cleavage was induced in them, which commonly coincides with the stratification and trends N. 45° W. (true). In places, such as in the arches of those folds which are standing on edge, the cleavage is conspicuously across the bedding. The cleavage, therefore, rather than the stratification, is the most constant structural feature of the formation.

An enormous amount of quartz veining in the form of stringers following the foliation of the rocks has affected the slates and graywackes, but the amount of pyritic mineralization of these veinlets is nearly insignificant.

[a] This term is used in a purely descriptive sense, as advocated by Pirsson in "Rocks and rock minerals."

PETROGRAPHY.

The graywackes typical of the region consist of gray or greenish-gray rocks in which none of the mineral constituents are discriminable by the eye. Some, however, contain innumerable small fragments of black slate, and isolated beds are found that contain angular fragments of slate several inches long. A more or less thorough schistosity has been impressed upon the graywackes, the perfection of which increases as a rule with the thinness of the beds and the fineness of grain of the component materials. Some of the more highly foliated varieties can not be distinguished by the eye from sheared igneous rocks.

Under the microscope the graywackes are found to consist largely of altered fragments of plagioclase, some of which is referable to Ab_7An_3, embedded in an argillaceous matrix which is somewhat chloritic. The entire absence of quartz in typical graywackes taken from several localities—the mouth of Independence Creek, Jualin Cove, and others—is rather remarkable. Many of the feldspar fragments are partly bounded by crystallographic outlines and show rounded corners; others are highly angular. Fragments of andesitic rock and slivers of slate and possibly other sedimentary rock are of occasional occurrence. Numerous fragments of augite are present in the rock from Jualin Cove, and in the graywackes on the east side of Berners Bay this mineral, or what appears to be its metamorphic equivalent, fibrous hornblende, occurs in quantities appreciable to the eye. Other minerals found in subordinate amounts are calcite, epidote, hornblende, pyrite, magnetite, and apatite. In certain beds, however, calcite becomes an important constituent.

The slates require no particular description. Black or bluish-black clay slates predominate. Locally, as in the gorge of Sherman Creek, they are characterized by a brilliant black luster due to the presence of finely disseminated graphite. Slates of green color are found in small amounts at many places throughout the region, and are particularly well exposed on both sides of Berners Bay. They are more massive and less fissile than the black slates.

A rock of somewhat marked individuality belonging to the class of graywacke slates has a scanty distribution in the Berners Bay region but becomes increasingly prominent as a member of this formation in its extension to the southeast, and therefore deserves mention here. In its general aspect this rock resembles a black clay slate, but differs from that in containing numerous small augen of quartz and of a black glassy cleavable mineral, the presence of the augen producing a porphyritic effect. In thin section the black glassy mineral proves to be a feldspar whose color is due to the infiltration of carbonaceous material. The quartz is seen to show strong undulatory extinction. These two constituents rest in a thoroughly schistose matrix of chlorite, quartz, and carbonaceous matter, throughout which is scattered a small amount of accessory pyrite.

AGE AND CORRELATION.

This formation was regarded by Spencer as the northwestern extension of the slate-greenstone band of the Juneau region, and on account of the presence of fossils found in intercalated limestones at Taku Harbor, which is 25 miles southeast of Juneau, was believed to be of Carboniferous age.

Some fossil plants were collected during the present investigation from the east side of Berners Bay just north of Sawmill Cove. The rocks here consist of an interdigitating series of thick lenses of graywacke and argillite standing on edge. The graywackes show cross-bedding and the argillites are ripple marked. The argillaceous rocks are as a rule too highly cleaved to have retained the imprints of leaves, which are now commonly represented by graphitized flakes. Leaf-bearing beds seem to be scarce, and the best fossils collected were obtained from a roughly schistose argillite which was gashed by quartz veinlets. F. H. Knowlton, of the United States Geological Survey, reports on the plants as follows:

> This material is very difficult to study, for practically all traces of nervation are absent and dependence must be placed on outline, which has obviously been more or less modified by pressure. With these limitations in mind, I think I have been able to demonstrate the presence of *Tæniopteris*, *Asplenium* or *Dicksonia*, *Thinnfeldia*(?) and possibly another fern something like *Dryopteris*.
>
> The choice appears to lie between Jurassic and Lower Cretaceous, and if what has been supposed to be *Tæniopteris* is really such the odds favor the former. I have not found anything that can be identified as a dicotyledon, which also is favorable to the probability of its being Jurassic. Although the evidence as adduced is not very strong and the identifications are tentative, it seems most probable that they are of Jurassic age.

According to this determination the rocks of the Berners Bay region are to be correlated in an approximate way with the *Aucella*-bearing terrane found by C. W. Wright on Admiralty Island.[a] This is regarded as of Lower Cretaceous or possibly Upper Jurassic age. The lithology is described as including conglomerates, graywackes, and slates. The Admiralty Island rocks were probably laid down subsequent to the intrusion of the Coast Range diorites, though this is a moot point in the geology of southeastern Alaska; the rocks of the Berners Bay region are predioritic. The invasion of the province by the plutonic masses of the Coast Range is the most important event in the geologic history of the region, and the determination of the exact stratigraphic relations existing between these two terranes is therefore a problem of prime importance.

[a] Bull. U. S. Geol. Survey No. 287, 1906, p. 144.

DIKES.

Under this heading are described various minor bodies of igneous rock of widely diverse characters that occur within the area of the slates and graywackes. The diorite porphyry dikes that are found as offshoots from the main mass of the Jualin diorite are not discussed here.

In a prospect trench dug in the boss in the lower part of the valley of Johnson Creek is exposed a quartz porphyry schist. The relation to any incasing rocks is effectually concealed under a growth of moss. The quartz porphyry schist is a thoroughly foliated rock of light-greenish color and of oily appearance. On jointage surfaces cutting across the schistosity can be seen numerous quartzes, more or less bounded by crystal faces, resting in a dense matrix. Rocks of this character were not observed elsewhere in the region, nor have they been previously noted in the Juneau gold belt. Under the microscope some of the quartz phenocrysts prove to be characteristically embayed, and this feature affords a most convincing criterion of the originally igneous character of the rock. Feldspar phenocrysts occur but are obscure; epidote pseudomorphs, apparently after hornblende, are found. These constituents are embedded in a highly schistose matrix of sericite and quartz. Titanite in typical wedge forms is a fairly abundant accessory, and apatite, in unbroken prisms where lying in the lee of phenocrysts, is of sporadic occurrence and is especially common in the epidote pseudomorphs. Calcite, pyrite, and tourmaline are present in small amounts.

Some thin dikes of lamprophyric character are occasionally found. Two were noted injected parallel to the stratification along the shore of Lynn Canal near the mouth of Independence Creek. They are dark, heavy rocks, rudely schistose, and the dikes show dense chilled borders. Numerous crystals of augite constitute the sole phenocrystic constituent; abundant idiomorphic augite, though the individual crystals are not of uniform size, occurs in the groundmass. Some laths of highly pleochroic biotite and a little brown idiomorphic hornblende appear also, and labradorite forms an interstitial filling. Magnetite is present as an accessory, and calcite, chlorite, and pyrite are secondary minerals.

On the east side of Berners Bay one of these lamprophyric dikes was noted which seemingly consists mainly of pyroxene phenocrysts. Under the microscope, however, it was found that the pyroxene had been completely transformed into fibrous amphibole, typical pyroxene cross sections showing pleochroism and characteristic amphibole cleavage. The original character of the groundmass is undecipherable from the new growth of amphibole and calcite.

North of the Portland mill on the shore of Lynn Canal a dike of diorite porphyry 50 feet thick is well exposed. This rock is rendered highly porphyritic by the presence of numerous prisms of hornblende, ranging in length from 1 inch down; no other phenocrysts are present. The matrix is gray in color and aphanitic in texture; microscopically it proves to consist mainly of much altered plagioclase.

BASIC VOLCANIC ROCKS.

GENERAL CHARACTER AND DISTRIBUTION.

A series of ancient lavas, mainly of basaltic character, form a belt trending northwestward from Berners River to Lynn Canal. These old volcanic rocks make up the mountainous mass known as the Lions Head and form the precipitous peaks flanking Lynn Canal north of Independence Creek. Brown, red, greenish-blue, and other dark hues are the prevailing colors. As a rule the rocks are conspicuously spotted with yellowish-green amygdules of epidote, and as this is in places their most prominent feature they may conveniently be called epidotic amygdaloids. Sporadically the amygdules carry a small amount of chalcopyrite.

This volcanic series consists almost wholly of a superposed succession of lava flows. Intercalated sheets of breccia were observed at only one locality. The bedded character is commonly obscure, but occasionally sheets differing in color and texture can be found in juxtaposition. These contacts may in places be rendered conspicuous by the highly amygdaloidal character of the marginal portion of one or the other of the lava sheets. In such places the structure can be determined, and where thus measured it is found to strike northwest and southeast and to dip 70° N., coinciding therefore with the general structural trend of the region.

In places the rocks exhibit a rough schistosity, which is best developed near the quartz diorite gneiss bordering them on the northeast. There they approach hornblende schists in structure and composition. The schistosity coincides in direction with the bedding.

PETROGRAPHY.

Some variation in the appearance of the basalts is noticeable from place to place, but on the whole the differences are mainly due to the different kinds of metamorphism to which the various rocks have been subjected.

The basalts so well exposed along Lynn Canal north of Independence Creek are dark greenish-gray rocks, nonporphyritic and fine textured. They are highly amygdaloidal, epidote being most commonly distinguishable as the filling of the vesicles, and quartz more rarely. Microscopically they prove to be plagioclase-augite rocks of doleritic texture. Little or none of the augite has escaped alteration to epidote and chlorite, and the numerous amygdules that occur throughout the rock are filled with the same minerals.

Rock taken above the Ivanhoe mine at an altitude of 3,100 feet is coarser textured and, on account of the abundance of ferromagnesian mineral in it, resembles a dark-colored fine-granular diorite. It contains scattered amygdules of epidote. Under the microscope large sporadic phenocrysts of plagioclase are found to lie embedded in a coarse ophitic matrix, but instead of augite brown amphibole appears. This amphibole occurs also in tufts and irregular aggregates of fibers in the feldspars, and the ends of the large hornblendes fray out in bundles of diverging prisms. Granular epidote is commonly associated with the amphibole. These features clearly indicate the derivative origin of the amphibole and show that the rock was originally a vesicular diabase porphyry.

Rocks of this character are the prevalent variety in the region. Toward the northeast, as already stated, they take on a schistose structure, and the microscopic diagnosis is as a rule insufficient to establish their volcanic character. The field evidence, however, is conclusive on this point.

Certain rocks from Independence Gulch prove to be amygdaloidal andesites. They carry numerous small, rather inconspicuous feldspar phenocrysts in a groundmass which is of denser texture than that of the basalts. The multitude of yellowish-green amygdules is the most striking feature of the rocks. The feldspar, when examined optically, proves to be andesine; the groundmass consists of forked feldspar microlites embedded in a decomposed glassy base. The amygdules are filled with epidote and subordinate chlorite.

CONTACT-ALTERED PHASES.

The amygdaloids have been invaded by the Jualin diorite and considerable changes have been produced in them around the borders of the intrusion. These changes consist mainly of a recrystallization, during which the grain of the volcanic rock has become sufficiently coarse to be perceptible to the eye. The metamorphism is most pronounced in those places where the rock is pierced by dikelets, and the resulting product may resemble a hornblende-rich diorite. In places the intrusive diorite has caught up fragments of the basalts and has recrystallized and partly dissolved them, so that a most heterogeneous sort of rock has been produced which is of very erratic composition and appearance. These features are particularly well shown between the upper and lower workings of the Kensington mine.

In general the principal effect has been to produce a rock in which hornblende is the most abundant constituent. The structure is that typical of contact-metamorphic rocks; the larger mineral individuals show a spongiform development, and droplike particles of one mineral are commonly included in the other. The fibrous, weakly pleochroic amphibole has been converted into a compact, strongly pleochroic brown-green hornblende; the feldspar, which is commonly subordinate, is clear, glassy, and largely unstriated, and ranges from $Ab_{67}An_{33}$ to $Ab_{60}An_{40}$. Magnetite is relatively abundant. In some rocks biotite, which nowhere in the region is a pyrogenetic constituent of the basalts, is developed as a product of contact metamorphism.

AGE.

The contact between the bedded volcanic rocks and the Berners formation is hidden by vegetation and talus slopes, so that no inferences as to the relative ages of the rocks could be drawn. Other lines of evidence must be used. An area of basaltic greenstone of obscurely amygdaloidal character surrounded by slates and graywackes occurs on the south side of Sherman Creek, as shown on Plate I. Other such areas may possibly be found, but on account of the poor exposures and dense vegetation no attempt was made to delimit them. Although the contacts were not seen, the amygdaloidal character suggests that the rock is an intercalated flow or series of flows, and inasmuch as it is lithologically similar to the rocks of the volcanic belt of metabasalts, the conclusion seems to follow that all are essentially of the same age, probably Jurassic. The only fact apparently not in harmony with this conclusion is that the augite melaphyres, which clearly form an integral portion of the Berners formation on the east side of the bay, are petrographically different from the epidotic amygdaloids. This difference may be due to the fact that these two volcanic members represent different eruptive periods during the accumulation of the sedimentary formation.

INTRUSIVE FELSITES.

Some felsitic dikes and sills were found associated with the amygdaloids. They are aphanitic flintlike rocks weathering white on exposed surfaces, and some show a well-developed flow banding. Minute quartzes form the main porphyritic constituent, but as a rule are detected only with difficulty. Microscopically the rock shows embayed quartzes and small sporadic plagioclase feldspars resting in a cryptocrystalline groundmass in which there is scattered a little flaky biotite, some magnetite, and accessory zircon.

The intrusive rocks range in thickness from a few feet to 100 feet and are massive even where intercalated between schistose amygdaloids. Similar rocks are known to occur in the vicinity of Skagway, 40 miles north of Berners Bay, where they are associated with a pink quartzose granite that is intrusive into quartz diorite.[a] They are therefore tentatively considered to be the youngest rocks in the Berners Bay area.

[a] Information from L. M. Prindle.

QUARTZ DIORITE GNEISS.

GENERAL CHARACTER.

The northern part of the Berners Bay region is occupied by quartz diorite, which makes up the mountains on both sides of Berners River and extends as far as the eye can see into the glacial fastnesses of the Coast Range. It is a rock mass of uniform character except along the zone bordering the contact. A coarsely schistose or gneissic structure has been developed in the quartz diorite, trending N. 40° W. (true) and dipping steeply to the northeast, and coincides thus in direction with the cleavage displayed by the slates and graywackes. The quartz diorite gneiss breaks parallel to the structure in thick tabular blocks, and in distant views presents the appearance of a stratified formation. It maintains its petrographic character and gneissic structure for many miles to the southeast of Berners Bay and forms, in local parlance, the hanging wall of the Juneau gold belt.

PETROGRAPHY.

The quartz diorite gneiss is a granitoid rock of medium to coarse grained texture, consisting macroscopically of plagioclase, quartz, biotite, hornblende, and sporadic crystals of titanite. The feldspars range from 3 to 5 millimeters in diameter. The foliated structure is readily apparent in hand specimens. Under the microscope the texture is seen to be hypidiomorphic granular modified by cataclastic phenomena. The plagioclase approximates $Ab_{60}An_{40}$, but the average composition of the feldspar is difficult to determine accurately on account of the strongly developed zonal banding. On a section parallel to the brachypinacoid it was found that the large core was $Ab_{57}An_{43}$; this was succeeded by zones alternately more sodic and more calcic, though all were more sodic than the core; the narrow zone next to the outermost, however, was $Ab_{51}An_{49}$ and the broad outermost zone $Ab_{65}An_{35}$. The feldspars are somewhat granulated peripherally. Quartz forms crushed and elongated areas composed of interlocking grains which show strain shadows. Biotite and hornblende, sliced and wrapping around the feldspars, constitute the dark minerals. Orthoclase is present in insignificant amounts or is entirely absent. Titanite, apatite, and magnetite occur as accessory minerals, and secondary epidote, chlorite, and sericite are present in small amounts.

A typical specimen of the quartz diorite gneiss, taken at a distance of over a mile from the contact, was measured according to Rosiwal's method, the traverses being run across the structure, in order to obtain an approximate quantitative measure of the mineral composition. The following percentage composition by weight was obtained:

Mineral composition of quartz diorite gneiss, Berners Bay region, Alaska.

Plagioclase ($Ab_{60}An_{40}$)	51.1
Orthoclase	1.0
Quartz	25.0
Biotite	13.6
Hornblende	4.8
Titanite	1.1
Apatite	.1
Chlorite	1.9
Epidote	.8
Sericite	.6
	100.0

This composition is closely similar to that determined for the average Coast Range intrusive rock in the Ketchikan region [a] and is characterized by the same unusual percentage of titanite.

CONTACT PHENOMENA AND AGE.

The quartz diorite gneiss shows various modifications along its contact with the rocks that it has invaded. On the east side of Berners Bay the gneiss includes for thousands of feet from the contact vast numbers of rock fragments and detached masses of stratified sediments, which show a crumpling in conformity with the structure of the rock inclosing them. These inclusions were highly metamorphosed—a fact of which muscovite, on account of its absence in the truly igneous rock, is the most notable token—and were partly dissolved, so that it is in places impossible to distinguish between original diorite and altered sedimentary rock. Near the main contact the gneiss becomes finer textured and deficient in femic minerals. At other points, however, the gneiss becomes richer in biotite at the contact, and in consequence takes on a more thoroughly foliated structure than ordinarily prevails throughout the main mass. A peculiar-looking rock results, which consists of numerous augen of feldspar embedded in a foliated groundmass of biotite and hornblende. Under the microscope the feldspars prove to be Ab_1An_1; the augen effect is seen to be due to the fact that corners of the feldspars have been rounded off by peripheral granulation. Biotite and hornblende, both sliced, envelop the feldspars. Titanite (much of which is crushed and dispersed), apatite, and magnetite occur as accessory minerals. The basic character of this marginal phase is therefore expressed by the greater prevalence of femic minerals, by the more calcic composition of the feldspar, and by the absence of quartz. This phase of the gneiss does not occur along the contact with the sedimentary rocks, but only in places along the amygdaloids.

[a] Wright, F. E. and C. W., Bull. U. S. Geol. Survey No. 347, 1908, p. 64.

The contact relations clearly prove the intrusive nature of the quartz diorite gneiss. The age indicated is therefore post-Jurassic or post Lower Cretaceous. The quartz diorite gneiss of the Berners Bay region is part of the composite batholith of granitoid rocks that form the core of the Coast Range. Spencer showed that in the Juneau region the period of intrusion was post-Carboniferous and argued that it was subsequent to the deposition of the Lower Cretaceous rocks on Admiralty Island and before the Upper Cretaceous strata were laid down.[a] The Wright brothers, with the same evidence before them, concluded that the intrusions are of pre-Cretaceous Mesozoic age and continued at least to late middle Jurassic time.[b] More detailed work is needed to fix the period of intrusion with a higher degree of finality.

JUALIN DIORITE.

GENERAL CHARACTER AND OCCURRENCE.

The Jualin diorite is economically the most important lithologic unit in the region. It occupies the drainage area of Johnson Creek and the upper part of that of Sherman Creek, and most of the auriferous lodes are located within the confines of this area. The number of lodes is large compared to the size of the area, and the diorite has consequently been subjected to the attack of vein-forming solutions. Its minerals have therefore undergone more or less alteration, and the diorite tends to assume a greenish color, contrasting in this respect with the fresh, unaltered appearance of the quartz diorite gneiss. This alteration is especially noticeable in the narrow northwest end of the diorite area, where the massing of ore bodies is greatest.

The intrusion of the Jualin diorite has produced some contact-metamorphic alteration of the slates and graywackes, but this change is comparatively small in extent. Perceptible changes up to several hundred feet from the contact have been brought about in the metabasalts, as already described.

Dikes or offshoots from the main mass of diorite are found at various places along the contact. They differ somewhat in appearance from the granular diorite, being diorite porphyries, and consist of closely packed phenocrysts of plagioclase and some hornblende in a dense blue matrix.

PETROGRAPHY.

The Jualin diorite is a granular rock, consisting, so far as the eye can determine, of plagioclase feldspar, hornblende, and biotite. It varies from place to place both in mineral composition and in texture. Hornblende is the most prevalent dark mineral, but locally biotite

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a Bull. U. S. Geol. Survey No. 287, 1906, p. 19.
b Bull. U. S. Geol. Survey No. 347, 1908, p. 76.

exceeds it in prominence and in other places fails entirely. Texturally the diorite ranges from finely granular, as at Jualin, to coarsely granular, as at the Kensington mine. As seen in thin section, the diorite displays a hypidiomorphic granular structure. The plagioclase feldspar is a labradorite near Ab_1An_1 in composition and shows idiomorphic development. Hornblende and biotite are the ferromagnesian minerals. Allotriomorphic orthoclase and interstitial quartz are present in subordinate amounts, although at certain localities, as at the Jualin mine, they are sufficiently abundant to cause the rock to approach a granodiorite in composition. Magnetite, titanite, and apatite occur as accessory minerals. Secondary alteration products, such as epidote, chlorite, calcite, and sericite, are everywhere prevalent.

The Jualin diorite is as a rule a massive rock unaffected by the parallel structure exhibited by the quartz diorite gneiss. Locally, as adjoining certain quartz veins, the diorite has been reduced to a schist, and at a number of localities there occur what are locally designated "slate dikes." This misnomer is perhaps sufficiently descriptive of their physical appearance. The center of one of the "dikes" which is about 30 feet thick consists of black, closely foliated schist; laterally this schist, by progressively wider spacing of the foliation planes, grades into the undeformed diorite country rock. The black schist, when examined microscopically, was found to consist largely of albite feldspar with considerable flaky biotite. Calcite is fairly common, and apatite, titanite, and magnetite occur as accessory minerals.

AGE.

The Jualin diorite is younger than the Berners formation, which it intrudes, and as it has escaped the dynamic deformation to which the quartz diorite gneiss was subjected, it is an intrusive mass of later age than that of the great body of granitoid rocks which form the backbone of the Coast Range in this latitude. No evidence is at hand to fix any limit to the length of time elapsing between the two periods of intrusion, but so far as our present knowledge of southeastern Alaska geology shows the interval was not great.

HORNBLENDITE.

A small area of a granular basic rock strikingly different from the Jualin diorite occurs about 2 miles north of the mouth of Johnson Creek. It is poorly and unsatisfactorily exposed on account of the deep growth of moss, the profusion of vegetation, and the talus slopes from the cliffs of Jualin diorite, and its relation to the adjoining rocks was not determined. It may be either a basic phase of the Jualin diorite or an independent intrusion.

The hornblendite is a heavy black rock composed mainly of hornblende. Abrupt variations in texture and composition are of general occurrence and give the rock a wide range in appearance. The hornblende in places forms prisms up to 2 inches in length and is characterized by its brilliant cleavage faces and metallic luster on cross-fractured surfaces. Locally feldspar, in part converted to epidote, occupies the triangular interstices between the hornblende prisms.

THE ORE BODIES.

INTRODUCTORY STATEMENT.

The ore bodies of the Berners Bay region are gold ore deposits of low grade. On the basis of form they may be classified into three varieties—(1) fissure veins, (2) stockworks or irregular masses of diorite ramified by quartz veinlets, and (3) stringer lodes. This threefold division, although of no genetic significance, expresses certain well-marked characteristics of the ore bodies and can in most of them be maintained.

The largest number of ore deposits, as well as those economically most important, lie within the area of the Jualin diorite and are either in the form of fissure veins or stockworks. The stringer lodes are numerous in the slates and graywackes of the Berners formation, but have not yet proved to be of commercial value.

The outcrops of the ore bodies lying below timber line are much obscured by vegetation. Some are completely grown over with moss and have trees growing on the very tops of the ledges; they were therefore most effectively concealed over the greater part of their lengths prior to discovery. Above timber line the exposures, where not hidden by talus slopes, are better. The longest known outcrops range from 1,500 to 2,000 feet.

The deepest continuous development work has attained a depth of 600 feet below the outcrop of the ore body, and one stockwork has been intersected at 850 feet, although the continuity of the deposit has not been tested. At the time of examination the length of any level on the strike of any ore body accessible to the writer did not exceed a few hundred feet.

FISSURE VEINS.

The fissure veins, with few exceptions, are restricted in their occurrence to the area occupied by the Jualin diorite. Most of the ore bodies belong to this type but are exceeded in size by the stockwork deposits. They are simple quartz-filled fractures with well-defined walls. The average vein has a mean thickness of 5 feet; the maximum width of solid quartz known at any point is 15 feet. A marked tendency to swell and pinch gradually along the strike and dip is exhibited by many of the veins, which thereby form, as it were, a connected series of long flattened lenses. The scanty data at hand seem to show that the average length of the longer axes of these lenses is 400 feet. This tendency is in part an original character-

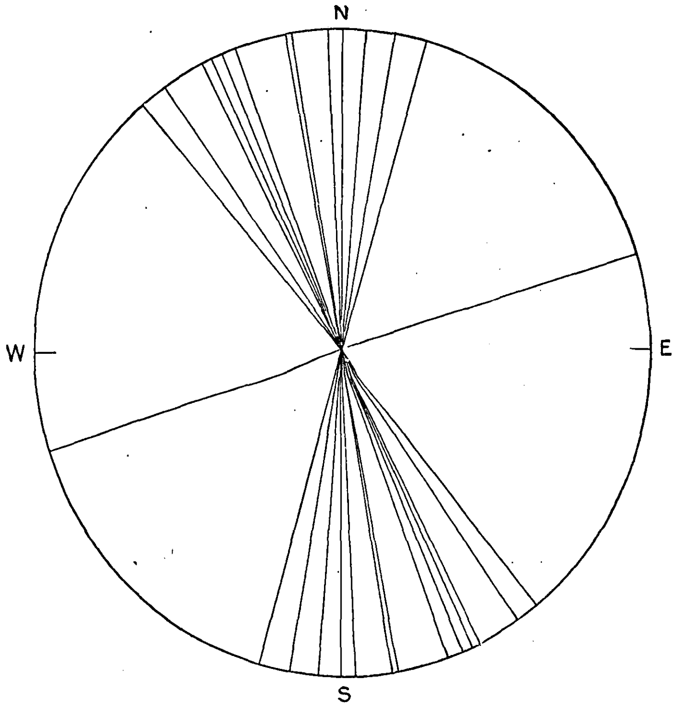

FIGURE 2.—Diagram showing strike of veins.

istic due to the mode of formation of the veins, and is in part due to movements along postmineral fractures making a narrow angle with the plane of the vein. Where the variation in the width of a vein is due to such displacements the swelling or pinching is usually more abrupt than where it is due to the original shape of the fissure.

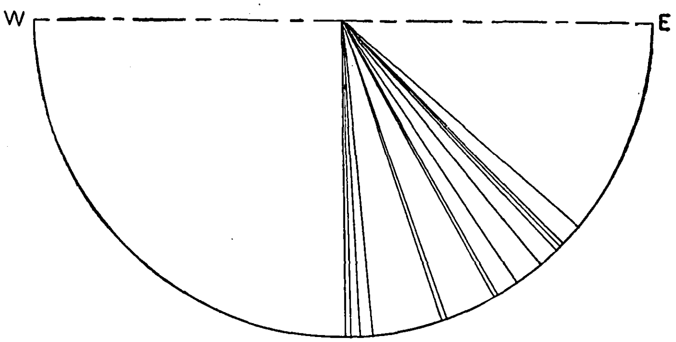

FIGURE 3.—Diagram showing dip of veins.

The strike of individual veins is fairly regular, but no system in the strike of the veins as a whole can be observed. The greater number, however, lie in the northwest-southeast quadrants (fig. 2). The veins dip, almost without exception, to the east or northeast at angles ranging in different ledges from 40° to 70° (fig. 3), but certain veins show as great a variation as this from level to level.

STOCKWORKS.

The stockworks are masses of broken country rock intricately penetrated by quartz stringers. The representatives of this type are not numerous and are of low grade, but on account of the large tonnage of ore which they seem capable of furnishing they appear to form the most valuable asset of the region. They lie in the area of the Jualin diorite. They are irregular in shape and are not bounded by walls. The whole mass of country rock and included network of quartz veins constitutes the ore body, and as the tenor of the ore is dependent on the amount of included quartz, the size of any ore body is determined partly by the dictates of economic expediency—that is, the distinction between what is ore and what is not ore is determined by the working costs. At the Kensington mine, on a study of which our knowledge concerning these deposits chiefly rests, the ore body approximates an ellipse in cross section 160 feet long by 80 feet wide. The quartz veins are most closely spaced near the center of the ore body but toward the periphery become more widely spaced, so that the large amount of barren diorite included in the deposit decreases the assay value of the ore below a profitable limit.

STRINGER LODES.

The stringer lodes are belts of schistose country rock ribboned with veinlets of quartz. They are characteristically developed in the graywackes and slates of the Berners formation and follow the structure of the inclosing rocks. An enormous number of quartz stringers occur in the sedimentary rocks, but few of them carry any metallic minerals, so that comparatively little exploration work has been attempted on them. At a few localities stringer lodes have been partly developed, but not sufficiently to demonstrate economic importance.

At other points in the Juneau gold belt stringer lodes in slate have proved to be of great value, so that the discovery of commercially valuable lodes of this character in the Berners Bay region is not inherently improbable. The general law of the occurrence of stringer lodes in the Juneau gold belt shows that they are most likely to lie along the contact of a belt of slate with a harder bed, which is commonly either a sheet of greenstone or a stratum of graywacke.

MINERALOGY OF THE ORE DEPOSITS.

Introductory statement.—The mineralogy of the ore deposits is extremely simple. In the veins the minerals constitute the material that forms the filling of the fissures; in the stockworks and stringer lodes they include the minerals of the country rock or the minerals derived from their alteration under the action of the mineral-bearing solutions. The variety is not great, nor are the minerals distinguished by any peculiarities of crystallization. Oxidation products are not common.

Gold.—The low-grade ores rarely show any gold visible to the eye. It is reported, however, that gold was found intergrown with quartz in masses of considerable size in pockets in the Comet mine. In the upper parts of some lodes it appears in bright-yellow particles embedded in iron ocher, where it has evidently been derived from the oxidation of a pyritic mineral. At the Jualin mine it is closely associated with chalcopyrite, commonly intergrown, and is with difficulty distinguished on account of the almost identical similarity of color between gold and chalcopyrite. Gold occurs also embedded in calcite.

Copper.—Native copper was not observed in any of the mines, but is reported to have been found in the stream bed of Johnson Creek below the Jualin mine. The presence of chalcopyrite and some of its oxidation products, azurite and malachite, in that lode leaves little doubt that the native metal was derived, like the carbonates, from the oxidation of copper pyrites.

Galena.—The lead-gray sulphide of lead occurs in small particles embedded in the quartz of the veins and stringers. It occurs nowhere in the altered wall rock, differing notably in this respect from pyrite. It shows no crystallographic boundaries, but exhibits the characteristic cubical cleavage.

Sphalerite.—Sphalerite was noted at only two of the properties in the district—the Jualin and the Fremming. At the Fremming it is of yellowish-brown color and occurs together with galena, pyrite, chalcopyrite, and free gold. Minute amounts of black sphalerite occur at the Jualin mine.

Chalcopyrite.—Chalcopyrite, the gold-yellow sulphide of copper and iron, is, next to pyrite, the commonest metallic sulphide in the region. Its presence seems favorable to good values in gold, and gold is often found inclosed in it at the Jualin mine. As a rule, the chalcopyrite occurs embedded in quartz in irregular particles without crystal faces, but where it lines drusy cavities it forms small tetrahedrons. Chalcopyrite may be distinguished from pyrite, with which it may sometimes be confused, by its comparative softness, for it scratches readily, and its deeper yellow color.

Pyrite.—The pale brass-yellow sulphide of iron, pyrite, is the most abundant metallic mineral in the region. Unlike the other sulphides—galena, sphalerite, and chalcopyrite—it occurs both in the vein fillings and in the altered wall rocks. The pyrite is both massive and crystalline; where crystallized it is commonly in the form of striated cubes and rarely, as at the Indiana property, in fine octahedrons.

Quartz.—The principal nonmetalliferous mineral forming the vein-filling material of the region is a white quartz of fairly coarse texture. Some of the veins are characterized by a drusy structure, and in these the quartz is partly bounded by crystal faces, and terminated prisms project into the vugs. The central portion of the Ophir vein contains cavities several feet long, and these are implanted with large glassy crystals of quartz.

Calcite.—Calcite occurs as a subordinate constituent in all the quartz veins but as a rule is prominent only in the stringers. Sparry masses occur in places in the altered diorite wall rock; some is of reddish-brown color, but as it is easily soluble in cold hydrochloric acid, it is probably a ferriferous calcite and not siderite, as was suspected.

Dolomite.—The presence of dolomite is indicated by the microscope as an alteration product of the diorite adjoining quartz veins. It is recognized in the larger aggregates by its strongly curved cleavage and by its tendency to form perfect rhombohedrons scattered throughout the altered diorite. It was positively identified by determining the value of the refractive index ω.

Feldspar.—The feldspar of the Jualin diorite is an important constituent of the stockwork ore bodies, such as the Eureka, the Kensington, and the Johnson. It is a plagioclase (commonly andesine) or labradorite, but instead of showing the white, pearly appearance of ordinary feldspar, it is light greenish and possesses rather an oily luster due to a more or less thorough alteration to sericite. A clear glassy feldspar, which the microscope shows to be albite, is in places associated with the altered plagioclase feldspar, from whose transformation it has been derived by the action of vein-forming solutions. It is also found in microscopic veinlets in the altered diorite along with quartz and calcite or dolomite. Its presence throws important light on the character of these solutions and allies the mineralization with that which has taken place at the Treadwell deposits. Albite has not been noted as a macroscopic component of the larger quartz veins, but its discovery seems not unlikely.

Sericite.—Scales of silvery-white mica occur in the vein quartz, but nowhere in large amount. It is, as already indicated, abundant as a microscopic constitutent of the altered feldspar of the diorite wall rock.

Hornblende.—Hornblende in its unaltered condition is a dark-green or black prismatic mineral, which is a prominent constituent of the Jualin diorite. Under the action of mineralizing solutions it has been converted into epidote and chlorite.

Epidote.—Epidote, a hydrous aluminum silicate of calcium and iron, is a mineral of bright yellowish-green color. It is present in the hydrothermally altered diorite in a finely disseminated condition, and is responsible in considerable measure for the greenish hue that the diorite assumes in the vicinity of the ore bodies.

Chlorite.—Chlorite is a micaceous or foliated mineral of deep-green color. It is abundant in the stockwork deposits as an alteration product of biotite, which is one of the pyrogenetic constituents of the Jualin diorite. It is in part derived also from hornblende. The pyrite in the country rock is commonly associated with chlorite, much of which shows sagenitic webs. The fibers or prisms making up these webs are in some places sufficiently coarse to show the diagnostic properties of rutile, such as deep pleochroism, straight extinction, and relief.

VALUE OF THE ORES.

The ores, if $10 a ton is considered to fix the upper limit in value of low-grade ores, are commonly of low grade. The Comet mine, one of the two largest producers in the region, averaged $9.20 a ton for a production of 50,000 tons. On the other hand, a number of strong fissure veins averaging 5 feet in thickness, from which a considerable tonnage of ore has been mined and milled, have yielded only $3 to the ton—an amount that under present conditions is below the working costs.

The highest grade ore in the region was extracted from one of the veins of the Jualin mine and averaged $30 a ton over a width of 7 feet. It is a noteworthy fact that the ore of this mine is comparatively high in metallic sulphides.

Few data are available concerning the value of the ore of the stockwork deposits. The general rule seems to hold that the values increase proportionately to the size and number of quartz stringers per volume of country rock. The Eureka is said to average $7 a ton over a width of 18 feet, the Kensington from $3 to $5 over a width of 80 feet.

FISSURE AND VEIN FORMING PROCESSES.

The formation of the veins required the intervention of two separate processes—the fracturing and opening of the fissures and the filling of the fissures with quartz and the metalliferous constituents. The second process tends to obscure and obliterate certain of the records of the first.

Some of the veins are in places adjoined by belts of mashed diorite which have the structure of a closely foliated green schist. Fragments of this schist inclosed in the veins prove that the crushing of the diorite took place prior to the introduction of the vein-filling material, but it is improbable that this green schist with its present mineral make-up is the product of the mechanical alteration of the diorite. It has been too thoroughly affected by the ore-depositing agencies to retain its original composition. Viewed under the microscope, the schist proves to be composed largely of altered plagioclase and sericite, with a minor amount of calcite and accessory chlorite, magnetite, and apatite. The green color of the schist is due to the presence of the sericite.

Narrow portions of some of the veins are occupied by schistose diorite or are filled with broken masses of diorite interlaced with quartz stringers. All these features indicate that powerful compressive forces were operative in producing the fractures.

At other points in the region these stresses have produced belts of schist in the diorite, but these schistose zones have remained unmineralized, possibly because they were too tight to furnish free circulation to the ore-depositing agencies. One of the schists—a light-green foliated rock from a zone 10 feet thick in the Indiana tunnel—was found to consist of highly altered plagioclase which is much obscured by sericite and carbonate. The sericite shows no schistose arrangement like that, for example, characterizing deformed quartz porphyries; the carbonate is commonly scattered throughout the feldspars in the form of small rhombohedrons. Both minerals are characteristic of the chemically altered wall rock that adjoins the ore bodies. A number of small radiate groups of bluish-brown tourmaline occur throughout the rock, and pyrite, magnetite, and apatite are present as accessory minerals. The tourmaline was introduced subsequent to the shearing of the rock, and tourmalinization appears to have been contemporaneous with the sericitization and carbonatization.

In addition to the mechanical alteration of the wall rocks, they have been affected by a chemical alteration due to the activity of the agencies that brought in the quartz and metallic minerals. The width of wall rock affected by this alteration varies, ranging up to several feet. The alteration is most intense where the wall rock is irregularly penetrated by stringers branching from the main lode.

The general course of the alteration of the diorite leads to the chloritization and destruction of the ferromagnesian minerals, to the partial sericitization of the plagioclase feldspar, to the formation of albite, and to the introduction of carbonates (dolomitic in part) and pyrite. In short, the diorite is transformed mainly by recrystallization, during which there is some addition of carbon dioxide and sulphur and probably of iron and potash. The process is very similar to that determined for the Treadwell ore deposit by Spencer,[a] who pointed out that, though the occurrence of albite is fairly common in certain types of gold-quartz veins, it had not previously been detected in the metasomatically altered wall rocks of any veins that had been studied. It has been noted by Lindgren[b] to form in albite-rich amphibolites.

The most thorough alteration observed in the Berners Bay region was that adjoining portions of the Bear vein. Here the diorite has been converted into a nearly snow-white rock impregnated with small cubes of pyrite. In thin section this rock is seen to have a crushed granulated structure healed by recrystallization and obscured by metasomatic alteration. Plagioclase is the main constituent and is largely altered. It is sericitized, especially where pyrite has been introduced, and in places contains rhombohedrons of carbonate. Patches of recrystallized clear glassy feldspar, which proves to be albite, occur sporadically. Replaced areas consisting of carbonate that shows strongly curved cleavage, quartz, and subordinate albite are present. The carbonate was proved to be dolomite by determining the value of ω according to Schroeder van der Kolk's method;[c] this value was found to be 1.69.

It is not possible to obtain the fresh diorite from which this wall rock was derived. At 550 feet from the vein the diorite shows numerous hornblende prisms resting in dull-green aphanitic matrix. In thin section this apparent matrix is found to consist of highly altered feldspar and primary interstitial quartz. The feldspar, mainly plagioclase with some orthoclase, is thoroughly sericitized. Epidote, chlorite, and carbonate are common; pyrite occurs sporadically. The presence of magnetite as a relatively abundant accessory mineral is noteworthy. The hornblende which is so readily seen in the hand specimens proves to be considerably altered; the presence of chloritized biotite is suggested but can not be established.

Where the metasomatic alteration has been less intense, as in the diorite of the Kensington stockwork or at the Jualin mine, the altered wall rock consists essentially of an aggregate of sericitized plagioclase and chloritized biotite which shows sagenitic webs. No recognizable vestiges of hornblende are present. In places considerable apatite occurs as an accessory mineral. The veinlets of quartz that traverse this altered rock contain dolomite and calcite, a little sericite and chlorite, and some glassy striated subhedral albite. In places the

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[a] Bull. U. S. Geol. Survey No. 287, 1906, p. 113.
[b] Lindgren, Waldemar, Econ. Geology, vol. 2, 1907, p. 11
[c] Determined by E. S. Larsen.

limpid new albite adjoins highly sericitized feldspar, and the contrast between original and secondary feldspar is strikingly apparent. Some of the smaller veinlets are composed entirely of dolomite and albite.

At a greater distance from the ore bodies, hornblende begins to appear in the diorite. It is partly epidotized and chloritized; epidote appears also in the plagioclase, together with carbonate and sericite. The biotite is partly chloritized, commonly around the edges, and contains finely developed sagenitic webs, especially in the chloritized portions. Zoisite is noted here and there. Magnetite appears among the ordinary accessory minerals of the diorite.

The mineralogical study of the metamorphism of the diorite wall rocks shows that where the alteration was most profound the femic minerals, especially the hornblende and magnetite, were destroyed and all traces of their former presence completely obliterated. The iron of these minerals was used to form pyrite; the lime and magnesia of the hornblende to form dolomite. The feldspar has been partly sericitized and recrystallized to albite. The potash of the sericite was, in part at least, furnished by the biotite. Apatite remains throughout the course of alteration. Epidote is not formed in the zone of most intense metasomatism, but appears in the zone of feebler alteration.

The alteration of the wall rock has been mainly in the nature of a chemical rearrangement of the constituent molecules, modified to some extent by the introduction of sulphur and carbon dioxide and by the partial elimination of soda. In general, the amount of pyrite developed in the wall rock seems to have been determined by the amount of iron originally present in the ferromagnesian minerals and magnetite.

The chemical work done by the ore-depositing agencies shows that they were hot ascending solutions carrying carbon dioxide, sulphur (probably as hydrogen sulphide), silica, potash, gold, iron, and several heavy metals in small quantities, and doubtless other constituents that have left no record of their presence because they remained unfixed either in the vein stuff or in the altered wall rocks. At one locality the solutions were capable of causing the formation of tourmaline as well as producing sericitization and carbonatization. The occurrence of this tourmaline tends to corroborate the conclusion previously reached concerning the comparatively highly heated character of the vein-forming solutions. Too weighty a superstructure of argument should not be built on this single occurrence, but it suggests that when the mining development of the region is further advanced and increased facilities for investigation are provided the relation of the tourmalinization and auriferous mineralization can be more firmly established.

ORIGIN OF THE ORE DEPOSITS.

The problem concerning the origin of the ore deposits involves the consideration of two factors—the origin of the fractures and the origin or source of the vein stuff and its metalliferous constituents.

Compressive forces, as indicated by the schistose nature of the wall rocks, caused the initial fracturing of the rocks. The surfaces along which this rupturing took place were not simple planes, but were rather of gently undulating character along both the strike and the dip, as shown by the stoped-out portions of the veins, and subsequent movements along the fractures produced the open spaces in which the quartz and metallic minerals were later deposited.

The fissures show neither conjugate relations nor any other discernible systematic arrangement. In a highly speculative paper Spencer [a] has put forth a conception of the origin of the fissures in the Juneau gold belt, but inasmuch as the conditions postulated in his argument do not exist in the Berners Bay country his ideas can not be applied to that region.

The localization of the largest number of ore bodies in the area of the Jualin diorite is the most striking fact in the geology of the region. It suggests a genetic dependence on that rock mass, but what that genetic relation is can not easily be established.

The mineralogical character of the veins throws no light on the origin of the deposits. The metallic minerals—gold, pyrite, chalcopyrite, galena, and sphalerite—and the gangue mineral quartz all belong to the group of persistent minerals,[b] and are therefore of little genetic significance.

The character of the metasomatic alteration of the wall rock affords a more hopeful line of attack on the problem. The study of that process has shown that the vein-forming solutions were capable of effecting an intense hydrothermal metamorphism, a characteristic feature of which is the development of albite in the altered rock as well as in the narrow veinlets penetrating the altered wall rock. This feature, as already pointed out, allies the character of the mineralization to that which has produced the Treadwell lode, so that this similarity is one of both practical and theoretical significance. The presence of albite appears to be a regional characteristic of the Juneau gold belt, and, on account of the known instability of soda minerals in veins formed at moderate or shallow depths,[c] indicates a deep-seated origin for the gold veins.

The hypothesis of a magmatic origin for the vein-forming waters in southeastern Alaska was first advanced by Spencer [d] and was

[a] Spencer, A. C., The origin of vein-filled openings in southeastern Alaska: Trans. Am. Inst. Min. Eng., vol. 36, 1906, pp. 1211-1216.

[b] Lindgren, Waldemar, The relation of ore deposition to physical condition: Econ. Geology, vol. 2, 1907, p. 122.

[c] Lindgren, Waldemar, op. cit., p. 117.

[d] Spencer, A. C., Trans. Am. Inst. Min. Eng., vol. 36, 1906, p. 971; also Bull. U. S. Geol. Survey No. 287, 1906, p. 30.

based mainly on the facts observed in the Juneau district. These included the relation of mineralization to intrusive rocks, the nature of the metasomatic processes, and the sporadic presence of pneumatolytic minerals in the veins.

All subsequent work has tended to support this hypothesis. The geologic map[a] published on the completion of reconnaissance work in southeastern Alaska shows most strikingly the clustering of mineral deposits along the intrusive contacts of granitoid rocks. The force of this suggestive relation gains cumulative strength when it is found that a similar association exists along the eastern margin of the diorite core of the Coast Range.

It is therefore probable that in a regional treatment of the ore deposits of southeastern Alaska the hypothesis of Spencer embodies an important generalization, the plausibility of which may not always be readily apparent when applied to individual deposits or localities. At Berners Bay the massing of the ore bodies in the area of the Jualin diorite is so striking a feature that a certain mental restraint is required to keep from precipitately embracing the magmatic hypothesis.

The independent evidence that the region as an isolated unit offers to the magmatic hypothesis consists, first, in the spatial relation of the ore bodies to the diorite, and, second, in the character of the metasomatic alteration of the wall rocks. From the present status of knowledge concerning the origin of ore bodies it may be regarded as established that the vein-forming agencies were ascending thermal solutions. That they were released from a cooling magma is strongly suggested but not proved. The tourmalinization effected by solutions essentially similar in composition to those that produced economic mineralization is a fact lending support to the magmatic hypothesis, but in view of the meager distribution of the tourmaline, so far as known, it is one on which much weight can not be laid.

PRACTICAL DEDUCTIONS.

Any enriched surface ores that may have existed within this region have been swept away by the powerful glacial erosion to which the region was subjected in the recent geologic past. The ores exposed at the surface are therefore of primary origin, modified to an unimportant extent by postglacial oxidation, and the outcrop of any ore deposit will furnish a true index of the value of the lode as a whole, depending on whether the distribution of values in the ore is or is not uniform. As some of the veins have been found to be pockety and as many an undeveloped prospect is known from a single outcrop only on account of the generally poor exposures in the region, it

[a] Wright, C. W., Bull. U. S. Geol. Survey No. 345, 1908, Pl. II.

may happen that a surface ore may give results that are either higher or lower than the average value of the whole ore body.

The continuity of the ore deposits in depth is a matter of the highest practical interest. It is dependent on two factors—the persistence of the fissuring and the character or quality of the mineralization. As shown by the microscopic study of the vein-forming processes, the quality of the mineralization is such as to assure its maintenance to a depth which is below the limit of profitable mining. This conclusion is enforced by both theoretical and practical considerations. The Kensington lode outcrops at an altitude of 2,800 feet; the Treadwell, which outcrops near sea level, has been proved to a depth of 1,700 feet without diminution of its values. This gives a known vertical range of practically 4,500 feet through which the auriferous solutions were capable of precipitating gold in the Juneau district. The probabilities are that this is a minimum estimate, but it is perhaps well to point out that this figure is based on the assumption that the ore deposits have not been displaced vertically with reference to each other since they were formed, either by faulting or by crustal warping.

It does not follow, however, that the quantity of mineralization persists downward. This is a function of the extent of the fissuring in depth and the persistence of size of the veins or the amount of veination in the stockworks. These factors can be determined much less satisfactorily than those relating to the quality of mineralization.

It has been pointed out in previous pages that the veins were formed by the movement of the walls past each other along gently sinuous fractures. Pinches and swells are therefore encountered on the levels along the strike of the veins. Similar variation is to be expected vertically also, although development has not yet been sufficiently extensive to demonstrate this as a law.

Inasmuch as narrow portions of the fissures are commonly occupied by masses of schistose diorite which are here and there interlaced with quartz stringers, such schistose zones are worth exploring or drifting on in the chance of striking other valuable ore bodies. This possibility was forcibly illustrated at the Jualin mine, where an 18-inch zone of crushed diorite of most unpromising appearance opened out when followed along the strike into a strong and valuable ore body. That this is no infallible rule, however, is clearly demonstrated by certain fruitless attempts that have been made under its guidance. In the most conspicuous example 500 feet of tunnel was drifted along a schistose zone in the diorite without encountering a ledge. The probability of striking an ore body is apparently strongest in those belts of crushed or sheared diorite that are penetrated by quartz stringers.

On the whole, the downward persistence of fissuring would seem to be proved by the deep-seated origin of the vein-forming solutions, as shown by the alterations that they were able to effect in the wall rocks. The ore bodies will doubtless show variations in size along the dip and strike, but the character of the diorite country rock is favorable to their continuity in depth.

The conclusion that the ore deposits are of deep-seated origin and due to the ascent of thermal waters is ultimately based on empirical generalizations and is independent of any speculative conceptions as to the magmatic origin of those solutions. It therefore rests upon a firmer foundation and lends assurance to the belief that the ore deposits will, as a rule, persist downward below the limits of profitable extraction without essential change of values.

DESCRIPTIONS OF INDIVIDUAL MINES AND PROSPECTS.[a]

The mines and prospects are described in geographic order, those in the Sherman Creek drainage basin being taken up first and those on the Berners Bay side being considered last. A large number of partly developed prospects or locations are not described, in order to avoid a monotonous repetition of uninstructive details.

IVANHOE MINE.

The main tunnel of the Ivanhoe mine is situated 2½ miles northeast of Comet, at 2,350 feet above sea-level. This, the upper working, was connected with the stamp mill, which is situated on Sherman Creek at an altitude of 500 feet, by a tramway system consisting of 3,000 feet of cable tram and 2,700 feet of gravity tram. This system has been largely destroyed by rock and snow slides. The mill is equipped with 20 stamps and 8 Frue vanners and houses the compressor plant.

The principal tunnel bears east for 185 feet to a point where it intersects the vein at a depth of 45 feet below the outcrop; a drift opens the vein over a length of 850 feet. At one point ore has been stoped out to the surface, and 3,000 tons was extracted, reported to have yielded about $7,000. The property has been idle since 1903.

The vein averages 5 feet in thickness, ranging from 1 to 9 feet, and is inclosed between well-defined walls. The strike is N. 10° W. and the dip ranges from 30° to 60° E., averaging 50°. The country rock in the vicinity of the Ivanhoe mine consists of altered basalts or diabase porphyries. These are dark-colored fine granular rocks spotted with conspicuous blebs of yellowish-green epidote. The original bedded character of the rocks is obscure, but differences of

[a] The writer has made free use of the unpublished notes of C. W. Wright for economic data and for information concerning the underground development of mines that were inaccessible in 1909.

texture can be noted from place to place. The rock 50 feet west of the tunnel entrance is more porphyritic than the prevailing variety. Tabular feldspars one-half inch long form the phenocrysts and are arranged here and there in stellate groups.

HORRIBLE MINE.

The Horrible group of five claims was located in 1896 and was sold late in the same year to the Portland-Alaska Mining Company. Mining operations were begun in the spring of 1897, and an aerial tramway 2 miles long was erected which connected the mine workings with a 10-stamp mill built on the shore of Lynn Canal. Work was suspended during the winter of that year and was resumed only for a short time in 1901.

The mine is opened by a tunnel 400 feet long drifted on the ledge, which strikes north and south and dips steeply to the east. The ore body consists of a quartz-filled fissure whose walls are commonly well defined and which ranges in width from a seam to 10 feet, averaging 5 feet. The quartz is sparingly mineralized with metallic minerals; the only one visible to the eye is pyrite. The country rock inclosing the vein is a green diorite of rather fine texture. The hanging-wall side has been explored by a drift 240 feet long, but no ore body was encountered.

Some stoping was done on the vein and 500 tons of ore was extracted; this is reported to have yielded $1,500 in gold.

OPHIR GROUP.

The Ophir vein outcrops prominently at an altitude of 1,500 feet along the flank of the mountain north of Sherman Creek. Three tunnels have been driven on the property, two of which cut the vein. The third, which is 300 feet long, is planned to undercut the ore body at a depth of 200 feet, but has not been completed. The two upper tunnels are 400 feet apart on the strike of the vein, and drifts aggregating 300 feet have been driven along its course.

The country rock at the Ophir vein is a greenish diorite characterized by an abundance of small black prisms of hornblende. The ore body is a simple quartz-filled fissure vein striking N. 30° W. and dipping on an average 45° E. It ranges in thickness from 2 to 6 feet. The quartz is practically devoid of pyritic mineralization, sporadic particles of iron pyrite only being present. The Ophir vein is rendered notably different from others in the district through the presence of numerous vugs and cavities lined with large glassy quartz crystals.

BEAR MINE.

The Bear mine is situated on the north slope of Sherman Creek at an elevation of 1,350 feet and is connected with the 40-stamp mill of the Berners Bay Mining and Milling Company by a gravity tramway

1,700 feet long. The mine is developed by an adit level 1,100 feet long, which crosscuts the Bear vein 500 feet from the portal and 200 feet below the outcrop. The additional 600 feet is said to have been driven in pursuance of a plan to eventually undercut the Kensington lode at this greatly increased depth. A raise was put through to the surface on the Bear vein and three levels from 250 to 300 feet long have been worked. From these considerable ore has been stoped in places, the stopes reaching the surface. During the years 1895 to 1897 about 5,500 tons was extracted.

The country rock at the Bear mine is a greenish diorite whose green color in due mainly to the presence of finely disseminated epidote and chlorite. The vein trends approximately N. 20° W. and dips somewhat irregularly, from 70° E. at the surface to 40° E. on the adit level. The walls are well defined; the thickness of the vein averages 2 feet on the surface and 5 feet on the adit level. In places the diorite wall rock is highly altered to a snow-white rock cut by quartz stringers and studded with numerous small perfect cubes of pyrite. The vein is practically barren of metallic minerals but carries a small amount of pyrite and chalcopyrite.

Another vein, smaller than the Bear vein, was crosscut by the adit level at 300 feet from the portal. It is from 2 to 5 feet thick, strikes N. 15° W., and dips from 10° to 40° E. About 100 feet of drifts have been driven on the ledge.

KENSINGTON MINE.

The Kensington mine is situated on the north slope of Sherman Creek 2 miles due east of Comet. During the years 1897 to 1900 some 12,000 tons of ore was mined from the outcrop and from shallow underground workings. In 1904 a long crosscut tunnel was driven to prove the persistence of the ore body in depth. Since that time no further work has been done on the property, but on the settlement of certain legal difficulties it will undoubtedly be reopened.

The portal of the crosscut tunnel is situated at an altitude of 2,100 feet and is connected with the gravity tram of the Bear mine by an aerial tramway, but this is now in a state of extreme disrepair. (See fig. 4.) The tunnel, which will serve as the main working adit, is 1,950 feet long, and drifts and crosscuts aggregating 640 feet have been driven to explore and define the limits of the ore body. The upper workings of the Kensington are situated at an elevation of 2,800 feet, or 800 feet above the crosscut tunnel. Here some large, irregular galleries have been stoped out, in places 30 feet high, but none of the tunnels extend over 250 feet into the mountain. Some mining has also been done on the surface croppings 40 feet above the entrance to the tunnels.

The geologic features of the Kensington ore body as shown in the outcrop and in the tunnels on both levels are essentially similar. The ore body consists of an irregular mass of diorite gashed by a multitude of quartz stringers, which range in thickness from a seam to a foot but commonly average a few inches. In plan the ore body, as shown on the main crosscut level, rudely approximates an ellipse 80 feet in width and 160 feet in length, with the major axis trending north and south. The two levels give cross sections 800 feet vertically apart and apparently show that the deposit constitutes an inclined column or chimney of ore dipping 67° E.

The quartz veinlets in the main interlace the diorite irregularly, but show an ill-defined tendency to trend parallel to the major axis of the lode in cross section. They carry pyrite as the only metallic mineral visible to the eye, though a small amount of galena was noted at one point. The diorite adjoining the quartz veinlets is heavily pyritic in places, but more commonly it contains scattered

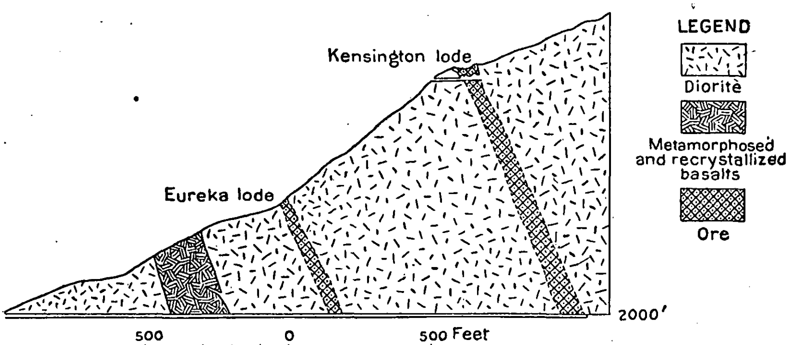

FIGURE 4.—Diagrammatic section along the Kensington tunnel.

grains of pyrite disseminated through it. The diorite has not undergone sufficient alteration from the action of vein-forming solutions to obscure its dioritic appearance. Nevertheless it differs noticeably from the barren diorite, being in general of a greener color—a change that is due largely to the conversion of the lustrous flakes of black biotite to dull-green chlorite. The feldspars are sericitized and other changes have taken place, described in detail elsewhere in this report. The larger stringers are practically solid quartz; the small veinlets, especially those that finger out into the country rock, contain carbonates, with which, as shown by the microscope, is associated some albite feldspar.

A lamprophyric dike 16 inches thick, with strongly chilled margins, was encountered in the north drift on the main crosscut level. It is a dark fine-textured porphyritic rock showing numerous phenocrysts of hornblende. Under the microscope hornblende is found to be the most abundant constituent and to form both the phenocrysts and a large proportion of the groundmass; it is partly epidotized and chloritized. Plagioclase occurs interstitially but is obscured by sericitization; some quartz is associated with it. Titanite is a notable accessory; magnetite occurs sparingly. Pyrite and calcite are sporadic secondary minerals. Such a rock would be designated a spessartite in the classification of Rosenbusch. It is probably related to the dike near the Portland mill described on pages 18-19, which was called there a diorite porphyry but which, as can be seen from the description, has lamprophyric characteristics. The dike at the Kensington mine was intruded before the ore body was formed, so that it is of little practical significance.

The ore body is not defined by walls. The values vary with the abundance of quartz veinlets and are said to range from $3 to $5 a ton for the width of 80 feet. The mill returns are reported to have shown the following distribution of values: Bullion 5 per cent, concentrates 62 per cent, tailings 33 per cent.

EUREKA MINE.

The Eureka lode outcrops several hundred feet below the Kensington and has been undercut by the Kensington tunnel at a depth of approximately 350 feet below the exposed outcrop and 1,300 feet from the mouth of the tunnel. The geologic features are essentially similar to those of the Kensington ore body, but in form the Eureka is longer and narrower. It is 400 feet long on the surface and where intersected by the crosscut is from 30 to 40 feet wide, consisting of a mass of coarse diorite closely interlaced with quartz stringers. No drifting has been done along the lode on the crosscut level. Careful assays across a width of 18 feet are reported to give a minimum value of $6.56 a ton for the ore body as exposed in the Kensington tunnel.

COMET MINE.

The Comet mine is situated near the head of Sherman Creek, the veins outcropping at an elevation of 2,300 feet and the main crosscut entering the mountain at an elevation of 1,650 feet. The property was located in 1890 by six owners, who sold it to Thomas Nowell in 1892. Developments began in 1893, the main crosscut was commenced in 1896, and the property was operated until 1901; since that time it has laid idle, being tied up by litigation. The improvements have gone to ruin, the buildings have collapsed, and the tunnels have partly caved in. The underground developments were consequently not accessible at the time of visit in 1909.

Two veins are exposed on the surface at an elevation of 2,300 feet. They lie in the diorite near the contact of the slates and graywackes of the Berners formation, strike N. 5° E. and dip 70° E. Their trend is therefore nearly at right angles to the contact. The veins are about

50 feet apart; the western one appears to be the larger and in the outcrop is 2 to 3 feet thick, though carrying relatively large horses of diorite. It is a well-defined fissure vein and, as shown by the lower levels, ranges up to 8 feet in thickness.

The main crosscut, which is connected by an aerial tramway 5,000 feet long with the 40-stamp Kensington mill, is 1,900 feet long. It traverses a belt of slates, encountering a number of intruded dikes of diorite porphyry, penetrates the main mass of diorite at 1,500 feet from the portal, and undercuts the ore body at approximately 600 feet below the apex. The foot-wall vein has been stoped out from this level to the surface. Drifts extending north and south have been driven on ten different levels and range in length from 300 to 500 feet. The vein is faulted at the north and its extension has not yet been recovered.

The Comet vein is famous throughout the Juneau district for its pockety character. Masses of golden quartz difficult to break in mining were found, and pockets containing $50,000 or more in value have been extracted, but it is believed that much gold has been lost by "high grading." The total recorded production is $460,000, extracted from 50,000 tons of ore. The ore yielded 87 per cent of its value in free gold and 5 per cent in the concentrates.

JOHNSON MINE.

The Johnson property is situated high up on the side of the amphitheater at the head of Johnson Creek, but is most easily reached by means of a good trail starting from the Sherman Creek side of the divide. The developments consist of a number of shallow surface cuts and a tunnel situated at an altitude of 2,500 feet. The property is located near the contact of the series of amygdaloids with the intrusive diorite, which is coarsely granular and resembles that at the Kensington mine. The amygdaloids have been greatly changed by the effects of the diorite intrusion; they are cut by innumerable dikelets and have been recrystallized, so that they resemble dark finely granular diorites, but they contain numerous small white oval areas representing former amygdules.

The ore body consists of shattered country rock penetrated by quartz stringers, forming a huge stockwork extending up a precipitous gulch from 2,500 feet to the ridge line at an altitude of 3,300 feet, but the upper portion is buried under slide rock. The maximum pyritic mineralization is exposed at the mouth of the tunnel. Here a lenticular mass of fractured and somewhat sheared diorite, 150 feet long and 30 feet wide, forms a compact body of ore in which the quartz stringers are closely spaced and heavily impregnated with pyrite. The trend of the deposit as exposed on the surface is N. 15° W. The tunnel bears N. 69° W. and is 75 feet long. The face is in barren diorite, so that the tunnel is not calculated to develop this portion of the ore body.

The zone of mineralization extends up the gulch as a compact stringer lode 6 to 8 feet thick, broadening out in places so that the individual stringers become widely spaced. At an altitude of 2,800 feet large, irregular bodies of quartz occur and veins and stringers interlace the country rock, including both diorite and greenstone, through a width of 100 feet or more. The quartz here is nearly barren of metallic sulphides, contrasting strikingly in this respect with the large amount shown at the portal of the tunnel. It is reported that commercial sampling shows an ore body 1,500 feet long and from 50 to 70 feet wide, having a minimum average value of $3.90 to the ton.

INDIANA PROPERTY.

The Indiana group, the property of the Alaska Gold Mining Company, is situated on Johnson Creek, three-quarters of a mile northwest of the Jualin mine. It was located in 1896, after the Jualin had been opened, and was acquired by the company in 1897. During the latter year most of the present improvements were made. A 10-stamp mill and accessory buildings were erected and a steel water pipe line several thousand feet in length was laid. The mill has never been operated, and it and the buildings have been demolished by winter snows.

Three tunnels have been driven into the diorite country rock in the attempt to develop the property. The lowermost and main tunnel is 1,100 feet long and trends S. 63° W.; at 1,000 feet from the entrance drifts aggregating 500 feet in length have been driven to the southeast and northwest. They follow a vertical shear zone approximately 10 feet thick, along which the diorite has been reduced to a green schist. Neither quartz veination nor other mineralization appears along this zone. Other belts of schistose diorite (one nearly 100 feet in width) have been crosscut by the main tunnel. They let in large quantities of surface water. A narrow lode of quartz stringers was encountered 60 feet from the mouth, but owing to its proximity to the surface it can not be explored by drifting. The quartz contains considerable pyrite, which is crystallized in large octahedrons, and some chalcopyrite. A second tunnel 100 feet above the lower tunnel is 900 feet long, and the uppermost, 100 feet still higher, is 400 feet long; but neither has encountered any ore.

JUALIN MINE.

The Jualin mine is situated on Johnson Creek at an altitude of 750 feet, and is connected with tidewater at the head of Berners Bay by a horse tramway 4 miles long. Supplies can be lightered at high tide from deep water in Jualin Cove to the wharf at the terminus of the tramway. The mine was located in 1896 by Frank Cook and was purchased in the same year by the Jualin Mines Company, which opened the property and operated the mine continuously until 1901. By that time the larger part of the ore lying above the adit level had been worked out, and deeper development was effected by winzes sunk from drifts on the drainage level. Heavy inflow of surface water impeded the extraction of the ore on the deeper levels, and the mine has been operated only intermittently since 1901. In 1905 the tramway was built to facilitate transportation to the mine. During 1909 the mine was idle, but it is now planned to develop the property systematically. With this end in view it is proposed to sink a shaft during 1910 in the hanging-wall side of the lode.

A 10-stamp mill equipped with Frue vanners and operated by water power is situated on the bank of Johnson Creek below the portal of the working adit of the mine.

The apex of an ore body on the Jualin property was discovered outcropping in a rounded, glacially smoothed knob of diorite projecting through the mat of moss and vegetation that generally obscures all bed rock in the valley of Johnson Creek. The country rock at the Jualin mine is a massive diorite of fairly fine grain and is composed of plagioclase feldspar, small prisms of hornblende, and flakes of biotite. Even in the freshest looking rock many of the feldspars can be seen to have a delicate green tint. In addition to these minerals, which are visible to the eye, the microscope shows that orthoclase and quartz are present in some amount and that therefore the rock approaches a granodiorite in composition. The rock has evidently been permeated by mineral-bearing solutions, and owing to the chemical activity of those waters the primary minerals have suffered considerable alteration. Epidote, chlorite, the scaly green mica sericite, and calcite have been formed at their expense. This alteration is of course most pronounced in proximity to the veins, where in some places a complete transformation of the diorite has occurred, and none of the original minerals have remained intact.

Three parallel veins spaced 75 feet apart on the adit level have been exploited. They trend N. 40° W. and dip steeply to the northeast at angles ranging from 60° to 90°. The foot-wall or west vein, as it is called, has proved to be the most valuable. It has been exposed for 400 feet in length and has averaged 5 feet in width. It has been developed by winzes to a depth of 200 feet below the adit level. At the southeast end of the drift on the adit level the vein has completely pinched out and the diorite at the face is firm and massive; before pinching, the dip is abruptly reversed to a flatter angle and the vein apparently loses itself in a zone of crushed diorite. About 50 feet to the northwest along the trend the vein is 16 to 24 inches thick and the hanging wall is splendidly defined, dipping steeply to the northeast; the foot-wall is marked by a closely foliated green schist produced by the mashing of the diorite. That this crushing took place prior to the filling of the vein is proved by the fact that the quartz near the foot-wall incloses fragments of the schist. From this point the vein abruptly expands to 10 feet in width. Part of this increased thickness seems to be due to movement along a fault plane traversing the vein at a narrow angle with the trend of the vein. Faults of small displacement have been encountered at other points in the mine, but have occasioned no difficulties in the exploitation of the ore bodies.

The middle vein as exposed in the main adit shows well-defined walls, which break clean, but the vein is only 18 inches thick at this point and consists of quartz and partly replaced diorite. The dip is rather flat—30° N. More or less shattered country rock adjoins the vein and is penetrated by sporadic stringers of quartz. The next 120 feet of the adit is driven on a shear zone of irregular width ranging from 4 to 8 feet; quartz is present only as stringers. The dip of the ore body gradually steepens, and at 120 feet a large body of quartz was encountered which averaged 10 feet in width throughout its length of 400 feet. This vein has yielded several thousand tons of ore in past years, but its value is said to be too low to warrant further extraction.

The third or hanging-wall vein is 4 to 5 feet thick and is of somewhat better grade than the second ore body. It is characterized by a clean, well-defined hanging wall, but the foot-wall is less regular and is reticulated by a considerable number of quartz veinlets, which are accompanied by an impregnation of the diorite with cubical pyrite.

The quartz of the veins is of milk-white color and open texture and is characterized by the presence of numerous druses or small vugs, into which terminated quartz crystals project. Metallic sulphides are present in considerable abundance and consist mainly of pyrite, chalcopyrite, and galena. Black sphalerite occurs also, but is extremely rare. Free gold is not uncommon and seems to be associated particularly with the chalcopyrite, in which it is usually embedded. The ore and wall rock show to some extent the oxidizing effect of surface waters, as indicated by the presence of red iron ocher and of malachite and azurite, though the copper carbonates are comparatively rare. Free gold can be found here and there in the midst of small masses of iron oxide, where it has undoubtedly been freed by the oxidation of the pyritic mineral that originally inclosed it.

The oxidation affecting the upper parts of the lodes is of postglacial origin and is comparatively feeble. The products of any earlier oxidation and enrichment of the outcrops of the lodes have been swept away by the powerful glacial erosion to which the region was subjected. These facts—the lack of oxidation and the glacial erosion--make it probable that the distribution of the gold in the veins has undergone only slight rearrangement from the action of descending solutions and that therefore the tenor of the ore is not likely to decrease with depth.

FREMMING PROPERTY.

The Fremming property is situated on Johnson Creek about a mile below the Jualin mine. The valley floor at this point is mantled by several feet of gravel and black soil covered with sod. Stripping shows that the bed rock is glacially polished and striated. Near the blacksmith shop an intrusion contact of the Jualin diorite with a series of green schists is exposed. Small dikes of diorite penetrate the schist, which, if the relations were not clearly shown, might be regarded as a chloritic schist produced by dynamic metamorphism of the diorite itself. Both the diorite and the green schist are interlaced with irregular quartz stringers.

A shaft 85 feet deep has been sunk near the contact in the green schists. The main development consists of a crosscut tunnel 360 feet long, commencing on the east bank of Johnson Creek and trending N. 28° E. A short drift connects the crosscut tunnel with the bottom of the shaft. The tunnel crosscuts a nearly vertical series of green schists. These are derived from slates and graywacke-slates of the Berners formation and owe their stronger green color to a greater abundance of chlorite in them. Near the end of the crosscut a belt of schists is irregularly penetrated by stringers across a width of 6 feet. The veinlets and partly replaced chloritic rock consist of quartz and calcite containing pyrite, chalcopyrite, galena, resinous sphalerite, and free gold. Rich specimen ore can be obtained, but the present developments are inadequate to show whether a body of milling ore exists.

GREEK BOY PROPERTY.

The Greek Boy property is situated 4 miles north of the tidewater terminus of the Jualin tramway and half a mile from Berners River. It is the lowest lying property in the region, the principal workings being only 100 feet above sea level.

The main development consists of a tunnel nearly 700 feet long, trending northwest. For the first few hundred feet it makes a narrow angle with the strike of the lode; the last 300 feet is driven on the lode. The ore body follows the contact of the quartz diorite gneiss with the basalts, which are here thoroughly schistose, and is a strong stringer lode bounded by definite walls. It stands nearly vertical, dipping steeply to the south. The hanging wall is a black hornblende schist, which the microscope shows to be composed mainly of hornblende and some plagioclase.

The first rock encountered on entering the tunnel is a gneissic or schistose diorite consisting of numerous white rounded feldspars embedded in a black matrix made up of hornblende and biotite. With increasing proximity to the lode this rock becomes finer grained and nearly barren of dark minerals. As the lode lies along the contact of an intruded formation, this change means that the rock is a marginal phase of the diorite, a change noted in other parts of the field where it is not obscured, as it is here, by the subsequent alterations produced by vein-forming solutions.

The lode consists of the schistose marginal phase of the diorite reticulated with quartz stringers, forming in places an ore body of nearly solid quartz. At other places considerable country rock is included in the lode. The thickness ranges from 4 to 9 feet and averages perhaps 7 feet. The only metallic mineral noted in the quartz is pyrite, and this is present in sparse amount only.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey, but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. $1.

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The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4–9.

The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, pp. 30–53. 45 cents.

The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21–62.

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Railway routes, by A. H. Brooks. In Bulletin 284, 1906, pp. 10–17.

Administrative report, by A. H. Brooks. In Bulletin 259, 1905, pp. 13–17.

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*The distribution of mineral resources in Alaska, by A. H. Brooks. In Bulletin 345, pp. 18–29. 45 cents.

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*Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 362 pp. 35 cents. Abstract in Bulletin 259, 1905, pp. 32–46.

*Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin 345, 1908, pp. 54–77. 45 cents.

Geographic dictionary of Alaska, by Marcus Baker; second edition by James McCormick. Bulletin 299, 1906, 690 pp.

*Water-supply investigations in Alaska in 1906–7, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp. 25 cents.

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Map of Alaska showing distribution of mineral resources; scale, 1 : 5,000,000; by A. H. Brooks. Contained in Bulletin 345 (in pocket).
Map of Alaska; scale, 1 : 5,000,000; by Alfred H. Brooks.

SOUTHEASTERN ALASKA.

*Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by Alfred H. Brooks. Professional Paper 1, 1902, 120 pp. 25 cents.
*The Porcupine placer district, Alaska, by C. W. Wright. Bulletin 236, 1904, 35 pp. 15 cents.
The Treadwell ore deposits, by A. C. Spencer. In Bulletin 259, 1905, pp. 69–87.
Economic developments in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 259, 1905, pp. 47–68.
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*Copper deposits on Kasaan Peninsula, Prince of Wales Island, by C. W. Wright and Sidney Paige. In Bulletin 345, 1908, pp. 98–115. 45 cents.
The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright. Bulletin 347, 1908, 210 pp.
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CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

*The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall. Professional Paper 15, 1903, 71 pp. Contains general map of Prince William Sound and Copper River region; scale, 12 miles =1 inch. 30 cents.
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*Notes on copper prospects of Prince William Sound, by F. H. Moffit. In Bulletin 345, 1908, pp. 176–178. 45 cents.
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Coal resources of southwestern Alaska, by R. W. Stone. In Bulletin 259, 1905, pp. 151–171.

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*A reconnaissance of the Matanuska coal field, Alaska, in 1905, by G. C. Martin. Bulletin 289, 1906, 36 pp.
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*Occurrence of gold in the Yukon-Tanana region, by L. M. Prindle. In Bulletin 345, 1908, pp. 179-186. 45 cents.
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Rampart quadrangle; scale, 1:250,000; by D. C. Witherspoon and R. B. Oliver. For sale at 10 cents a copy or $6 per hundred.
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Topographic maps.

The following maps are for sale at 5 cents a copy or $3 per hundred:

Casadepaga quadrangle, Seward Peninsula; scale, 1:62,500; by T. G. Gerdine.
Grand Central special, Seward Peninsula; scale, 1:62,500; by T. G. Gerdine.
Nome special, Seward Peninsula; scale, 1:62,500; by T. G. Gerdine.
Solomon quadrangle, Seward Peninsula; scale, 1:62,500; by T. G. Gerdine.

The following maps are for sale at 25 cents a copy or $15 per hundred:

Seward Peninsula, northeastern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, northwestern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.
Seward Peninsula, southern portion of, topographic reconnaissance of; scale, 1:250,000; by T. G. Gerdine.

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