58TH CONGRESS, 2d Session. } HOUSE OF REPRESENTATIVES. { DOCUMENT No. 713.

Professional Paper No. 25

Series { A, Economic Geology, 32
B, Descriptive Geology, 37

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE

COPPER DEPOSITS OF THE ENCAMPMENT DISTRICT

WYOMING

BY

ARTHUR C. SPENCER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

CONTENTS.

Part II. Economic Geology.

ILLUSTRATIONS.

THE COPPER DEPOSITS OF THE ENCAMPMENT DISTRICT, WYOMING.

By A. C. Spencer

INTRODUCTION.

During the last few years prospecting in the Medicine Bow and Park ranges in northern Colorado and southern Wyoming has proved that copper-bearing minerals occur frequently and are very generally distributed over a wide region in this portion of the Rocky Mountains. This has gradually become known through the discovery of several more or less promising copper deposits and also through the exploitation of a few properties which have produced ore on a commercial scale. The increase in the number of prospectors has kept pace with the increasing interest in the region, until now every part of it has been at least cursorily examined. In spite of this activity and of a considerable amount of development work at several localities, the productive mines in actual operation are few, but the search for valuable deposits continues, and it is to be expected that other mines will eventually be discovered.

FIELD WORK.

The field party was in charge of the writer, who had the assistance of Prof. J. Volney Lewis from July 12 until October 1, 1902. Mr. J. E. Spurr was associated in the work during a portion of September and October, and made a special study of the principal mines and prospects of the region. The writer has made full use of Mr. Spurr's notes, and has had the advantage of his suggestion and criticism during the preparation of the report. Both the field work and the office work have been carried on under the supervision of Mr. S. F. Emmons.

GEOGRAPHY.

The Continental Divide, which, in the latitude of Denver, Colo., lies in the north-south trending Front Range of the Rocky Mountain system, passes westward between North and Middle parks, and is then continued toward the north along the Park Range. The Park Range in Colorado trends north and south from Grand River to the vicinity of Mount Zirkel, where it swerves toward the west, beyond the spreading tributaries of Elk River, and continues northwesterly for nearly 40 miles under the local designation Sierra Madre. Midway between the State line and the Union Pacific Railroad these mountains give place to a watershed of gentle slope and slight topographic relief, which is still the main divide of the continent. The waters falling upon the western side of the Sierra Madre flow to Green and Colorado rivers and thus to the Gulf of California, while the streams on the eastern side reach the Gulf of Mexico by way of the Mississippi drainage.

The portion of the Encampment district which has been mapped lies between latitutes 41° and 41° 15′ north and longitudes 106° 45′ and 107° 15′ west. It is an oblong area extending east and west across the central portion of the Sierra Madre. By reason of the faulty determination of the forty-first parallel, fixing the line between Wyoming and Colorado, the State boundary was located approximately one-third of a mile north of its proper position; consequently a narrow strip along the southern edge of the district, about 9 square miles in area, is in the State of Colorado, while the remainder, comprising approximately 441 square miles, lies within Carbon County, Wyo. A sketch map of northern Colorado and southern Wyoming is given to show the location of the district (fig. 1).

The town of Encampment and the settlements of Battle, Rambler, Copperton, Dillon, and Rudefeha are the direct outgrowth of interest in the mineral resources of the region. Encampment, or Grand Encampment, as it was originally called, is the distributing point. It is situated near Encampment River, on the eastern slope of the Sierra Madre, 43 miles by wagon road from the Union Pacific Railroad at Walcott, Wyo. From Encampment all parts of the region are accessible by wagon roads, though the southwest corner of the district is more easily reached from the south by way of the valley of Little Snake River.

TOPOGRAPHY.

Topographic map.—The topographic map (Pl. I, in pocket) of the quadrangle was made in 1901, by Frank Tweedy, topographer of the United States Geological Survey, and is used as a base for the geologic map (Pl. II, in pocket) accompanying this report. Several additions to the original drawing have been made, mainly from the geologists' notes. These additions comprise two important wagon roads—the one from Encampment to Hog Park, in so far as it is new, and the Tram road, together with the line of the aerial tram. The latter is plotted from a blue print obtained through the courtesy of Messrs. Emerson & McCaffery, of Encampment.

The position of the area and the elevations are based upon a line of levels carried from the bench mark of the United States Coast and Geodetic Survey, at Laramie, Wyo.

The topography is shown by three colors—brown for the contour lines, representing intervals of 100 feet; blue for the streams and lakes; and black for such data as boundaries, roads, houses, and names. The scale of the map is 1 to 90,000, or approximately 1½ miles to the inch.

Description of the area.—The Encampment district is crossed diagonally from southeast to northwest by the irregular line of the Continental Divide, which is the crest of the Sierre Madre. The waters which fall upon the eastern and northern

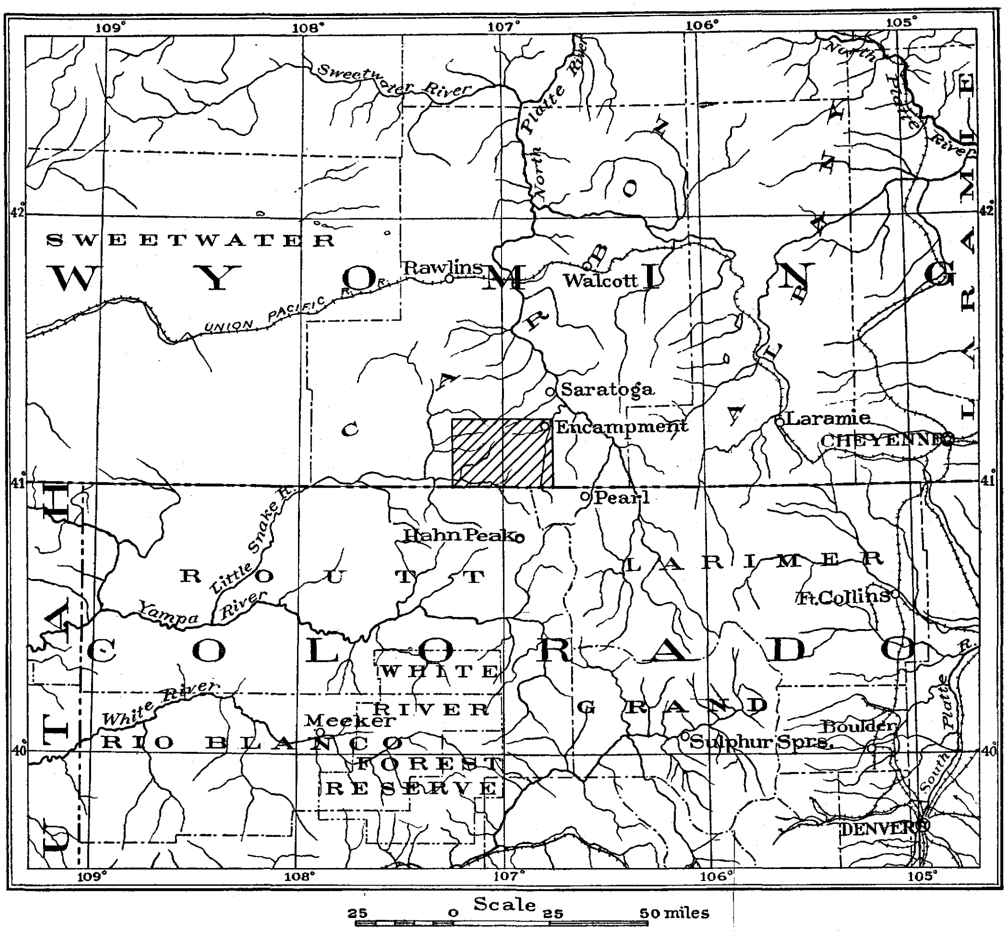

FIG. 1.—Index map showing location of the Encampment district.

side of the mountains flow to the North Platte by way of Encampment River and Cow, Spring, and Jack creeks; while the drainage of their southwestern face finds an outlet by way of Little Snake River and its tributaries, Battle, Sandstone, and Savery creeks.

The minimum elevation indicated is about 6,650 feet, while the greatest altitude, which is reached by Bridger Peak, is 11,007 feet. The local variations in elevation are by no means slight, but the topography as a whole is of a subdued type. Steep slopes are confined to the middle courses of a few of the main streams and to a few basins or amphitheaters near the main divide, which were formerly occupied by glaciers.

The mountain summits along the main divide are generally broad and form an upland surface the elevation of which varies from 9,200 feet in the lowest pass to 11,000 feet on the highest summit. The steep declivities near the heads of opposite streams on the two sides of the divide are often a mile or more apart, and the effect of breadth is emphasized by the frequent continuance of the summit level out onto lateral ridges for several miles. The high portion of the range thus presents the appearance of an elevated plateau, incompletely dissected by existing streams.

Many of the ridges between the streams which cut back into the heart of the mountains decline gently toward the main valleys, and are readily approached from the lowlands. In general character, therefore, the topography is subdued, rather than rugged, and consequently wagon roads have been easily constructed in almost every portion of the area without the excessive expense which often attends the opening of transportation routes in elevated regions.

HISTORY.

The first serious attempt to develop the mineral resources of the Sierra Madre region seems to have followed the discovery, in 1872, of quartz veins on the ground now held by the Kurtze Chatterton Company. According to Mr. Frank O. Williams, of Saratoga, the veins were first noted in 1868 by J. W. Southwick, but no work was done upon them, and it is stated by Mr. Boney Ernest, of Ferris, Wyo., that in the year mentioned Tom Sun and himself located four claims at this place, and that two years later a fifth claim was taken up by Bill Savage. Assessment work was done on these claims until the year 1876, when they were surveyed and application was made for patents. However, the issue of the desired patents was delayed, and the enterprise was abandoned by the original locators, but the claims were relocated several years later by Kurtze Chatterton and held until they were purchased by the company which bears his name.

Mr. Ernest is also authority for the statement that the ground of the present Doane mine was originally located in 1874 by a man named Harper, who endeavored to find the vein from which a large amount of copper-bearing float had been derived. A 10-foot hole was sunk, but the property was soon abandoned. In 1881 it was taken up by George Doane and others associated with him. Gossan containing copper carbonates was found in place and followed to a depth of 75 feet, where copper glance was encountered, leading to the first systematic mining in the region. Since the discovery of valuable ore the mine has been in operation at intervals, and is active at the present time.

In 1876 silver-lead deposits carrying some gold were discovered by Frank O. Williams on the Bridger group of claims, near the Continental Divide, several miles north of the area mapped on Pl. I. Considerable development work was done, but the ores were not found to be sufficiently rich to be mined at a profit under existing conditions. The Charter Oak copper mine, which has produced some good ore, was also discovered by Mr. Williams, and developed by him and his partner, Henry Jones. It was purchased from them by the Charter Oak Company.

No other properties seem to have come into prominent notice until 1896, when some large bowlders containing free gold were discovered by Al. Huston and Ben Cullerton in Purgatory Gulch. The actual source of these bowlders seems never to have been found, though some small veins carrying gold were located.

This discovery of gold seems to have started the present interest in the region, though the search for gold soon gave place to prospecting for copper.

The Ferris-Haggarty, or Rudefeha, as it was formerly called, is the largest mine of the region, and though it has been producing rich ore since 1899, it still contains large ore reserves. The property was located in 1898 by Ed. Haggarty, and was operated by a Wyoming company until the summer of 1902, when it was purchased by the North American Copper Company. This company also owns or controls concentration and reduction works located at Encampment, and an aerial tramway 16 miles in length connecting them with the mine.

No producing mines have been developed since the discovery of the Ferris-Haggarty, but careful exploration is being carried on by well-equipped operators at several places, and the value or worthlessness of a number of more or less promising prospects will soon be determined in a practical way.

PART I.—GENERAL GEOLOGY.

CHAPTER I.

GENERAL DESCRIPTION.

GEOLOGIC MAP.

The topographic map of the Encampment quadrangle serves as a base for the geologic map accompanying this report (Pl. II, in pocket). On it the different formations are represented by distinct colors and patterns, the significance of which may be determined from the legend. Geologic cross sections are also given to indicate the general structure.

In collecting the data for the geologic map the greater amount of study was given to the northern portion of the district, including the whole of the quartzite belt in which the principal mines are located. For the southern portion, comprising the areas covered by the volcanic series and the red granite, such detailed work was deemed unnecessary.

PRELIMINARY OUTLINE OF GEOLOGY.

The rocks which occur in the Sierra Madre belong for the most part to the oldest pre-Cambrian formations of the Rocky Mountain region, but comprise as well formations of Mesozoic and Tertiary age, and surficial deposits of glacial or fluviatile origin.

The rocks of the pre-Cambrian complex form the main mass of the mountains, while the Mesozoic formations outcrop on the foothills on either side and dip away beneath the surrounding prairie. The general structure is thus a low arch or anticline, the axis of which is parallel with the mountain crest. The gradual uplift of this arch was accompanied by general erosion, which removed the Mesozoic rocks from its axial portion and revealed the ancient formations below. The pre-Cambrian formations comprise both sediments and igneous rocks. They had been closely folded and eroded long before the deposition of the Mesozoic strata upon their upturned edges, and the uplift which produced the Sierra Madre occurred as a still later event in the series of geologic changes.

While the effects of this arching upon the Mesozoic sediments are readily discernible, they can not be recognized in the pre-Cambrian rocks, because of the previously acquired complex structures and metamorphosed condition of the latter.

The sedimentary portion of the pre-Cambrian series forms a system of nearly east-west folds transverse to the trend of the range and to the axis of the post-Mesozoic arch. Certain of the igneous rocks are older than the sediments, and have been folded with them. Others were intruded later and so were unaffected by the earlier movements.

The older igneous rocks are thus greatly metamorphosed, and some of those intruded after the principal folding have also been subjected to a high degree of alteration.

The metallic deposits of the Sierra Madre are almost entirely confined to the pre-Cambrian formations. For this reason a description of these rocks and their mutual relations must precede any account of the nature, occurrence, and distribution of the metallic ores. First, however, the overlying unmetamorphosed sedimentary formations of the Mesozoic will be briefly described.

DESCRIPTION OF THE MESOZOIC AND LATER FORMATIONS.

The Mesozoic rocks of the Encampment district are confined to the southwest corner of the area mapped, where they occur well down in the foothills, outcropping along lines nearly parallel with the crest of the range and dipping rather steeply toward the west or southwest. Their distribution is indicated on the geologic map.

The "Red Bed" series of the Triassic is the oldest unmetamorphosed formation present, though Upper Carboniferous rocks are known to occur at no great distance in the Elk Mountains. The "Red Beds" have an aggregate thickness of about 1,200 feet and are made up of sandstones and limestones with occasional beds of coarse conglomerate. They are characterized by the brilliant red color typical of equivalent strata throughout the Rocky Mountains.

The "Red Beds" are usually overlain by alternating shales and sandstones, regarded as equivalent to the fresh-water Jurassic of the Front Range in Colorado, but locally limestone occurs between these formations in the form of lenses having a maximum thickness of 35 feet. This limestone contains marine Jurassic fossils in great abundance. The total thickness of the Jurassic is approximately 400 feet.

The Jurassic beds are followed in turn by the Dakota sandstone, the Colorado and Montana groups of shales and sandstones, and the Laramie formation. The Montana and Laramie contain many beds of coal, some of which have proved to be of good quality and of workable thickness.

The following analysis of coal from the Carbondale mine was made in the laboratory of the Geological Survey by Dr. E. T. Allen:

Analysis of coal from Carbondale mine, sec. 18, T. 13 N., R. 87 W.

Moisture	3.56
Volatile combustible matter	42.36
Fixed carbon	49.06
Ash	5.02
Total	100.00

The coal is bright, clean, and noncoking. It is now hauled to Rudefeha for use at the Ferris-Haggarty mine, and it is also sent by tramway to Encampment.

In the southwestern portion of the district thick deposits of Tertiary conglomerate overlap the upturned and beveled edges of the Mesozoic rocks. These conglomerates, which have a nearly horizontal position, are known to be present over a considerable area west of the region studied, and they have been mapped under the name Wyoming conglomerate, in accord with the usage of the Fortieth Parallel Survey.

The importance of glacial and other recently formed deposits lies mainly in the fact that they locally hide the bed-rock formations. Surficial deposits which have originated in various ways are represented on the map as Pleistocene.

PRE-CAMBRIAN FORMATIONS.

The pre-Cambrian rocks comprise a variety of types, including those of sedimentary, igneous, and metamorphic origin. They may be conveniently divided into bedded and igneous rocks. The first class will then include, in order of age, (1) a series of hornblende-schists derived from bedded volcanic rocks, (2) a formation made up of limestones and shales, (3) a quartzite and slate formation, and (4) a heavy conglomerate. The second class will include quartz-diorites, granites, and gabbros, and other rocks of igneous origin, together with both massive and gneissic rocks derived from them by metamorphism

In the Encampment field the quartzite and slate formation is more in evidence than any other of the bedded rocks, but all occur in a limited area having the form of a narrow triangle, with its apex on the Encampment River about 5 miles south of Encampment, and its base, about 7 miles wide, in the foothills on the west side of the range. The belt of quartzites and associated strata is exposed for about 20 miles, but on the west their extent is not known, since they are overlapped by younger formations.

The rocks within the sedimentary belt strike in general nearly east and west, and they seem at first sight to have an enormous thickness, since they dip almost invariably toward the south. However, the recurrence of easily identified beds of conglomerate associated with the otherwise monotonous slates and quartzites has led to the recognition of an east-west synclinorium, composed of several minor folds, closely appressed and overturned toward the north, so that the strata on opposite limbs of all the folds dip in the same southerly direction, producing what is known as isoclinal structure.

The formations of the sedimentary belt are intruded throughout by basic igneous rocks related to gabbro, of later origin than the folding. Similar masses also occur between the stratified rocks of the synclinorium and the outside granites, gneisses, and schists, effectively obscuring their relations.

On the north gray quartz-diorite occurs in large masses, intruded, however, by great amounts of the same sort of gabbro rock which has invaded the sediments, and also by coarse red granite and by dikes of aplite or pegmatite. The quartz-diorite usually has a platy or gneissic structure, which follows the same trend as the strike of the quartzites, and which has controlled the distribution of the invading rocks in parallel east-west dikes. It appears to be the oldest of the intrusive igneous rocks.

On the south the main country rock is red granite, though quartz-diorite and gabbro also occur; all are intrusive into hornblende-schist. The red granite is usually a coarsely crystalline rock which seldom shows gneissic structure. Where it occurs with the gray quartz-diorite the latter is intruded by it.

The oldest rocks of the limited region here under discussion are the hornblende-schists, which have been classed with the bedded rocks. On the north side of the synclinorium, west of Bridger Peak, the only place where they are known to occur in contact with the sedimentary rocks, their well-marked schistose structure runs parallel with the bedding of the quartzite adjacent, striking nearly east and west, and dipping toward the south, so that the series passes beneath the quartzite as though forming the bottom of the great trough-like fold or synclinorium. The size of this northern patch of hornblende-schist is limited, for it has been invaded by large masses of quartz-diorite, and by dikes of the later gabbro. No hornblende-schists are found north of the eastern half of the synclinorium, the quartzites being separated from the gneissic quartz-diorite by masses of gabbro.

South of the sedimentary belt the hornblende-schists occur more extensively, but they are separated from the quartzites either by red granite or by gabbro. The structure of the schist and the strike of the igneous contacts, on this side as on the north, are in general parallel with the east-west lines of the sedimentary formations, but the dips are steeper and not constant in their direction.

In the pre-Cambrian areas of the general region igneous rocks similar to the quartz-diorite, granite, and gabbro of the Encampment district cover more ground than the bedded formations. Next to them in extent come the hornblende-schists, which are older than all of the igneous rocks thus far recognized, while the quartzites and associated strata are of the least importance.

The synclinorium in the pre-Cambrian sedimentary formations of the Encampment district is enveloped by a complex of metamorphic schists and intrusive igneous rocks. The structural relations between the sediments and the outside formations suggest that the former are all younger than any of the latter except the intrusive gabbros. It is believed, therefore, that the hornblende-schist, with its intrusive rocks, originally formed a basement upon which the sediments were laid down. All the basement rocks must then have taken part in the downfolding by which the synclinorium was produced. Folding was, however, greatly complicated by faulting, and probably all the contacts now observed between the sediments and the older rocks are fault contacts along which the invading gabbro found easy lines of intrusion.

In different parts of its cross section the sedimentary portion of the synclinorium comprises from three to seven closely appressed synclines, with anticlines between. Thus the limestones, quartzites, slates, and conglomerates, with the masses of gabbro which have invaded them and have been controlled by their structure, appear at the surface in parallel bands striking east and west parallel with the axis of the great fold. The number of folds increases from east to west with the widening of the sedimentary belt, but the depth of the great fold is greatest in the central portion of the belt. Here the conglomerates are exposed in two synclines, which merge toward the east and finally disappear as a result of an upward rise of their axis, assisted by faulting along the strike.

Outside of these two bands there is often difficulty in following individual folds, but prominent groups of strata in the quartzite-slate formation may be traced for several miles in certain cases, and one band of slate probably occurring in a syncline can be traced with practical continuity throughout the whole length of the belt.

The limestone formation is best exposed along an anticlinal axis near the south side of the synclinorium, but its outcrop is interrupted several times by pitching of the fold along its trend. Evidence of rising and falling along other folds is seen in several limited areas of the limestone which has been locally brought up from beneath the quartzite and exposed by erosion.

The southern half of the anticlinal just mentioned is cut off south of Rambler town site by a strike fault which brings its northern limb in contact with the red granite occurring south of the synclinorium. Eastward from this place there is no quartzite between the limestone and the granite as in the vicinity of Copperton and in Quartzite Peak. This fault is one of many which follow the general strike of the sedimentary rocks and cause numerous complexities of structure. The anticline of quartzite which passes through Bridger Peak is cut out on the north side of Cow Creek by such a strike fault. Again, between Bridger Peak and the upper parts of Cow Creek and North Spring Creek two great faults, having a general parallelism with the bedding of the sedimentary rocks, bring the underlying hornblende-schists in contact with the conglomerate which occurs at the top of the bedded series. Doubtless many strike faults exist which have not been recognized because rocks of similar appearance have been brought together.

Besides the strike faults there are transverse breaks, which sometimes produce north-south offsets of the strata. Marked displacements are rare, but those which have been noted are parallel to a very general system of jointing observable throughout the district. In the quartzites and in the basic intrusives north-south fractures are frequently filled with quartz, forming more or less continuous veins, and in both the Doane and the Ferris-Haggarty mines breaks belonging to this system have a very close bearing upon the origin of the ore bodies.

CHAPTER II.

THE BEDDED ROCKS.

HORNBLENDE-SCHISTS.

The oldest bedded rocks, and possibly the most ancient of all the rocks of the Encampment region, are hornblende-schists or hornblende-mica-schists derived by metamorphism from volcanic lavas and fragmental tuffs.

As they now exist, the rocks of the series are typical fine-grained dark or black schists composed principally of hornblende and quartz, or hornblende, mica, and quartz, with epidote and zoisite in almost constant occurrence, and frequently containing garnet, calcite, and more rarely feldspar and magnetite.

The cleavage of the schists varies somewhat in its perfection, but is usually strongly developed. Under the microscope the schistose structure is found to be due to the arrangement of the minerals in alternating parallel plates of quartz and dark minerals. The hornblende needles usually have their long dimensions in the plane of schistosity, though in this plane they have no definite orientation. The mica flakes commonly lie parallel to the platy structure.

Considering that the schists are believed to have been derived from igneous rocks, which usually contain large amounts of feldspar, the almost complete absence of this mineral from the schists is noteworthy. In possible explanation of this fact it may be suggested that the rearrangement of material attendant upon metamorphism has been so complete that the feldspar originally present has been broken up into its constituents and, through metasomatic changes, its substance now enters into the composition of the freshly crystallized hornblende, mica, and epidote or zoisite, leaving a residue of silica in the form of quartz, which was not present in the original lavas.

In those instances where feldspar still remains it is present in granular aggregates of small crystals similar in morphology to the secondary quartz which is universally present. Without exception it has been entirely recrystallized and probably also changed chemically, so that it is of a different species from the feldspar which existed in the unmetamorphosed rock.

The original characters of the surface volcanics can seldom be recognized in the present condition of the rocks because of their complete recrystallization, but this origin of the schists is suggested by the uniform nature of the metamorphic product. The composition of different layers in thick accumulations of lava flows and volcanic scoria often varies but little, however great the variations in texture, and the metamorphism of such a volcanic series would give a homogeneous mass of schist without important minor variations. Moreover, the original nature of the schists is shown by the occasional preservation of amygdaloidal structure, which is regarded as characteristic of surface lava flows, and the occurrence of layers composed of angular fragments, which closely resemble volcanic tuffs. The original rocks seem to have been andesites and andesite tuffs.

The bedded nature of the series is indicated by the occurrence at several places of a few thin, though persistent, strata of sandy shale and impure limestone; by the fact that the layers of amygdaloid and breccia lie parallel to these strata when they occur in sufficient proximity for comparison, and by a general parallelism between these features and slightly varying tabular masses within the rather homogeneous schist. When the bedding recognized in this way is compared with the secondary platy structure produced through recrystallization, it is found that the two are practically parallel, and, as a rule, schistosity can therefore be taken to represent the stratification of the schists. A similar relation exists in the overlying formations whenever they possess secondary platy structure, and, in general, stratification and schistosity in the entire sequence of bedded rocks are found to be parallel features.

In the central part of the district, south of the sedimentary belt, andesites and granite-porphyries, which are in a relatively unmetamorphosed condition, are associated with the hornblende-schists. Original flow structures are often discernible in the porphyries, and, though they are not entirely fresh, they are seldom crushed or recrystallized. The andesites are greatly changed from their original condition, though their igneous character may still be recognized under the microscope. It is suggested that they may be similar to the great masses of volcanic flows which have been so generally altered to hornblende-schists, though this is an inference which can not be definitely proved, since the mineralogical composition of the schists gives but little clue to the exact nature of the rocks from which they were derived.

The alteration which produced the schists is of the sort ordinarily attributed to regional metamorphism, and while it can not be definitely proved that the transformation was not produced during the folding and crushing of the younger pre-Cambrian sediments of the region, the completeness of recrystallization in the schists suggests that they may have been independently metamorphosed at an earlier date.

There is indirect evidence that an unconformity of erosion exists between the hornblende-schists and the other formations which have been folded down to form the great synclinorium, but all of these rocks have been crushed together in the process of folding, and in the few places where the contact is exposed the schists pass beneath the great fold, with the quartzites and associated clastic rocks lying upon them in apparently conformable position.

The hornblende-schists are cut by rocks of all the principal massive types occurring in the region. This fact points to the great antiquity of the schists and forms the basis of the supposition that the younger bedded formations are really uncomformable upon the older volcanic series, for the gray granites are not known to cut any strata above the schists, and even the red granites, which are of later origin than the gray, can not be found cutting the later sediments of the pre-Cambrian, excepting in a few unimportant dikes, which, though similar to the granite of the main masses, are possibly of a much later date. It seems, therefore, that the greater part of these intrusions of granitic rock took place before the deposition of any of the sediments which lie above the metamorphosed volcanic series, and it is probable that a long interval ensued after the intrusions and before the younger rocks were formed.

The hornblende-schists often contain sulphides of iron and copper in small amounts in the form of disseminated grains or lenticular impregnations. At several places they have been found to yield promising amounts of metallic minerals, as at the Creede property, and at other localities on the north side of the quartzite belt in the head of Spring Creek, at the Sun Anchor and other prospects on the north slopes of Green Mountain, and at the Verde, located several miles farther south. At each of these localities there is an evident connection between the metamorphism of the country rock and the genesis or origin of the ores which have been discovered. These features will be discussed under the description of the properties mentioned and in the statement regarding the origin of the ores.

The general distribution of the schists is indicated upon the geologic map, though the representations of its extent in the different portions of the district are not equally accurate. The area upon the north side of the divide near the head of Spring Creek is, however, well shown, though the boundary between it and the gray granite-gneiss which occurs to the north is hidden by a mantle of débris.

In the vicinity of the tunnel of the Battle Lake Tunnel Site Company, and extending eastward into the head of Cow Creek, there is a patch of schists lying between two bands of the conglomerate which belongs at the top of the pre-Cambrian formations. This relation can be explained upon the supposition that there are two faults of great throw, between which the underlying schists have been forced up into the very center of a syncline in the pre-Cambrian sediments. The schist is in every respect similar to that which occurs near the Creede mine, but the two areas are separated by an intrusion of diorite, as shown upon the map. Reference to the sections which indicate the natural order of succession of the bedded formations will show that in order to bring schist and conglomerate together the displacement along the faults which limit the block must have been at least as great as the entire thickness of the formations between the strata which come into contact. The actual movement upon the faults, however, greatly exceeded this amount, since the breaks form low angles with the bedding planes of the deeply folded formations.

The boundaries of the schist areas just south of the middle of the district are closely represented, but the massive porphyries and partly altered andesites have not been distinguished from the entirely metamorphosed rock. In the south-central region the distribution is greatly generalized, for here there is locally an intricate penetration of the schists by dikes of granite and by masses of diorite (metagabbro), neither of which have been distinguished.

LIMESTONE.

The second formation in point of age comprises massive limestones and associated shales. Where it is composed almost entirely of limestone its maximum observed thickness is about 200 feet, but where the shales partly displace the limestone it is usually somewhat thinner. Measurements are often difficult and unreliable, because of strike faults which cut out a portion of the normal section. As a rule these strike faults and the invading igneous rocks greatly obscure the stratigraphic relations of the formation. This is especially true in regard to the base of the formation; but since the hornblende-schists show a greater degree of metamorphism than the limestone, and are intruded by rocks which do not cut the sedimentary formations, there is probably a great unconformity of erosion between the schists and the limestone. In the few places where the relations of the quartzite and the limestone can be observed the former arch over the latter, and their bedding planes are strictly parallel.

The principal outcrops of limestone occur along an anticlinal fold, which can be traced from Big Sandstone Creek eastward to Encampment River. From Big Sandstone Creek to Battle Creek both limbs of the anticline are present, and the overlying quartzite occurs on each side of the limestone whenever it appears at the surface. Eastward from Battle Creek the southern half of the fold has been cut out by faulting or intrusion, and the limestone comes in contact with the igneous rocks outside the synclinorium.

Two small areas of limestone which occur north of the main belt have been brought up from beneath the quartzite by local doming along other anticlines.

The distribution of the formation and its structural relations are shown by the geologic map and cross sections (Pl. II). As a rule the limestone has been but slightly altered either by pressure or by the influence of igneous rocks. In a few places it has been recrystallized and its impurities have segregated into knots of silicate minerals, leaving the carbonate of lime in a granular form. This feature is well illustrated in the patch of limestone which occurs in Nellie Creek, northeast of Battle; and in the case of a thin limestone stratum which is locally developed about 1 mile northwest of Elwood post-office the impurities have separated in the form of well-defined crystals of green hornblende. As a whole the limestone has been less metamorphosed than would be expected in a region so greatly disturbed, and the changes which have taken place are less apparent to the eye than are the alterations in the other sedimentary rocks. At many places it seemed so unaltered that it was carefully searched for fossils, though without success.

The limestone has nowhere been found to be strongly mineralized, though it has been explored in many places.

QUARTZITE AND SLATE.

The third formation of the bedded rocks, and the most prominent as a feature of the region, is mainly composed of two sorts of rocks—massive quartzites and slates derived from shales. These occur in frequent alternation to a minimum thickness of about 1,000 feet, though this figure is largely a matter of estimate with the possibility that it should be doubled.

In the lower part of the series beds are frequently found which contain small rounded pebbles of red granite, showing that crystalline rocks were exposed to erosion somewhere in the general region at the time the quartzite was deposited.

The quartzites are sandstones which have been silicified through the deposition of silica throughout their mass. They are uniformly of a vitreous nature, and though varying in color from place to place, are usually white. Generally the silicification has been so complete and has been accompanied by recrystallization to such a degree that the quartzite has the appearance of vein quartz. In such instances it is usual to find minute crystals of feldspar, resulting from the recrystallization of arkose material derived from the igneous rocks which furnished the quartz sand for the original sandstone.

Both the bands of slate and of quartzite run parallel with the general trend of the country, but the internal structure of the folded complex is still undetermined, though it is apparent that individual beds are several times repeated. The quartzite beds occur in east-west reefs, which seldom form prominent topographic features, but are striking to the eye because their whiteness brings them into sharp contrast with the associated rocks, and especially with the black diorite or metagabbro.

The series has not been subdivided upon the geologic map because the complete separation of the quartzite and slate would have involved the expenditure of more time than was available, but their combined distribution is clearly indicated, together with their relation to the bands of limestone and conglomerate and the intrusive masses of diorite. The cross sections still further illustrate these relations and indicate diagrammatically the complex way in which they have been folded.

Locally a portion of the upper beds of this series seems to have been removed by erosion previous to the deposition of the overlying conglomerate.

Quartzite is the country rock of the ore bodies at the Ferris-Haggarty and Doane mines, the most important thus far developed in the district, and sulphides occur in it at many places, so that it has been very generally prospected.

CONGLOMERATE.

The fourth and youngest series of the pre-Cambrian is composed of massive beds of conglomerate resting unconformably upon the quartzite-slate series. The component pebbles or bowlders are gray granite, hornblende-schist, and quartzite. The granite pebbles are similar to the gray granites which cut the volcanic series, especially to the north; but the red granite, which outcrops in large amounts south of the clastic belt, does not seem to occur, though careful search was made for it at many points. The schist pebbles were doubtless derived from the old metamorphosed volcanic rocks already described, and the quartzite doubtless from the strata which immediately underlie the conglomerate. The proportions of these pebbles indicate that granitic rocks exposed to erosion contributed the greatest amount of material to the formation, while the volcanic rocks and quartzite furnished a relatively small amount of detritus.

The conglomerate formation has a maximum observed thickness of about 700 feet, though it often appears to be thinner, this being sometimes due to partial cutting out by faults rather than to an actual decrease in the mass originally deposited.

Locally the conglomerate seems to have been little changed from its original condition, but as a rule it has been metamorphosed, and often to such an extent that its original characters are masked or entirely obliterated. This metamorphism has been both mechanical and chemical, and the rock has often acquired marked schistose structure due to the mashing of the granite bowlders and pebbles into disk-like plates. By recrystallization, feldspar, hornblende, and garnet have been formed from the pebbles and interstitial material, and in extreme phases the conglomerate has been converted into gneiss, so distinct in its aspect that its origin would be entirely indeterminate except for the observation of complete gradations into the unaltered rock.

The distribution of the conglomerate and its derived gneisses in two parallel bands uniting toward the east is well shown on the geologic map, together with its surface relations to the intrusive diorite and to the quartzite upon which it was originally deposited. Its preservation from erosion results from two deep synclinal folds, the opposite sides of which have been pressed together and overturned toward the south.

In certain localities, where the conglomerate has been much crushed, quartz veins containing metallic sulphides have been found, following the gneissic or platy structure of the inclosing rock, and in some instances copper sulphides without quartz have been deposited in small amounts along planes of movement parallel to the schistosity. The diorite masses inclosed in the conglomerate have been locally prospected for copper, but so far as known without encouraging results.

CHAPTER III.

THE GABBRO ROCKS AND THEIR METAMORPHIC PRODUCTS.

GENERAL DESCRIPTION.

The rocks to be described in this chapter comprise all the dark intrusives which occur in the Encampment district and pass under the name "diorite" as locally employed. They are found as a rule in relatively small masses, frequently having the nature of intercalated sheets in the bedded rocks of the pre-Cambrian, but they occur also as intrusions in the other rocks of the area. Their field relations and petrography indicate that the different and separated bodies of dark rock were all intruded at the same time, subsequent to the period in which the bedded formations were folded, faulted, crushed, and partly recrystallized. Other dark rocks intruded before this period may be present in the district, but they have not been récognized in place, and their existence is only surmised from a few pebbles of basic rock occurring in the conglomerate of the bedded series, which may indicate that there were earlier intrusions in the basement rocks of the region, though these fragments may readily have been derived from the underlying volcanic series.

The rocks are dark colored, of variable though usually fine grain, tough, hard, and of a fresh appearance in outcrops. As observed in the field considerable variation in mineral composition is to be noted, and such general types as gabbro, diorite, and serpentine may be distinguished. More minute study with the microscope bears out this classification, and not only shows the presence of several well-marked rock species, but reveals the fact that most of the original rocks have been very greatly metamorphosed, the occurrence of the rocks in their original unaltered state being extremely rare. Out of nearly 200 specimens collected to represent these rocks, only 8 or 10 are practically fresh, and but one is entirely unchanged as regards all of its constituent minerals.

From a study of the relatively fresh material, together with the partly altered and entirely metamorphosed specimens, it is known that the original rocks occurred in three related types or facies of gabbro. The intermediate type, which is the only one which has been found in a fresh state, is norite; the basic type was olivine-norite or peridotite; and the most siliceous facies was a gabbro, or possibly norite, containing pyroxene and oligoclase feldspar, either alone or together with labradorite like that of the norite.

The metamorphic products of the several portions of the original rock are serpentine and hornblende-feldspar rocks similar to diorite in mineral composition, together with others composed of hornblende, quartz, and epidote, in which the original feldspar has been entirely destroyed.

Traces of copper were found in all of the 18 selected samples representing the outcrops of the various varieties of the dark intrusive rock which were tested.[a] From this it may be inferred that the gabbro rocks contain a small amount of this metal in all parts of the field, and since it occurs in fresh and altered rocks alike, it is probably an original constituent of the magma, and the source of many of the segregations of copper minerals present in the other rocks of the region.

NORITE.

Practically fresh norite was collected near the Elkhorn mine, about 1 mile west of the Verde location, at the Octavia property and at the Creede tunnel, and between Bridger Peak and the head of Cow Creek. The mineralogic composition of the specimens from these localities represents the original character of much of the rock which elsewhere has been changed to diorite. The norite has a fine-grained, evenly granular structure. All of the specimens examined contain orthorhombic pyroxene, mainly hypersthene, as their principal constituent, with a variable though somewhat subordinate amount of labradorite feldspar. Biotite is of frequent occurrence, and when present has titaniferous magnetite associated with it. A few grains of quartz are present. Olivine was not observed in any of the fresh rocks, though present in many cases where considerable alteration has taken place. In most of the specimens a small proportion of the hypersthene has been altered to the common secondary mineral bastite, and the pyroxene is sometimes surrounded by narrow bands of secondary hornblende. The feldspar is usually fresh, though it has a clouded appearance, due to minute inclusions, the nature of which is not revealed by the highest powers of the microscope.

In partly metamorphosed examples of norite the pyroxene has usually been more readily altered than the feldspar, though there are exceptions to this rule in which the feldspar has been almost completely changed and pyroxene only partly altered. In those instances where the pyroxene has been converted to hornblende and feldspar still remains, the rock acquires the composition of diorite, while the final product of change due to deep-seated metamorphism, without the added effects of hydration brought about by atmospheric weathering, is a rock composed of hornblende, epidote or zoisite, and quartz. Numerous examples of this rock are found throughout the region. A specimen of fresh norite collected near the head of Cow Creek, on the north slope of Bridger Peak, was analyzed in the laboratory of the Geological Survey by Dr. E. T. Allen, with the result which is given in Column I of the table of rock analyses on page 32.

PERIDOTITE.

The rock known as peridotite is closely related to norite, from which it differs in containing a smaller proportion of feldspar and hypersthene, the place of which

[a] These tests were made by Dr. E. T. Allen in the chemical laboratory of the Geological Survey by a method excluding the possibility of copper having been introduced from outside sources.

is taken by olivine. In many areas all gradations between norites containing no olivine and peridotites composed almost entirely of the latter mineral are observed, and more careful observation than has been possible in the present fieldwork might show a complete series between the two types. However, from the relations already known, there can be no doubt that the peridotites and norites of the Encampment district were derived from the same rock magma, and that the differences observed in the secondary rocks derived from them are based upon original local differences in the composition of the primary intrusions. The peridotites do not occur as large masses in a fresh state; they have been almost completely changed to serpentine, though sufficient specimens in which the change has been only partial have been examined to definitely show the original fine-grained granular structure and the mineralogical nature of the unaltered rock.

OLIGOCLASE-GABBRO.

A third facies of the original intrusive rock related to the norite no longer exists in an unaltered state. Its partly metamorphosed products show that it contained oligoclase as its principal feldspar instead of the labradorite which is characteristic of the norite and peridotite. Examples are not wanting to show that there were intermediate types between this and the normal norite. The feldspars of this rock are usually much altered, but sometimes show relatively fresh remnants, surrounded by aggregates of sericite and quartz. The presence of pyroxene in the original rock is not certainly known, since nothing but hornblende is now found, but the evident relationship with the other members of the gabbro family furnishes strong ground for the inference that this was the nature of the dark mineral. If so, it may have been either hypersthene, as in the norites, or diallage, which is the pyroxene forming the ordinary dark-colored constituent of normal gabbros as distinguished from norites.

The feldspar crystals in the rocks intermediate between this type and the norites frequently show zonal growths, with oligoclase upon the outside and labradorite within.

As in the case of the norites, the moderate metamorphism of the oligoclase-gabbros has resulted in the formation of a rock with the mineralogic composition of diorite, and changes more complete have produced hornblende rocks in which the original feldspar has been entirely destroyed, with the formation of epidote and quartz.

METAGABBRO, OR "DIORITE."

By definition diorite is a wholly crystalline granular rock made up essentially of hornblende and plagioclase feldspar. True diorite occurs as the result of original solidification of molten rock material, but rocks of the same composition are often derived—as in the Encampment district—by the metamorphism of rocks whose dark constituent is some variety of pyroxene. When of this origin they are properly called metagabbros, a term devised to indicate that they are altered gabbros. The metagabbros of the Encampment district are not distinguishable from true diorites by the unaided eye nor with an ordinary magnifying glass, and resident mining men commonly use the latter term for a variety of dark rocks more or less specked with white. While the present investigation has shown that none of the rocks can be strictly classed as diorites, and that many of them are essentially different from diorite in mineral composition, the present usage is a convenient one, which may well be continued.

Several types of these dark rocks have already been described under the names appropriate to their original mineralogic composition; the secondary diorites have also been incidentally mentioned, and their metamorphic derivation indicated. They are fine-grained black or gray granular rocks composed of hornblende and feldspar or minerals derived from decomposition of the latter. Mica frequently occurs accompanied by titaniferous magnetite and titanite; epidote and its iron-free relative, zoisite, are always present as secondary products, while calcite and chlorite, though present, are less often found.

Schistose structure, which is of almost constant occurrence in all of the older sedimentary formations and in certain of the crystalline rocks, is practically absent from the gabbro rocks and their metamorphic products. This fact alone would be sufficient to show that the dark intrusives originated subsequent to the production of the parallel structures of the older rocks, but this is independently proved by the manner in which the invading dikes follow the stratification and schistose structure of the folded formations. The examples of schistosity observed are confined to small masses of the secondary diorite, in which, as a result of irregular transmission of pressures due to heterogeneity, local strains were produced by earth movements probably much less revolutionary than those which had previously folded and mashed the quartzites and associated strata.

No extended discussion of the mineralogic changes observed in the passage of these gabbro rocks into metagabbros will be attempted in this place, and it must suffice to recapitulate the statements already given of what these changes have been.

In the least altered of the rocks free from olivine, pyroxene has been the only mineral attacked. Here it may be only partly changed to hornblende, or it may be entirely replaced by that secondary mineral. Epidote is always found as a side product of the hornblende formed in this way. Its presence may be readily explained by the well-known fact that the percentage ratio of magnesia to lime in hornblende is greater than in pyroxene; consequently if all of the magnesia of the pyroxene is taken up by the hornblende, there is a residual of lime.

Furthermore, the hornblende molecule contains a smaller ratio of silica, which, being likewise liberated, combines with the lime and a small amount of iron derived from the pyroxene and forms epidote.

The first decomposition of the feldspar results in the development of a few small needles of zoisite or epidote distributed through the crystal. This change involves the liberation of alumina, which, being needed in the hornblende, has doubtless been taken up by that mineral. Further alteration shows a progressive increase of the zoisite or epidote until finally an aggregation of these minerals inclosed in quartz completely fills the space originally occupied by the feldspar.

In proportion to the extent to which these secondary minerals have been formed, the rock has been partly or completely recrystallized. It may therefore be concluded that the observed metamorphism has resulted from internal reactions between the original minerals, involving molecular transfer and interchange of substance with the formation of new mineral combinations. A comparison of the original and secondary minerals shows that there has been no important gain or loss of material, an indication the value of which is greatly increased by the similarity of the bulk analyses of fresh and altered types of rock here appended.

Analyses of norite and other rocks from the Encampment district.

[Analyst, E. T. Allen.]

	I.	II.	III.	IV.
SiO_2	52.00	50.03	50.20	46.39
Al_2O_3	11.59	10.89	15.54	16.17
Fe_2O_3	2.72	2.32	2.14	2.65
FeO	7.18	7.99	6.49	9.30
MgO	12.87	11.84	7.33	8.58
CaO	10.49	9.73	11.96	8.90
Na_2O	1.06	1.66	2.03	2.25
K_2O	.92	.57	.40	.73
H_2O-	.18	.46	.43	.47
H_2O+	.37	2.61	2.52	2.59
TiO_2	.99	1.23	1.00	1.59
CO_2	None.	.78	None.	None.
P_2O_5	None.	.02	.09	.06
S	Trace.	Trace.	.03	.01
Cr_2O_3	Trace.	Trace.	Trace.	Trace.
NiO				Trace.
NiO+CoO	.04			
MnO	Trace.	Trace.	Trace.	Trace.
BaO	Trace.	.04	None.	.02
CuO	Trace.	Trace.	Trace.	.02
	100.41	100.17	100.16	99.73

I. Norite, occurring near head of Cow Creek, about three-fourths of a mile from Bridger Peak. This rock is made up largely of colorless hypersthene and labradorite which has been slightly changed to sericite. There are a few grains of diallage and also a few small crystals of orthorhombic hornblende. Original biotite occurs and with it considerable magnetite.

II. Diorite derived from norite, occurring near head of Cow Creek, about three-fourths of a mile north of Bridger Peak; altered form of I. The pyroxene has been completely changed to uralite, and the feldspar largely decomposed.

III. Diorite probably derived from gabbro, from cutting on new Rawlins road, near the head of Big Sandstone Creek. In this rock paramorphism and recrystallization have been practically complete. The feldspars have given rise to a large amount of zoisite, but the rock is not at all crushed.

IV. Diorite derived by metamorphism from norite, from ridge east side of West Fork of Battle Creek, 2 miles west of the Verde mine, Encampment district. This rock shows the evidence of regional metamorphism by comparison with other fresh rocks. It seems to have been composed originally of pyroxene and labradorite, with small amount of biotite and magnetite. The microscope shows no evidence of hydration, and recrystallization has been confined to the pyroxene, which now occurs in the form of uralite.

The mineral transformations described are regarded as having been produced by dynamic pressures, but the forces involved were not sufficient to inaugurate mass movements amounting to crushing, nor was their action accompanied by the invasion of water in amounts adequate for any general hydration. Lindgren[a] has defined the term "dynamo-chemical metamorphism" in a discussion of rock alteration in his report upon the gold-quartz veins of the Nevada City and Grass Valley districts, California. The following extract from that report gives a clear comprehension of the nature of the general process, and indicates that the above-described variety of metamorphism, without crushing and without hydration, is comprised in Lindgren's dynamo-chemical class.

"Large metamorphosed areas are often spoken of as affected by regional metamorphism, a general term not designating the cause of the action. A large part of the Sierra Nevada may thus be said to have been subjected to regional metamorphism. The main cause, however, undoubtedly being orogenic pressure, the rocks are referred to as altered by dynamo-metamorphism. Strictly speaking, this term refers only to the purely dynamic processes of crushing and shearing by compressive stress distributed evenly through the rock or relieved along certain planes. A stretching action produced by a tensile stress has also been recognized by several investigators, but no decided evidence of its existence can be said to have been found during the examination of the rocks in this district.

"While examples of dynamo-metamorphism without extensive mineralogical alteration occur, chemical forces are nearly always involved and very generally play a most important part, incited by the increase in temperature accompanying the pressure at points far below the surface and aided by the moisture of the rocks. It is not at all probable, however, that the heat during the dynamo-metamorphic proc-

[a] Lindgren, Waldemar, The gold-quartz veins of Nevada City and Grass Valley districts, California: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 90-96.

esses in the Sierra Nevada has exceeded a few hundred degrees Centigrade, and of fusion there is no indication at all. It is not necessary for the initiation of the recrystallizing action that the pressure should have been carried to a point at which the limits of cohesion were reached and schistose structure produced.

"The process should, perhaps, more fittingly be designated dynamo-chemical metamorphism. It is generally characterized by a very moderate hydration and the formation of clear, fresh aggregates of mosaic structure. It usually produces a rock of finer texture than the original one. Igneous and sedimentary rocks are similarly affected, though the ultimate products usually differ. The chemical composition of the rock does not appear to be greatly altered by the process.

"Dynamo-chemical metamorphism, best illustrated in this district by the Indian Flat amphibolite area and by the Grass Valley Calaveras slates area, ordinarily produces the following minerals: Feldspar (probably very largely albite), quartz, hornblende, biotite, muscovite, chlorite (?), epidote, titanite, magnetite, pyrite, and pyrrhotite. The original feldspars are converted into albite, epidote, hornblende, quartz, and muscovite. The pyroxene alters to uralite and recrystallized hornblende, biotite, and epidote. The larger grains of clastic or porphyritic character are not only crushed but also resolved to secondary aggregates by a corrosively acting process of substitution, the new-formed minerals projecting into the primary grains."[a]

Dynamo-chemical metamorphism, producing nonhydrous secondary minerals, has affected the original gabbro rocks in all parts of the field; but, as already stated, the amount of alteration varies from place to place, and examples of nearly fresh rock are frequently to be observed. From these facts two inferences may be drawn, namely, that the metamorphosing pressures were not uniformly distributed, and that they were probably not excessive. The first inference may be explained as due to the great heterogeneity of the large rock masses which have been affected, a feature which introduces the possibility of local relief or compensating increase of the average pressure, through a partial deflection of strain by the strongest or most competent members of the complex. That the average pressure was moderate is an inference which follows from the fact that the strongest rocks were sufficiently rigid to cause a change in the direction of transmission, for if the pressures were greater than they had the ability to resist, uniform yielding throughout the complex would have been the necessary result. Only the maximum strain, occurring where transmission was most complete and where the deflected pressures were added to the average pressure, was sufficient to produce internal molecular rearrangement of the rock minerals without causing recognizable mass deformation. The minimum strain was not adequate to produce any important disturbance, the absence of which is evidenced by the unaltered portions of the rock.

---

[a] Lindgren, Waldemar, The gold-quartz veins of Nevada City and Grass Valley districts, California: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 90-91.

SERPENTINE.

In describing the peridotites of the Encampment district it was noted that they have been generally altered to serpentine. This form of alteration is the ordinary one for rocks containing large amounts of olivine, and the presence of this mineral usually controls the secondary changes of all the dark rock-making minerals associated with it. Thus, instead of appearing as hornblende in the serpentine rock, the pyroxene of the peridotite has changed to the mineral serpentine along with the olivine.

Like the peridotites from which they have been derived, the serpentines contain a small amount of chromium, and in common with all the dark gabbroic rocks they carry traces of copper. They also contain more magnetite than the related types excepting peridotite.

The alteration of olivine to serpentine involves hydration or the taking up of water which enters into the constitution of the secondary mineral. The transformation of the peridotites into serpentine is therefore regarded as the result of hydrometamorphism, and though the change may have taken place when these rocks were deeply buried, and have been contemporaneous with the general metamorphism of the gabbro rocks, it is regarded as more probable that it is of relatively recent origin and due to processes similar to those which have caused a less complete hydration of other phases of the gabbro rock, as outlined in the following section.

Serpentine is found only in the western part of the area, where it was noted at several points in the drainage of Big Sandstone Creek. No important ore occurrences have been noted in this rock, but sulphides are found inclosed in it at some prospects situated in the northeast corner of sec. 20, T. 14 N., R. 87 W.

MINERALIZATION OF THE GABBRO INTRUSIVES.

The chemical tests, which have been mentioned, indicate that copper is present in every facies of the intrusive gabbro rock, both original and metamorphic. In these rocks the metal, however, occurs in very minute quantities, and copper minerals can not ordinarily be detected by microscopic examination of the rocks in thin sections. It may therefore be suggested that the copper is disseminated through the rock, either in the rock-forming minerals as inclusions beyond the power of the microscope, combined with oxide of iron in magnetite inclusions which are almost universally present, or entering chemically into the molecular constitution of one or all of the ferromagnesian minerals. Each of these suppositions is in accord with the belief that the copper present in the dark rocks was an original constituent of the magma from which they were derived.

It has already been stated that this original or indigenous copper is never visible though always present in the gabbro rocks. Visible minerals of copper are, however, encountered in the same rocks in all parts of the field, but these are regarded as secondary segregations resulting from the action of water in circulation. The usual copper mineral is chalcopyrite, excepting where surface oxidization is to be plainly recognized. It is always accompanied by decomposition of the country rock, through the body of which it occurs in grains or irregular masses. The products of this decomposition are mainly calcite, chlorite, and chalcedony, the presence of which shows that hydration has taken place, for calcite is ordinarily deposited only from aqueous solution, while chlorite and chalcedony contain water chemically combined.

From the relation of the chalcopyrite to the other secondary minerals, as seen under the microscope, it is apparent that all were deposited at the same time. The hydration of the rock and the deposition of the chalcopyrite are regarded as due to the action of circulating meteoric waters, but whether hot or cold there is no way of determining. The date of this water action has not been determined, but the alteration produced by it can not be in any way confused with the dynamo-chemical metamorphism of the dark rocks, which is undoubtedly an earlier phenomenon.

None of the secondary segregations, where they occur entirely within the basic gabbro rocks, have the form of veins, and none of them have thus far proved rich enough or of sufficient size to constitute ores. When, however, as occurs in some instances, the secondary deposition follows a contact between the gabbro and some other rock, the amount of mineral may become of economic importance. The reason that such contacts are favorable to mineral deposition and to the occurrence of segregations of good size and extent is doubtless to be found in the existence of a readier circulation in these places than in the body of the rock.

CONTACT METAMORPHISM.

The pyrrhotite ores carrying copper, nickel, and cobalt at the Creede prospect occur in a country rock of hornblende-schist near a large dike of norite. The exact nature of this deposit could not be determined for lack of sufficient exposures to show the complete relations, but it is possibly the result of contact metamorphism and impregnation caused by mineralizing emanations from the norite at the time of its intrusion.

CHAPTER V.

THE SILICEOUS IGNEOUS ROCKS.

GENERAL DESCRIPTION.

With the exception of a few unimportant dikes, all the siliceous igneous rocks of the district are found outside of the area occupied by the sedimentary pre-Cambrian rocks. They are much older than the dark nonsiliceous rocks described in Chapter IV.

There are two types of coarse granular rock occurring in large masses, one of which is a quartz-diorite, with a general gray color, and the other a granite, exhibiting various shades of red. A third type, nearly white, occurs in dikes or flattened lenticular bodies in the gray diorite, especially where it has a gneissic structure, and also forms part of a complex of crystalline rocks which occurs in the northeast corner of the district, but which has not been studied with sufficient care to warrant its detailed description.

The age of these rocks in reference to that of the bedded series has not been determined, for, while masses of both the gray and red rock cut the old metamorphic schists, contacts with the quartzites or associated strata are not found. Diorite younger than the sedimentary rocks is everywhere intruded between the quartzites and the crystalline rocks except in localities where the former rest directly upon the hornblende-schists.

The quartz-diorite and granite have been distinguished upon the geologic map, which shows their general distribution and areal relations. In representing the areas in which these rocks predominate their occurrence has been greatly generalized, and many masses of the younger dark intrusives and of other rocks occur which are not shown at all. No attempt was made to indicate the distribution of the light-colored granitic rocks which form the third type mentioned above, which occur only in relatively small masses.

QUARTZ-DIORITE AND DIORITE-GNEISS.

The quartz-diorite is partly massive and partly schistose, but aside from differences in structure due to local mashing, the type holds its identity throughout the areas which it occupies. It is a gray granular rock composed essentially of feldspar, biotite, and quartz, with a little hornblende. Titaniferous magnetite is of frequent occurrence, and rutile, which is also a titanium mineral, sometimes occurs as needles inclosed in the mica. Epidote and zoisite are invariably present as products of alteration, being principally derived from the feldspar of the original rock, and often, with quartz, completely filling the place once occupied by that primary mineral. The zoisite products are usually more thickly set in the center of the original crystal, and sometimes outside of them there is a rim of relatively clear siliceous plagioclase which is probably secondary. Occasionally, also, clear particles of similar feldspar are found in the interior of the altered crystals. A large number of determinations shows that the secondary feldspar varies in composition from oligoclase near albite to normal oligoclase, but the latter is the more abundant. Regarding the epidote as derived from lime set free by the alteration of the original feldspar, the latter must have been more calcareous than the secondary residual oligoclase. To the unaided eye the rock appears like granite, but it can not be classified under that head, since the feldspar is plagioclase instead of orthoclase, which is characteristic of granites. It differs from ordinary diorite in the presence of large amounts of quartz, and is therefore designated quartz-diorite.

The rock has been universally affected by metamorphism, which is evident in its entirely massive portions as well as where it possesses gneissic structure. The mineral transformations which can be made out are almost wholly such changes as are not dependent upon the addition of water, and where hydration has taken place it has been subordinate in amount to the other alterations. Locally, where the gneisses show the most marked evidence of mashing, they contain more quartz than the massive portions of the rock. This mineral is commonly distributed along the planes of schistosity, and has apparently been introduced through circulating waters, which either accompanied the dynamic action or were active at some subsequent time.

Analytical tests of specimens representing this rock show the absence of copper in some cases and its presence in minute amounts in others, but none of the thin sections examined with the microscope contain visible segregations of sulphides, nor have important bodies of copper ore been discovered in the quartz-diorite as country rock. It, however, incloses portions of the Alma and Meta veins, north of the area shown on the accompanying map, the values of which are mainly silver, occurring in galena with some associated copper minerals.

The quartz-diorite incloses irregular masses of red granite which have been intruded into it; also intrusions of dark gabbro rock, and in its gneissic portions segregations or intrusions of aplite.

Secondary gneissic structure may be observed over the greater portion of the area covered by the quartz-diorite. Along the southern side of the area north of the quartzites this structure shows a notable parallelism with the structures of the bedded rocks in the adjacent synclinal fold. As shown upon the map, this feature is brought out by the dark intrusive dikes which follow the gneissic structure of the quartz-diorite, and run parallel with the near-by reefs of quartzite and their included dikes. The dips likewise are toward the south as in the quartzites. The parallelism of this gneissic structure with the general structure of the bedded rocks suggests that the structure of the gneiss may have been produced at the same time as that of the bedded rocks—that is, during the compression of the great syncline. At a distance from the folded sedimentaries this parallelism does not persist. This may be seen in the region between the forks of Spring Creek, where the platy structure of the gneiss lies nearly horizontal, and in the vicinity of the Charter Oak and Home Fraction mines, where a distinct dish-shaped synclinal structure is to be made out (see p. 83).

RED GRANITE.

A few masses of red granite occur north of the synclinorium of bedded rocks in the area occupied mainly by the quartz-diorite-gneisses, but the principal development of this rock is south of the sedimentary belt, where it is found locally cutting the gray quartz-diorite, and generally intrusive into the hornblende-schists. It contains many included masses of the last-mentioned series, and is penetrated by dark basic intrusives similar to the gabbros which cut the quartzites in the sedimentary belt.

The red granite is extremely variable in its appearance, being very coarse in some localities and elsewhere fine grained. The depth of its coloring also changes from place to place, but it is always recognizable in the field as true granite. Examination with the microscope shows that it is composed mainly of orthoclase or microcline and quartz. These minerals are frequently intergrown, forming micropegmatite if the rock is fine grained, or graphic granite if the crystallization is coarse. Besides the usual alkali feldspars, the lime-soda feldspar, oligoclase, is an almost constant accessory constituent, and the dark minerals, which are relatively small in amount, are biotite, or rarely hornblende. The rock is thus very siliceous, a fact which makes the constant occurrence of magnetite particularly worthy of note, since this mineral is ordinarily associated with the dark rock-making minerals. In almost all specimens of the red granite magnetite—which is often, and perhaps usually, titaniferous—may be detected without the assistance of a glass. Locally in coarse phases of the rock it occurs in crystals half an inch or more in diameter.

The red granite is the least altered of all the rocks of the region. In no important part of its mass have secondary gneissic structures been developed, in which respect it stands in contrast with the gray quartz-diorite, which is usually gneissic. Locally parallel structures are present, but they never occur over extensive areas. In most of the rock the microscope fails to show any broken or distorted mineral grains.

Besides being free from any general crushing, the rock does not give evidence of any important mineral transformations. The feldspars are usually perfectly fresh and when slight alteration is noticed it seems that sericite is always formed. This secondary mineral is noted principally in the oligoclase and but rarely in the orthoclase. Its production involves the introduction of a small amount of water, and may well be the result of surface weathering. If it can properly be referred to this cause, the granites are practically unmetamorphosed rocks. Their relatively fresh condition compared with the gabbro derivatives may be explained on the principle that masses of siliceous rocks are, in general, less sensitive to changes in physical condition than rocks which contain a high proportion of dark ferromagnesian minerals. This principle seems to apply in the present case, for such evidence as we now have indicates that the granites are probably of about the same age as the gabbro rocks which have been so generally altered; and, therefore, both rocks have been subjected to the same changes in physical conditions, whatever these changes may have been. It seems that the assumed increase of molecular activity attributed to static pressure and consequent rise of temperature was sufficient to set up chemical changes and metasomatism, resulting in recrystallization of the dark complexly constituted rocks, but not enough to start similar processes in the granites of more simple composition.

It is believed that the red granite as a whole is at least as old as the intrusive gabbro rocks, though this is a question open to fuller investigation. That it is younger than the gray quartz-diorite is evident from the field relations, and it was probably intruded during or after the metamorphism of the gray rock. This last conclusion is based upon the presence of parallel structures in the gray rock, and their absence in the red, where the two are in contact. If, as seems likely, the gneissic structure of the quartz-diorite was produced by the same compression as that which folded the bedded rocks, the relation indicated proves that the red granite, as well as the gabbro-rocks, was intruded after the folding. Data are not at hand for a complete discussion of the age relations between the various igneous rocks, so that the problems presented by this line of inquiry must be left for future investigation.

The red granite was nowhere observed as the sole country rock for important mineral veins, though the dark rocks inclosed in it, and certain pegmatite veins or dikes apparently related to it, have been mineralized to a certain extent. Throughout the region where it is the principal rock, local occurrences of copper minerals have been noted by prospectors, but each of these occurrences observed is associated with more or less important masses of rock different from the main mass of granite. This fact is illustrated for instance at the Jesse, or Scott, group of claims in Hog Park, where encouraging indications of copper ore have been revealed.

APLITE AND PEGMATITE.

The term aplite as a rock name is here used for white, fine-grained rocks which are composed principally of quartz and oligoclase feldspar. Pegmatite is used for related rocks which are more coarsely crystalline than the aplite and of pink or reddish color. The feldspar of the pegmatites is usually orthoclase or microcline. Aplite occurs throughout the gneissic portion of the quartz-diorite, and especially in the eastern portion of the district where, in alternation with dark, often schistose, hornblende rock, it often exceeds in amount the mass of the gneiss into which it appears to be intrusive. The aplites always closely follow the platy structure of the gneiss, but actual intrusive relations are rarely recognizable since, instead of sharp contacts, there is often a mineralogical gradation from one to the other, resulting from secondary crystallization.

The geologic relations of the aplite have not been completely determined, but bodies of the rock composed of feldspar and quartz and having the form of dikes were found to pass by gradation into quartz veins, a fact which suggests that they may not be true igneous intrusions in the same sense as the gabbro rocks, but rather that they have been formed through aqueo-igneous activity, an origin to which many pegmatites have been assigned.[a]

The coarse pegmatites have been noted mainly in the region south of the sedimentary belt, and they are somewhat prominently developed along the southern edge of the red granite with which they are probably connected in origin. Like the aplites, they are found to grade into quartz veins, a feature which may be observed to advantage in the vicinity of the Kurtze Chatterton mine. The pegmatite here, as on the Cascade property west of the Encampment River, occurs in the form of veins which, though showing a general parallelism to the east-west structure of the country rocks, still exhibit considerable irregularity.

The origin and distribution of the aplites and pegmatites, and their possible relationship to each other, are questions which must be made the subject of future inquiry. The aplite is not known to have any importance in relation to the ore deposits of the region, for while the origin of certain quartz veins is connected with that of this rock and certain of these veins carry small amounts of gold, the latter has not been found in encouraging amounts, if a single exception is made for the discovery of a rich bowlder in Purgatory Gulch, the source of which was never determined. No copper deposits are associated with this rock so far as is known.

The pegmatite contains copper minerals in the veins of the Cascade property, but here the metallic mineral is of later origin than the pegmatite itself. The latter is found to be slightly broken and crushed, and the copper has been introduced along with a small amount of quartz, as a deposit from circulating waters.

[a] Crosby, W. O., and Fuller, M. L., Origin of pegmatite: Mass. Inst. Technology Quarterly, vol. 9, No. 4, 1896.

PART II.—ECONOMIC GEOLOGY.

CHAPTER I.

GENERAL FEATURES.

CONDITIONS OF STUDY.

The ore deposits of the Encampment district have not, as a rule, been developed to a sufficient depth to afford opportunity for extensive underground examination. For this reason, while the few mines which have extensive workings have been studied with all the care possible, the information which has been obtained concerning the occurrence of copper minerals in the field at large, and their relations to the rocks which inclose them, has come largely from surface examinations incidental to the study of the general geology of the district. It has been possible, however, to make these data the basis of some general conclusions which may have a practical bearing upon the future development of the field.

At the time the district was visited, in the summer of 1902, there were but two copper mines which contained known ore reserves, namely, the Doane and Ferris-Haggarty properties. A third mine, the Charter Oak, had formerly produced some ore, but was then abandoned, while the Kurtze Chatterton property, from which a few tons of good mineral had been taken, was also idle.

In addition to the copper ores, others containing lead and silver had been shipped from the Meta mine, which is located just north of the Encampment district, between the forks of Spring Creek, and also from the Elkhorn mine, situated south of the area, near the Continental Divide. In the fall of 1902 parties had taken a lease upon the last-named property with the intention of reopening it during the winter.

ORES.

Copper is the predominant metal of value in the ores of the district, though there are a few occurrences of lead-silver ores, and gold occurs either by itself in quartz veins or in variable but always small amounts accompanying the other metals. The copper minerals comprise chalcopyrite, bornite, chalcocite, and covellite and their usual alteration products, malachite, azurite, chrysocolla, and cuprite. The metal occurs also in some instances in magnetic pyrites of iron or pyrrhotite, where it is usually accompanied by small amounts of nickel or cobalt.

The silver-bearing ore is argentiferous galena associated with sphalerite and pyrite in veins of quartz carrying some calcite or carbonate of iron.

PRIMARY AND SECONDARY ORES.

The word primary is employed in this report to denote ores which do not show evidence of having undergone any mineralogical alteration since their first deposition, while ores which have resulted from changes in preexisting primary ores involving the formation of new minerals and the removal, concentration, or redistribution of their metallic contents, are termed secondary.

Both primary and secondary ores of copper are found in the mines and prospects of the Encampment district, and the relations between the two may be clearly determined in certain instances, but in order to clearly present the significance of these relations some of the general characteristics of copper deposits, as they have been observed in other fields, will be briefly outlined.

Many deposits of copper ore are represented at and near the surface of the ground by materials quite different from those which form the productive portion of the ore body. The superficial portion of a vein often exhibits a mass of iron oxide, either spongy limonite or more massive hematite, mixed in varying proportions with minerals of a nonmetallic nature. Such surface cappings or gossans are frequently quite free from copper minerals at the surface, but as the rusty material is followed downward these are encountered, at first in small amounts, in the form of carbonates and silicate mixed with the iron oxide; and later, as the amount of these minerals increases, in the form of red copper oxide and black powdery sulphide.

At greater depth the solid sulphides appear and the proportion of iron oxide decreases, until, after a mixture of the two is penetrated, the former occur either alone or accompanied by the copper minerals first encountered in the gossan.

The ores occurring immediately beneath the oxidized surface capping are iron-bearing sulphides in some instances, while in others they are sulphides, such as chalcocite and covellite, which contain a high percentage of copper and little or no iron. In mining the high-grade sulphide ores, an admixture of the leaner sulphides is often encountered, and as lower levels are reached these gradually take the place of the richer ores, so that if the mineralization continues to a sufficient depth low-grade sulphides are always found.

It may be stated as a rule that in regions of copper deposits gossan eventually leads either to chalcopyrite or to other ferruginous copper-bearing sulphides, whether rich sulphides occur between the two or not.

The relations which have been outlined naturally suggest that both the gossans of copper veins and the rich sulphide ores sometimes occurring beneath them result from the alteration of low-grade sulphides. The investigations by Emmons and Weed of the copper deposits at Butte, Mont., have led to the general recognition of this genetic relationship between the minerals of the gossan and rich sulphide zones and those of the deeper zone in which the copper is associated with iron in the form of relatively lean sulphides.[a]

The gossans and rich sulphides are regarded as the result of alteration of the low-grade ore which formerly filled the space which they now occupy through the action of oxidizing meteoric waters; the ores of the two upper zones are therefore secondary ores, while the low-grade material is unaltered primary ore.

Since secondary ores are derived from earlier existing deposits of a primary nature, they seldom occur entirely alone, and in any instance where they are found they are ordinarily mixed in variable amounts with primary material.

The primary copper ores of the Encampment district are chalcopyrite and pyrrhotite. The secondary ores are known to include azurite, malachite, chrysocolla, cuprite, bornite, chalcocite, and covellite, and still others may exist.

GANGUE MINERALS.

The gangue minerals of the region comprise quartz, calcite, siderite, feldspar, hornblende, epidote, and garnet. As a rule neither these minerals nor those which carry copper are found in the form of veins, for though veins do occur, the metallic mineral usually permeates the rock in which it occurs, replacing its minerals to a greater or less extent. It follows from this that the gangue of many ores represents simply the minerals of the country rock. When veins are present they are ordinarily composed of quartz and calcite, alone or in combination, though the iron carbonate, siderite, is sometimes present.

GROUND WATER.

The annual precipitation in the Sierra Madre is known to be rather great, and while no data are at hand for determining its seasonal distribution or average amount, it is known in a general way that the portion which falls as snow during the winter months greatly exceeds the rainfall during the summer. A considerable area within the mountains, particularly within the Encampment district, lies above 10,000 feet elevation, and the snow, which accumulates to a depth of from 4 to 8 feet, invariably lingers until June, and in many places large snow banks are to be found until the end of July, while at several places upon the northern summit slopes great accumulations, due to drifting, are practically perennial.

Under these climatic conditions it is not unnatural that the upper level of

[a] Weed, W. H., Enrichment of mineral veins by later metallic sulphides: Bull. Geol. Soc. America, vol. 2, 1900. pp. 179–206. Emmons, S. F., The secondary enrichment of ore deposits: Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 177–217.

general saturation, which is usually termed the ground-water level, should lie very near the topographic surface, as is found to be the case. In traversing the area a large number of prospect pits were examined, and only rarely was standing water absent if a depth of 25 feet had been reached. In some places the water rises to within 10 or 15 feet of the surface, and as an average it may be safe to say that ground water is encountered at a depth of less than 30 feet.

It appears also, at least locally, that the ground water has a lower as well as an upper limit, and though the opportunities for observation are extremely limited, it may be mentioned that in the case of the 800-foot tunnel driven by the Battle Lake Tunnel Site Company, which attains a depth of nearly 450 feet under the north slope of Bridger Peak, the rocks penetrated were found to be entirely dry, excepting that a single fracture yielding only a few gallons of water per hour was encountered. The material penetrated was a very homogeneous hornblende schist belonging to the lowest bedded formation of the region, which is described in another place in the present report. In the case of the Beulah tunnel, which attains a considerable depth, only a very small amount of water enters the mine beyond the first 200 feet of the tunnel. Here both diorite and quartzite are encountered. On the other hand, the Hidden Treasure tunnel is extremely wet, though the covering approaches 500 feet; but here distinct zones of crushing give access to surface waters.

It is to be observed that the lower limit of complete oxidation, in the case of those ore deposits that have a distinct capping of gossan, coincides very closely with the natural level of the ground water as it was encountered in sinking upon the leads.

GOSSAN.

The surface capping of the ore bodies which have been thus far discovered in the region is usually composed almost entirely of spongy oxide of iron or limonite.

At the Ferris-Haggarty mine there was a strong capping of spongy limonite containing no visible copper minerals. At the Doane mine green copper minerals were mixed with the limonite encountered at the surface, and continued to be present to a depth of 100 feet or more.

From the fact that marked gossan was characteristic of these two mines, a general search has been made for other ferruginous surface indications in all parts of the region, and while several rusty deposits have been found, only a few of them have been thus far proved to denote the presence of copper ore, though it must be remarked that adequate prospecting has been done in very few cases.

The Hinton mine is located upon outcrops of rusty rock of some prominence, which, though differing materially in appearance from the gossan of the two mines mentioned, was found to pass into practically undecomposed rock, highly impregnated with chalcopyrite at a depth of only 12 feet.

At the Itmay claim, near the head of Roaring Fork, an ordinary limonite capping upon the surface led to the discovery of sulphides within a depth of 3 or 4 feet. At this place and also at the Hinton property only small amounts of copper carbonates were found.

A somewhat different capping from the foregoing occurs at the Jesse, or Scott, prospect in Hog Park. Here there is practically no spongy limonite, but there is a considerable amount of carbonate of iron and some bunches of red hematite, and the rock shows a good deal of decomposition and green copper stains. The work done is insufficient to prove that this material is the gossan of any considerable amount of copper sulphide, though it may be so.

Still another type of ferruginous surface material which may eventually prove to be true gossan occurs on the Gertrude claim, located just north of the wagon road, about one-half mile east of Battle. At this place a bed of solid hematite from 2½ to 4 feet in thickness occurs between strata of quartzite, which dip rather steeply toward the south. The deposit has been opened by an incline to a depth of 80 feet and found to be very homogenous and quite different from the ordinary spongy limonite capping of sulphide veins. The red oxide of iron appears to be in a very pure condition and is reported to carry gold to the average amount of $7 per ton. No copper minerals were detected in opening this deposit, but it is regarded as probable that it is a true gossan, which will lead to the discovery of sulphides at a very moderate additional depth. However, the sulphides, if they exist, may be in the form of pyrites, and may not be found to carry important amounts of copper. Likewise, it may prove that the hematite was deposited in its present form, and that it is not the product of oxidation of an original sulphide. Nevertheless, it is one of the most striking evidences of mineralization at present remaining undeveloped in the district, and it is remarkable that the property has been allowed to lie so long without being completely proved.

In this connection it should be noted that many occurrences of copper sulphide have been discovered which do not show any notable capping of oxidized material, and though such deposits of gossan as have been found do not continue to great depth, it is apparent that the presence or absence of oxidized material along the surface is likely to indicate very closely the nature of the underlying materials. In general it may be said that where gossan is absent and metallic minerals are found the rocks inclosing them will prove to be very tight and impervious to water. In such cases the idea that the ore will necessarily increase in amount or value in depth is regarded as entirely unwarranted, while in the case of deposits covered by a heavy oxidized capping it may be expected that rich sulphides will ordinarily occur, as at the Ferris-Haggarty and Doane mines, though from the instances which have been cited it is plain that a shallow capping may exist over deposits of chalcopyrite which have not been enriched to any important degree.

DISTRIBUTION OF COPPER MINERALS AND ORES.

Copper ordinarily occurs in the form of chalcopyrite, which is present in small amounts in every part of the Encampment district where pre-Cambrian rocks are found.

The yellow sulphide of copper is of very frequent occurrence in the hornblende schists in the form of small segregations which commonly follow the platy structure of the inclosing rock. It is shown by the microscope to have crystallized at the same time as the minerals which make up the greater part of the schist, and since these are the product of recrystallization through regional metamorphism, as has been shown in another part of this report, it seems that the segregation of the metallic mineral accompanied this metamorphism and was a result of it.

As a whole the hornblende-schists constitute a series of fairly homogeneous composition, and though they are metamorphic rocks, their original materials have been altered to practically the same extent throughout. These features may explain the formation of small bodies of copper sulphide distributed through this rock instead of larger local segregations of less frequent occurrence. At the time the rock was undergoing recrystallization metallic solutions had equal freedom of movement through all parts of its mass. The migrations of these solutions were only confined to definite channels under exceptional conditions, the presence of which has resulted in a few deposits of the Hinton type which promise some economic importance.

The source of the copper in the sulphides of the schists is not known, but since the rocks in which the segregations occur appear to be the oldest in the district, it is possible that the metal was originally distributed through the surface volcanics which have been metamorphosed into the present hornblende-schists.

The schists contain, besides the copper segregated during metamorphism, other deposits of copper-bearing sulphides introduced at dates corresponding to later mineralization which has affected the remaining formations of the region.

In the pre-Cambrian sedimentary rocks copper minerals are of common occurrence, and while often accompanied by quartz in the form of small stringers, or more rarely in larger veins, the ore minerals also occur without quartz, particularly in zones where brecciation or schistose structure is conspicuous. It may be said in general that the limestone and conglomerate have been less favorable for the deposition of sulphides than the quartzites and slates.

Copper deposits in these rocks were doubtless derived from outside sources, having been introduced by water circulating through the surrounding formations. As also observed in the hornblende-schists, large segregations of sulphides are the exception, and for a similar reason, the nature of the rocks being such that very general circulation through them was possible—a condition which was generally unfavorable for marked localization in the movement of metal-bearing solutions, and consequently for the formation of important bodies of ore. Among the exceptions to this rule are the Doane and Ferris-Haggarty mines, where important concentrations of ore have been formed in the sedimentary rocks under special conditions which will be brought out in the description of these properties.

In the dark intrusive rocks which have been classified together as gabbros, but which are commonly called diorites, a minute amount of copper is invariably present, as has been shown by a considerable number of very careful tests which have already been referred to. The metal occurs in the freshest examples of the gabbro, as well as in portions which have been altered in one way or another, but the manner in which it occurs can not be detected by a most careful search with the microscope. The copper is regarded as an original constituent of the basic magma, and the gabbro intrusives are believed to be a real and adequate source for the visible segregations of this metal which have been formed since the gabbro invasion.

The gabbro rock has been variously metamorphosed and weathered. In its fresher portions chalcopyrite is seldom observed, but in its altered representatives small amounts are very frequently to be detected, even in surface outcrops, and this mineral is especially liable to occur where even a slight amount of schistose structure is present, or where the silicate minerals of the rock have been hydrated through the action of circulating water. Secondary structures and metamorphism have been very irregularly developed, but both are general features to be observed in these intrusive rocks in all parts of the field, so that, as in the other formations which have been mentioned, the copper, though widely distributed, is seldom concentrated to form important deposits. The absence of large segregations of ore is therefore again to be ascribed to the absence of well-defined or sharply localized structures which might have served as channels for circulating waters.

The area represented on the map as red granite contains many surface indications of copper, but this field has been less thoroughly prospected than have the other portions of the region. So far as observed the mineral does not occur in the granite itself, but always in associated rocks which have either the form of inclusions or are intrusive into the granite.

The quartz-diorite is perhaps less prominently the host for copper minerals than any other in the region, though it is not entirely free from the metal. The sulphides which occur seem to be confined to veins which penetrate the rock, and impregnations of the rock itself, such as are observed in other formations, have not been noted.

From the correlation of observations upon copper prospects in all parts of the field, it seems that the wide distribution of copper in small segregations throughout the various rocks and the rarity of large deposits is due to the fact that by whatever process the migration of copper may have been brought about, penetration of the rocks was accomplished with practically the same ease in one place as another. This condition may be attributed to the general arrangement of the varying rock masses of the district in relatively narrow and highly inclined plates. Variations in the original composition, differences in the amount of metamorphism or in the perfection of schistose structures have produced channels favorable to circulation, but these variations are so many times repeated that the effect has been to produce a large number of minor segregations rather than a few large concentrations.

SOURCES OF COPPER.

The dark-colored gabbro rocks which are present in all parts of the Encampment region are regarded as the original source of a large part of the copper which occurs in the ores. Eighteen samples representing various phases of the rock, fresh and altered, were tested by Dr. E. T. Allen in the laboratory of the Survey under conditions which preclude the possibility of the metal having been introduced from outside sources, and in each case copper was found to be present. Several of the samples contained nickel and cobalt, and chromium is present in some of them.

A list of localities from which some of the rocks tested were collected is here given:[a]

5. Diorite from croppings near Jack Creek, above forks.

6. Diorite, half way between Charter Oak and Home Fraction claims on Calf Creek Mountain.

19. Specimen of fresh diorite from ridge on east side of west fork of Battle Creek, about 2 miles west of Verde mine. (See complete analysis given on page 32.)

117. Fresh diorite from the head of Beaver Creek, west of Elwood post-office.

133. Fresh diorite collected about three-fourths mile north of Elwood post-office.

140. Fresh norite from Creede tunnel near north side of sec. 10, T. 14 N., R. 86 W.

177. Specimen of fresh black diorite from Calf Creek Mountain, south of Charter Oak mine.

185. Fresh norite near head of Cow Creek, three-fourths mile north of Bridger Peak. (See complete analysis given on page 32.)

188. Fresh diorite, locality near that of 185. (See complete analysis given on page 32.)

195. Diorite from knob at 10,500 elevation, about one-half mile north of Bridger Peak.

210. Fresh diorite from new adit, Ferris-Haggerty. Contains mere traces of copper, nickel, and cobalt.

[a] For the definition of the rocks which are called diorites in this list, see page 30.

215. Fresh norite from Octavia tunnel.

290. Decomposed diorite, lower tunnel of Ferris-Haggarty mine.

253. Fresh diorite, from cutting on wagon road about 1 mile north of Bachelor's cabin in head of Big Sandstone Creek. (See complete analysis given on page 32.)

352. Serpentine collected below the canyon of Big Sandstone Creek.

In none of the rocks tested was it possible to recognize the presence of metallic minerals other than magnetite by microscopic examination, so that the metals may either enter into the composition of the silicates of the rock or may occur as sulphides included mechanically in the silicate minerals. If the tests had shown the presence of copper only in the metamorphosed phases of the igneous rock, it might be argued that the metal had been introduced during alteration, but since both it and the nickel and cobalt are also found in entirely fresh, unaltered norite, the fact that they were all present in the rock while it was still in a molten condition and when it was intruded may be accepted without serious doubt. Copper seems to have been universally present in the magma while nickel and cobalt occur only in the more basic phases. Traces of chromium were detected in four samples tested for that element.

The gabbro rock is a sufficient and probable source for the copper occurring in most of the observed ore bodies, but, as shown in the discussion of the disseminated ores in the hornblende schists and in deposits of the Hinton type, certain segregations must have been formed prior to the invasion of the dark intrusives.

Another independent and earlier source is therefore necessary for most of the copper in the schists. Nothing decisive can be suggested as to what this source may have been, for the schists appear to be the oldest rocks of the region. It is, however, entirely possible that the copper may have been derived from the same rocks from which the schists were formed. These were in large part basic igneous rocks, which, in the absence of contrary evidence, are as likely to have contained appreciable amounts of copper as the gabbros of later date.

Of five examples of the gray quartz-diorites tested for copper three gave no reaction, while of the two which contained a mere trace one came from the vicinity of a known ore occurrence and the other was from a thin sill in the hornblende-schists, about one-fourth mile from the Creede shaft, with a good deal of mineralization noticeable in the vicinity.

A sample of red granite from Huston Park gave no reaction for copper.

OCCURRENCE OF GOLD.

In the northern part of the area covered by the Encampment map and in the crystalline area beyond there are many veins of white quartz, and while some of them are of great size they all appear to be of lenticular form. Small amounts of pyrite or chalcopyrite, or cavities which formerly contained these minerals, may occasionally be observed in them, but as a rule they do not contain sulphides in important quantities. It is reported that they all carry gold, though certainly not in workable amounts. They were not considered of sufficient promise to warrant particular study during the present investigation.

Free gold in quartz has been found in several claims located in Purgatory Gulch, but the veins are small and not continuous, so that they are regarded as of no importance.

Mr. Frank O. Williams and Henry Jones, whose ranch is situated in the foothills of the Sierra Madre near Calf Creek, report the existence of gold-bearing gravels along nearly all of the streams which drain the northern slope of the range. The best placers are situated on Jack Creek and the head of Savery River, but though different parties made several attempts to work them the gravels could not be made to pay.

The existence of a sufficient amount of gold in the stream gravels to lead even to attempts at placer mining is indicative of its very general occurrence. However, much exaggeration exists concerning the universal presence of gold in all sorts of country rocks, samples of which are frequently reported to have given assays of one or two dollars' worth of gold per ton. The copper ores which have been mined do undoubtedly carry a small amount of the precious metal, which also occurs with such silver-lead ores as have been tested, but several assays of material in which sulphides could not be seen failed to reveal even traces of gold.

Results of assays of miscellaneous material for gold and silver.

[Tests made by Dr. E. T. Allen.]

Number.	Gold.	Silver.
	Troy oz. per ton.	*Troy oz. per ton.*
1	0.36	Not tested.
2	None.	Not tested.
3	None.	Not tested.
4	None.	Not tested.
5	None.	Not tested.
6	None.	Not tested.
7	None.	Not tested.
8	None.	Not tested.
9	None.	Not tested.
10	None.	Not tested.
11	None.	None.
12	.22	.24
13	Trace.	4.2
14	None.	None.
15	None.	None.
16	.02	Not tested.
17	.05	Not tested.

1. Quartz vein from prospect in Purgatory Gulch.

2. Quartzite from Sovereign claim in basin southwest of Bridger Peak. Reported to contain gold.

3. Spongy vein quartz from tunnel 1 mile east of Victoria post-office.

4 and 5. Two samples of rusty rock containing pyrite. Ground Hog claim, sec. 14, T. 13 N., R. 86 W.

6–9. Material from sheeted dikes in quartz-diorite containing stringers of quartz and a small amount of chalcopyrite. Four samples from prospect holes on Fudges claims, sec. 6, T. 13 N., R. 85 W.

10. Sample from 200 feet of brecciated quartzite in Hidden Treasure tunnel, near Battle.

11. Sample of pulverulent quartz stained with oxide of manganese from cavities in strong east-northeast fissure vein opened by 60-foot shaft near Continental divide, southwest corner sec. 10, T. 14 N., R. 86 W.

12. Upper of two veins on Ajax claim, north slope of Dexter Peak.

13. Lower vein, Ajax claim, north slope of Dexter Peak.

14. Sample of jaspery vein material from Lost Soldier claim, west side of Encampment River, opposite Purgatory Gulch.

15. Hematite stained with copper from Metal Chief claim of the Jesse group, in Hog Park.

16. Copper ore from Hinton mine.

17. Copper ore from Itmay shaft.

CHAPTER II.

CLASSIFICATION AND GENERAL DESCRIPTION OF COPPER DEPOSITS.

TYPES OF OCCURRENCE.

The present chapter is devoted to a general description of the copper deposits, apart from any discussion of their origin which forms the subject of the next chapter.

Though there is a great variety in the manner in which the copper minerals occur, it is possible to refer them to a few types which have been named after prospects or mines in which their characteristics are well illustrated.

HINTON TYPE.

In this type of deposit, which has its best example at the Hinton mine, located 7 miles south of Battle, chalcopyrite, sometimes accompanied by magnetite, occurs in zones of the hornblende-schists, which are characterized by a great deal of garnet and epidote in addition to the hornblende and quartz which ordinarily make up the mass of the schist. These minerals always render the zones somewhat conspicuous, and in some instances attention is further called to them by the presence of rusty material in their outcrop. Where this occurs it is probably in part a true gossan representing surface oxidation of sulphide ores, but it may be also produced by the weathering of masses of garnet, as may be observed in the croppings of the vein on the Hinton claim.

The epidote and garnet zones follow the general platy structure of the schists and are locally accompanied by thin strata of limestone and quartzite, and they may therefore be regarded as having been produced from intercalated beds of a more calcareous composition than those which were altered by recrystallization into hornblende-schists, and by the same process of metamorphism. In so far as zones of this sort have been observed to be mineralized, the ore minerals are found permeating the mass of the rock along some fairly distinct band within the zone, but there is no evidence of fractures nor any open channels whatsoever along which the material could have been introduced. Studied under the microscope, the silicate minerals of the rock are found to be entirely fresh and undecomposed, and their grains interlock with those of the chalcopyrite or magnetite in such a way as to indicate that all of them were crystallized at the same time.

Several zones of the Hinton type have been discovered within the area covered by the hornblende-schists, but promising amounts of sulphide ores have been encountered only at the Hinton mine. A prominent and persistent lode of this nature which has been opened on the Sun Anchor claim, located upon the north slope of Green Mountain, may be traced upon the surface for a distance of over 1 mile westward into sec. 34, T. 14 N., R. 85 W. Location pits at several points along the lode reveal the presence of magnetite and chalcopyrite inclosed in schist composed of hornblende, epidote, and garnet.

In other cases where an amount of rusty decomposed garnet associated with massive green epidote is found upon the surface the similarity to the Hinton lode is evident, though nowhere has sufficient exploration been done to prove the presence of sulphides.

CREEDE TYPE.

Because of imperfect exposures the studies of the Creede prospect were not sufficient to afford an accurate determination of the nature of the deposit. The relations of the sulphide mineral to the gangue material of the inclosing rock are similar to those observed at the Hinton property, both having crystallized at the same time, but the Creede deposit can not be classed with the Hinton type, since the distinguishing feature of the latter is the existence of a well-defined zone differing in mineralogical make-up from that of the general schist of the vicinity, and no zone of this sort exists at this place. The Creede ore is magnetic sulphide of iron, or pyrrhotite, which carries copper, nickel, and cobalt, and with it there is mixed a small amount of chalcopyrite. The sulphides occur in an unusually coarse granular phase of the hornblende-schist near an intrusive mass of norite, and it is suspected that they occur at the actual contact of the two rocks. Neither the surface outcrops nor the workings of the mine serve to indicate whether the deposit has a definite form or not. The coarse hornblende rock seems, however, to be limited in extent, and the finer-grained schists in the vicinity do not seem to have been mineralized by sulphides.

In the vicinity of the Creede, but usually at a somewhat greater distance from the mass of norite, there are several openings in the calcareous schist showing the presence of pyrrhotite in small amounts. This mineral seems to be almost entirely confined to deposits of sulphide adjacent to this particular mass of intrusive rock and is rarely present elsewhere in the region.

CONTINENTAL TYPE.

The type of deposit which has been named from the Continental claim, situated in the vicinity of the tramway transfer station upon the south side of Cow Creek, is characterized by well-defined veins of quartz accompanied in some cases by calcite or siderite and in others by feldspar, and contains sulphides which were deposited at the same time as the gangue material.

In the case of the Continental, and certain other prominent examples of the type, the veins follow openings along the schistose or platy structure of the rocks which inclose it, while in other instances they occupy strong fissures which are transverse to the general trend of the country rocks.

CASCADE TYPE.

At the Cascade property, situated on the west side of Encampment River above Purgatory Gulch, chalcopyrite occurs in a vein or dike of pegmatite composed of feldspar and quartz. In its general relations as observed upon the ground the deposit resembles the Kurtze Chatterton veins, which are classed with the Continental type, but examination of the ore under the microscope shows it to be distinct, since the gangue and the ore were not formed at the same time. The minerals of the vein are shattered and more or less brecciated, and the fractures are filled in with chalcopyrite and a small amount of quartz, both of which are therefore later in origin than the matrix in which they occur.

The Cascade vein is the only example of this type which was observed.

DOANE TYPE.

The ores of this type, which is commercially the most important occurring in the field, are mainly composed of the rich sulphide, chalcocite, mixed with a variable amount of chalcopyrite, and sometimes accompanied by covellite and bornite, or by oxide and carbonate minerals.

The two prominent examples of the type are seen in the Doane and Ferris-Haggarty mines, in both of which a strong gossan containing little or no copper marks the superficial portion of the lodes, and immediately beneath this the richest ore is found, a gradual decrease in value being observed as the ore bodies are followed downward.

This decrease in the valuable contents of the vein arises from a gradual increase in the proportion of chalcopyrite to chalcocite as depth is attained, the former mineral containing when pure only about 34 per cent of copper, while the latter carries nearly 80 per cent of the metal.

The manner in which the ore bodies occur is similar in both of the mines mentioned. The lodes follow the bedding of sedimentary quartzites very closely as a rule, and are invariably marked by a good deal of brecciation, the ore mainly occupying the spaces between fragments of the country rock.

The distinguishing characteristic of the Doane type is the presence of chalcocite as the principal ore mineral, which is regarded as an indication of the secondary derivation of the deposits, in accordance with the definition of primary and secondary ores given on page 43.

CHAPTER III.

GENESIS OF THE COPPER DEPOSITS.

TABULAR SUMMARY.

The origin and sequence of deposition of the different ore types which have been described form the subject of the present chapter, the conclusions of which are exhibited in the following table:

Relations of types of copper ores.

Type.	Formation.	Process.	Period.
Hinton	Hornblende-schist	Regional metamorphism	1
Creede	Hornblende-schist	Contact impregnation	2
Continental	All rocks	Deposition from circulating waters.	3
Cascade	Pegmatite dikes		
Doane	Quartzite		
Barren quartz veins	All rocks		

The discussion of the genesis and relative age of the ores will be given under four heads, corresponding to the periods of segregation given in the table and the subsequent period of secondary enrichment.

DEPOSITION OF THE FIRST PERIOD.

Origin of the ores.—Zones of intense metamorphism, of which the Hinton lode is the type, are confined, so far as has been observed, to the metamorphic hornblende-schists. It is regarded that they, and the ores which they contain, are of contemporaneous origin with the general recrystallization of the rocks in which they occur, and that the ores, therefore, originated during regional metamorphism at a very ancient period, prior to the Cambrian.

The main features of the metamorphic zones or lodes which, considered together, lead to the above conclusion are as follows:

(*a*) The zones bear no observable relation to the presence of igneous rocks which may occur in the same general region, and where the schists are cut by intrusives no distinctive contact minerals are developed. Therefore they can not be attributed to contact metamorphism.

(*b*) The lodes are not separated from the inclosing schists by gouge nor by distinct walls, so that they can not be filled fissures.

(*c*) There are no veinlets of quartz or other mineral which appear as though filling cracks in the rock, showing that the zones have not been fractured and afterwards cemented by mineralizing solutions.

(*d*) The lodes invariably follow the stratification of the original rocks, which is found to be parallel to the present platy structure of the metamorphic schists. The structure thus controls their direction.

(*e*) Examined in detail the material of the lodes themselves is found to be schistose, through the arrangement of the component minerals in parallel planes. A considerable amount of hornblende similar to that of the inclosing schist is usually present in the zones, and epidote, which is particularly associated with the ore, occurs in smaller amounts throughout the country rock. The lodes seem therefore to form an integral part of the schist series, and they are regarded as having been formed by the same causes and at the same time as the remainder of the series.

(*f*) The beds involved in the mineralized zones must have differed in their original composition from the mass of the rock which has produced the hornblendic portions of the schist. This is shown in all cases by the preponderance of epidote and garnet, both of which indicate a high proportion of lime in the material from which they were derived. Furthermore, at the Hinton property a stratum of fairly pure crystalline marble, and another of quartzite occurring in the midst of the lode, bear out the deduction that the distinct character of the present mineralogical aggregates is merely an expression of original differences in composition.

(*g*) The metallic sulphides are shown by the microscope to have crystallized contemporaneously with the silicate minerals of the rock. The metallic substance must therefore have been introduced at the time of metamorphism when the original materials of the present schists were being formed by recrystallization.

Source of the copper.—The hornblende-schists are regarded as the oldest rocks now exposed in the region which has been examined. When they were recrystallized the basic gabbro rocks which now cut them had not invaded the field, and therefore could not have furnished the copper which they contain. Neither does it appear that the copper could have been derived from any of the siliceous rocks now occurring with the schists, since apart from the probability that these are also of later origin than the metamorphism of the schists, they are not characterized by the presence of copper minerals of earlier origin than the gabbro intrusives. It is therefore believed that the copper which the schists now contain, so far as its minerals are of contemporaneous origin with their metamorphism, was probably derived from the original rocks from which they were formed. This point is, however, beyond proof since the hypothesis that the copper was introduced from another unknown source can not be controverted.

DEPOSITION OF THE SECOND PERIOD.

The origin of the Creede ore deposits remains in doubt, through the impossibility of making adequate observations, because of imperfect surface exposures, and because the shaft was filled with water at the time the property was visited. Occurring in the hornblende-schist series, it might be anticipated that the deposit was formed in the same manner as the ores of the Hinton lode. However, the ore mineral is different, and its possible genetic relation to the near-by norite must be considered. The age of the deposit is regarded as pre-Cambrian.

From the material which has been taken from the shaft it is seen that pyrrhotite and chalcopyrite occur in a mass of coarsely crystalline hornblende rock containing a small amount of quartz. No other minerals are present in the ore, though epidote occurs in the rocks which outcrop near by. The ore and gangue minerals are of contemporaneous origin, as in the case of the Hinton type, but the crystallization does not certainly date back to the original metamorphism of the schist, for a second recrystallization may have been caused by the intruded norite, which could at the same time have furnished all the elements of the ore, including the cobalt and the nickel. It is regarded as most likely that the deposit is an instance of segregation during contact metamorphism locally manifested.

If the Creede ore was formed in this way, it is not at all unlikely that other deposits of sulphide minerals were formed in various rocks adjacent to masses of the dark intrusive rock, by direct impregnation through the emanations from the cooling magma, but the main rôle of these gabbro rocks has been to furnish metallic elements to the circulating underground waters, which appear to have been most efficient during the time which has elapsed since their invasion of the pre-Cambrian sediments.

DEPOSITION OF THE THIRD PERIOD.

Origin of the ores.—A common origin by aqueous deposition is assigned to ore deposits which can be classed under the already described Continental, Cascade, and Doane types, for though these differ greatly among themselves, they all occur in veins which follow channels of easy circulation defined by structural breaks, such as joint fissures, planes of schistosity, or zones of brecciation.

Some of these channels may have existed previous to the invasion of the gabbro rocks, which are regarded as the main source of the copper occurring in the water-deposited veins, but others, as, for instance, the prominent north-south fractures in the vicinity of the Ferris-Haggarty and Doane mines, are certainly later than the intrusion of the basic rock, since they occur indifferently in the igneous rock and in the inclosing formations. All of them were probably filled subsequent to the gabbro intrusion.

At present no date can be confidently assigned to the vein phenomena of the third period, because data for determining the geologic events of Paleozoic time are incomplete, all sedimentary formations below the upper Carboniferous being entirely missing in this part of the Rocky Mountains. In the Encampment district the oldest sedimentary formation resting on the ancient metamorphosed rocks which contain the copper deposits are the Triassic Red Beds, and since none of the fractures of the older rocks corresponding to those which carry ore were found passing upward into these strata, the primary vein segregations are regarded as older than Triassic. In the Elk Mountains, some 30 miles north of the Encampment district, upper Carboniferous strata occur; but though the general geology of the region shows that there was gradual sinking which allowed the Triassic beds to overlap, there is no reason to suspect that fracture systems could have been formed and filled after the deposition of the Carboniferous and before the Triassic was laid down.

Concerning the interval between the upper Carboniferous and the beginning of Cambrian time, no direct evidence exists, and it would be extremely difficult to prove that the deposits were not formed some time during the Paleozoic. However, this is not regarded as probable, since in the Rocky Mountain region of the United States no ore deposits are known to have been formed during Paleozoic time, and in general the geologic history of the Rocky Mountain province is known to have been similar throughout. On the other hand, pre-Cambrian gold deposits occur in the Black Hills of South Dakota, and there is strong evidence in favor of a like age for the copper deposits near Salida, Colo., so that a certain analogy exists between the Encampment deposits and other ore occurrences in the ancient metamorphic complex of the Rocky Mountains, suggesting the possibility that the former, like the latter, are of pre-Cambrian origin.

Source of the copper.—The copper and other metallic elements which occur in deposits formed since the intrusion of the gabbro masses are regarded as having been derived mainly from these basic igneous rocks. These are obviously a possible source, since they invariably contain appreciable amounts of copper, and, in many cases, cobalt and nickel as well, as has been shown by a considerable number of tests which have been referred to on page 49 of this report. All the other rocks of the region are much more siliceous, and consequently less likely to contain even small amounts of any heavy metal excepting iron. Also in the few tests which have been made they are found not to contain sufficient copper to be revealed by chemical tests upon ordinary amounts of material.

SECONDARY ENRICHMENT OF THE ORES.

Several of the copper deposits of the Encampment district yield high-grade ores composed very largely of copper glance or chalcocite. This mineral, where it occurs in large amounts in other fields, is regarded as having been derived from the enrichment of ore bodies originally of poorer grade, through the leaching of the copper contents from the upper portion of the deposit by surface waters, and its concentration by redeposition in a deeper part of the vein. The changing nature of the deposit from above downward, where such secondary enrichment has occurred, has been described on page 43, and in the Doane and Ferris-Haggarty mines the sequence of the gossan, the high-grade ores, and the leaner sulphides corresponds completely with the normal conditions. It is therefore believed that the ore deposits in these mines, and also certain others in the district, have been the result of concentration of primary ores by the percolation of surface waters through the veins. In both the mines mentioned the ore occurs as a filling in brecciated quartzite, and from their nature the ore bodies form ready channels for circulating water. Both mines are also very wet, showing that conditions favorable to leaching and redeposition still exist.

The occurrence of secondary ores at some places, and their absence at others, may be attributed entirely to differences in the texture of the veins and country rocks. Where these have been loose and open concentration of primary ores has taken place, and where they have been tight and impermeable no leaching has been possible.

The secondary concentration now observed probably began after the topography of the region had reached practically its present development, and the period during which it has been going on is therefore regarded as very recent.

CHAPTER IV.

MINE DESCRIPTIONS.

DOANE MINE.

Location and development.—This property was formerly known as the Rambler mine, a name which is now applied to the town and post-office near which it is situated, in the upper part of the valley of Battle Creek, about 2 miles below the Continental Divide.

The surface indication of ore was a strong iron cap or gossan considerably stained by carbonates and silicate of copper, which was followed by an inclined shaft to a depth of 75 feet, where red oxide and copper glance or chalcocite were encountered. A crosscut tunnel, 260 feet in length, was then driven to cut the vein at a depth of 125 feet, the ore was stoped out to the surface, and a chamber excavated for the installation of a steam hoist, by means of which a shaft has been sunk to a further depth of 190 feet. There are crosscut tunnels at 115, 140, and 190 feet, respectively, and an exploration drift about 160 feet long westward from the lowest tunnel, with a 50-foot crosscut northward from its terminus. The relation of these workings may be seen from the sketch plan drawn from the writer's notes (fig. 2) and the cross section (fig. 3). The main ore body has been encountered in the workings of each level, and the ore between the levels, which was found to be practically continuous, has been stoped out. At the time of visit a winze from the lowest level had proved the presence of ore to a farther depth of 50 feet, and in April, 1903, this had been continued to a total depth of 287 feet below the tunnel level.

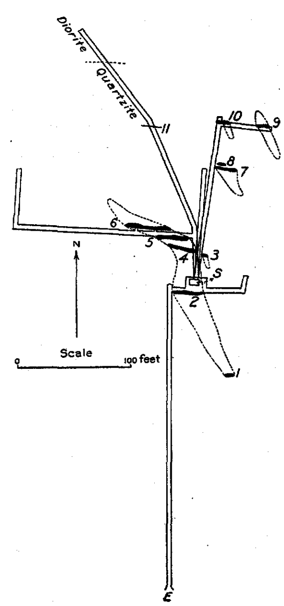

FIG. 2.—Doane mine; sketch plan of workings. E, mouth of adit; S, shaft; 1, discovery; 2-6, main ore shoot in different levels; 7-10, additional ore shoots on 115-foot level; 11, copper-stained fissure in quartzite. The stopes are represented approximately by dotted lines.

The tunnel at the 115-foot level is approximately 140 feet in length. By means of it the main ore body was opened, and two others were encountered 100 and 135 feet north of the shaft, and these have been stoped out, as shown in the cross section of the mine (fig. 3).

The workings of the mine are approximately as follows:

Lengths and depths of mine workings.

	Feet.
Tunnels and drift	975
Shaft	190
Stopes	715
Total	1,880

Upon the claim adjoining the Doane property upon the west similar ore bodies have been found, but the workings were not accessible for examination.

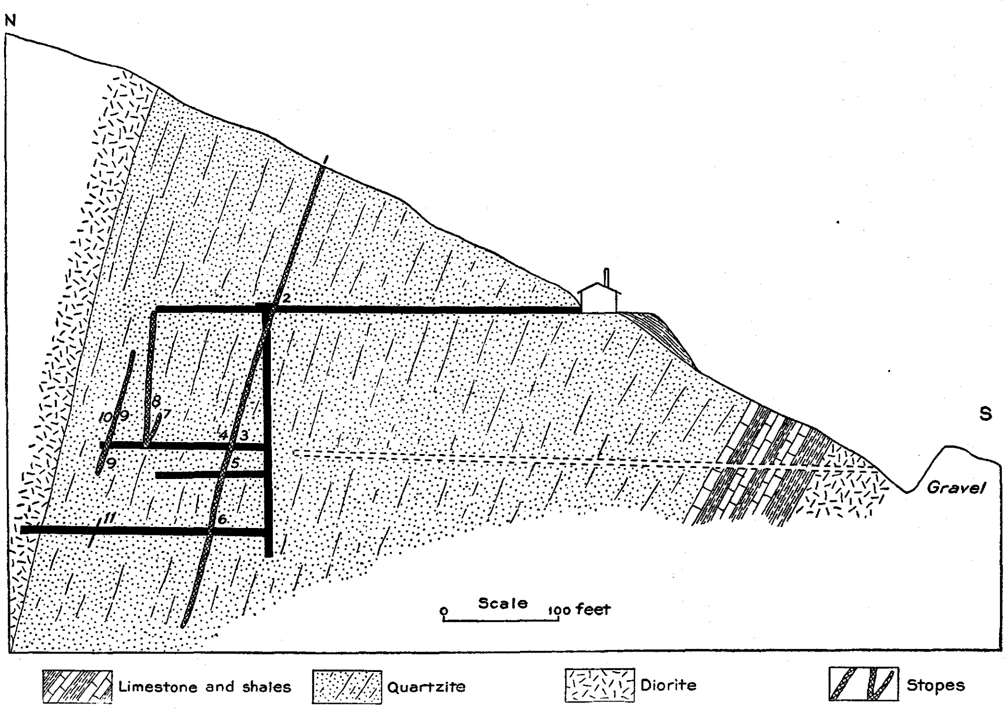

FIG. 3.—Doane mine; sketch projection of workings on vertical plane through shaft at right angles to stratification. Numbers of stopes correspond to those in fig. 2.

Country rock.—The rocks in the vicinity of the mine are quartzite and diorite of pre-Cambrian age. The quartzite is of rather uniform composition, and though its separate strata are very distinct, they do not usually alternate with beds of schist, as in the Ferris-Haggarty. In the tunnels which cut across the formations, practically no other rocks than quartzite are to be seen, excepting in the northernmost workings, where diorite is encountered on the 190-foot level, and in the tunnel located several hundred feet to the south, which has not been connected with the mine, where diorite, shale, and limestone were noted.

The strike of the country rocks is nearly east and west, and they have a fairly uniform dip of from 65° to 75° toward the north; that is, in the opposite direction from the ordinary or normal dip of the stratified rocks in the district at large.

Jointing of country rock.—Throughout the mine the rocks are broken by several sets or systems of joint fractures. These are less marked in the diorite than in the quartzite, where, in combination with the planes of stratification, they have produced zones of brecciation in the brittle country rock, some of which have been filled with metallic sulphides by deposition from mineralizing solutions (figs. 7–12). In fig. 4 the general course of the principal fractures as locally observed are given.

The set of fractures which is usually the most pronounced follows the stratification of the quartzites, striking nearly east and west and dipping steeply toward the north.

A second set of constant occurrence and marked development trends directly across the stratification, striking a few degrees east of north and west of south and invariably dipping toward the west at steep angles.

A third set of joint fractures which is commonly developed trends somewhat to the north and east, making an angle of from zero up to 15° or 20° with the strike of the rocks, but having a steep dip in the opposite direction; that is, toward the south.

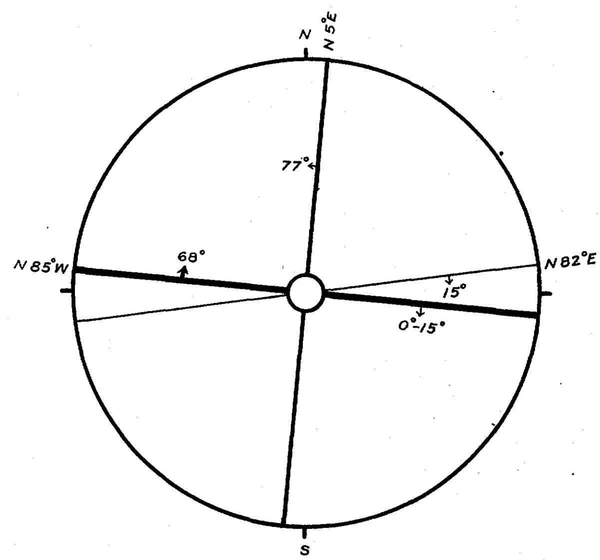

FIG. 4.—Doane mine; diagram to show strike and dip of principal joint systems. The dips given were observed in stope 7. Relative importance of fractures indicated by width of lines.

Of somewhat less importance, but still often to be observed, is the fourth set of joint planes, striking nearly with the strata and dipping steeply toward the south.

Breaks in still other directions are to be noted in various parts of the mine, but the main fractures may ordinarily be referred to one of the four systems enumerated. Throughout the workings all or several of them combine in various degrees of perfection to divide the quartzite into small blocks, and where movement has been especially localized the rock is very much brecciated.

The ore.—The principal ore mineral produced by this mine has been chalcocite or copper glance, though chalcopyrite, bornite, and a little covellite also occur. In the upper workings the red oxide cuprite, the carbonates malachite and azurite, and the silicate chrysocolla were found in some abundance, but these are unusual below the tunnel level. Pockets of a sooty mineral which has been called black oxide are reported to occur, though this is probably chalcocite in a finely divided condition, and not the copper oxide known as melaconite, which is a comparatively rare mineral.

There is ordinarily no gangue excepting the quartzite, which incloses the ore unaccompanied by nonmetallic vein minerals, though kidneys of ferruginous jasper sometimes occur. The chalcocite, mixed with varying amounts of chalcopyrite and bornite, is usually massive and by hand sorting produces a high-grade ore.

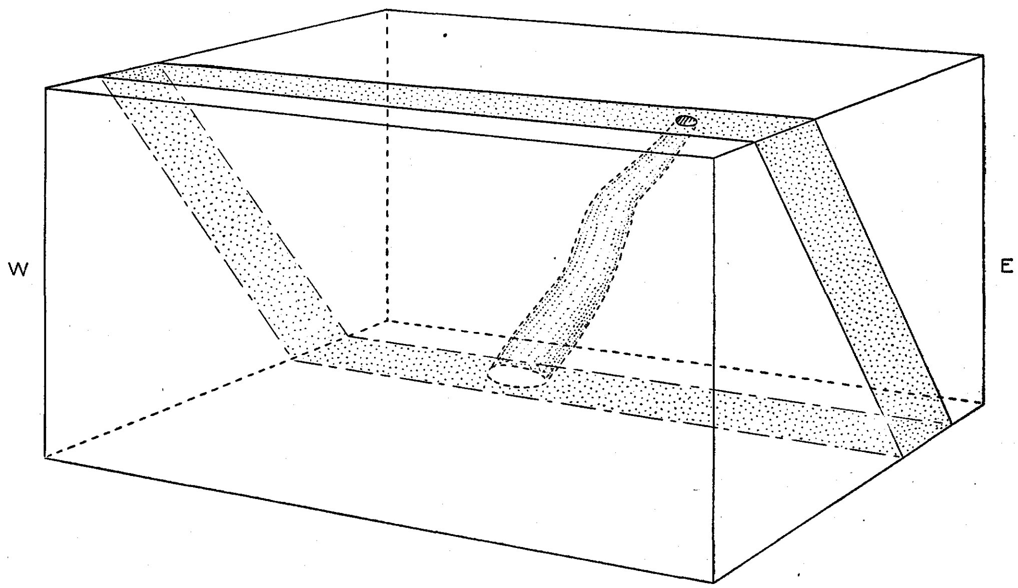

FIG. 5.—Doane mine; stereogram representing main ore body. The ore body follows a bed of quartzite, but has an independent dip toward the west.

Occurrence of the ore.—The occurrence of the ore depends in two ways upon the presence of fractures in the quartzite. In the first place, they have furnished channels for the movement of underground waters; and in the second place, by causing local brecciation, they have formed openings in which the ore has been deposited.

Mineralized zones of brecciation forming ore bodies have been discovered at three distinct horizons in the quartzite, and, except in one case, they follow the stratification of the bedded rocks very closely, as is illustrated in the north-south cross section of the mine workings and country rocks (fig. 3), in which the relation of the ore shoots to the inclosing quartzites is shown.

The blocks of broken rock in which ore has been formed may be described as pencil shaped, or as approaching the form of elongated prisms (fig. 5), the sides of which conform in different portions of their length to the various joint systems observed in the inclosing rocks. The structures which ordinarily and for the longest distances form the boundaries of the ore bodies are the actual bedding planes, or the fractures parallel to the stratification and those nearly normal to it. Thus, the ore bodies dip to the north because they follow the north-dipping strata, but are carried to the west as they gain depth because the north-south fractures dip in that direction; they therefore pitch toward the northwest as a resultant of these two dips. This relation is well exhibited in the plan of the mine (fig. 2), in which the main ore shoot is seen to lie successively farther to the northwest in the different levels from above downward.[a] The same feature is also shown in the stereogram (fig. 5). The dip toward the west, independent of the bedding, is shown in the diagram (fig. 6) representing the general form of the main ore shoot as it lies in the stratification.

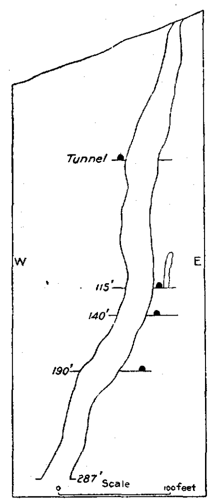

FIG. 6.—Doane mine; projection of main ore body on plane of stratification in quartzites, and at right angles to section shown in fig. 3. The drawing shows the independent dip of the ore body from east to west.

In the case of each ore body the westerly dipping north-south fractures are always in evidence. They have produced a large part of the brecciation, as already stated, and frequently form the east and west boundaries of the ore, as illustrated in the diagrams (figs. 7, 11, 12). Furthermore, it is noteworthy that a horizontal line joining the centers of the different ore bodies, as, for instance, upon the 115-foot level, has nearly the same general trend as the strike of these fractures, so that they are probably all situated upon the same zone of sheeting, along which mineralizing solutions have been introduced.

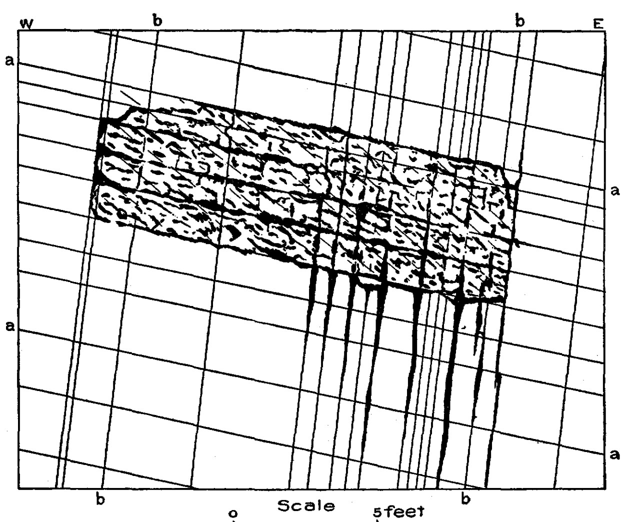

FIG. 7.—Doane mine; horizontal section of ore body in stope 9 about 25 feet above 115-foot level, showing relation of ore body to the layers of quartzite and the north-south fractures. *aa*, stratification; *bb*, north-south cross fractures. Compare with figs. 11 and 12.

The north-south fractures are regarded as the channels along which ascending mineral-bearing solutions were introduced because in several places in the stopes of the mine ore is found to penetrate the country rock of the foot wall along them (fig. 7).

[a] The position of the surface outcrop is estimated, while the other locations are known to be relatively correct.

In the Ferris-Haggarty mine the relations of similar fractures to the ore body are almost identical, and it seems that in both cases ore has been deposited where zones of north-and-south sheeting of the rock intersect with similar zones following the nearly east-west bedding of the strata, producing locally intense brecciation. Fractures belonging to other sets less prominently developed have added their effect to the subdivision of the more or less rectangular blocks formed by the intersection of the main systems, and have produced many minor irregularities in the shape of the ore bodies.

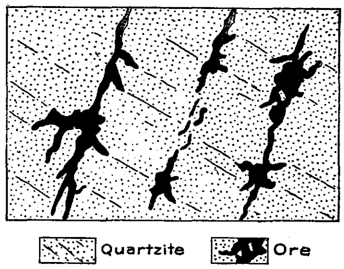

FIG. 8.—Doane mine: sketch showing relation of ore to inclosing rock, stope 9. The ore occurs mainly at the intersection of bedding and cross fractures, apparently having replaced the quartzite.

As a rule the ore appears merely to fill the openings in the quartzite breccia, but in some instances the quartzite seems to have been dissolved away and replaced by the sulphides (fig. 8).

In the following table some of the dimensions of the main body are given:

Dimensions of main ore body in Doane mine.

	Width east and west.	Thickness.	Depth.
	Feet.	*Feet.*	*Feet.*
Surface	Unknown.		
Forty feet above tunnel	25		85
Tunnel	30	3–6	125
First level	25	5	245
Second level	25	4	270
Third level	38	2–6	320
Winze	18		345
Winze	23		370
Bottom			412

Between the different levels the dimensions vary, showing considerable irregularity in the size and shape of the ore body, but the latter is reported to have been continuous from the gossan to the lowest point thus far reached. The general shape of the body in an east-west section, following the stratification of the quartzite, is shown in fig. 6.

In the case of all of the ore bodies thus far encountered, both the foot and hanging wall are very irregular, and often steppy, a condition which arises from the fact that the ore may be limited either by bedding planes or by joints, now one and now the other (figs. 10, 12).

Other ore bodies than the main one, which was the first discovered, have the same general characteristics. The one marked 3 in the plan was discovered by following a small green-stained seam which cut the tunnel on the 115-foot level.

This ore shoot is separated from the main body in the same level by a little more than the width of the tunnel, and while there may be a narrow fracture connecting them, such could not be traced at the time the mine was examined, and it is apparent that the eastern body lies at a slightly lower horizon in the quartzite. It has been stoped to a height of 45 feet above the tunnel and found to have an average width and thickness of about 3 feet each.

At the points marked 7 and 8 on the plan (fig. 2) there are two stopes which connect at the level of the 115-foot tunnel, but diverge upward. The southern one (No. 7) follows the inclination of the beds of quartzite which inclose the ore, while the other (No. 8) is nearly vertical. The former stope, representing approximately

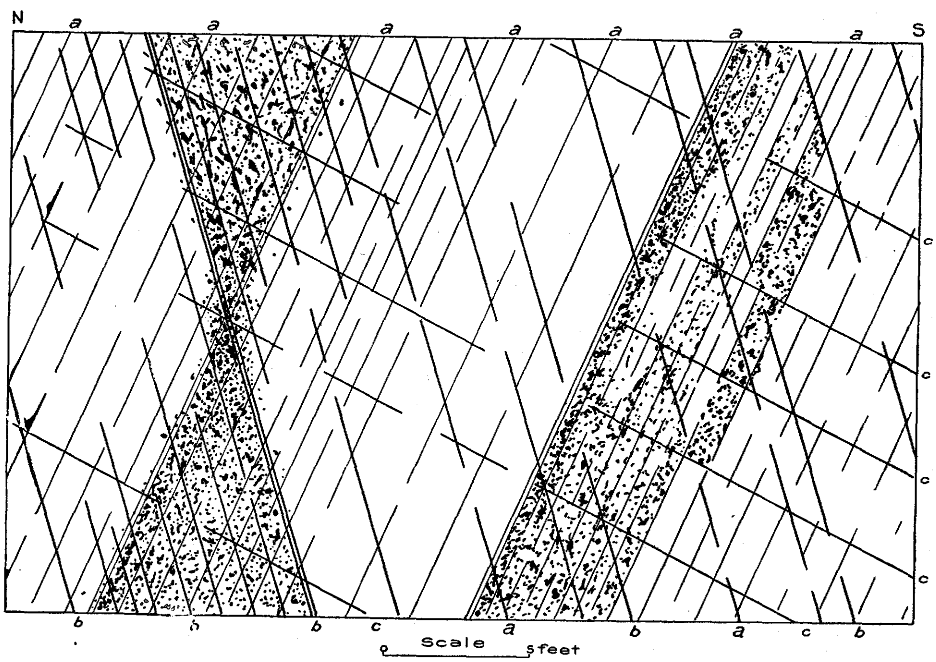

FIG. 9.—Doane mine; diagrammatic cross section in lower portions of stopes 7 and 8, showing occurrence of the copper sulphides in brecciated quartzite formed along intersecting joint systems. *aa*, bedding planes and parallel joint fractures; *bb*, strong system of joints; *cc*, subordinate joints; distribution of sulphides indicated by stippling.

the dimensions of the workable body of ore, is 30 feet long on the incline, 20 feet wide near the bottom, and from 3 to 5 feet across. Stope 8 is 80 feet high, 12 feet wide from east to west, and from 2 to 5 feet across.

Fig. 9 is a diagrammatic section of the lower portions of the ore bodies in stopes 7 and 8, near the 115-foot mine level, showing the relations of three of the four prominent systems of joints which are there developed. The fourth system strikes nearly north and south and is therefore nearly parallel with the plane of the section, so that it does not appear in the drawing. In the vertical stope the hour-glass form shown in the diagram just mentioned, which is due to the presence of intersecting joint planes, is repeated several times, so that the ore alternately widens and pinches as illustrated in the general north-south section of this ore body and its neighbor given in fig. 10. The ore shoot has a similar form in an east-west direction, as shown in the horizontal sketch section or plan (fig. 11), on which the north-south fractures also appear.

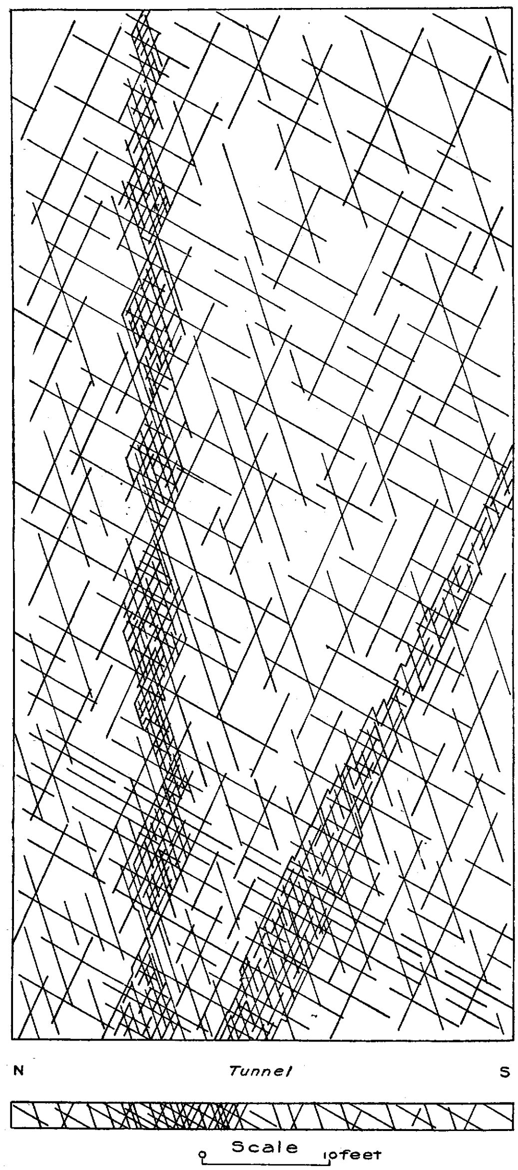

FIG. 10.—Doane mine; vertical north-south section through stopes 7 and 8, showing relation of ore channels to intersecting system of joints. Compare with figs. 3, 9, and 11.

About 35 feet north of stopes 7 and 8 two ore shoots were encountered which occur in the same beds of quartzite, but are separated along the strike by about 25 feet of barren rock. The relative positions of the shoots at the 115-foot level are shown in the horizontal plan (fig. 2), while their attitudes in regard to one another in the stratification are exhibited in fig. 12, which shows also the manner in which the ore bodies follow the westward dipping north-south fractures, which are more closely spaced opposite the ore shoots than elsewhere. A horizontal plan of the eastern shoot representing diagrammatically the original conditions about 25 feet above the tunnel level is given in fig. 7. In this stope there is abundant evidence of the important rôle which the north-south fractures have played in the formation of the ore, for besides constituting very well-defined end walls, they sometimes contain ore, and have every appearance of having been feeders, by means of which mineralizing solutions were introduced into the loose material in the brecciated zone. The eastern shoot (No. 9 of the plan) has been worked by an overhead stope, 80 feet in height, and by an underhand stope 25 feet deep; the western (No. 10 of plan) by an overhead stope for a distance of 40 feet on the incline, and by a shallow pit below the tunnel level which shows some ore.

Both shoots pitch toward the northwest in accordance with the general rule that the ore bodies follow the intersection of the northerly dipping stratification with the north-south fractures which dip toward the west.

Genesis of the ore.—From the preceding descriptions it will be be seen that the ore bodies occur in brecciated masses of the quartzite which forms the immediate country rock, and while there are zones of broken material which are not mineralized, in those cases where sulphides have been deposited, joint planes belonging to a north-south striking and westerly dipping system are particularly in evidence. They are prominent as rather close-set fractures sometimes filled with ore, or forming the end walls of ore bodies, or again through the invariable tendency which the ore shoots have of following the line of their intersection with the bedding planes of the quartzite. These north-south fractures correspond very closely, in their relations to the ore bodies, to those of the Ferris-Haggarty mine, and their significance is believed to be the same in both cases.

Adjustments within the mass of the quartzite seem to have caused a greater amount of movement along the transverse fractures than along any other structural surfaces, with the probable exception of the stratification planes, where any motion would be readily accommodated and its direction naturally controlled by the heterogeneity of the separate rock layers. Other joint systems are sometimes important elements in the brecciation of the quartzite, but these two are always the factors which control the direction of the zones or bands of broken rock whenever they are mineralized to any important degree.

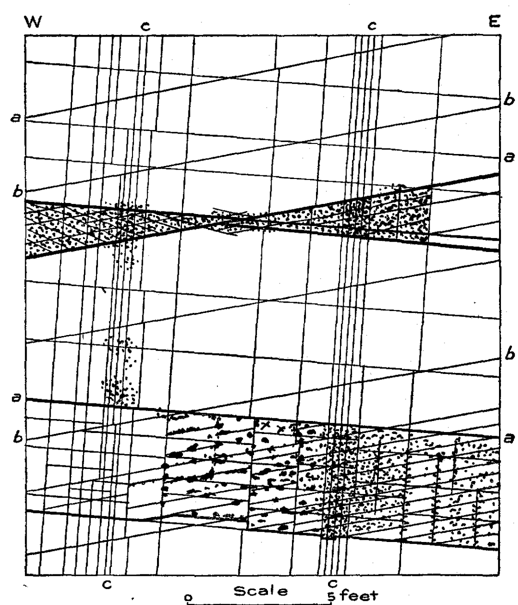

FIG. 11.—Doane mine; horizontal plan through stopes 7 and 8, showing relation of ore to fractures and bedding of quartzite. *aa*, bedding planes and parallel joint fractures, dipping north; *bb*, strong system of south dipping joints; *cc*, important north-south fractures with steep dips toward the west.

It is also along the north-south fractures that mineralizing solutions, by means of which the primary ore deposited in the brecciated zones was introduced, seem to have been in general circulation. While more detailed studies than have been made would be required to settle the point with certainty, it seems that the mineral-bearing solutions were ascending solutions, for while north-south fractures filled with ore seem to occur south of the ore bodies—that is, in the country rock forming the foot wall—they were nowhere seen to be filled above the ore horizon in the quartzite of the hanging wall, a relation which suggests that circulating solutions tending upward in the fissures were totally deflected into the brecciated zones wherever they were encountered.

Direct evidence in regard to the source of the copper was not secured, but the fact that the metal is so universally present in the basic intrusives, which are found in all parts of the field, as already brought out in the general discussion upon an earlier page, seems to warrant the belief that it has been derived from these rocks.

That the ore shoots as first formed consisted of chalcopyrite can hardly be doubted, because the derived or secondary nature of the chalcocite ore is evident. In almost any specimen selected at random grains of yellow chalcopyrite are found embedded in a mass of the dark copper glance, and specimens of low-grade material

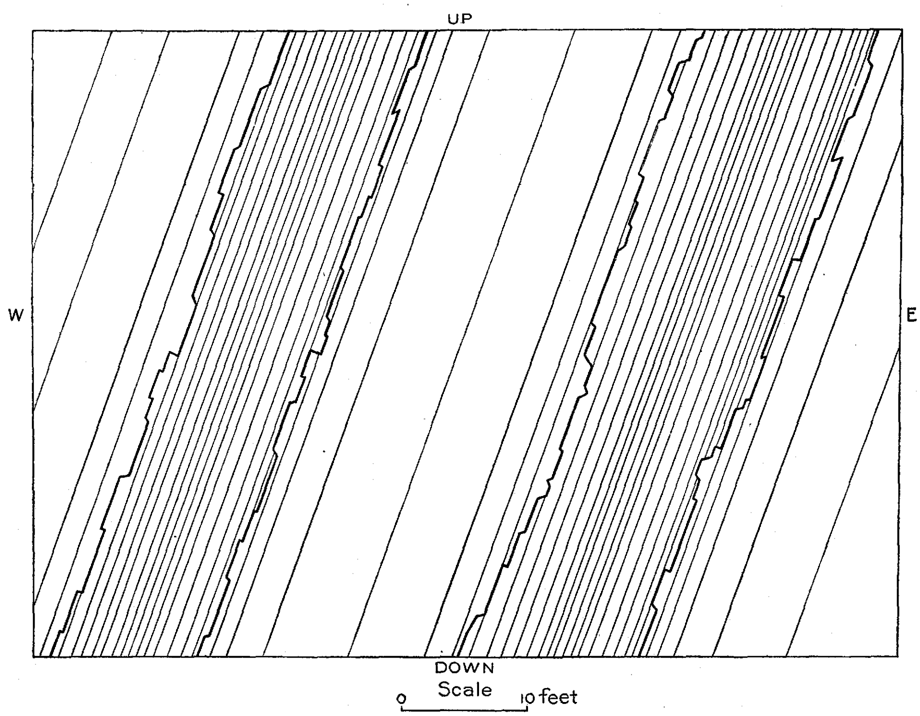

FIG. 12.—Doane mine; section parallel to stratification of quartzite through stopes 9 and 10, showing relation of ore shoots to zones of close jointing, which strike nearly north-south and dip steeply toward the west. Brecciation in these shoots is principally controlled by the intersection of these fractures and the bedding planes. Other less important fractures are present though not represented in the diagram. The bedding of the quartzite, which corresponds with the plane of the paper, dips toward the north. Compare with drawings of the main ore body in figs. 5 and 6.

from the wall rock in which to the natural eye the quartzite seems to be specked with chalcocite are found, when examined under the microscope, to contain both chalcopyrite and chalcocite, the former being confined to the centers of the ore specks and entirely surrounded by the latter. The chalcocite has been derived from the primary chalcopyrite through leaching and redeposition by surface waters percolating through the ore bodies, and to the fact that this alteration has taken place the richness of the Doane ore is to be attributed.

The ore occurs mostly as a filling or cement in the quartzite breccia, but in some cases it seems to be partly interstitial and partly a replacement of the quartzite, as though the mineralizing solutions had dissolved and carried away the quartzite near the channels of circulation and deposited the ore in its place (see fig. 8).

Future of the property.—Gradual improvement with increasing depth is not commonly observed in mines where rich secondary sulphides form the principal ore, and it is therefore to be expected that, as they are mined downward, the ores of the Doane mine will decrease in value. There can be little doubt that the ore which has already been taken from the lower workings contains a smaller percentage of copper than that from some of the higher levels, for, though no studies based upon assays have been made to bring out this relation, there is a notable increase in the proportion of chalcopyrite and a corresponding decrease in the amount of secondary chalcocite, which is quite sufficient to show this tendency. Accepting this as true, the richer sulphides will sooner or later give place to chalcopyrite ores of comparatively low grade, which, though they could possibly be worked in connection with richer ores, might not be able to bear the expense of operation alone. For these reasons the future success of the property is regarded as largely dependent upon the discovery of additional high-grade ore bodies. Whether such ore bodies exist or not can not be decided out of hand, but the relations which have been brought out in the preceding descriptions seem to warrant the suggestion that they may be found. Rich ore has been taken out of workings on the claim which adjoins the Doane property upon the west, and at whatever horizon in the quartzite this ore occurs, its presence is presumptive evidence that north-south sheeting of the rocks exists in this ground. If future exploration should demonstrate this to be the fact, then there is a possibility of encountering several ore bodies by prospecting along this sheeted zone; and, moreover, between it and the known zone of sheeting which carries the ore bodies in the Doane mine others may occur with ore shoots locally developed in them. Similar zones of localized shattering may also occur in the ground to the east, and on the whole it is believed that careful exploration underground, close attention being paid to changes in the extent to which the north-south fractures are developed, is fully warranted by the conditions which can now be made out. It need hardly be added that before making a search for zones of fracturing not now apparent, the one upon which the known ore bodies exist should be thoroughly prospected to the north of the present workings. In this direction the line of intersection between the fracture zone and the contact of the quartzite and diorite may prove a favorable position for the occurrence of ore, a suggestion which, though purely speculative, could be followed up at small expense.

FERRIS-HAGGARTY MINE.

Location and development.—The Ferris-Haggarty property is located about 2 miles west of Bridger Peak, on the east side of Haggarty Creek. It was formerly known as the Rudefeha, a name which has since been given to the post-office located at the mine.

The surface outcrop of this important ore deposit was a small exposure of gossan surrounded by the loose surface wash which covers the general slope of the hillside in the vicinity. This gossan, which is composed of spongy iron oxide mixed with quartz, was penetrated to a depth of 35 feet with little or no evidence of the presence of copper, but at this depth sulphide ores, occurring in kernels and bunches within

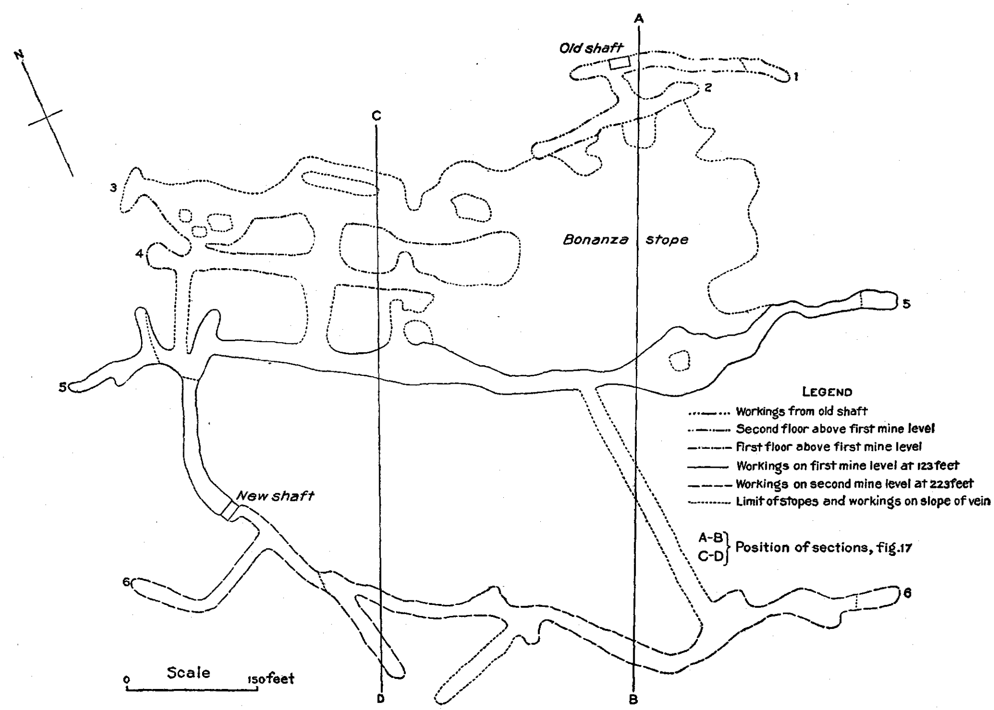

FIG. 13.—Ferris-Haggarty mine; plan of mine workings. Successive floors and levels are numbered to correspond with fig. 14.

the spongy iron oxide of the gossan, were encountered. The inclined shaft was continued to a depth of nearly 80 feet, and the ore was opened up both to the east and west in drifts at two levels (figs. 13, 14). A new shaft was then sunk at a point down the slope of the hillside, about 240 feet distant from the discovery. More than 30 feet of loose surface débris was penetrated before striking bed rock. The ore body was encountered at about 165 feet, and the shaft was continued to a total depth of 248 feet. At 123 feet a crosscut toward the north penetrated the hanging wall of the ore at a distance of 60 feet, and 100 feet lower the foot wall was reached by a crosscut to the south, within a distance of about 40 feet. From these levels the ore body was developed by raises and intermediate floors in the vein, and in addition a large amount of high-grade ore was stoped out, especially in the eastern part of the mine. The horizontal length of the ore body varies from 250 to 300 feet.

It is reported that the ore has been proved to continue downward some 50 feet or more to the level of the new adit which was opened in the spring of 1903. It is by means of this adit that the known reserves and the future possible discoveries of

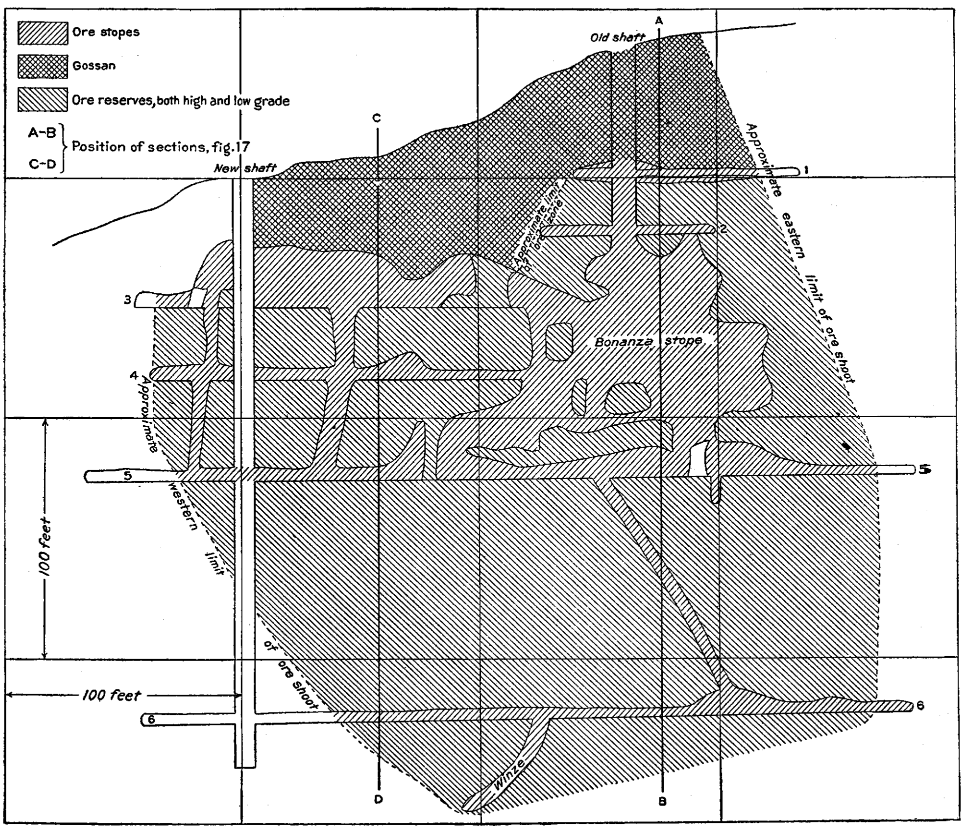

FIG. 14.—Ferris-Haggarty mine; projection of workings on vertical plane parallel to strike of ore body.

ore are to be taken out. At its mouth the ore may be conveniently loaded into the buckets of the aerial tramway which connects the mine with the concentrator and smelting plant at Encampment.

Because of the high cost of transportation, only high-grade mineral has been hitherto mined, excepting where the removal of low-grade material was necessitated in winning the shipping ore. Being developed in this way, practically no dead work had been done at the time this examination was made, and the workings were almost entirely confined to the vein.

Country rock.—The country rock at the Ferris-Haggarty mine is mainly quartzite and schist, belonging to the pre-Cambrian quartzite and slate formation. Intrusive gabbros, known in the district as diorites, occur near by, but are not encountered near the ore body.

The ore occurs at and follows a definite horizon situated between 200 and 250 feet below the top of the quartzite-slate formation, the upper limit of which is marked by the appearance of heavy beds of conglomerate. A section of the bedded rocks as they are exposed upon the ridge which forms a spur from the Continental

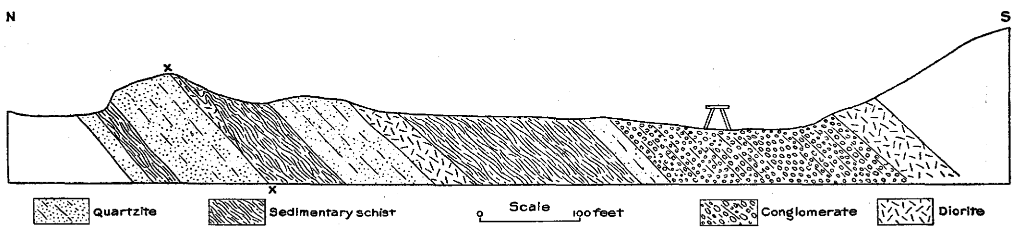

FIG. 15.—Section of bedded formations on ridge about one-half mile east of Ferris-Haggarty mine. The so-called "contact" horizon is marked by crosses. It is not mineralized at this place. Compare fig. 16.

Divide about one-half mile east of the mine, near the point where the tramway crosses, is given in fig. 15. This illustrates the alternation of varying strata below the ore horizon, while a complementary section (fig. 16), observed upon the ridge on the opposite side of Haggarty Gulch, gives the similar features of the strata which lie stratigraphically lower. Both sections show the intercalation of igneous rock and disclose the general attitude of the beds, which strike nearly east and west, dipping to the south at angles varying from 35° to 50°. In the mine work-

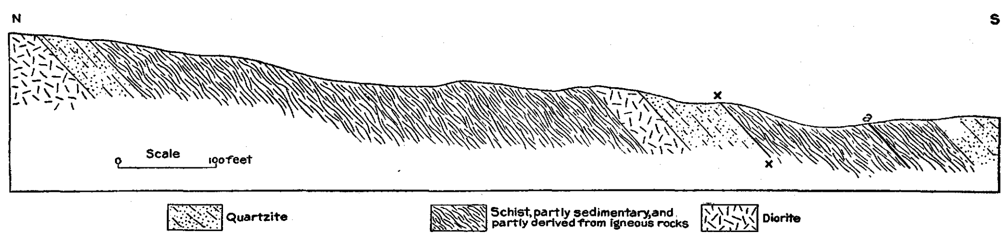

FIG. 16.—Section of bedded formations and intrusive rocks about one-half mile west of Ferris-Haggarty mine. The so-called "contact" horizon is marked by crosses. At *a* there is evidence of a considerable fault parallel with the bedding of the rocks.

ings the strata are observed to have a corresponding structure, though there are local minor variations, both in strike and dip, which bear an important relation to the ore deposit.

Jointing of country rock.—Throughout the mine the quartzite is broken by different sets of fractures, but these are rarely, if ever, represented by breaks in the hanging-wall schist, for in it adjustments and accommodations to movement caused bending of the strata and crumpling of its separate folia, while the brittle quartzite was fractured and brecciated. The most prominent fractures observed in the rocks of the vicinity run in a direction nearly north and south—that is, nearly normal to the course of the vein—and, while nearly vertical, usually have a slight inclination to the east or west.

In the massive sandstone corresponding to the ore horizon, where it outcrops upon the crest of the ridge to the east of the mine, there are many small veins of quartz having a width of several inches near the contact of the quartzite and schist, but gradually becoming thinner toward the north, and finally disappearing at a distance of 30 feet or so. Other rocks, such as the intrusive diorite, likewise contain similar veinlets of quartz, showing the general occurrence of these fractures. They may be observed in exposures upon the west side of Haggarty Gulch opposite the mine, and in this vicinity there is also some evidence in the relations of outcrops of the rocks that important faults break the continuity of the strata along north and south fractures, and cause offsets of the beds toward the south as they are followed from east to west.

In the mine, fractures of the north-south system are to be observed at several places, though they are not uniformly developed throughout the workings. Locally they are rather closely spaced, as observed in the quartzite of the foot wall, and where this is the case, the schist which lies over the vein is often bent outward toward the south, and in the hollow thus formed the ore body is thicker than usual and the ore ordinarily of higher value. It seems that by bending in this way the more pliable schist has been able to take up or accommodate itself to movement which caused fracture in the brittle quartzite. The occurrence of fractures striking nearly parallel with the bedding of the quartzite and dipping in a contrary direction was noted at several points (figs. 24, 25), but there is less opportunity in this mine than in the Doane to observe the characteristics of the joint systems, since so great a share of the workings have been in the ore. Undoubtedly several sets of fractures have acted together to cause the brecciation of the brittle quartzite beneath the pliable schist, and in all probability there has been an important amount of crushing caused by movement along this horizon, in addition to adjustments along the different joints.

The ore.—The principal ore minerals which have been extracted from this mine are chalcocite and chalcopyrite, though bornite and covellite are occasionally found. Carbonate and oxide ores are present in small amounts only. The richest ore is found in the upper workings, where the proportion of chalcopyrite is less than on the lower levels. Much of the ore requires concentration, being mixed with the quartzite country rock, but no other gangue is present, and in the past all of the ore shipped has been practically free from foreign matter.

Occurrence of the ore.—The ore body in this mine follows a somewhat irregular zone of brecciation in the upper part of a definite stratum of quartzite, which, in common with the beds associated with it, strikes nearly east and west and dips about 40° toward the south. Above this quartzite and sharply separated from it there is a bed of very fine-grained schist, which, though very much crumpled, contrasts with the quartzite below by reason of the practical absence of brecciation. This schist, which has a thickness estimated at about 50 feet, forms the hanging wall of the vein throughout the mine (figs. 15, 16, 17). There is no definite continuous foot wall, but the ore makes back into the quartzite in an extremely irregular manner, dependent either upon the completeness of brecciation or upon

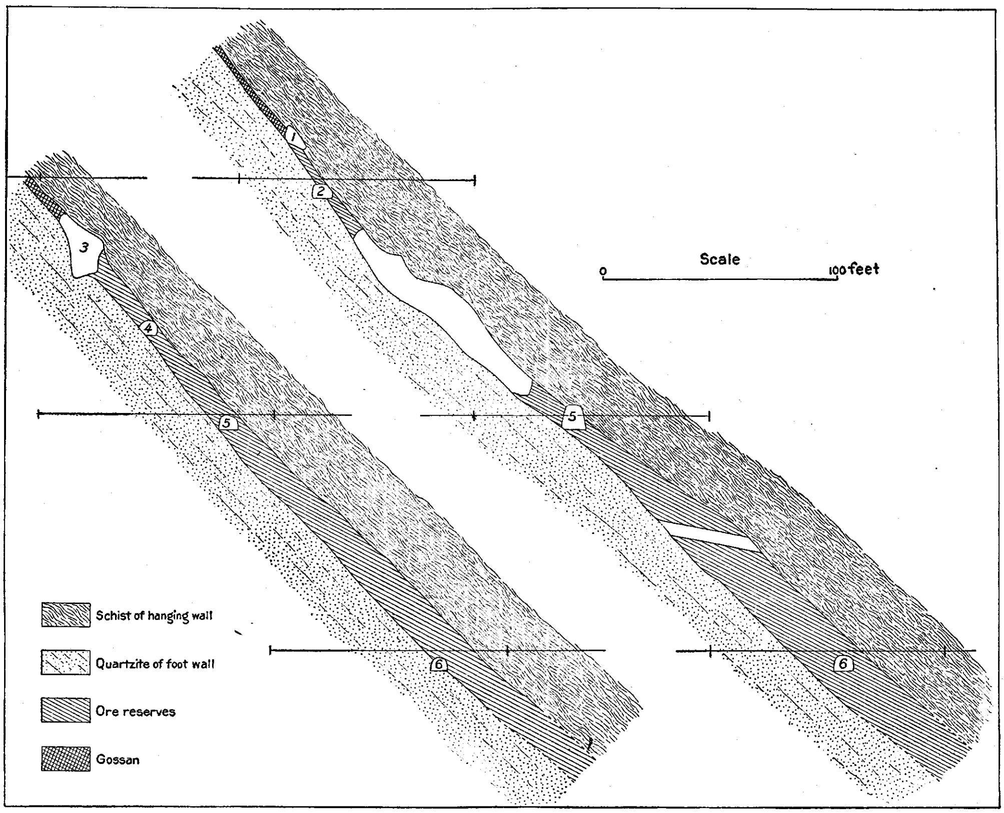

FIG. 17.—Ferris-Haggarty mine; transverse sections of the ore body along lines A B and C D in figs. 13 and 14.

the presence of cross fractures. The deposit has many of the characteristics of the Doane ore bodies, and is regarded as being of the same general type.

At the time the mine was visited the Ferris-Haggarty ore body had been followed from its outcrop to a depth of 266 feet below the surface, giving a known length on the dip of over 400 feet (figs. 14, 17). It is reported that the ore has been found to extend into the lower workings which have been opened from the new adit completed in the winter of 1902–3, so that the full depth to which the mineralization continues has not been ascertained as yet.

The upper limit of the ore where it passes into the gossan which forms the surface capping has been fully determined in the upper stopes and found to be rather irregular at a depth of from 35 to 60 feet (fig. 17). The drifts and stopes which have been opened at different levels show that the high-grade ore, at least, is rather sharply bounded. In the first mine level, at a depth of 125 feet, the horizontal length of the ore shoot is about 300 feet, while in the second level, 100 feet below, it is some 50 feet less (figs. 13, 14).

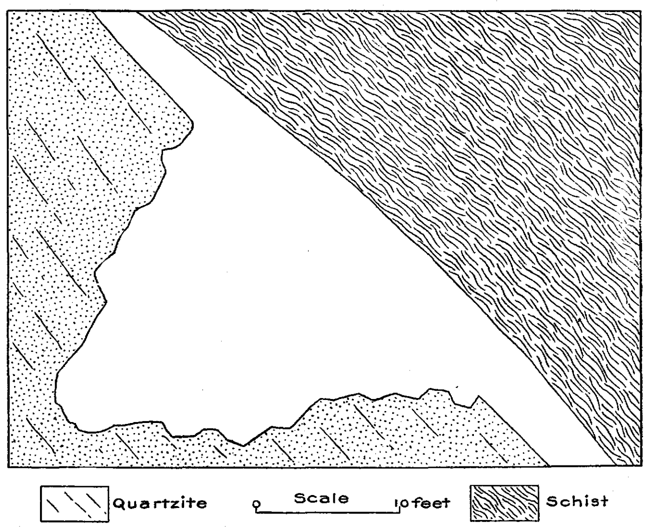

FIG 18.—Ferris-Haggarty mine; north-south sketch section through Bonanza stope at first mine level. Shows form of ore body and irregularity of foot wall. Compare fig. 19.

Along its strike the ore body seems to be limited by the disappearance of brecciation in the quartzite, but there is often low-grade ore beyond the present excavations, and few opportunities were afforded for conclusive observation

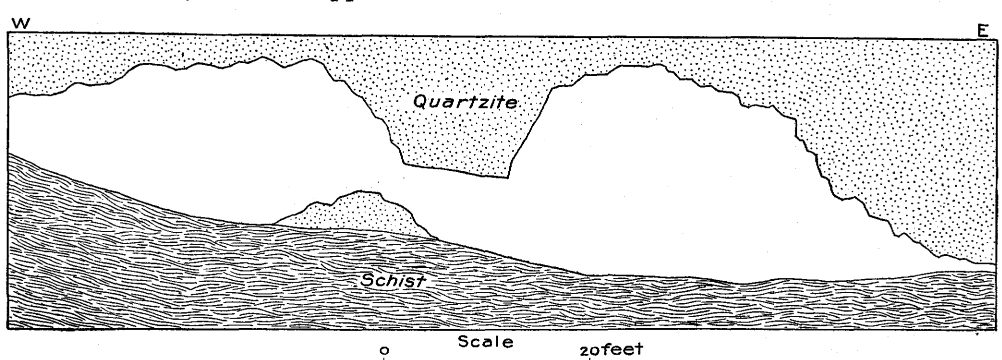

FIG. 19.—Ferris-Haggarty mine; sketch section through Bonanza stope parallel to strike and at right angles to dip of ore body. Compare figure 18.

upon this point. The thickness of the vein is extremely irregular, varying from a few inches near the ends up to 30 feet, or even more in some places (figs. 11, 18, 19).

Upon any level in the mine the intersection of a horizontal plane with the surface formed by the hanging wall is a curve concave toward the north. This is illustrated in fig. 20, in which the general shape of the vein upon the first

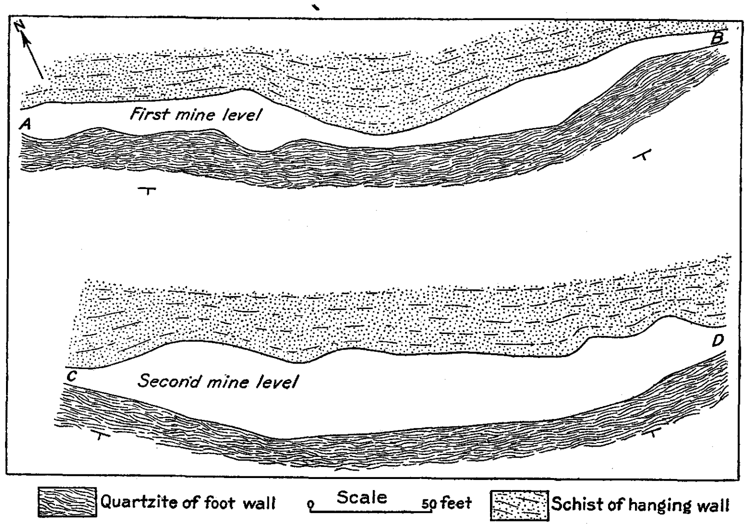

FIG. 20.—Ferris-Haggarty mine; plans of ore body on first and second mine levels. The general bowing toward the south is well shown. Compare levels 5 and 6 in figs. 13 and 14.

and second mine levels is given in horizontal plan, and in fig. 21, which is an idealized diagram showing in horizontal section the relation of the ore body to the country rock and to the north-south fractures.

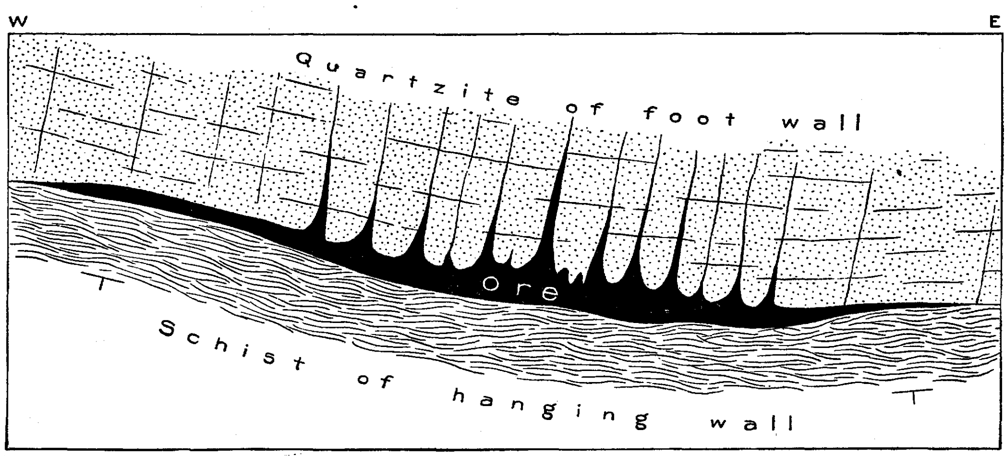

FIG. 21.—Ferris-Haggarty mine; idealized horizontal section of ore body, showing general convexity toward the south and the filling of north-south fractures.

Combined with the horizontal curving of the hanging-wall surface there is variation in dip, or irregular bending up and down from the plane of average inclination, so that the under surface of the schist overlying the ore is seen to be a warped surface of very intricate contour. However, its irregularities are gentle rather than abrupt, and the fidelity with which the ore body follows the surface of division between the quartzite and the schist gives a sharply defined hanging wall, a feature which is illustrated in several of the accompanying diagrams.

The foot wall has none of the regularity of the hanging wall, where the ore makes in the country rock in various ways, doubtless dependent upon local differences in the development of the fractures and brecciation in the quartzite (figs. 23, 24, 25).

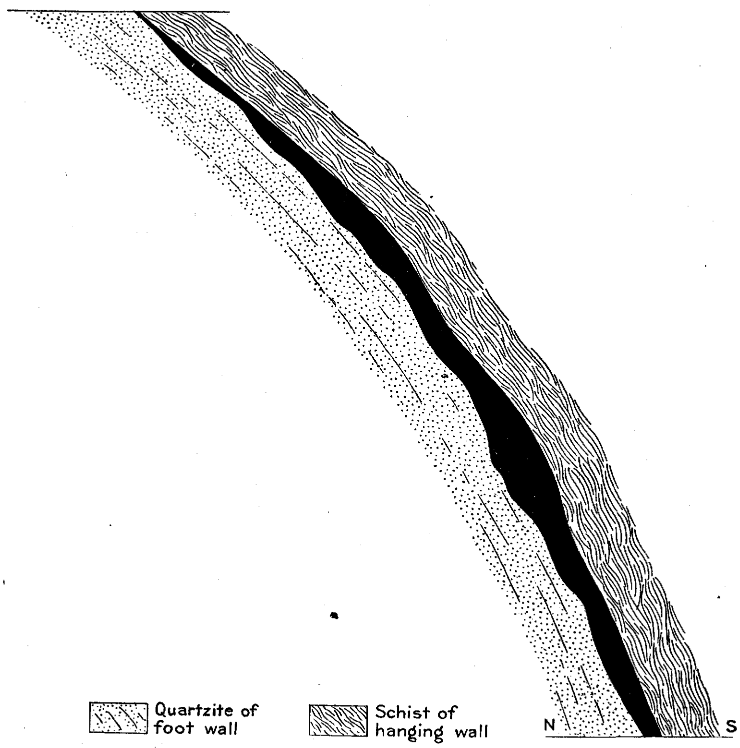

FIG. 22.—Ferris-Haggarty mine; idealized vertical north-south section across the ore body, showing convexity and irregular dip.

A certain amount of ore is found in north-south fractures in the quartzite country rock beneath the ore shoot, and a portion of the sulphides in the latter may have been formed by a replacement of the quartzite, but the main mass of the ore occurs filling the mass of broken or brecciated quartzite, the fragments of which are sharply limited against the ore and contain metallic minerals only in the form of veinlets with sharp walls (figs. 23, 24).

The sketch diagram (fig. 25) represents the relations of the vein to the inclosing rocks in the west end of Bonanza stope. The bottom of the section is 90 feet above the first mine level. In the foot wall north-south fractures are prominently developed, but there is no marked horizontal bowing of the strata. The ore minerals are chalcocite with some chalcopyrite, and these form a matrix for brecciated fragments of quartzite. The foot-wall material is much fractured and seamed, while the overlying schist appears to be perfectly intact, though it is considerably crumpled.

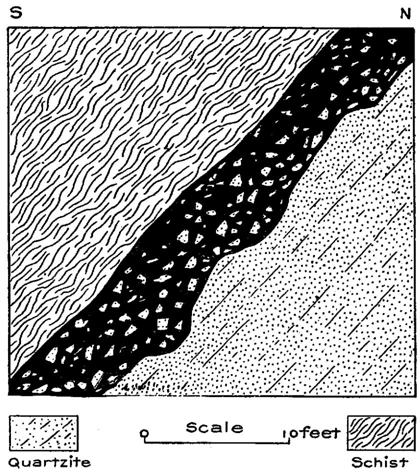

FIG. 23.—Ferris-Haggarty mine; face of stope west of old shaft, 90 feet above first mine level. The sketch shows the brecciation of the quartzite and irregularity of foot wall. At this place north-south fractures are strongly developed in the foot wall, but do not cut the overlying schist.

At several places in the mine the ore body was found to have more or less continuous bands of schist running through it, and in such cases the ore is found to be formed just under the bands of close-grained rock, while the quartzite above them is barren for some distance (fig. 26), indicating that the ores were deposited by ascending waters.

Genesis of the ore.—The reference of the Doane and Ferris-Haggarty copper ores to the same type of deposit is founded on the very close similarity in their mode of occurrence. In the latter the upper part of a bed of quartzite, striking nearly east and west and dipping south, has been greatly broken and brecciated along its contact with a thick overlying stratum of schist. The brecciation has been caused in part by

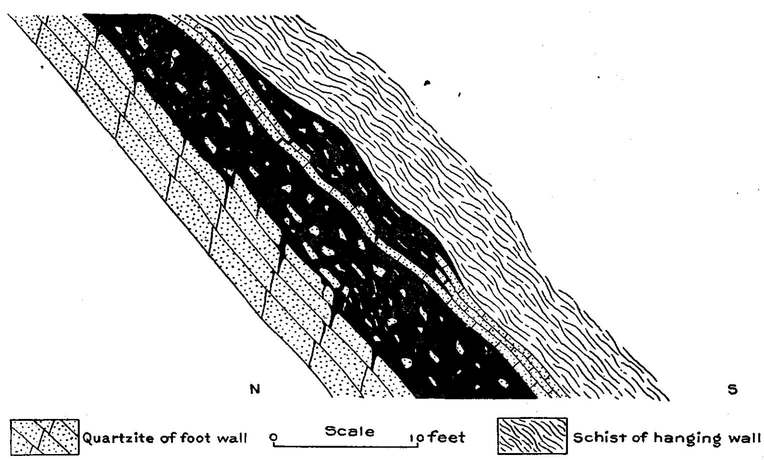

FIG. 24.—Ferris-Haggarty mine; idealized sketch of ore body as seen near old shaft at depth of 135 feet, showing false hanging wall and nature of brecciation.

movements essentially parallel with the bedding, and in part by movements along fractures transverse to the stratification. Cross fractures, which strike nearly north and south and dip steeply either to the east or to the west, are to be observed in various parts of the mine, and in some cases they are filled with ore in the quartzite of the foot wall, but they do not break the continuity of the hanging-wall schist. The latter has almost invariably adjusted itself to movement in the direction of these fractures by bending, instead of by breaking. This being the case, and the schist being fine grained, it forms a capping over the open quartzite breccia which has been very impervious to the passage of water in circulation.

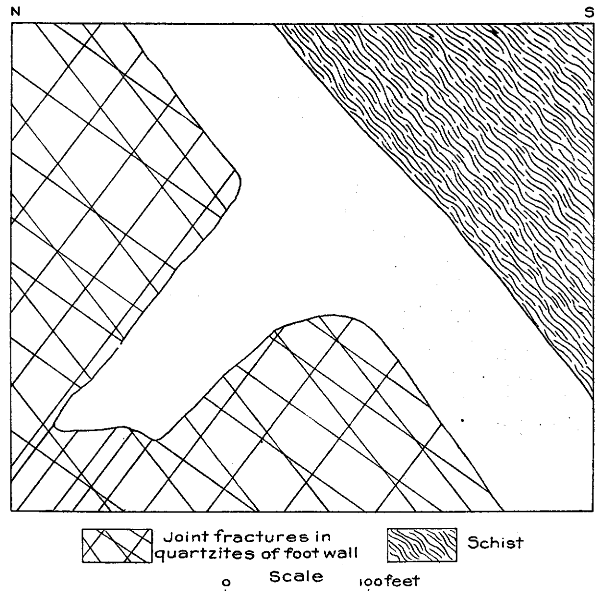

FIG. 25.—Ferris-Haggarty mine; north-south diagrammatic section through stope on first mine level near head of incline to second level, showing intersection of bedding and fissures, and an offshoot of ore into the foot-wall quartzite.

From the relations which have been described in detail in the foregoing pages, and which are here briefly summarized, it is believed that the existence of the Ferris-Haggarty ore body depends upon the presence of the north-south cross fractures, the brecciated quartzite, and the overlying impervious schist. The cross fractures being in many places filled with ore are regarded as having been channels of easy circulation for ascending solutions. Since the fractures do not continue through the schist, the moving waters were completely deflected by the impervious stratum into the fractured rock beneath, along which they continued to ascend, and found conditions favorable for the deposition of their metallic contents.

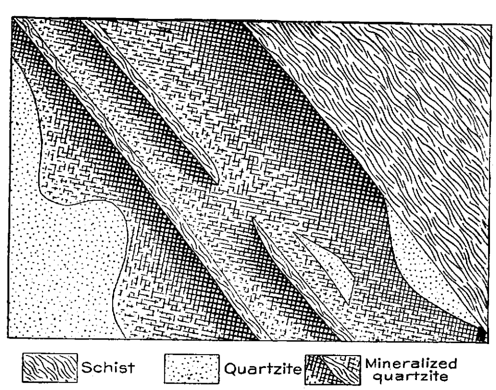

FIG. 26.—Ferris-Haggarty mine; diagrammatic section of ore body, illustrating the manner in which the richness of the ore increases just beneath layers of close-grained schist interbedded with the quartzite.

The occurrence of ore in these north-south fractures beneath the ore horizon, and the relation of the latter to them, suggests that they have been feeders for the main ore body, and while sufficient observations have not been made to prove the point, it is believed that there is a zone of excessive sheeting transverse to the strike of the rocks which inclose the ore body, and as wide as its horizontal length. Outside of this zone parallel fractures exist, but they are probably few and widely spaced.

That the mineralizing waters were ascending and that the schist was practically not penetrated by them is shown by the clearness of the contact of ore and schist and the rarity with which any ore occurs in the material of the hanging wall. The same thing is brought out even more clearly in certain places where thin beds of schist occur within the mineralized part of the quartzite (fig. 26). In such cases the ore is mainly segregated beneath the different schist bands, and immediately above them little or no mineralization has taken place.

The basic gabbro rocks of the region are regarded as the source from which the deeply circulating waters derived their metallic contents.

The primary ore was chalcopyrite with perhaps some iron sulphide free from copper, and the rich ores which have been encountered have resulted from secondary concentration of originally leaner ores, through the action of surface waters percolating through the vein, dissolving copper from the upper portions and redepositing it lower down. Examination of the ore in the mine workings shows the gradual increase of primary chalcopyrite and the corresponding diminution of chalcocite as depth is attained, and it is probable that eventually the former will entirely replace the latter.

Future of the property.—The prosperity of the Ferris-Haggarty mine for the immediate future is practically assured by the existing ore reserves (see figs. 13, 14), and the conservative policy of developing and exploring while production is going on will doubtless be adopted.

The ore body itself will naturally be followed downward, and exploration of the ore-bearing horizon between the schist and quartzite toward the east may lead to the discovery that another zone of north-south sheeting has produced mineralization in it. Also the ground north of the present workings may contain ore bodies located beneath other slaty or schistose layers intercalated in the quartzite, and related to north-south fractures in a manner similar to the known deposit.

CHARTER OAK MINE.

The Charter Oak property is located a short distance north of the area shown on the Encampment special map, in sec. 24, T. 14 N., R. 85 W., about 6½ miles northwest of Encampment.

The country rocks in the vicinity are gneissoid or schistose granite and metamorphosed basic rocks related to gabbros, but having the composition of diorite. The greater part of these diorites are schistose, but occasionally they are massive. They are intrusive in the granite gneiss, and the contacts between them and the schistosity of the diorite follow the platy structure of the older granitic rock.

The mine is situated near the east side of a broad synclinal fold, the axis of which pitches northwest from the high hill about 1 mile to the southwest, in sec. 29, T. 14 N., R. 85 W. In this locality the influence of the fold may be noted eastward to Otto Creek and westward to Calf Creek, a distance of nearly 2 miles (fig. 27).

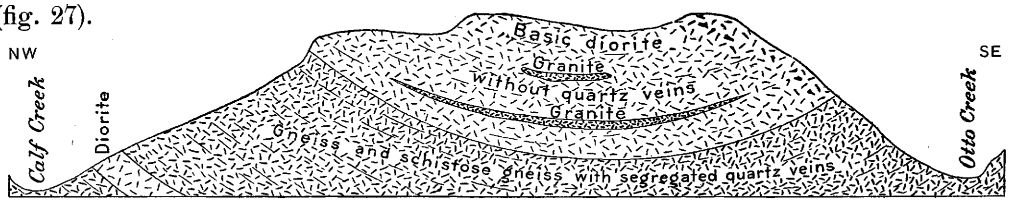

FIG. 27.—Sketch section of main syncline in prominent hill southwest of Charter Oak mine. View looking northeast.

Near the mine the rocks within the general syncline are greatly twisted, and are also faulted, as is illustrated in the sketch map (fig. 28) showing their local structure, and in the cross section (fig. 29).

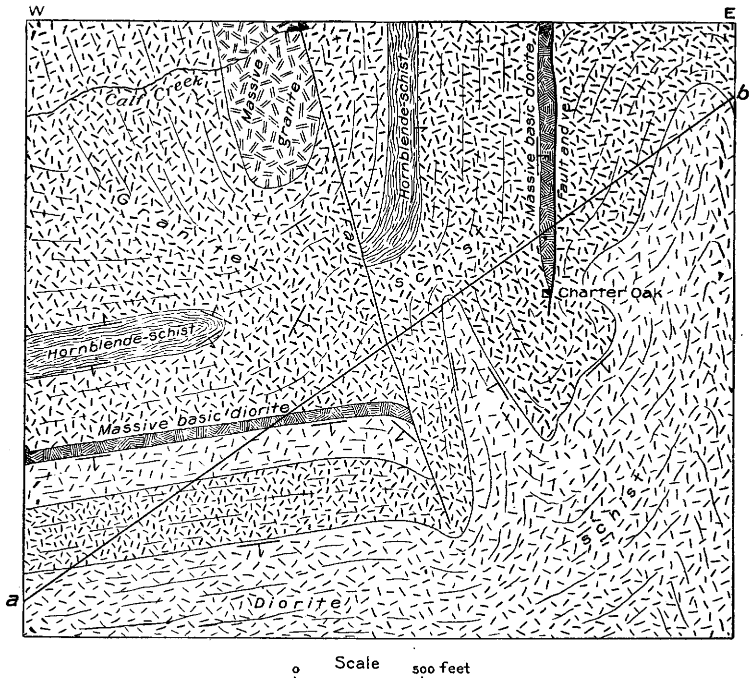

FIG. 28.—Sketch map of vicinity of Charter Oak mine, showing structure and distribution of rocks.

An inspection of the sketch map and section will show the position of two nearly north-south faults which follow the axes of two minor anticlines pitching toward the

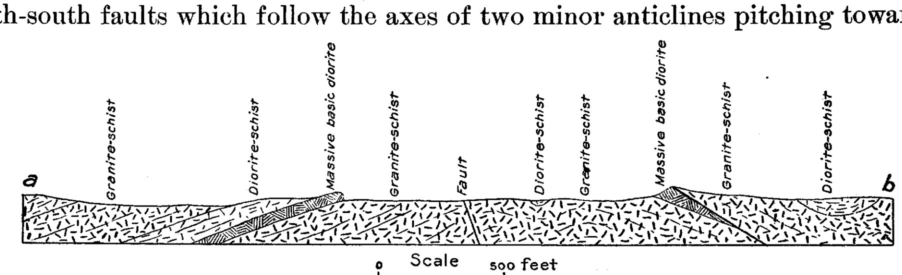

FIG. 29.—Charter Oak mine; sketch section along line *a b*, fig. 28.

north. The eastern of these two faults forms the fissure in which the Charter Oak vein occurs; the other is not known to be mineralized.

A more detailed sketch in the immediate neighborhood of the Charter Oak vein is given in fig. 30. The fault with basic diorite on the west and gneiss upon the east may be readily traced for nearly 1,500 feet, and vein material outcrops at intervals along it.

The vein proper consists of quartz carrying a variable amount of copper and iron, but the wall rock is often fractured and mineralized as well. Its relations are shown in the cross section, fig. 31, taken at the point *a*, fig. 30, while the more detailed sketch represents its characteristics at the point marked *b* on the plan.

From the most northerly outcrop the vein is nearly straight southward to the incline where the main ore body was found. At this place the gangue was mainly quartz, brown jasperoid, and schistose wall rock, with some calcite and a little chalcedony. The primary ore was chalcopyrite, some of which still remains, while the alteration of this mineral has given rise to secondary chalcocite, bornite, azurite,

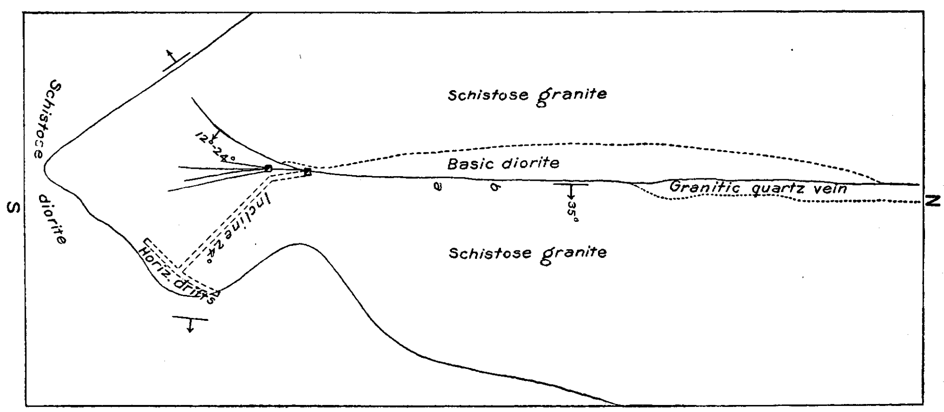

FIG. 30.—Charter Oak mine; surface plan of vein.

hematite, and limonite. A massive brown mineral, which occurs in some quantity, is said to assay 25 per cent copper, and is probably a mixture of iron oxide with a a rich sulphide of copper.

After the incline in the ore had disclosed a sharp bend in the vein its course was changed to follow the new dip, as shown in fig. 30. The strike of the vein in the lower working is shown by the course of the drifts represented in the sketch, and its dip is about 24°. About 100 feet south of the main opening an open pit in the granite shows a brown jasper vein containing oxide of iron, with some green copper stains and a little chalcopyrite. This is directly in line with the north and south portion of the main vein, so that the latter seems to have divided between this point and the mouth of the incline. Closer examination shows that this portion of the vein consists of several splinters, the main one of which dips about 35° toward the east.

In figure 30 the curved line trending southwestward from the top of the incline represents approximately where the northeast-southwest portion of the vein encountered in the workings would outcrop at the surface if continuous. This ground is covered so that it is not actually known to appear in outcrop.

The Charter Oak deposit belongs to the general type which has been named from the Continental vein. The primary sulphides and the quartz forming the gangue were deposited at the same time in a fault fissure by circulating waters which found in it an easy channel of movement. As frequently happens where

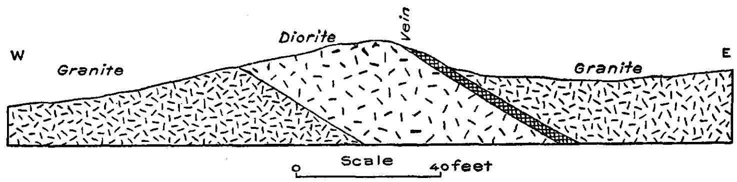

FIG. 31.—Charter Oak mine; general cross section showing relation of vein to inclosing rocks.

several fractures exist, a greater amount of metallic sulphides was precipitated at their intersection than elsewhere, giving rise to the body of ore which has been worked out. The reason for this relation may be either that the rock openings were greater near their intersection than at other points or that here solutions carrying different chemical salts in the different fractures came together and caused precipitation of the metallic minerals.

The basic igneous rocks of the region have been shown by the tests made during the study of the Encampment district to be an adequate source for all the

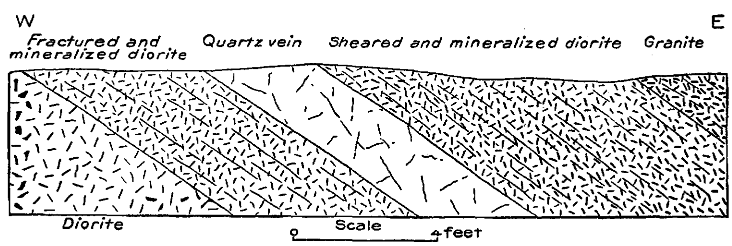

FIG. 32.—Charter Oak mine; detailed cross section of vein and adjacent rocks.

copper deposits which have been formed since their intrusion, and the copper sulphides in the Charter Oak mine are regarded as of this origin.

OSCEOLA PROPERTY.

The Osceola claim is situated to the south of the first extension of the Rudefeha claim toward the west, and is undoubtedly crossed by the apex of the Rudefeha or Ferris-Haggarty lead, since the drop of the ore horizon toward the south causes the outcrop beneath the heavy covering of surface débris to run from north-northeast to south-southwest upon the slope of the hill, while the side lines of the claims trend more nearly east and west. If exploration should prove that the contact between the schist and quartzite is not mineralized in this vicinity, the fact will furnish strong corroborative evidence that ore bodies of the Doane type, such as that in the Ferris-Haggarty mine, will be found only where marked zones of sheeting cross favorable horizons, and the possibility of the occurrence of other zones of this sort to the west of the Osceola shaft should be taken into consideration.

At the time the property was visited a shaft 56 feet deep had been sunk and a crosscut 35 feet long had been run toward the north, traversing quartzite excepting for an intercalated bed of schist about 4 feet in thickness and a thicker bed in which the drift terminated. This last bed of schist is probably the same as the contact schist in the Ferris-Haggarty, but it was not found to be mineralized at this point.

CREEDE PROPERTY.

The Creede claim is situated about 2 miles northwest of Bridger Peak, and about a quarter of a mile east of the road from Rudefeha to Saratoga. The deposit at this

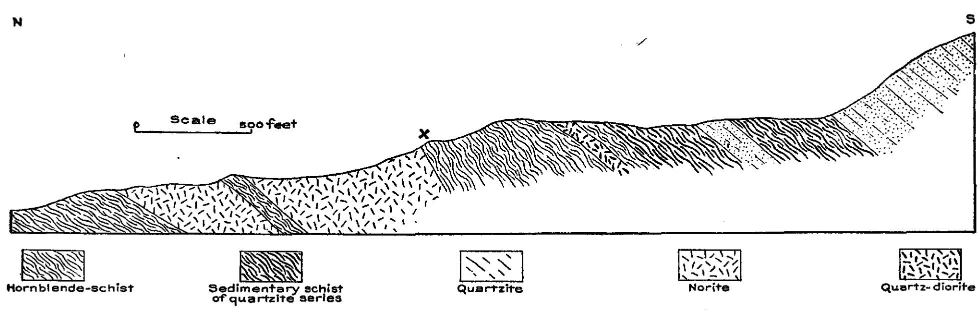

FIG. 33.—Geologic section on north side of Continental Divide through Creede claim. The position of Creede shaft shown by cross.

place has been taken as a type of ores which seem to have been formed as a direct result of contact metamorphism caused by intrusions of norite. The general description of the ore and its occurrence are given on page 54.

The geologic cross section, fig. 33, shows the position of the deposit in the hornblende-schist, near the south contact of an intrusive mass of norite.

Several other prospects in the vicinity also occur near the same body of norite and in each the ore is partly pyrrhotite, as at the Creede. The relative positions of the openings on the Creede, Island City, and Lucky Find claims are shown in fig. 34, which also shows in plan the approximate local distribution of the country rocks. In the three openings west of the Creede calcareous strata are found, which seem to have offered favorable conditions for the deposition of sulphides from solutions which probably derived their metallic contents from the norite, either at the time of its intrusion, as is supposed to have been the case at the Creede, or later.

The calcareous beds mentioned lie in a position parallel with the platy structure of the hornblende-schist (fig. 35), which also controls the general strike of the igneous contacts.

LEIGHTON-GENTRY PROSPECT.

This property is situated near the Continental Divide at the head of Jack Creek. At the surface a band of gossan about 3 inches in thickness is overlain

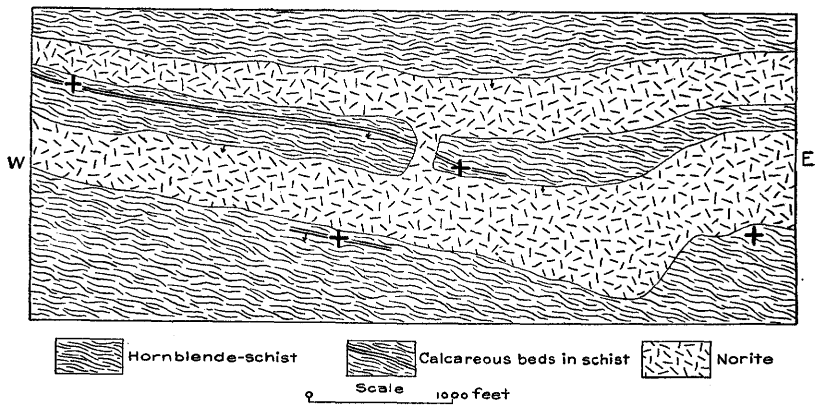

FIG. 34.—Sketch plan to show the position of openings in the vicinity of Creede mine relative to the intrusive norite. The cross on the right indicates the position of the Creede shaft, the two near the center openings are on the Island City claim, and the one on the left is the Lucky Find shaft.

by a black crumbling mica-schist, 4 feet thick, with a thick sill of norite above that.

An inclined shaft has opened up the lead for a distance of 150 feet, and demonstrated the existence of pyrite, pyrrhotite, and chalcopyrite in a band of the bedded limy quartzite about 11 feet in thickness. The ore occurs partly

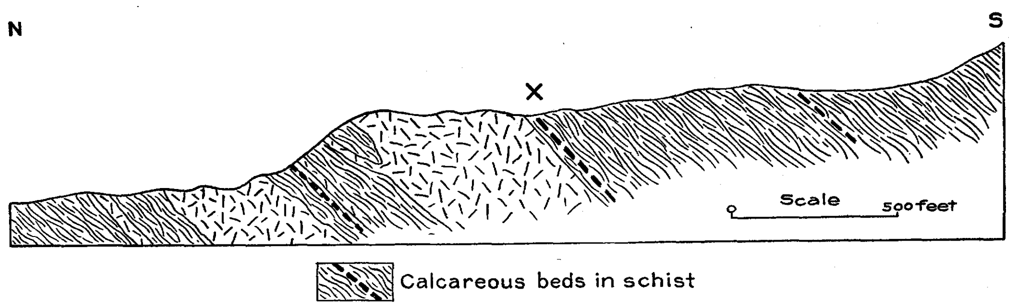

FIG. 35.—General cross section through the Island City claim, showing occurrence and structure of rocks, and relation of ore-bearing horizon. Cross shows position of main opening.

along the bedding planes, and partly disseminated through the rock. Beneath the mineralized quartzite there is a stratum of rather pure limestone which seems to contain no sulphides. This rests upon quartzites, the thickness of which is not apparent, but these soon give place to the hornblende-schist series, as is known from neighboring outcrops.

The strata strike N. 80° W. and dip 30° toward the south. The gossan is very superficial and unaltered sulphides occur within 10 or 12 feet of the surface.

An assay upon a sample of pyrrhotite made in the laboratory of the Geological Survey by Dr. E. T. Allen gave the following result:

Assay of pyrrhotite, Leighton-Gentry mine.

	Per cent.
Copper	3.07
Nickel, Cobalt	00.67
Zinc	Trace.
Platinum	None.

The accompanying diagram (fig. 36) illustrates the mode of occurrence, which is very similar to that at the Island City and other prospects in the vicinity of the Creede. Moreover, a certain resemblance to the Ferris-Haggarty deposit is

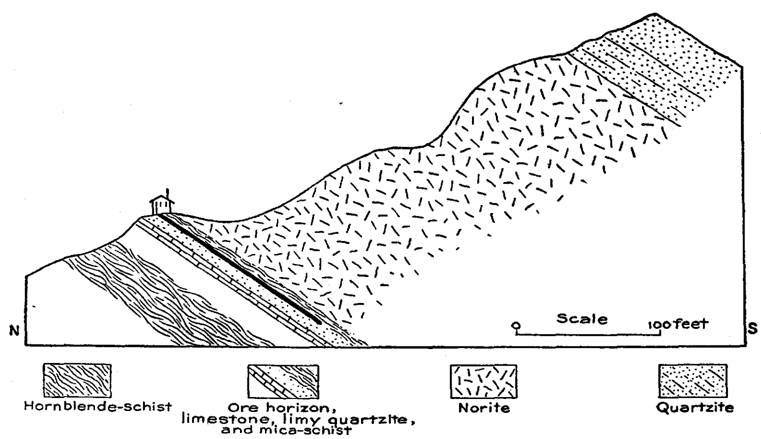

FIG. 36.—Sketch diagram showing position of Leighton-Gentry ore horizon relative to inclosing rocks. The black line represents the inclined shaft.

seen in the situation of the mineralized rock beneath a stratum of close-grained schist which may have been instrumental in localizing the deposition of the ore minerals, by deflecting ascending solutions along the thin-bedded, comparatively permeable, quartzites immediately beneath it.

SYNDICATE PROPERTY.

The Syndicate property is situated at the head of a tributary of Savery River, near the crest of the ridge which continues northwestward from the bend in the Continental Divide toward Dexter Peak.

The immediate country rock is quartzite, certain beds of which are very calcareous. The strata strike nearly east and west and dip to the south at a much lower angle than the vein. The latter therefore crosses the stratification, filling a well-defined though irregular fissure (fig. 37). A sill of diorite about 150 feet wide outcrops about 30 feet south of the shaft. An inclined shaft 135 feet in depth has been sunk upon a fissure vein originally filled with calcite, which has been partially dissolved away, leaving open caves. At 90 feet a drift 35 feet long has

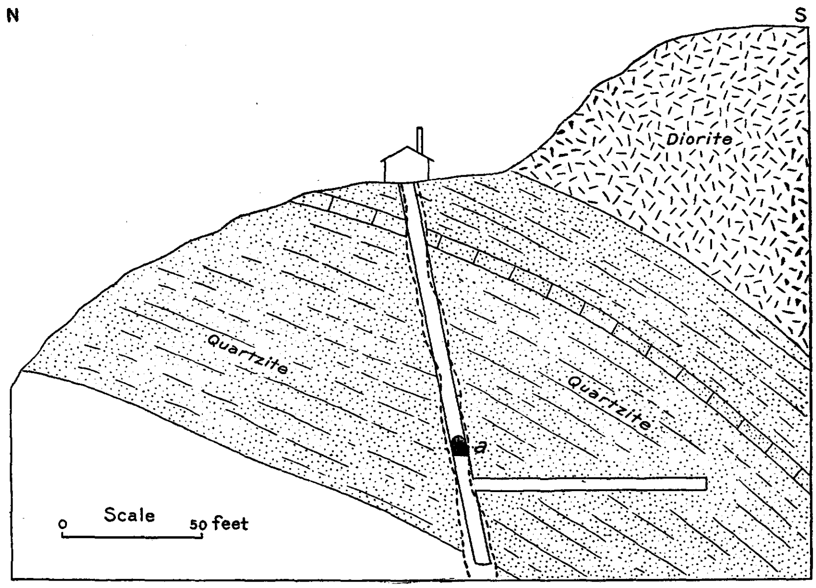

FIG. 37.—North-south section through Syndicate shaft, showing manner in which the vein crosses the beds of quartzite. Position of drift on vein is shown at *a*.

followed the vein toward the east. The strike of the vein is N. 70° W., and it dips 65° from the horizontal toward the south.

The calcite forms a filling for a breccia of quartzite, the whole vein varying from 3 to 11 feet in width. Chalcocite or copper glance in small grains or pellets is disseminated through the calcite, and is also found in the quartz fragments. A diagram showing these characteristics is given in fig. 38, which represents the vein at a depth of 110 feet. At this place there is an unbroken band of quartzite in the center of the vein.

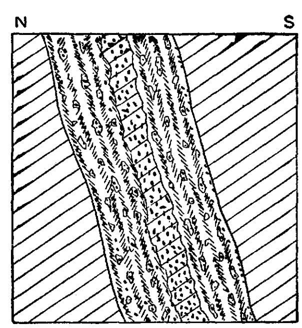

FIG. 38.—Detail of Syndicate vein at depth of 110 feet.

Little or no vein quartz accompanies the calcite, but this mineral was noted in the crosscut tunnel at the 100-foot level beneath a thin stratum of schist interbedded with the quartzites.

As elsewhere in the region, various systems of joint fractures are in evidence in this vicinity, though any important relation which they may bear to the origin of ore in the Syndicate vein is not apparent. Being chalcocite, the ore as it now occurs is regarded as secondary, and when sufficient depth is attained it is to be expected that leaner sulphides will be encountered.

CONTINENTAL VEIN.

The Continental claim is located on the south side of Cow Creek, near the transfer station of the Ferris-Haggarty tramway. The country rock belongs to the conglomerate member of the pre-Cambrian sedimentary series, but these rocks have been metamorphosed to such an extent by compression during the folding of the quartzite belt that they now appear as laminated schists, striking about northeast by east and dipping at a rather low angle toward the south.

The Continental vein follows the platy structure of the conglomerate-schist, alternately widening and pinching along its outcrop, which has been traced for several hundred feet. From this feature it is believed that it will be equally irregular when followed downward (fig. 39). As seen in the discovery pit, it has a width of from 2 to 4 feet, and is composed mainly of quartz and a small amount of siderite, but has chalcopyrite distributed irregularly through its mass. About

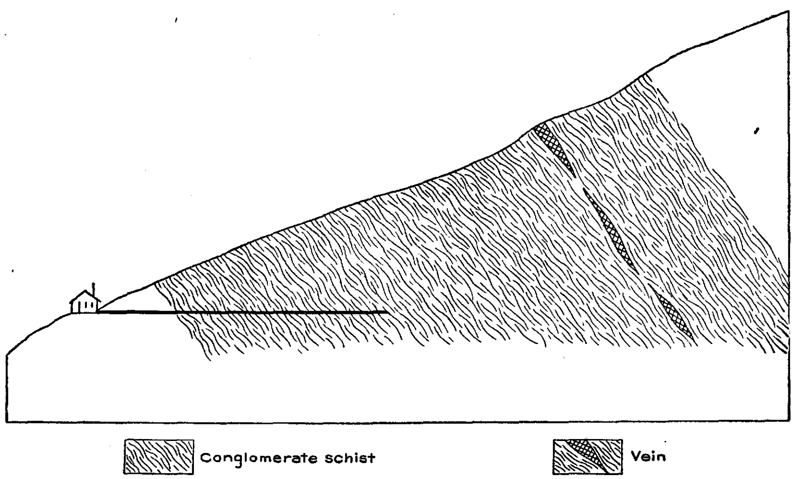

FIG. 39.—Sketch section showing probable relation of Continental vein to inclosing rocks.

200 feet farther west it has been cut at a depth of perhaps 20 feet by a short tunnel, and here its thickness is more than 6 feet, and copper pyrite is still present.

The property is being developed by a tunnel located about 150 feet below the outcrop, by means of which the character of the vein at that depth will be ascertained.

PORTLAND AND HERCULES MINES.

The Portland and Hercules shafts are located on adjoining claims about one-half mile south of Battle, a short distance west of the top of the range.

Various sorts of rocks occur in this vicinity (fig. 40), including a large mass of red granite on the south and massive pre-Cambrian quartzites on the north, with limestones and red shales intruded by basic igneous rock, now altered to chlorite-schist, between. The general strike of the sedimentary rocks, and of their igneous contacts, is nearly east and west, which is likewise the course of a profound fault which forms the northern boundary of the granite, while the schistose structures in the chlorite rock trend about N. 65° E. All these structures dip steeply toward the north. The two shafts were sunk for the purpose of investigating the contact between the red granite and the rocks north of it. A shallow shaft upon the Portland claim had encountered an encouraging amount of rich copper glance just south of the present shaft house, but the owners, being unable to cope with the large amount of water, formed a company and decided to sink a working shaft a short distance to the north, with the expectation of finding the ore by crosscutting to the granite.

At the time of our visit the shaft was 200 feet deep, and a crosscut toward the south at 100 feet had encountered a strong watercourse accompanying a mass of soft red mud which required the construction of a bulkhead to keep it from forcing its

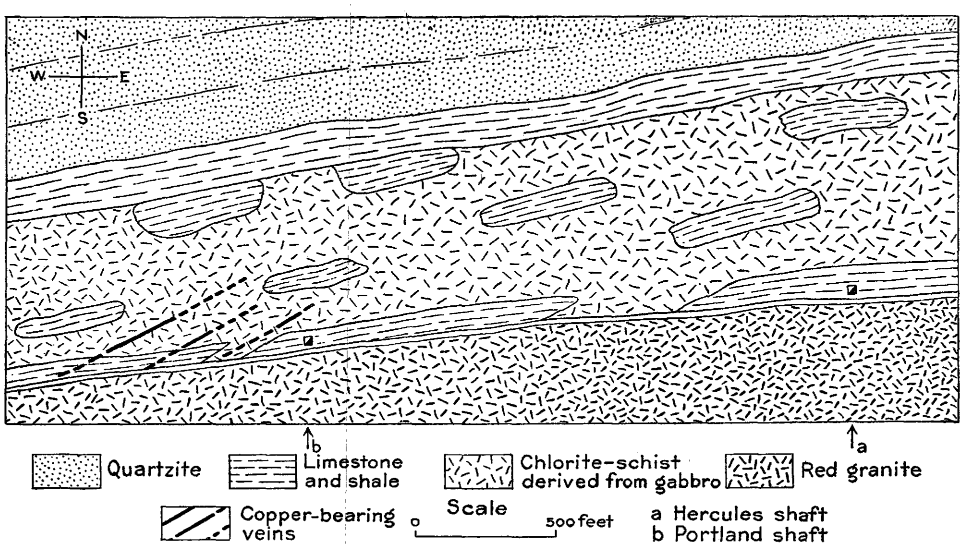

FIG. 40.—Diagrammatic sketch map to show general distribution of rocks in vicinity of Hercules and Portland shafts. Between the granite and the adjacent rocks there is a gouge of soft red mud, sometimes several feet in thickness, which has probably been produced by faulting along this contact.

way down into the workings. No evidence of strong mineralization was found, but the limestone which the shaft and crosscut traversed was much broken and impregnated in spots by chalcopyrite.

At 200 feet the granite is said to have been encountered, but is now hidden in the sump. A crosscut toward the north at this depth has been partly in limestone and partly in chlorite-schist, both of which are very much fractured and crushed, showing many slips not constant in their direction. Occasionally ore is encountered impregnating the country rock, but so far as seen does not occur in any regular way.

The object of this tunnel was to cut in depth several copper-bearing veins which outcrop west of the shaft and strike about N. 65° E. (fig. 40). These veins have been opened by trenching and found to have a width of a few inches only; however, they seem to be persistent, and it is claimed that the float of one of them has been traced for several hundred feet. They are composed of chalcopyrite and hematite, with a gangue mainly of quartz with some calcite and siderite (carbonate of iron). There is some chalcocite, but considering that these veins are to be seen only in outcrop, the small amount of secondary sulphides which they contain is noteworthy. Probably the looseness of the inclosing rock is greater than that of the veins, so that there has been no tendency for them to become channels of circulation.

In the summer of 1902 the Hercules workings were not accessible. It is said that a small northeast-southwest quartz vein carrying sulphides was found in the shaft, and that granite was reached at a depth of between 70 and 80 feet.

GERTRUDE PROPERTY.

The Gertrude property is located just north of the wagon road, about one-half mile east of Battle. The surface near the mine is largely covered by loose material,

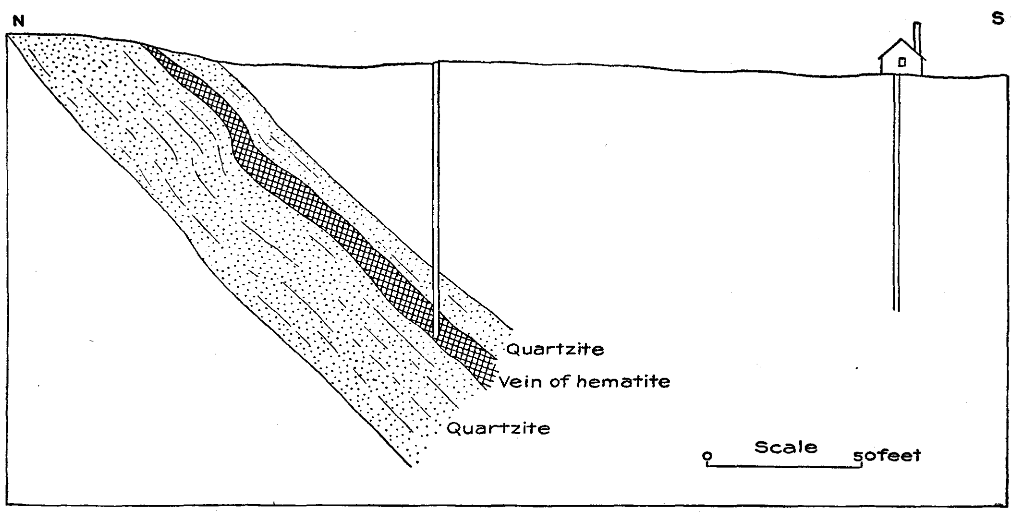

FIG. 41.—Sketch cross section through Gertrude workings.

so that there are no outcrops, but both quartzite and basic intrusive rock are exposed south of the workings. The quartzites strike nearly east and west, and dip about 40 degrees to the south. Between them and the mass of red granite farther south the bed rock in the covered ground is probably like that just north of the Portland shaft, and the quartzite exposed is supposed to be the same horizon as that shown in the sketch map of that vicinity (see fig. 41, and the geologic map, Pl. II, in pocket).

In the quartzite, and following its bedding, with sharp walls above and below, a body of massive hematite, or red iron oxide, has been followed by an incline 80 feet long. It has also been tapped by a vertical shaft north of the incline at a depth of 80 feet. The thickness of this body of mineral varies from 2½ feet near the surface to about 9 feet at the bottom, but its extent along the strike has not been investigated. It is said to give an average assay of $7 per ton in gold, and that certain portions of it show higher values. It can not be foretold whether or not this bedded deposit of hematite is gossan capping a body of sulphide (either pyrite or chalcopyrite), but it may prove to be so, and is regarded as deserving the expenditure necessary to reveal it in depth.

The new shaft which is located about 250 feet south of the discovery should cut the vein at an estimated depth of about 225 feet if the observed dip continues.

HIDDEN TREASURE TUNNEL.

The Hidden Treasure group of claims is situated about one-half mile from the Gertrude, or 1 mile east of Battle.

The country rocks penetrated by the tunnel are quartzites, quartz-schists, and altered diorite. All of the rocks are greatly mashed and brecciated, but at their

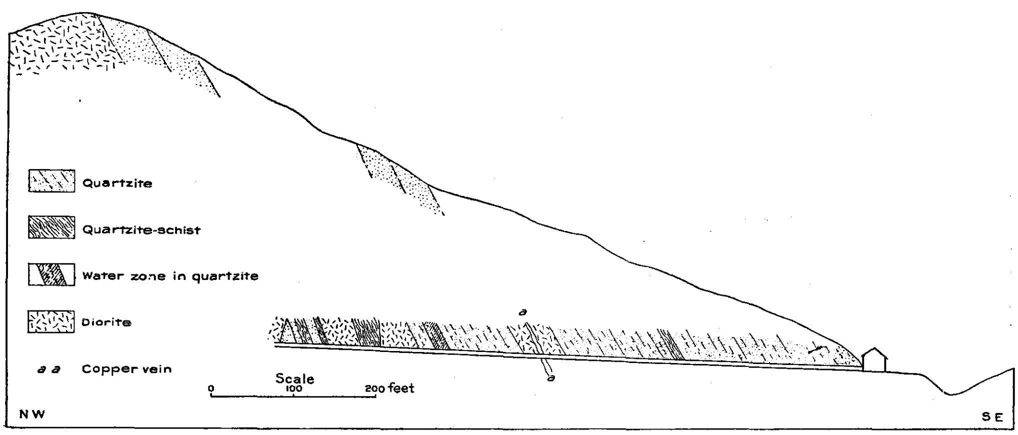

FIG. 42.—Section of first 720 feet of Hidden Treasure tunnel. Compare fig. 43.

contacts a general northeast-southwest strike may be readily made out, and the dip is toward the south (fig. 42). Surface outcrops are almost wanting except on the upper slopes of the ridge above the tunnel; here, however, the northeast strike and southerly dip may also be observed. The rock, which is here called diorite, is often

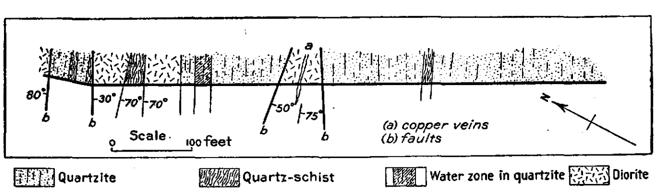

FIG. 43.—Plan of Hidden Treasure tunnel, showing relative course of faults and trend of strata.

composed largely of chlorite, and is ordinarily much crushed and full of slips, and is even schistose in some places as a result of having been squeezed between the formerly massive beds of quartzite into which it is intrusive. This rock has been derived from a facies of the basic gabbro rock which occurs throughout the region. The quartzite and quartz-schist are both greatly crushed and brecciated, especially adjacent to the first 500 feet of the tunnel, where the quartzite breaks into small cubes when exposed to the air. The whole ground shows the effects of subterranean movements which have brought the rocks into a condition to allow of the ready penetration of surface waters. Slips and faults occur throughout the mine, some of them forming the boundaries of different rocks, and others in rock of a single variety. Mineralization occurs at many points, but it probably originated previous to the general crushing of the rocks, as a rule, since they are too open to allow of the concentration of circulating waters in local channels.

The object of driving the tunnel was to cut a vein which had been located on the summit of the ridge at a distance of 1,000 feet or more, and while this had not been reached at the time the mine was visited, a well-defined vein was encountered about 575 feet from the mouth of the tunnel. This vein has been opened by a shallow winze, and its characteristics were shown in a chamber excavated for the installation of a hoist. It strikes about N. 70° E. and dips steeply toward the south. It occurs near the center of a mass of diorite intrusive in the quartzite, where it fills an irregular fissure (fig. 44). Twelve feet above the level of the tunnel its width is 4 or 5 inches, 5 feet above, 18 inches, and at the floor of the chamber, 2½ feet.

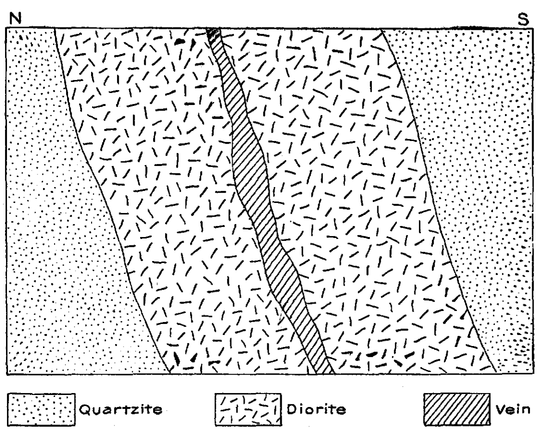

FIG. 44.—Sketch of vein formed in fracture in dike of diorite, Hidden Treasure tunnel. Compare figs. 42 and 43.

The gangue of the vein is composed of quartz, calcite, and siderite, sometimes accompanied by a small amount of feldspar. The ore minerals are chalcopyrite, chalcocite, and malachite. A small amount of specular hematite also occurs. The chalcocite seems to be in excess of the other copper minerals, showing that considerable secondary alteration has taken place.

Assays of nine samples of sulphides from various parts of the Hidden Treasure workings, made for the management by Prof. H. H. Nicholson, of Lincoln, Nebr., show an average of three-tenths ounce of gold per ton, while a single sample gave over 11 ounces per ton.

SUN ANCHOR AND SWEET CLAIMS.

These claims are situated upon a zone of metamorphism in the hornblende-schist series, extending in a general east-west direction along the northern face of Green Mountain, and crossing the southern branch of North Fork.

The zone is marked by the occurrence of considerable massive green epidote and small bright-red garnets, and is said to have been traced for a distance of more than 2 miles. It has the same strike as the black hornblende-schist which occurs on either side of it, and at several points where it has been opened shows the presence of magnetite and chalcopyrite. These prospects are practically undeveloped, but the nature of the occurrence is readily recognized as similar to the deposit at the Verde or Hinton mine.[a]

KURTZE CHATTERTON MINE.

The Kurtze Chatterton property is located on Copper Creek about 5 miles southwest of Encampment. The country rock is mainly chlorite-schist derived from basic rock related to the gabbro intrusives, which are prominent throughout the region, but this is cut by dikes of red granite which are probably offshoots from the large mass of this rock situated to the south of Copper Creek. The chlorite schist occurs in a band between this granite and the steeply inclined quartzites to the north. The strike of the quartzites is nearly east and west, while the structure in the schists is somewhat more northerly.

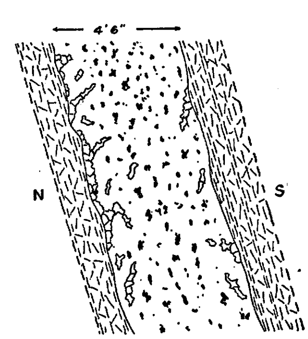

FIG. 45.—Structure of quartz and feldspar vein, Kurtze Chatterton claim. The black dots represent chalcocite distributed through the quartz.

Several veins from 3 to 10 feet wide outcrop at the surface, and three were encountered in the tunnel. On the surface they strike somewhat north of west and appear to dip steeply toward the north, but in the tunnel their dip is rather flat in the opposite direction.

The ore is chalcocite in the shallow surface workings and chalcopyrite in the tunnel. The mineral is scattered through the vein matter, so that the whole must be mined as a low-grade ore which requires concentration. The veins, though mostly composed of quartz, contain some feldspar, which gives them a general resemblance to the pegmatite veins at the Cascade mine situated about 5 miles to the southeast. In the Cascade deposit, however, the ore fills fractures in the veins, showing that it is of later origin, while in the Kurtze Chatterton veins the ore was formed at the same time as the quartz of the gangue. It is also confined to the quartz which often occupies the center of the vein, with the feldspar largely confined to the well-defined walls. The diagram (fig. 45) represents one of the veins which outcrops at the surface.

The deposits are classed with the type named from the Continental vein in Cow Creek, which is characterized by the contemporaneity of the ore and gangue minerals in veins between well-defined walls.

---

[a] See pp. 53 and 97.

The property has been opened by a tunnel about 1,500 feet long, running in a northerly direction. The first 700 feet is mainly in barren granite, but at this distance chlorite-schist is encountered, and between it and the granite there is a quartz vein, about 1 foot wide, which carries chalcopyrite. This vein strikes nearly east and west and dips about 45° to the south. It has been opened by a drift 20 feet in length, which shows that the country rock, especially in the hanging wall, is much crushed.

At 1,300 feet a second ledge has been followed a short distance and found to be made up of very irregular lenses of pegmatite carrying chalcopyrite.

A third body of ore-bearing quartz and feldspar from 5 to 10 feet wide was encountered 150 feet farther toward the north, but this pinches out along its strike and is not a continuous vein.

A concentrator has been built at the mine.

CASCADE MINE.

At the Cascade mine, located on the east side of Encampment River near the mouth of Cascade Creek, copper sulphides occur in a large dike or vein of pegmatite, inclosed in a complex of considerably sheeted granite and diorite. The property has been developed by a shaft 100 feet deep, and by a tunnel which was 425 feet long in October, 1902, and which it was the intention to continue to a distance of 800 feet to connect with the shaft. The general course of the vein is approximately parallel with the structure of the inclosing rocks—that is, N. 20° W., and it dips irregularly toward the south, though at the outcrop it appears to be nearly vertical. In the shaft the vein was cut at a depth of 80 feet and developed by a crosscut, in which it was shown to have a width of 24 feet and to have well-marked walls with clay gouge. Ore is generally distributed through the vein, but occurs in the greatest amounts upon the foot wall. Upon the northeast side the country rock is diorite, while upon the southwest side it is granite. In the vicinity of the shaft the country rock is found to be generally gneissic, and near the mouth of the tunnel the country rock is composed of bands of alaskite[a] and granite, with some diorite, both siliceous and basic phases of which occur in narrow bands. The material thrown out of the shaft indicates that surface waters have accomplished a slight amount of enrichment of the chalcopyrite, which forms the main portion of the ore.

About 6,000 feet northwest of the Cascade shaft a vein of pegmatite is found which is supposed to be the same lead.

In the field it was regarded as probable that the chalcopyrite had originated in the vein as a primary constituent, along with the quartz and the feldspar, but an

[a] Alaskite is a rock related to granite, but composed essentially of quartz and orthoclase feldspar without dark silicate minerals.

examination of the specimens under the microscope shows that the sulphides are in part at least later than the other minerals, having crystallized after the pegmatite has been fractured.

ITMAY MINE.

The Itmay property is located near the head of Roaring Fork, south of Huston Park, in sec. 14, T. 13 N., R. 85 W. The country rock is gray quartz-diorite. The ore occurs along the walls of a much altered basic dike intrusive into the quartz-diorite. The course of this dike is about N. 70° E., and it dips steeply toward the south. A section of the vein, showing its general characteristics is given (fig. 46).

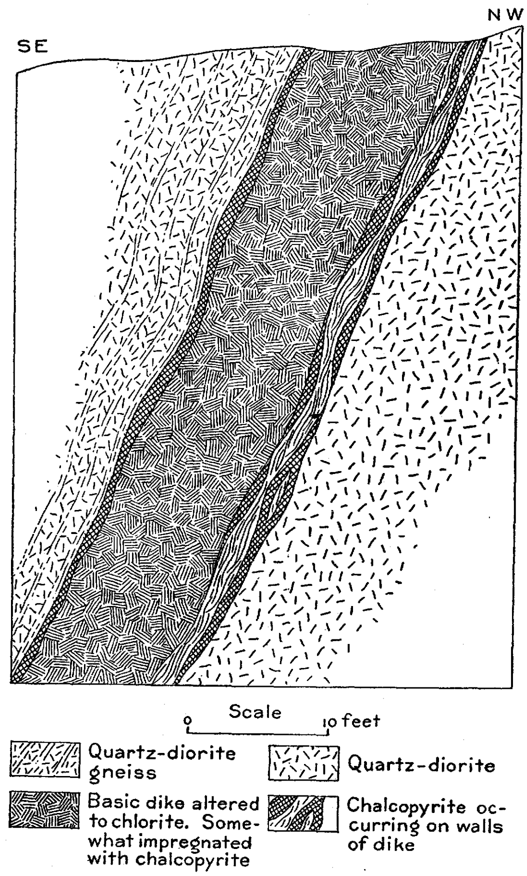

FIG. 46.—Sketch of Itmay vein, looking southwest.

On the north side the country rock is massive excepting for a band of schistose gouge next to the dike. This band is 2½ feet wide at the surface, and a streak of ore, occurring somewhat irregularly in it, varies from a few inches up to 2 feet. The dike is about 10 feet wide and is often impregnated with ore. Along the hanging wall the sulphide streak has been found to be from 3 to 10 inches wide. Only a small amount of quartz occurs with the ore, the gangue being mostly composed of the inclosing rock.

But little secondary alteration has taken place, and there are practically no other copper minerals besides chalcopyrite, which appears within 3 feet of the surface outcrop. A sample of sulphide ore from the dump gave 17.92 per cent copper and $1 per ton in gold.

In August, 1902, the vein had been opened by a shaft which was about 50 feet deep, but a steam hoist has since been installed for the purpose of more extensive development.

HINTON MINE.

This property is located about 7 miles due south from Battle. The main characteristics of the deposit have been given on page 53, and its probable genesis is discussed elsewhere in this report (pp. 56, 58).

The gossan of the vein, which is very shallow, consists of spongy iron oxide, mixed with decomposed and iron-stained garnet, and with the other material of the lead which is relatively fresh in appearance more or less distributed through it. Practically, no secondary sulphides were encountered, and unaltered chalcopyrite occurred in one instance within 12 feet of the surface. The very superficial extent to which the vein has been leached by surface waters, is undoubtedly due to the very tight nature of the ground, the lead having no gouge or slips along its walls. An average sample from the mine dump gave 8.18 per cent copper and 40 cents in gold.

From the strength which the lead exhibits in outcrop, and from the fact that the richness of the ore which occurs, though moderate, is not due to secondary enrichment, it may be expected that it will continue to a considerable depth.

At the time the mine was visited, in July, 1902, several shafts, from 30 to 50 feet in depth, had encountered ore, though hardly in sufficient amounts to be mined profitably. Since that time a steam hoist has been installed, and one of the shafts was reported to have reached a depth of 110 feet in June, 1903.

On an adjoining claim to the east a good body of ore is reported at 40 feet.

This deposit is believed to have been formed during the metamorphism of the schists in which it occurs, as stated on page 56.

ARGENTIFEROUS VEINS.

Deposits of galena, variously associated with other sulphides and carrying silver, occur in veins both to the north of the immediate area of the Encampment map, and also in one instance near its southern border. This mineral is always associated with quartz, usually in veins filling well-defined fissures, which may cross or follow the stratification or schistosity of the inclosing rocks. Though they were not specifically mentioned in the classification of the copper ores of the district, their mode of occurrence allies them with copper veins of the Continental type, in which the sulphides and quartz were formed at the same time.

Pyrite and chalcopyrite ordinarily occur with the galena, and chalcocite is ordinarily present where primary minerals carrying copper have been altered.

META MINE.

The Meta property is situated at the head of a branch of South Spring Creek about 1 mile north of the boundary of the area covered by the Encampment map.

The rocks in the vicinity are gray gneiss derived from quartz-diorite, and black schistose diorite derived from gabbro, which occur in alternating beds, striking nearly northeast and southwest, and declining slightly toward the northwest. The surfaces of separation between masses of the two rocks are parallel to the gneissic structure, and several systems of joints are well developed. Nearly vertical fractures running northeast and southwest are very prominent, but these contain no quartz, which is a common filling in a system of east-northeast fissures, one of which contains the Meta vein.

As exposed in surface workings, the vein of quartz and calcite has a width of 7 inches. It is inclosed between sharp walls with considerable gangue on both sides and marked sheeting in the rock adjacent (fig. 47).

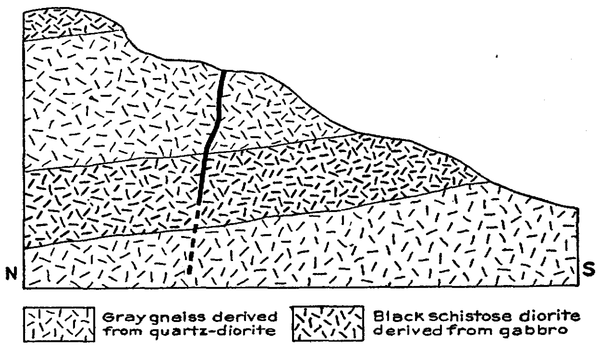

FIG. 47.—Sketch section of the formations at the Meta mine, showing relations of vein.

Underground the vein is reported to have a width of from 2 to 3 feet. When unoxidized the ore is mainly galena, with some chalcopyrite and a little zinc blende, but in the upper workings it is largely carbonate of lead, the mineral cerrusite. A single carload of ore is reported to have been shipped from this mine which gave a fairly good assay for silver, but seemed not to have been sufficiently high grade to stand transportation charges, since the property has been idle for several years.

ALMA PROPERTY.

This property lies southwest of the Meta, on the divide between North Spring and South Spring creeks, about one-half mile beyond the boundary of the map. The country rock is mainly black schistose diorite, but gray quartz-diorite also occurs near by, and there are some thin beds of sedimentary quartzite and a few dikes of alaskite.

The gangue of the vein is mainly quartz, with some siderite, and the principal ore minerals are galena and chalcopyrite. The width of the vein is about 18 inches, its course, like that of the Meta, east by northeast, and its dip from 40° to 60° toward the north.

BRIDGER MINE.

This property is situated on the Continental Divide, several miles north of the Sierra Madre. The vein was discovered by F. O. Williams in 1876. The country rock in the neighborhood is mainly quartzite and diorite (metagabbro), which is often schistose. There are many quartz veins outcropping in the vicinity, and most of them contain some feldspar, especially near their walls. When sulphides occur they are always in the quartz, usually without other gangue, though calcite sometimes occurs. Most of them are said to contain a few dollars in gold, but as a rule they are regarded as untrustworthy, since they are liable to disappear suddenly as they are traced downward.

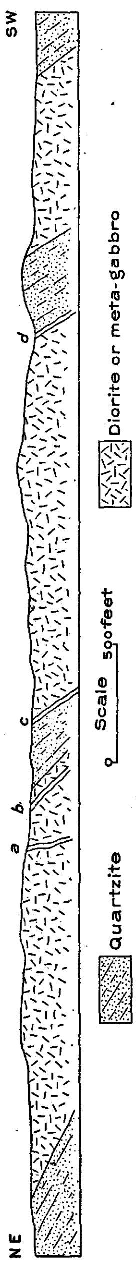

FIG. 48.—General section showing occurrence of veins in vicinity of Bridger mine. *a*, pegmatite vein, containing gold, silver, and copper; *b*, barren quartz vein following sheeted zone in diorite parallel to bedding of quartzite; *c*, Bridger vein, 13 feet wide (this vein outcrops at intervals for 3,000 feet); *d*, barren quartz vein, 15 to 20 feet wide, traceable for 3,000 feet.

A section representing the general relations of the Bridger vein is here given (fig. 48).

The strike of the vein and of the country rock is northwest and southeast, and the dip varies from 25° to 55°, the latter being observed at the Bridger shaft.

The section given in fig. 49 shows the general relations in the mine where there are three veins of quartz following the stratification and schistosity of the inclosing sheeted quartzite. Similar relations also exist in the discovery outcrop 100 yards toward the southeast, and the lead can be followed for a distance of nearly 3,000 feet.

The hanging-wall streak averages 10 inches in width in the mine. It is composed of altered quartzite which is greatly mineralized. At the surface it is very rusty, and it is somewhat oxidized to the bottom of the workings, which are 128 feet deep on the vein. It is said to give assays from a trace to 69 ounces gold per ton, the richest ore having been found near the surface. With depth the values in gold are said to decrease, though those in silver increase.

The middle streak varies from 6 inches to 3 feet in width. It is composed of hard quartzite filled with vein quartz, the two having almost the same appearance and containing some calcite. The sulphides are galena and chalcocite, but tellurium and selenium are present as well. A sample of 100 pounds representing the average of this streak is reported to have assayed 90 ounces silver and $5 in gold per ton. The foot-wall streak, which varies in width from 4 to 10 inches, contains both silver and gold in about the same proportion as the others.

GOLD COIN CLAIM.

On this claim, situated south of the Bridger property, there is a quartz and calcite vein about 1 foot wide, carrying bunches of galena and some pyrite and chalcopyrite. Both silver and gold are reported. The vein fills a well-defined fissure, striking about N. 75° E. and dipping at a high angle toward the south. It cuts across the schistosity of the black diorite which inclōses it and has several inches of soft selvage on each side separating it from the massive country rock. The vein has been developed by two shafts, 46 and 100 feet deep, respectively, and there are several drifts. Work was in progress during the autumn of 1902.

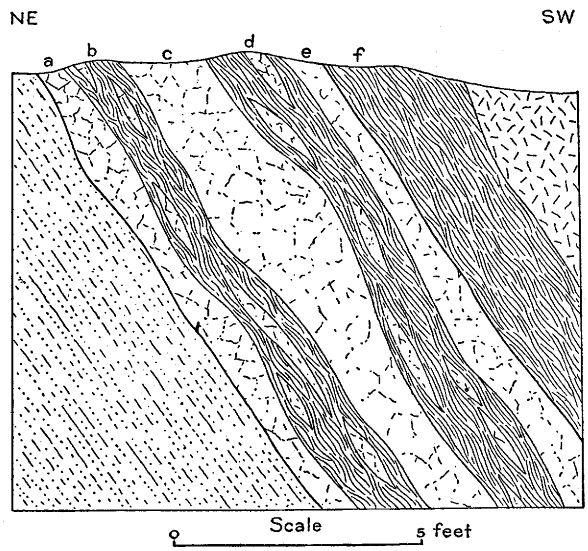

FIG. 49.—Detailed structure of Bridger vein as exposed in shaft. *a*, foot-wall vein, composed of quartz carrying sulphide minerals with gold and silver; *b*, schist containing lenses of quartz; *c*, middle vein, composed of quartz and indurated quartzite with some calcite, and containing galena and chalcopyrite carrying gold and silver; *d*, schist with lenses of quartz; *e*, hanging-wall vein, composed of indurated quartzite resembling vein quartz (this portion of the vein carries the best values in gold); *f*, schistose diorite forming hanging wall. The vein occurs between diorite and quartzite.

ELKHORN MINE.

This property, which lies in Colorado about 1½ miles south of the State line, was located in 1897. Considerable work has been done on the vein, and several carloads of ore have been hauled out to Rawlins, a distance of about 100 miles.

The country rock is a dark hornblende rock, probably belonging to the schist series, and the vein fills a well-defined fissure. It has been traced for a distance of several hundred feet upon the surface and has been opened at several points and found to have a general course about N. 6° W. It dips slightly toward the west. At the time the property was visited the workings were filled with water, but from the dumps the nature of the ore could be determined. The shipping ore seems to have been mainly galena and cerussite, containing some pyrite and chalcopyrite, while a considerable amount of zinc blende was removed by sorting. The ore which was shipped is reported to have yielded $97 per ton, $10 in gold and the remainder in silver.

CHAPTER V.

PRACTICAL SUGGESTIONS.

A question of prime importance to those engaged in the search for copper deposits in the Encampment country is whether or not deep exploration will reveal the presence of workable ore bodies which do not appear at the surface. The expectation that this will be the case, which is somewhat prevalent in the region, seems to be based upon the fact that in parts of Arizona and in certain other districts the upper edges of large, high-grade ore bodies are encountered at depths of 300 to 500 feet or more. In regions where the upper portions of copper veins are found to be barren, and where the ore is found in secondary concentrations at considerable depth, the mode of occurrence seems to be directly dependent upon climatic conditions which have never existed in the region here under discussion, and for the Encampment field it is believed that deep prospecting is not generally advisable. On the other hand, the value of underground work intended to demonstrate the presence of workable ore bodies depends upon the fidelity with which operations are confined to actual ore bodies, or to ore indications.

In the Encampment region wherever minerals of primary deposition, such as chalcopyrite, or pyrrhotite, are found near the surface unmixed with carbonates or oxides of copper, or with sulphides of higher grade, it is believed that there can be no sound basis for predicting any increase, either in the richness or the size of ore bodies with increasing depth. If the ore is found to improve in any particular case, it is as likely to decrease in value in the next, and in general it may be said that after an ore body has been lost the discovery of another by sinking will always be a matter of chance.

It is suggested that a fair estimate of the manner in which the copper minerals are distributed underground may be obtained from the distribution of mineralization upon the surface. The present topography is the result of erosion, which has removed a large amount of rock which formerly existed above the present surface, and ore segregations doubtless existed in the rock which has been removed as well as in the material which now remains, so that the present surface has only a chance relationship to the position and dimensions of the primary sulphide deposits. It therefore seems safe to say that after eliminating recognizable secondary concentrations a careful estimation of the importance of all deposits appearing in outcrop in any given area would not differ essentially from similar estimations which might be made were it possible to expose new surfaces to exploration by the removal of successive shells of constant thickness from the same area. Also it may be argued that the distribution of ore minerals in any vertical section across a given belt would not vary materially from the surface distribution of the same sorts of rocks. In the Encampment district no primary ore deposits of workable size have yet been developed at the surface, and if the amount of copper ore to be encountered below ground can be even roughly estimated from the surface occurrence in the manner suggested, the wisdom of confining all exploratory work to actual ore bodies will be at once recognized.

The foregoing remarks apply to the search for primary ore minerals, but there is equal reason for believing that where secondary enrichment is to be expected prospecting should also be confined to ore indications. If deep exploration is warranted at all it will be only in cases where gossan deposits can be followed; but from the fact that the known workable ore bodies of the region have been invariably encountered within from 15 to 75 feet from the surface, it is anticipated that where limonite cappings are found copper sulphides, if present, will be encountered at relatively slight depth. Where primary minerals occur at or near the surface it may be safely assumed that no secondary enrichment will be found lower down, and if any change in the value of the ores occurs they are more apt to become poorer than the contrary. Experience in other fields points to the probability that below a maximum zone the secondary ores will decrease in richness with increasing depth until the unaltered sulphides are reached.

The point can not be too strongly urged that copper stains or even fairly well-defined bodies of ore or gossan occurring in outcrops can not be taken as evidence that continuous veins or large bodies of ore exist in depth, waiting to be revealed by deep shafts or long tunnels.

INDEX.

O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Professional Paper No. 25.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of the United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the thirty-second in Series A and the thirty-seventh in Series B, the complete lists of which follow. (PP=Professional Paper, B=Bulletin, WS=Water-Supply Paper.)

SERIES A, ECONOMIC GEOLOGY.

B 21. Lignites of Great Sioux Reservation: Report on region between Grand and Moreau rivers, Dakota, by Bailey Willis. 1885. 16 pp., 5 pls. (Out of stock.)

B 46. Nature and origin of deposits of phosphate of lime, by R. A. F. Penrose, jr., with introduction by N. S. Shaler. 1888. 143 pp. (Out of stock.)

B 65. Stratigraphy of the bituminous coal field of Pennsylvania, Ohio, and West Virginia, by I. C. White. 1891. 212 pp., 11 pls. (Out of stock.)

B 111. Geology of Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. 1893. 106 pp., 6 pls.

B 132. The disseminated lead ores of southeastern Missouri, by Arthur Winslow. 1896. 31 pp.

B 138. Artesian-well prospects in Atlantic Coastal Plain region, by N. H. Darton. 1896. 228 pp., 19 pls. (Out of stock.)

B 139. Geology of Castle Mountain mining district, Montana, by W. H. Weed and L. V. Pirsson. 1896. 164 pp., 17 pls.

B 143. Bibliography of clays and the ceramic arts, by J. C. Branner. 1896. 114 pp.

B 164. Reconnaissance on the Rio Grande coal fields of Texas, by T. W. Vaughan, including a report on igneous rocks from the San Carlos coal field, by E. C. E. Lord. 1900. 100 pp., 11 pls.

B 178. El Paso tin deposits, by W. H. Weed. 1901. 15 pp., 1 pl.

B 180. Occurrence and distribution of corundum in United States, by J. H. Pratt. 1901. 98 pp., 14 pls. (Out of stock.)

B 182. A report on the economic geology of the Silverton quadrangle, Colorado, by F. L. Ransome. 1901. 266 pp., 16 pls. (Out of stock.)

B 184. Oil and gas fields of the western interior and northern Texas Coal Measures and of the Upper Cretaceous and Tertiary of the western Gulf coast, by G. I. Adams. 1901. 64 pp., 10 pls. (Out of stock.)

B 193. The geological relations and distribution of platinum and associated metals, by J. F. Kemp. 1902. 95 pp., 6 pls. (Out of stock.)

B 198. The Berea grit oil sand in the Cadiz quadrangle, Ohio, by W. T. Griswold. 1902. 43 pp., 1 pl.

PP 1. Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by Alfred Hulse Brooks. 1902. 120 pp., 2 pls.

B 200. Reconnaissance of the borax deposits of Death Valley and Mohave Desert, by M. R. Campbell. 1902. 23 pp., 1 pl. (Out of stock.)

B 202. Tests for gold and silver in shales from western Kansas, by Waldemar Lindgren. 1902. 21 pp.

PP 2. Reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. 1902. 70 pp., 11 pls.

PP 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. 1902. 68 pp., 10 pls.

PP 11. Clays of the United States east of the Mississippi River, by Heinrich Ries. 1903. 298 pp., 9 pls.

PP 12. Geology of the Globe copper district, Arizona, by F. L. Ransome. 1903. 168 pp., 27 pls.

B 212. Oil fields of the Texas-Louisiana Gulf Coastal Plain, by C. W. Hayes and William Kennedy. 1903. 174 pp., 11 pls.

B. 213. Contributions to economic geology, 1902. S. F. Emmons, C. W. Hayes, geologists in charge. 1903. 449 pp.

PP 15. The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall and F. C. Schrader. 1903. 71 pp., 10 pls.

B 218. Coal resources of the Yukon, Alaska, by Arthur J. Collier. 1903. 71 pp., 6 pls.

B 219. The ore deposits of Tonopah, Nevada (preliminary report), by J. E. Spurr. 1903. 31 pp., 1 pl.

PP 20. A reconnaissance in northern Alaska in 1901, by F. C. Schrader. 1904. 139 pp., 16 pls.

PP 21. The geology and ore deposits of the Bisbee quadrangle, Arizona, by F. L. Ransome. 1904. 168 pp., 29 pls.

B 223. Gypsum deposits in the United States, by G. I. Adams and others. 1904. 129 pp., 21 pls.

PP 24. Zinc and lead deposits of northern Arkansas, by G. I. Adams, assisted by A. H. Purdue and E. F. Burchard, with a section on the determination and correlation of formations, by E. O. Ulrich. 1904. — pp., 27 pls.

PP 25. The copper deposits of the Encampment district, Wyoming, by A. C. Spencer. 1904. 107 pp., 2 pls.

SERIES B, DESCRIPTIVE GEOLOGY.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

MAY, 1904.

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but additional numbers should be added, as received, to the first entry.]

Author.

Spencer, Arthur C[oe].

. . . The copper deposits of the Encampment district, Wyoming, by Arthur C. Spencer. Washington, Gov't print. off., 1904.

107, III p. illus., 2 pl. (maps in pocket). $29\frac{1}{2} \times 23^{cm}$. (U. S. Geological survey. Professional paper no. 25.)

Subject series: A, Económic geology, 32; B, Descriptive geology, 37.

Subject.

Spencer, Arthur C[oe].

. . . The copper deposits of the Encampment district, Wyoming, by Arthur C. Spencer. Washington, Gov't print. off., 1904.

107, III p. illus., 2 pl. (maps in pocket). $29\frac{1}{2} \times 23^{cm}$. (U. S. Geological survey. Professional paper no. 25.)

Subject series: A, Economic geology, 32; B, Descriptive geology, 37.

Series.

U. S. Geological survey.

Professional papers.

no. 25. Spencer, A. C. The copper deposits of the Encampment district, Wyoming, 1904.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.