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GEOLOGY
OF A
PART OF THE
DILLON QUADRANGLE,
COLORADO

59

Submitted in partial fulfillment of the requirements of the degree of Master of Science at the University of Michigan.

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CONTENTS

CONTENTS - Continued

ILLUSTRATIONS

INTRODUCTION

FIELD WORK AND ACKNOWLEDGEMENTS

The surface mapping and underground work in the portion of the Dillon quadrangle discussed in this thesis were done in the summer of 1940.

Dr. T. S. Lovering guided the writer on this problem and assisted him in the field. Mr. Norman Snively, then mapping an area near Idaho Springs, Colorado, also made valuable suggestions for the field work. Mr. L. J. Emore of Dillon allowed the writer to examine and map his mines. He materially aided the writer on frequent occasions. Mr. William C. Fackler and Mr. Robert Hatch, then students at the University of Michigan, contributed suggestions and aid in the study of the field material. The writer is indebted to his wife for assistance in preparing this manuscript.

The facilities of the Departments of Geology and Mineralogy of the University of Michigan were always available and freely used. Mr. R. A. Steinmayer, professor of geology at Tulane University, kindly allowed the writer to use some of the facilities of the Tulane Department of Geology.

LOCATION AND POPULATION

The Dillon quadrangle lies in central Colorado about 60 miles west of Denver (about 80 miles by road) and 30 miles north of Leadville. It is located between parallels 39°30' and 39°45' and meridians 106° and 106°15'. The portion mapped by the writer, referred to in this report as the "subject area", lies approximately in the center of the quadrangle. This area is entirely within Summit County and largely within Township 5 South, Range 78 West. It is roughly 4 miles from east to west and 5 miles from north to south. Part of the Gore Range lies just within the western edge of the area, and the Williams River Mountains lie just outside the eastern edge.

The Breckenridge district which was studied by Ransome[1] in 1909 and Lovering[2] in 1928 lies about one mile southeast of the subject area. The Montezuma quadrangle which was studied by Lovering[3] in 1929 adjoins the Dillon quadrangle to the east and is about 3 miles east of the subject area. The Tenmile district studied by S. F. Emmons[4] in 1898 lies approximately 4 miles south of the subject area.

Dillon is located on the east edge of the area on Tenmile Creek near its junction with the Blue River. According to the 1940 census, it had a population of 161. It is connected with Kremmling to the northwest and Breckenridge to the south by State Highway No. 9, and with Idaho Springs to the east and Leadville to the southwest by State Highway No. 91. The Colorado and Southern Railway formerly had a narrow gauge line from

[1] Ransome, F. L,, Geology and ore deposits of the Breckenridge district, Colo.: U. S. Geol. Survey Prof. Paper 75, 1911.

[2] Lovering, T. S., Geology and ore deposits of the Breckenridge mining district, Colo.: U. S. Geol. Survey Prof. Paper 176, 1934.

[3] Lovering, T. S., Geology and ore deposits of the Montezuma quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 178, 1935.

[4] Emmons, S. F., Tenmile district special, Colo.: U. S. Geol. Survey Folio No. 48, 1898.

Leadville through Dillon to Breckenridge and Keystone but this is now abandoned. Stock and hay raising and a little mining are the chief industries of the village.

Frisco is in the southern part of the area on Tenmile Creek about 3 miles southwest of Dillon. It had a population of 60 according to the 1940 census. The industries of Frisco are similar to those of Dillon.

TOPOGRAPHY AND DRAINAGE

The western and southern parts of the area are high and rugged. The remainder of the area is generally rolling except the valley of Tenmile Creek between Dillon and Frisco which is very subdued. The altitude ranges from approximately 8,750 feet about 2 miles north of Dillon on the Blue River to 12,764 feet on Buffalo Mountain. The country was heavily glaciated during the Pleistocene. Steep U-shaped valleys are present in the Gore Range in the western part of the area. The valley of Tenmile Creek between the Gore and Tenmile Ranges is also steep and U-shaped. Buffalo Mountain, the highest in the area, and Chief and Wichita Mountains are outliers from the main part of the Gore Range to the west. The remaining high mountain, Royal Mountain, is the northernmost peak of the Tenmile Range.

The entire area is drained to the north by the Blue River and its tributaries. The chief one of these is Tenmile Creek which drains the southern part of the area. Numerous small streams flow off the Gore Mountains into Tenmile Creek and the Blue River. The valley of Tenmile Creek occupies about six square miles in the southeast part of the area.

BIBLIOGRAPHY

With the exception of Miss Steere's thesis and brief references to the area in statistical reports, very little has been written and few maps have been published on the subject area. The following references cite most of the literature and maps dealing with any part of the area and also some reports on adjoining regions. Several statistical works relating to mine production, mainly those published locally in Colorado, were not accessible to the writer and are not included in the following list. These are listed by Henderson in Professional Paper 138 and by Lovering in Professional Paper 178.

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_____ The stratigraphy of the east slope of the Front Range: U. S. Geol. and Geog. Survey Terr. 7th Ann Rept., for 1873, pp. 144-153, 1874. More descriptions of the pre-Cambrian rocks of the Front and Gore Ranges.

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U. S. Geol. and Geog. Survey, Atlas of Colorado, Plate XII, North central Colorado, 1876. Map shows two outcrops of Dakota group in subject area, one near Dillon and one in southeast part of area.

U. S. Geol. Survey, Geologic map of Colorado, 1935.

DESCRIPTIVE GEOLOGY

Pre-Cambrian granites, gneisses, and schists cover over a quarter of the subject area and occur on the west and south borders. Mesozoic sediments outcrop in a rather small area in the northeast part but are believed to underlie the glacial deposits in the north-central part of the area. A Tertiary intrusive porphyry may be located near the southeast edge of the area but the evidence is meager. Pleistocene glacial deposits and detritus from the Gore Mountains occupy over half the subject area and cover the entire central part. The pre-Cambrian rocks are similar to and have been correlated with those studied by Lovering in the Montezuma quadrangle, by Tweto in the Fraser quadrangle, and by Snively near Idaho Springs. The stratigraphy of the Upper Jurassic and Cretaceous is quite similar to the stratigraphy of these sediments from Kremmling to Breckenridge. The glacial deposits of the subject area and the entire east side of the Gore Range have been studied by Margaret Steere.[1]

AlGONKIAN (?) FORMATIONS

Idaho Springs Formation

Distribution and Structure. The Idaho Springs formation is exposed over much of the southwest part of the subject area on Wichita and Chief Mountains. It is less well-exposed in the southeast part on Ophir Mountain and in the northwest part on Buffalo Mountain. It is the chief schistose rock in the Front Range to the east and is widespread in the nearby Montezuma quadrangle.

On and near Wichita and Chief Mountains the formation occurs in the west limb of a large steeply dipping fold anticline ? which trends north. Many minor folds and wrinkles are superimposed on the major structure. On Ophir Mountain the beds are part of what may be the gentler dipping, faulted east limb of the same major structure. In the vicinity of Buffalo Mountain the schist occurs principally as xenoliths. While many of these are mere fragments some are rather large. The structural continuity of the formation has been destroyed in this area by the intrusion of the granite.

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[1] Steere, Margaret, unpublished thesis for master's degree at the University of Michigan, 1938.

Correlation and Age. The schists and gneisses referred to as theIdaho Springs formation are correlated with the Idaho Springs formation of the Montezuma quadrangle immediately east of the Dillon quadrangle. Correlation is made on the basis of lithologic similarity, similar stratigraphic relations with the Swandyke hornblende gneiss, and intrusive granites, and proximity to established outcrops of the formation. The nearest outcrop of the formation in the Montezuma quadrangle is only approximately 4½ miles east of the easternmost exposure in the subject area.

The above schists and gneisses are older than the granite of Buffalo Mountain which is part of the Gore Range granite. The latter is older than the Cambrian Sawatch quartzite. The pre-Cambrian age of the schists and gneisses is thus established. Since the schists and gneisses are correlated with the Idaho Springs formation, their age is more specifically believed to be Algonkian, though there is a distinct possibility that it may be Archean.[1]

Lithology. Megascopic features. The Idaho Springs formation consists of a number of different metamorphic rocks, ranging from nearly monomineralic schists to complex schists and gneisses. A great quantity of igneous material is present as lit-par-lit injections and crosscutting pegmatites and aplites. The principal types of rock are described below.

Quartz-biotite schist and gneiss are the most common rocks of the formation. The quartz-biotite schist is generally a gray

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[1] Lovering, T. S., Geologic history of the Front Range, Colo.: Colorado Sci. Soc. Proc., vol. 12, pp. 73-74, 1929.

to nearly black, rather fine-grained rock. It contains biotite and quartz in about equal quantities and a small amount of feldspar and magnetite. Quartz-biotite gneiss is a dense, gray, medium-grained rock with a somewhat rude banding. The bands are spaced 2 millimeters to 2 centimeters apart. They are not usually continuous for long distances, but are frequently lens-like. The dark bands range in thickness from a knife edge to 2 centimeters. Biotite almost entirely composes these bands. The principal minerals of the gneiss are biotite, quartz, and feldspar (microcline and oligoclase). Small amounts of muscovite, magnetite, hornblende, and sillimanite are present in megascopic proportions. Feldspar ranges from about 20 to 50 percent of the rock. The quartz-biotite gneiss grades into the quartz-biotite schist and into quartz gneiss. The quartz-biotite gneiss and schist were probably originally sediments closely akin to sandy clays in composition. They have been brought to their present state by regional and thermal metamorphism. They occur in all the major outcrops of the Idaho Springs formation and are abundant on Ophir Mountain.

Quartz "gneiss" is uncommon in the subject area and quartz schist was not observed. Quartz "gneiss" is a dense, fine-grained rock with very faint banding. Quartz constitutes approximately three-fourths of the rock. Feldspar (oligoclase and orthoclase) and a small amount of biotite compose the remainder. This rock grades into quartz-biotite gneiss. It was found only on Ophir Mountain.

Quartz-biotite-garnet schist is common on and west of Chief

Mountain. It is a medium-grained, gray, strongly foliated rock. In addition to quartz, biotite, and garnet it contains megascopic amounts of feldspar (oligoclase, orthoclase, and microcline), muscovite, and magnetite. Garnet is fairly abundant and occurs in grains as large as 5 millimeters in diameter. The rock grades into a gneiss with prominent bands of biotite and hornblende about 2 to 5 millimeters thick and 3 to 5 millimeters apart.

Two varieties of lime-silicate rock outcrop as rather thin beds on Ophir and Wichita Mountains. The variety on Ophir Mountain is a gray, coarse-grained gneiss composed principally of calcite, hornblende, feldspar (orthoclase and oligoclase), and minor quartz. Calcite occurs as coarse, twinned crystals throughout the rock and in long stringers and veinlets ranging in width from very thin to 5 millimeters. These stringers are parallel to the gneissic structure. The latter is caused chiefly by the parallelism of the hornblende grains. The calcite is readily soluble and on weathering leaves characteristic solution channels.

The variety on Wichita Mountain is a dark green, medium- to coarse-grained gneiss composed principally of diopside, calcite, and feldspar (orthoclase and microcline). Hornblende and quartz are also present. Calcite occurs in very prominent pink veinlets which run both parallel to and across the schistose structure. The schistosity is due to the parallel lineation of diopside, hornblende, and calcite.

These rocks were probably originally limy sediments which were subjected to regional and to thermal metamorphism. Impure limy shales probably provided the material for calcium silicates as well as calcite. The diopside-bearing variety is in proximity to granite and pegmatite bodies which were probably instrumental in the thermal metamorphism of this rock.

Injection gneiss is very common throughout the entire outcrop of the Idaho Springs formation. It is nearly impossible to walk over a hundred feet of outcrop of the schist or gneiss without encountering at least veinlets of the injected material. The seams injected into the schist are aplitic, pegmatitic, or granitic in composition. In many outcrops the igneous material injected parallel to the schistosity constitutes most of the rock. This rock, with its thin parallel bands of biotite, actually is a granite gneiss both in composition and appearance, although it should properly be called injection gneiss to denote its origin. Where injection has been extreme, the schist has been almost entirely assimilated and is indicated only by dark, shadowy, biotite-rich layers. The movement of the injection liquids in some places has contorted these layers into complex patterns. A large part of the rocks mapped on Buffalo Mountain consists of these extreme varieties of injection gneiss. Most of the schists present here were assimilated to such a degree that it was not practical to map them as schists but rather to include them with the intimately associated granite and pegmatite as shown on plate 1.

"Ellipsoidal masses" or"pebble-bearing gneiss", a facies of the Idaho Springs formation resembling metamorphosed conglomerate, was not seen in the subject area. It has been observed in the Montezuma[1] and Fraser quadrangles.

Microscopic features. The schistosity of the Idaho Springs formation is developed chiefly by the parallelism of the biotite. Hornblende, calcite, and diopside are elongated in the direction of the schistosity in some of the lime-silicate rocks. Quartz, feldspar, and andalusite are sometimes elongated parallel to the schistosity, but they are not instrumental in causing it. Sillimanite is not abundant enough to be an important schistose mineral.

The commonest minerals in approximate order of abundance are quartz, biotite, oligoclase, orthoclase, and microcline. Locally garnet, andalusite, epidote, hornblende, calcite, diopside, muscovite, sillimanite, and magnetite are fairly abundant. Magnetite is usually present in small amounts. The hydrothermal alteration products - chlorite, sericite, and some magnetite - are nearly everywhere present.though in small amounts. A clay mineral, probably kaolinite, is usually present on the feldspars which have been surficially altered. Apatite, pyrite, zircon, hematite, and titanite are accessory minerals.

Quartz occurs generally as grains ranging from about .1 to 2 millimeters in diameter and only rarely larger. It frequently shows secondary growth, prominent sutural contacts between grains, and wavy extinction. It occurs as wormy intergrowths and as micrographic intergrowths in feldspars. Quartz occurring in this fashion was probably injected into the formation and is not residual quartz of the original sediments. Small grains of quartz are frequently completely enclosed within much larger

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), pp. 7-8.

grains of albite and microcline. Similarly, albite occurs as small "islands" in quartz grains.

Biotite is generally very much longer than wide and is the chief schistose mineral. All the biotite seen was brown. It is in many places very corroded and embayed by later minerals such as quartz and feldspar. Some biotite is almost entirely replaced by chlorite and magnetite.

Muscovite is a rather uncommon, fine-grained mineral of the schist. Some muscovite replaces biotite, but usually they are contemporaneous in origin.

Orthoclase and plagioclase are about equally abundant. Microcline is less abundant than either. The predominant plagioclase is medium oligoclase. Albite is abundant and andesine is rare. Orthoclase is intergrown with microcline in places. In some slides, oligoclase and orthoclase show a prominent basal and side pinacoidal cleavage. These cleavages may indicate an early stage of crushing. Sericite is very common as a hydrothermal alteration product of the feldspars, and is less common as a ground mass in the schists.

Andalusite is sparingly present in some schists which are near the granite or have been thoroughly injected. It occurs in clusters of small grains and in aggregates of medium-sized crystals. Muscovite is always associated with andalusite, wither as rims around andalusite grains or as large enclosing crystals. This suggests that potash-bearing hydrothermal solutions may have attacked andalusite and converted it to muscovite. Microcline is not present in the slides near andalusite, which suggests that the hydrothermal solutions may have drawn in part on microcline as a source of potash.

Sillimanite is less abundant than andalusite and is usually an inconspicuous mineral. It occurs in little clusters of long slender needles which are oriented parallel to the schistosity. It is found in quartz-biotite schist and gneiss. Andalusite and muscovite occur in constant association with it in the sections examined. Andalusite and sillimanite together in the schist indicate that both regional and thermal metamorphism were instrumental in the formation of the rock. The original sediment from which the schist was formed was probably very aluminous. It was very likely a shale with considerable iron and magnesia impurities, possibly as chlorite or residual biotite.

Magnetite occurs as more or less euhedral crystals and as a dust-like hydrothermal alteration after biotite. Diopside occurs as greenish, anhedral crystals lineated parallel to the schistosity in the lime-silicate rocks. It was also found in a quartz-biotite schist in which it was associated with andalusite. Diopside can be formed by either regional or thermal metamorphism of a calcareous and magnesia bearing sediment. Both metamorphic processes were active in this area and sediments of this nature were undoubtedly present.

<u>Structure and origin</u>. The writer concurs in the conclusion that the schistosity of the Idaho Springs formation is nearly everywhere parallel to the bedding planes of the original sediments. This view was originally stated by Lovering[1] as a result of his study of the formation in the Montezuma quadrangle. The

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), pp. 8-10.

reader is referred to his detailed discussion for the cause of this coincidence. It is the writer's intention to show only that the conditions necessary for the formation of schistosity parallel to bedding prevailed in the subject area.

It is believed that schistosity will develop parallel to and along the bedding if deformation of the beds takes place at moderately high temperatures and pressures and in the presence of moisture. The schistosity of the Idaho Springs formation was probably developed principally during the intrusion of the granite gneiss, quartz monzonite gneiss, quartz diorite, and possibly during the intrusion of the granite of Buffalo Mountain. This is probable because of the extremely intimate association of these igneous bodies with the schist. Lit-par-lit injection is exceedingly common and definitely took place while the sediments were being crumpled. Evidence of this is the extreme crenulation of the injections themselves over large areas. Certain minerals in the schists which are indicative of thermal metamorphism show that igneous activity of some nature was instrumental in the formation of the schists. This igneous activity must necessarily be the emplacement of the granites, monzonite and diorite.

Since the schistosity very likely developed during the intrusion of the granites, monzonite, and diorite, the conditions for the formation of schistosity parallel to the bedding necessarily existed. The stresses generated in the emplacement of these rocks were the deforming pressures and the heat of the intrusions was the thermal agent. The moisture necessary was provided by the lit-par-lit injection of countless water-rich seams of magma.

Swandyke Hornblende Gneiss

Distribution and Correlation. The hornblende gneiss described below is correlated with the Swandyke hornblende gneiss of the Montezuma quadrangle, named from its type occurrence near the "ghost town" of Swandyke.[1] The correlation is based principally upon lithologic similarity and upon similarity of occurrence with the other pre-Cambrian rocks, particularly upon the general conformity with the Idaho Springs formation. The nearest outcrops of known Swandyke gneiss are only about 4½ miles to the east in the Montezuma quadrangle.

Structure. The general strike of the hornblende gneiss and of its schistosity is north to northwest corresponding to that found in the Montezuma quadrangle. On Chief and Wichita Mountains the formation outcrops in the center of the large anticline trending north through this area. A part of the hornblende gneiss outcrop on Chief Mountain is separated from the main outcrop by a band of pegmatite and the Idaho Springs formation which lies in a small syncline superimposed on the main anticline. On Ophir Mountain it outcrops in the northeast-dipping faulted limb of the fold which forms the north side of the mountain. The gneiss was inclined from 60° to 80° wherever measured.

Lithology. The Swandyke gneiss consists principally of hornblende gneiss and subordinate hornblende schist. It is in many places intimately injected by quartz, pegmatite, aplite,

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 10.

granite gneiss and quartz monzonite gneiss. Injection of the gneiss is very common in Tenmile Creek canyon between Royal and Wichita Mountains where the acidic rocks form about half of the outcrops. In parts of this area the injections are so abundant that the structure of the Swandyke gneiss can not be determined.

The commonest variety of the formation is a dark gray, medium-grained hornblende gneiss. It exhibits imperfectly defined alternate light and dark bands, spaced about 1 to 7 millimeters apart. Hornblende and biotite compose the dark bands and also occur throughout the rock. The light bands are composed of feldspar and quartz; these minerals also being distributed throughout the rock.

The gneiss grades into chloritized hornblende schist in Tenmile Creek canyon near the edge of the area. It grades into the Idaho Springs formation wherever seen and also into the quartz monzonite gneiss.

Injection gneiss has been developed in some of the massive hornblende gneiss. While this rock is not as favorable a host to the injecting fluids as the Idaho Springs schists, yet thin sills of injected acidic material are so common in places that the injected rock must be called injection gneiss. Injection gneiss is especially common in Tenmile Creek canyon as previously noted.

Hornblende and plagioclase, the chief minerals, compose approximately 70 to 90 percent of the gneiss. The plagioclase usually is basic oligoclase, but sometimes is andesine. Some quartz is present and frequently a little biotite. The long axes of hornblende and biotite are generally aligned parallel to the planes of foliation. The feldspar generally has a random orientation. The hornblende and plagioclase crystals range from about 2 to 4 millimeters in length. Common accessories are magnetite, apatite, and titanite. Zircon is less common.

Origin. The Swandyke gneiss is a regionally metamorphosed rock rather than an unmetamorphosed primary (igneous) gneiss. This is indicated principally by the gradation of the gneiss at places into hornblende schist. The banding is too sharply defined to resemble igneous banding. The bands also contrast rather sharply in mineral composition, which suggests a metamorphic rather than an igneous origin of the rock. Some exposures of the rock adjacent to granite gneiss and quartz monzonite gneiss show little or no foliation and resemble a basic igneous rock. The change in texture is thought to be due to "soaking" and intimate injection by the acidic liquids.

Before metamorphism the hornblende gneiss was in all probability basic igneous rock of a composition approximating diorite or its extrusive equivalent, andesite. The minerals now found in the gneiss are those which would be expected in a rock of this composition which had been subjected to a high grade of regional metamorphism. Also suggestive of an igneous origin before metamorphism is the limitation of the plagioclase to one variety of basic oligoclase. The accessories listed above are also somewhat suggestive of igneous origin. The field occurrence of hornblende gneiss interbedded and generally conformable with the Idaho Springs formation suggests that the gneiss was originally a series of basic flows or sills intruded into the original Idaho Springs sediments.

ALGONKIAN SYSTEM

Quartz Monzonite Gneiss

Distribution and Structure. Quartz monzonite gneiss is fairly abundant in the subject area. It outcrops in the southwest part of the area on Wichita, Chief, and Royal Mountains. Most of Royal Mountain is composed of this rock. It intrudes the Swandyke hornblende gneiss and probably also the Idaho Springs formation. It has generally been injected parallel to the foliation of the Swandyke gneiss, although it occasionally cuts across the gneissic structure. The quartz monzonite gneiss injected into the hornblende gneiss frequently shows a fairly sharp boundary, but occasionally it grades imperceptibly into the hornblende gneiss. It can be distinguished then partly by the appearance of biotite and the disappearance of hornblende and partly by a lightening in color. An actual contact of definite quartz monzonite gneiss and Idaho Springs formation was not observed but undoubtedly much of the acidic material which injected the schist originated from the nearby quartz monzonite magma.

Lithology. The quartz monzonite gneiss is a light to medium gray, fine- to medium-grained gneiss. The grains range from approximately .5 to 2 millimeters in size. Banding is rather rough and the folia are generally continuous for only short distances. Many of the folia consist only of thin lenses of the dark minerals. They are 2 to 4 millimeters apart and 1 to 2 millimeters thick. The dark bands are composed of biotite and to a small extent of hornblende. The light-colored portions of the rock are predominantly feldspar and quartz. Some of the quartz is darker in color than the feldspar and stands out in contrast to the latter. Hornblende is not abundant except where the quartz monzonite gneiss is near hornblende gneiss.

The microscope shows the feldspars to be microcline, orthoclase, and basic oligoclase. Orthoclase is much less abundant than microcline and together they usually constitute somewhat less than half the total feldspar. Quartz occurs rather frequently in micrographic intergrowths with both microcline and oligoclase and also as vermicular intergrowths in plagioclase. Biotite replaces hornblende which is usually very corroded. Feathering out of biotite against other grains suggests that it has recrystallized. Accessories are apatite, titanite, and zircon. Apatite occurs as very small needles and also as well developed crystals.

Inclusions of hornblende gneiss are fairly common. The foliation of these inclusions is parallel to that of the quartz monzonite gneiss. Most of the inclusions have been rather thoroughly injected and some have been partially or completely assimilated. This is apparent from the long streamers of hornblende which fade out into the surrounding quartz monzonite gneiss and from shadowy remnants which indicate former inclusions. Assimilation and mechanical mixture have thus locally been important in determining the composition of the quartz monzonite gneiss.

Quartz monzonite gneiss is similar megascopically to the granite gneiss. There does not appear to be a definite criterion for separating them in the field, hence they have been mapped together. The principal difference between them is in the composition and amount of plagioclase which necessarily must be determined microscopically. Quantitatively quartz monzonite gneiss is more important.

Granite Gneiss

Distribution and Structure. Granite gneiss occurs in small masses in the southwest part of the subject area on Wichita and Royal Mountains. It is well-exposed in the canyon of Tenmile Creek. The gneiss follows in part the strike of the Idaho Springs formation and the hornblende gneiss but is also crosscutting and occurs as irregularly shaped bodies. Some of the gneiss has been injected into the above two rocks in seams ranging from a few inches to several feet in thickness. It is closely associated with the quartz monzonite gneiss both in composition and in the outcrops. Two generations of the granite gneiss are present - a sparingly present, younger, finer-grained type which occurs in dikes cutting an older coarser-grained type.

Lithology. The granite gneiss is generally a gray, medium-grained rock with fairly prominent foliation. Coarser grained varieties which grade into pegmatite are also present. The banding is not sharp, as single bands do not usually continue unbroken over a few inches. In some of the more massive outcrops the bands are highly contorted. The dark bands are usually made up of biotite and a little hornblende. Gneisses carrying a considerable amount of hornblende are a darker gray than those carrying principally biotite. Quartz is very abundant and together with feldspar forms the major part of the rock. Occasionally these two minerals occur in small lens-like segregations, somewhat resembling augen, which are approximately 1 centimeter long and half a centimeter wide. Biotite is fairly abundant but muscovite is rare. Biotite is scattered throughout the rock in addition to occurring in the dark bands. Garnet is present as small red crystals about 1 millimeter in diameter.

Under the microscope the feldspar is seen to be principally microcline. Orthoclase and a plagioclase in composition near basic albite and acidic oligoclase are less abundant. Quartz occasionally occurs as wormy intergrowths in orthoclase and in micropegmatite. Some of the biotite and hornblende are parallel to the gneissic structure. Hornblende is uncommon and that which is present is very corroded and frayed. Magnetite, apatite, garnet, zircon, titanite, and, in one specimen, augite occur as accessories.

The granite gneiss has locally injected hornblende gneiss and has partly assimilated this rock. Schlieren of hornblende gneiss are present in the granite gneiss and die away at the ends into the granitic material. Some hornblende crystals are separated from the schlieren and scattered throughout the granite gneiss. Granite gneiss adjacent to and intruding hornblende gneiss is richer in hornblende than the granite gneiss further removed. The composition of the granite has thus been locally altered by partial assimilation and mechanical mixture.

Quartz Diorite and Associated Basic Rocks

Distribution and Structure. The largest mass of quartz diorite occurs on the ridge between the north branch of Meadow Creek and Meadow Creek near the west border of the subject area. A small body was found on the east side of Chief Mountain in a prospect hole and dikes of quartz diorite occur on and near the top of Buffalo Mountain. Massive quartz diorite intrudes the Idaho Springs formation and the hornblende gneiss. The dikes on Buffalo Mountain cut the granite. The contact of the massive quartz diorite and granite was obscured by float and detritus in the valley of the north fork of Meadow Creek.

Lithology. Quartz diorite is usually a dark gray rock with a mottled black and white appearance which becomes light with an increasingly acidic composition and darker as the composition becomes more basic. The quartz diorite from the larger intrusive mass is rather coarse-grained whereas that in the dikes is finer-grained. The grains in the massive quartz diorite range from about 1 to 4 millimeters in diameter, except those of biotite which are usually somewhat over 5 millimeters. Gneissic structure is uncommon. The only gneissic structure observed was due to a rather faint parallelism of some quartz and feldspar grains and to a crudely parallel lineation of biotite.

Plagioclase (generally andesine), hornblende, biotite, and quartz are the most abundant minerals of the quartz diorite. Although the proportions of these minerals vary considerably, quartz constitutes approximately 10 to 15 percent, plagioclase

30 to 40 percent, biotite about 20 percent, and hornblende 25 to 40 percent. Quartz has locally been crushed and recrystallized. One indication of recrystallization is the pronounced sutural contacts of the grains. Orthoclase is only sparingly present. Some hornblende in the massive occurrences of the rock has been altered to tremolite. The change from hornblende to tremolite is very sharp in some crystals. Frequently a single grain will consist partly of the usual green hornblende and of colorless or faint green tremolite with no gradation between the two minerals. Gneissic structure was not observed in this rock. The presence of tremolite is ascribed to moderate regional metamorphism of insufficient intensity to metamorphose the rock to a gneiss. Biotite is very abundant in some facies of the quartz diorite. It occurs in clusters of large flakes as well as disseminated throughout the rock. Accessory minerals are apatite, zircon, pyrite, magnetite, and hematite. Hematite occurs as small, deep red crystals.

A quartz gabbro dike which may be related to the quartz diorite cuts the Swandyke gneiss on the west side of Royal Mountain. It is very dark gray and exhibits a rather poorly developed gneissic structure. Some of the feldspar and quartz is segregated into parallel lenses 1 to 2 millimeters long which resemble small phenocrysts. The rock is composed mainly of hornblende and augite with smaller amounts of labradorite and quartz.

The fact that quartz diorite dikes cut the granite on Buffalo Mountain indicates they are later in age. However, some facies of the quartz diorite, such as on Chief Mountain, closely approach granite in composition. This suggests that they may be differentiation products of the same magma and hence approximately the same age. If the quartz diorite belonged to a much later period of intrusion, it could reasonably be expected that the composition of the two rocks would not grade so closely into each other. While the quartz diorite dikes on Buffalo Mountain cut granite, the relation of the main mass of quartz diorite to the granite is not clear. It may be the same age as the dikes on Buffalo Mountain but in view of the lack of field evidence its age cannot be stated. The quartz diorite in the Montezuma quadrangle is believed to belong to the same general period of magmatic invasion as the quartz monzonite, granite gneiss, and Pikes Peak granite.[1]

Granite

Distribution and Structure. Granite is abundant in the northwest part of the subject area. Numerous outcrops are present on Buffalo Mountain, on the ridge between the north fork of Meadow Creek and Meadow Creek, and on the south side of Meadow Creek valley. The granite appears to be a portion of a larger mass which extends to the north and to the west.

The granite is in contact with the schist and hornblende gneiss country rock only on the south side of Meadow Creek Valley. The contact is generally quite irregular and tongues of the granite project into the schist and gneiss. The granite also grades at many places along its borders into pegmatite, tongues of which inject the gneiss and schist country rock.

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 12.

Pegmatite dikes are also very common within the granite mass.

Inclusions of partly assimilated schist and gneiss are very common. They exceed the granite in areal extent in some portions of the mass. They range in size from small fragments to large blocks which were only slightly attacked by the granite. The inclusions do not show much concordance in their schistosity, which suggests that many are xenoliths rather than roof pendants. The great number of inclusions suggests that the present eroded surface of the granite is rather near the top of the batholith.

Lithology. The commonest kind of granite is a moderately coarse-grained, light gray rock. A greenish cast is in places imparted by an abundance of chlorite. The grain size ranges from about .2 to 1 centimeter. Schlieren composed of biotite and a little hornblende are common especially near inclusions. Partly assimilated schist inclusions have evidently furnished much of the biotite of the schlieren. Stringers of biotite in places extend from the ends of partly assimilated schist inclusions. The schlieren in many places have no definite lineation, but wind in all directions. The complexity of the folds in some of the schlieren indicates considerable turbulence during the emplacement of the granite. Flow structure is also caused by the parallel lineation of short stringers of biotite and hornblende. Flow structure due to lineation of feldspar crystals was not seen.

Orthoclase and microcline compose well over 50 percent of the rock, quartz about 20 to 30 percent, and biotite about 5 to 10 percent. Medium oligoclase, muscovite, and hornblende usually constitute a minor amount of the rock. Microcline is much more abundant than orthoclase. The crystals of the latter two minerals are the largest in the granite. Some grains of quartz and a small amount of orthoclase exhibit a pronounced mortar structure indicating deformation of the granite. Sutural contacts of quartz grains, suggesting recrystallization, are common. Micrographic intergrowths of quartz are present. Quartz replaces muscovite, indicating that at least some muscovite is earlier. Muscovite in turn is later than biotite, which was the earliest major mineral to crystallize. Biotite generally increases in quantity near schist inclusions. A few orange scales of hematite are present. The usual chloritic and sericitic alteration products of the principal minerals are present. A considerable amount of fine-grained magnetite replaces biotite. Accessory minerals are zircon, apatite, magnetite, and a very little ilmenite.

A much less abundant pink variety of granite occurs on the eastern slopes of Buffalo Mountain and on the ridge between the north fork of Meadow Creek and Meadow Creek. As this granite grades into the gray granite, it is considered a variety and not a separate type. This granite is finer-grained than the light gray variety and exhibits similar flow structures. In places its texture becomes aplitic. Quartz and feldspar grains are about 1 to 3 millimeters in size and hornblende slightly larger. Essentially the same minerals are present as in the light gray variety but in different proportions. Quartz constitutes over 50 percent of the rock and orthoclase, microcline, and albite together about 30 percent. The remainder consists principally of muscovite and biotite. Orthoclase is much more abundant than microcline. Fine veinlets of orthoclase cut across large crystals of albite. Perthitic intergrowths of orthoclase in albite occur also. Both muscovite and biotite occasionally occur in thick, platy, book-like accumulations. Some small crushed zones of quartz and feldspar and bent crystals of muscovite indicate deformation. The sutured contacts of quartz grains indicate recrystallization of this mineral. The usual alteration products are present. Chlorite and magnetite are exceedingly abundant and have almost entirely replaced biotite. Zircon, apatite, and ilmenite were not seen in this variety as in the gray granite.

The distance between the subject granite and the Silver Plume and Pikes Peak granites of the Montezuma quadrangle is too great to permit definite correlation. (See page 53 on Geologic History.) However the subject granite somewhat resembles the Silver Plume granite. The grain size of both is quite similar, although the feldspars of the Silver Plume granite tend to be a little larger. The mineral compositions and proportions in both granites are similar. Both the Silver Plume and subject granites carry muscovite and biotite. Orange-colored hematite inclusions are rare in both granites. However the local granite shows no marked flow structure of the feldspars which is a conspicuous feature of the Silver Plume granite. The gneissic structure in the subject granite is caused by the parallel orientation of biotite and hornblende and also by long schlieren which are uncommon in the Silver Plume granite.

Probably the Boulder Creek granite, earlier than Pikes Peak.

The age relations of the subject granite to the quartz monzonite gneiss and smaller granite gneiss bodies can not be determined from data in the subject area as the granite was nowhere in contact with these other rocks. If the subject granite correlates with the Silver Plume granite, the subject granite would be younger than the quartz monzonite gneiss or granite gneiss.[1] If it correlates with the Pikes Peak granite, which seems unlikely, it would still probably be somewhat younger than the granite gneiss or quartz monzonite gneiss.

Pegmatites

Distribution. Pegmatite and associated aplite intrude nearly all the pre-Cambrian rocks of the area. They are especially abundant in the Idaho Springs formation, the Swandyke hornblende gneiss, and in the granite of Buffalo Mountain. The largest masses occur at the southern edge of the granite and on Chief Mountain. Smaller masses are mapped on Royal and Ophir Mountains. Most of the pegmatite could not be mapped because of its occurrence in the schist, gneiss, and granite as a network of fine veins and small, irregularly shaped masses.

Structure. A large part of the pegmatite is injected lit-par-lit into the Idaho Springs formation and the Swandyke hornblende gneiss as seams ranging from paper-thickness to several feet in width. Some crosscutting dikes and sills are also present. Tongues from these crosscutting bodies in places inject the schists and gneisses. The contacts of the fine seams in the schist and gneiss are generally quite sharp, but some of the

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), pp. 12-13.

larger bodies have assimilated and "soaked" their walls and show a gradational contact. Pegmatite very commonly grades into granite on Buffalo Mountain, although some dikes cut sharply across the granite. Similarly, pegmatite grades into quartz monzonite gneiss and cuts across it with sharp contacts. At the borders where pegmatite has partly assimilated the quartz monzonite the latter is locally changed to a granitic composition because of the large admixture of potash feldspar. Most of the pegmatite dikes do not persist over a thousand feet and most of them are less than 10 feet wide. Some pegmatite masses are in turn cut by later bodies of pegmatite. Three generations of crosscutting pegmatite dikes and seams can be seen in places on one outcrop.

The relationship of the pegmatites with respect to other rocks and themselves indicates they were injected over a long period of time. Some pegmatite was probably injected as early as the time of formation of the Idaho Springs schist and the hornblende gneiss. Thin injections of the pegmatitic liquid were probably necessary for the development of schistosity parallel to the bedding of the Idaho Springs formation. Some of the pegmatite is contemporaneous with and some is definitely later than the granite, quartz monzonite and granite gneisses.

Lithology. The predominant minerals of the pegmatites are sodic plagioclase, microcline, and quartz. Biotite, muscovite, oligoclase, and magnetite are common. In general the mineralogy of most of the pegmatites is simple and few minerals other than the above are present. One dike which intruded the Idaho Springs schist on Wichita Mountain carried garnet and epidote in addition to muscovite, biotite, quartz, microcline, orthoclase, and oligoclase. Another in the granite of Buffalo Mountain carried epidote and biotite in addition to quartz, oligoclase, orthoclase, muscovite, and magnetite. The writer could not confirm the generalization made by Ball[1] in the Georgetown quadrangle and Lovering[2] in the Montezuma quadrangle that the pegmatites contain biotite but little or no muscovite where their walls are granite, and muscovite but little or no biotite where the walls are schist. Pegmatite in both kinds of rock carried both muscovite and biotite. However muscovite may be present in the pegmatite cutting the granite because of the great abundance of Idaho Springs schist xenoliths in the granite which would tend to contaminate the pegmatite with muscovite.

Quartz grains in some places show mortar structure indicating partial crushing. Sutured contacts of some quartz grains suggest recrystallization. Microscopic veinlets of fine-grained quartz cut microcline and orthoclase in the earlier pegmatites which invaded the schist and gneiss. Quartz also occurs in micrographic intergrowths in these same pegmatites. Some albite grains show further evidence of deformation by the bent twinning lines. Albite and microcline appear to be simultaneously formed in the pegmatites associated with the granite of Buffalo Mountain. Orthoclase is earlier than albite in these pegmatites as albite veinlets cut orthoclase. Perthitic intergrowths of oligoclase in microcline are present in the earlier pegmatites. Some mus-

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[1] Ball, S. H., et al, Economic Geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, 1908, p. 64.

[2] Lovering, T. S., op. cit. (Prof. Paper 178), p. 16.

covite crystals in the pegmatites associated with the Buffalo Mountain granite are bent. Biotite and garnet are earlier than quartz and feldspar as the latter embay biotite along its cleavage and corrode garnet.

SEDIMENTARY FORMATIONS

The unmetamorphosed sedimentary rocks of the subject area are all post-Cambrian and exposed principally in the northeastern quarter in sections 12 and 13, T. 5 S., R. 78 W. A small area of sediments is just outside the southeast corner of the area. All the visible sediments are Mesozoic. Paleozoic rocks do not outcrop in the area but may underlie the youngest exposed rock (Morrison formation) not far below the surface about one mile northwest of Dillon near Salt Lick Gulch. The total thickness of the exposed rocks is estimated to be 1,600 feet, but a large part of the known section for this general area is covered. The sediments are in general poorly exposed and at no place could a section be measured. Many details of the section are thus lacking and the reader is referred to the reports specified in the following pages for a detailed discussion of the stratigraphy.

Jurassic System (Upper Jurassic Series)

Morrison Formation

Distribution and stratigraphic relations. The Morrison is very poorly exposed in two localities in the subject area. The larger exposure is about one mile northwest of Dillon on the west bank of the Blue River where it is faulted in a saddle between two prominent knobs of Dakota quartzite. The contact between the Morrison and the overlying Dakota, outcropping north of it, could not be observed. The smaller exposure is on the east side of Ophir Mountain where the Morrison apparently overlaps the pre-Cambrian schist. The formation is known here only from float.

Lithology. The exposures of the Morrison north of Dillon consist of dense green and reddish-brown blocky shales, gray limy shales, and a gray gritty sandstone. These rocks are similar to those found in the upper part of the Morrison section at Rocky Point which is approximately 10 miles south of Dillon. The uppermost 116 feet exposed at Rocky Point are red, green, brown, and gray shales like the above shales. The next 15 feet is a grayish-white gritty sandstone resembling the above-mentioned sandstone. For a detailed discussion of the lithology of this formation the reader is referred to Lovering's paper on the Breckenridge district[1] which describes the Rocky Point section.

Correlation. The shales and sands here referred to the Morrison formation are distinguished from the vari-colored rocks of the Maroon formation of Carboniferous age by the absence of visible mica. The red and green shales are easily distinguished from the gray or black Dakota shales, but the gray shales of both formations are indistinguishable. The sandstone is softer and coarser-grained than most of the Dakota sandstone. The position of these shales and sands relative to the overlying prominent Dakota quartzite assists in assigning them to the Morrison formation.

[1] Lovering, T. S., op. cit. (Prof.Paper 176), pp. 6-7.

Cretaceous System (Upper Cretaceous Series)

Dakota Quartzite

Distribution and stratigraphic relations. The Dakota quartzite outcrops on the prominent ridge on the west side of the Blue River immediately north of Dillon and also outside the subject area on the east bank of the Blue River about a mile north of Dillon. Some slumped quartzite blocks lie just outside the southeast corner of the subject area on the east side of Ophir Mountain. A large amount of Dakota float is present in the morainal material and outwash east of Buffalo Mountain. The Dakota is probably very close to the surface in the southwest quarter of section 23, T. 5 S., R. 78 W. as an unusual number of large quartzite boulders are present in the till.

The exact contacts of the Dakota with the Benton shale and the Morrison formation are obscured in the subject area, but approximate contacts can be determined from nearly adjacent exposures of these formations.

Lithology. A fairly complete section of the Dakota cannot be measured anywhere in the subject area, hence the thickness must be inferred from information gathered from outside and from cross sections made across the strike of the formation. From the latter the thickness is estimated to be about 275 feet. The closest measured section to the subject area is near Keystone, 4 miles east of Dillon on the Snake River, where it is 225 feet thick.[1] The section is thinner to the south also being 175 feet thick at Rocky Point, southeast of Breckenridge. The thinning

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 17.

of the Dakota to the east in conjunction with the successive overlap of the Maroon (Pennsylvanian or Permian), Morrison and Dakota has been interpreted by Ransome[1] and Lovering[2] as reflecting the gradual submergence of a highland that occupied much the same area as the present Front Range.

The Dakota in this general area is commonly composed of upper and lower quartzite members separated by a carbonaceous shale. These three members probably all occur in the subject area. On the prominent knob immediately south of the junction of Salt Lick Gulch and the Blue River an estimated 30 to 50 feet of a very dense, fine-grained, thick-bedded, gray quartzite is present. This quartzite is probably part of the lower quartzite member as it occurs only a few feet above the projected top of the Morrison. An estimated 30 to 50 feet of buff, thick-bedded, blocky quartzite is on the high knob north of and overlooking Dillon. The position of this quartzite in the formation is not known. A bed of bluish-gray, thin-bedded quartzite, which may be part of the middle member, occurs on the top of the same knob. Quartzite beds belonging to this member are generally darker than the other members of the formations.

Topographic expression. The Dakota quartzite is the only cliff-forming sedimentary rock in the subject area. The above-mentioned outcrops form prominent topographic features. The prominent ridge which forms the north side of Tenmile Creek valley may be composed of the Dakota quartzite superficially

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[1] Ransome, F. L., op. cit. (Prof. Paper 75), p. 182.

[2] Lovering, T. S., op. cit. (Prof. Paper 176), p. 8, and (Prof. Paper 178), p. 17.

plastered with lateral morainal material. This is suggested by the profusion of quartzite blocks which occur near the end of the ridge in section 23, T. 5 S., R. 78 W.

Correlation. Correlation of this formation with the Dakota of central and eastern Colorado is based upon its distinctive lithology and upon its occurrence under beds resembling the Benton shales.

Benton Shale

Distribution and stratigraphic relations. The Benton shale occurs in a rather narrow band about one mile northwest of Dillon as shown on plate 1. The actual contact of the Benton shales with the underlying Dakota quartzite is not visible but the quartzite and loose shales occur within a few feet of each other. The contact with the overlying Niobrara lime is obscured by slumping and wash but probably is at the base of a grayish-white limestone which forms a low ridge on the north side of Salt Lick Gulch. The thin, black, fetid limestone which marks the top of the Benton and which in many places underlies the grayish-white limestone was not observed. No definite outcrops of the Benton were present between the Dakota quartzite and the Niobrara lime.

Lithology. In the bottom of Salt Lick Gulch loose, fissile, gray to grayish-black shale that breaks into flakes about half an inch long is abundant. Much of this shale has been turned up by the placer workings around the gulch. This shale may correlate with the rather fissile, dark gray shales of the Benton at Rocky Point. The latter shales occur in the interval approximately 30 feet to 250 feet above the base of the Benton.[1]

[1] Lovering, T. S., op. cit. (Prof. Paper 178), pp. 18-19.

The thickness at Salt Lick Gulch is estimated at 400 feet. This is obtained from calculations using the width of exposure of the Benton and dips of the Dakota and Niobrara formations and so is somewhat inaccurate.

Topographic expression. The Benton shale is here marked by a fairly smooth valley between the Dakota knobs and the low ridge of Niobrara lime.

Correlation. No fossils were found in the shales designated here as Benton. Correlation of the shales is based on their stratigraphic position above the Dakota quartzite and on their lithologic similarity to known Benton shales. The shales are distinguished from the Niobrara by the absence of calcareous material and from the non-calcareous Pierre shales by their lower stratigraphic position.

Niobrara Limestone

Distribution and stratigraphic relations. The Niobrara limestone outcrops about 1½ miles north of Dillon along the west bank of the Blue River as shown on plate 1. The contacts with the overlying Pierre and the underlying Benton are not well defined. The Niobrara is conformable with both of these formations.

Lithology. The Niobrara is not well exposed in the subject area. A gray, blocky limestone about 10 feet thick, with beds about 1 foot thick, occurs near the base of the formation. The base of this lime is covered. This lime probably correlates with the upper part of the gray limestone 10 to 30 feet thick which is the base of the formation in the Breckenridge district.[1] The lime there overlies a fetid, thin, brown limestone of Benton

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 20.

age or locally overlies calcareous shales. In the subject area a few feet of gray, paper-thin, limy shales are exposed above the basal lime. These shales resemble lithologically the greenish-gray limy shales of the Breckenridge district which compose the succeeding 250 feet above the basal limestone. The top of the formation is chosen at the top of the above-mentioned calcareous shales. This contact cannot be picked in the subject area with certainty. The overlying clay shales resemble the Pierre more closely than the Niobrara. The thickness of the Niobrara is estimated at 350 feet by calculations using the width of exposure and the dip.

Topographic expression. The basal Niobrara limestone forms a low ridge which rises 10 to 20 feet above the shales on either side of it. The ridge is accentuated because the south side is steepened by a gulch. The Niobrara shales form smooth slopes.

Correlation. No fossils were found in the Niobrara. The correlation of these beds with the Niobrara depends on lithologic similarity to known Niobrara beds in other localities and on the stratigraphic position with reference to the Benton and Pierre formations.

Pierre Shale

Distribution and stratigraphic relations. The Pierre shale is known from a small area on the west bank of the Blue River valley about two miles northwest of Dillon. The formation does not outcrop but may be found by digging a few inches under the surface. The contact between the Niobrara limestone and the Pierre is chosen at the top of the calcareous shales which occur about 350 feet above the basal Niobrara limestone. The top of the Pierre is covered in this area. It is probably a considerable distance north of the subject area.

Lithology. Nearly all the observed Pierre shales are dark brown or black, generally fissile, clay shales. Some are slightly limy. These clay shales resemble lithologically the clay shales of the Pierre in the lower 1,975 feet of the section exposed on the north side of the Snake River near Keystone.[1] An estimated 550 feet of the lower Pierre is known in the subject area. The remaining part of the formation is covered by morainal material.

Topographic expression. The Pierre shale forms smooth slopes in this area. The topographic expression is similar to that of the upper Niobrara shales.

Correlation. No fossils were found in the limited section. The correlation of these shales with the Pierre is dependent on their lithologic similarity to known Pierre shales observed elsewhere, expecially in the Keystone section, and to their stratigraphic position above the Niobrara.

Quaternary Deposits and Topographic Evolution

Much of the topography of the subject area and the surrounding country was developed in the Quaternary, but some indications of two earlier surfaces are present. In the Gore Range and adjacent parts of the Front Range two Tertiary erosion cycles and three Quaternary cycles are recognized.

The glaciation and glacial deposits on the east side of the Gore Range including the subject area were studied in detail by

[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 21.

Margaret Steere.[1] The following discussion of the glacial topography and deposits only summarizes the more important features, as it was not the writer's chief purpose to study the glacial features.

Eocene Land Surface

In the northern part of the Gore Range near the Colorado River the Gore Range surface of probable Eocene age is well developed. This surface lies there at an altitude of about 12,500 feet. It is not as conspicuous to the south and is difficult to trace in the Dillon quadrangle. It is probably represented in the subject area by the more or less flat, small top of Buffalo Mountain which lies at an altitude of about 12,750 feet. Several other somewhat flat surfaces lie at about this elevation within a few miles west of Buffalo Mountain. This surface may correlate with the Eocene Flattop peneplain of the Front Range which is the highest surface present there also. No deposits are known in the subject area which were derived from the carving of this surface.

Late Tertiary Land Surface

In the northern part of the Gore Range near the Colorado River a post-Miocene land surface - the Sheephorn surface - is recognized. It occurs there as a low bench cut into the range between 8,500 and 10,500 feet. It is less conspicuously developed to the south and is difficult to trace in the subject area. Remnants of it may possibly exist on the high ridge west of Chief Mountain and on the high ridge southwest of Wichita Mountain.

[1] Steere, Margaret, unpublished thesis for master's degree at the University of Michigan, 1938.

(See plate 2 .) This surface may be equivalent to the Rocky Mountain peneplain of the Front Range. No deposits corresponding to this surface are known in the subject area.

Early Pleistocene Topography

Early Pleistocene (Kansan?) glaciation was widespread in the Gore Range as well as in the Front Range and a few remnants of the topography carved at this time are thought to be present in the subject area. However most of the early Pleistocene topography has been obscured by later erosion and glaciation. The more or less flat tops of Chief Mountain, Royal Mountain, and the ridge west of Wichita Mountain are probably remnants of an early Pleistocene valley floor. Interglacial erosion and subsequent glaciation deepened the valley to its present level. Erosion to this extent is in keeping with the amount of interglacial and glacial deepening of stream valleys noted elsewhere.[1] Much of the subdued, undulating topography east of Buffalo Mountain is also a result of early Pleistocene glaciation inasmuch as a large ground moraine was deposited here.

Early Pleistocene deposits

Much of the early Pleistocene till has been removed by later erosion, but a large early ground moraine comprising three to four square miles lies immediately east of Buffalo Mountain. The till of this moraine is composed of unsorted boulders and pebbles of Dakota quartzite and pre-Cambrian rocks embedded in a matrix of sand and some clay. The boulders vary greatly in size, some pre-Cambrian boulders being 8 to 10 feet in diameter. In an

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), pp. 23-24.

artificial cut about half a mile north of Ryan Gulch approximately 20 feet of sands and clay with some boulders were exposed.

An exposure of high-terrace gravel deposits extends about a mile along the north side of Salt Lick Gulch from near its junction with the Blue River. The highest part of the terrace is about 500 feet above the river. The terrace is made up of well-rounded boulders and pebbles of quartzite and pre-Cambrian rocks with some sand. Sand is more common in the lower parts of the terrace. Most of the boulders were less than a foot in diameter but some were over two feet. Some of the boulders are deeply weathered and can be easily broken up with a hammer. These deposits were laid down by the glacial streams of the early Pleistocene stage and by interglacial streams.

Late Pleistocene Topography

Much of the rugged topography in the subject area is due to glacial carving in the Wisconsin glacial stage. Also in Wisconsin time deposition of ground and lateral moraines and outwash formed much of the more subdued topography.

Of the glacial features in the subject area, the most conspicuous are the steep U-shaped valleys such as those of South Willow Creek, the north fork of Meadow Creek, Meadow Creek, North Fork Tenmile Creek, and Tenmile Creek. All of these valleys head in cirques in the Gore Range west of the subject area except Tenmile Creek valley which heads in several large cirques about 16 miles south of the subject area. In some of the valleys the cirques are compound and it is possible that some of the higher cirques were carved by the early Pleistocene glaciers. A sharp divide caused by the headward erosion of two cirques is located immediately southwest of Buffalo Mountain, about half a mile west of the subject area. Similar divides are numerous in the main part of the Gore Range to the west. Uneva Lake, about half a mile south of the subject area, fills a depression in the rock floor cut by the glacier which formerly occupied Tenmile Creek valley. Several small lakes fill depressions in the moraines in front of the mountains. Some of the moraines are rather swampy.

Late Pleistocene (Wisconsin) Deposits

Late Wisconsin till and outwash are common in all the valleys, and a broad area in Tenmile Creek valley from the end of the canyon to Dillon is covered with this material. In the central part of this valley the till is deposited as a large ground moraine. Large lateral moraines lie along the sides of the valley and two large recessional moraines are located just west of Dillon. Lateral moraines are present in all the smaller valleys except the canyon of Tenmile Creek. The till is heterogeneous, poorly sorted or unsorted material consisting of little-weathered boulders, pebbles, sand, and clay. Some of the boulders, particularly near Royal Mountain, are 15 or 20 feet in diameter.

The outwash was deposited by streams flowing from the melting glaciers and in several places it is deposited above the till. This indicates the glaciers were in a late stage retreating back up the valley towards the cirques. The deposits consist of well-rounded cobbles, boulders, and pebbles which are little weathered. They occur in places in well-defined gravel beds.

Recent Topography

The effects of erosion since the retreat of the Wisconsin glaciers are not particularly evident in the subject area. Weathering on the steep sides of Buffalo Mountain has resulted in the accumulation of large talus piles. Tenmile Creek and the Blue River and cut down a few feet into the till and outwash.

Recent Deposits

The chief recent deposit is the alluvium deposited along the borders of Tenmile Creek and the Blue River. These deposits are narrow and difficult to distinguish from the Wisconsin glacial outwash through which these streams flow. The alluvium and the outwash are mapped together. (See plate 1.) This material consists of sand, gravel, and cobbles and is derived from the outwash as well as from the present highlands. Talus piles are common on Buffalo Mountain, especially on the northeast side.

HYPOGENE ROCK ALTERATION

The principal hypogene rock alteration effects in the adjacent parts of the mineral belt resulted from contact metamorphism and deuteric action by hot solutions from the Tertiary intrusives and from hydrothermal action in the subsequent mineralization period. The chief alteration effects in the subject area are due solely to hydrothermal action during the mineralization period. No contact metamorphic effects were noted and the rather limited deuteric effects resulted from the intrusion of the older igneous rocks. No late intrusives were observed in the subject area other than a very small dike which cut the

Dakota quartzite.

Three principal types of hydrothermal rock alteration have affected the wall rocks of the veins. The first is chloritization wherein the ferro-magnesian minerals of the country rock have been altered to chlorite and epidote as much as several feet from the veins. The second is sericitization which is characterized by the development of sericite on the feldspars and to some extent on the ferro-magnesian minerals. This type of alteration occurs closer to the veins than chloritization. The third type is silicification wherein quartz has been introduced in the wall rocks adjacent to the veins and replaces both salic and mafic minerals. Some carbonate material and a little pyrite have also been introduced into the wall rocks adjacent to the veins. Wall rock affected by these types of alteration is especially common in the Hidden Treasure mine.

Chloritization of the wall rock usually occurs during the milder phases of hydrothermal action accompanying ore deposition. Sericitization usually takes place at a higher temperature and in a more active phase, and silicification occurs generally during the most active phase of alteration. This is indicated in the subject area by the occurrences of silicified, sericitized, and chloritized zones successively farther from the veins. In the Leadville district[1] a similar situation is noted wherein the silicified zone, a quartz-sericite zone, and a chloritized zone also occur at successively greater distances from the veins.

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[1] Emmons, S. F.; Irving, J. D.; Loughlin, G. F., Geology and ore deposits of the Leadville mining district, Colo.: U. S. Geol. Survey Prof. Paper 148, pp. 186, 214, 1927.

STRUCTURE

REGIONAL STRUCTURE

This area lies partly in the Park Range and partly between the Park and Front Ranges. The western part in the vicinity of Buffalo, Chief, and Wichita Mountains lies within the eastern edge of the Gore Range. The southcentral part in the vicinity of Royal Mountain forms the northern extremity of the Tenmile Range. Both ranges are included within the Park Range. The northeastern part of the area lies between the Williams River Mountains and the above-mentioned ranges. The Williams River Mountains are considered to be the westernmost range of the Front Range.

The pre-Cambrian structures are the most apparent ones in the areas of pre-Cambrian rocks which form the cores of both the Park and Front Ranges, but Laramide structures can also be observed in these rocks. Laramide deformation is most apparent in the areas of Mesozoic sediments lying between the older cores of the ranges. The pre-Cambrian rocks are mainly granite, schist, and gneiss. The granite is part of the batholith present throughout a large part of the Gore Range. This intrusion extends with slight breaks from about six miles north of Kokomo nearly to Mt. Powell, a distance of about 25 miles. A similar larger intrusion lies to the north, west of Kremmling,and a smaller one to the south around Climax. The regional trend of the schist and gneiss is generally to the northeast. In the northern part of the Gores the strike is slightly north of east and the dip is reported to be from 40° to 50° southeast.[1] Farther south in the subject area

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[1] Marvine, A. R., The Blue River or Mt. Powell group, U. S. Geol. and Geog. Survey Terr. 7th Ann. Rept., for 1873, pp. 188-189, 1874.

and in the Tenmile and Mosquito Ranges the strike is north to north-northeast[1] and the dips are usually steep. Minor folds and crenulations in the schist and gneiss are very complex.

Structural movements of Laramide time in this general region consisted of folding of varying intensity accompanied by normal and thrust faulting and by minor faulting preceding, accompanying, and following the intrusion of small bodies of quartz monzonite porphyry. Vein formation followed the porphyry intrusions.

The Park Range, like the Front Range, is made up in part of northwest-trending folds. In areas where deformation was less intense the folds are wide and open such as the large fold in the eastern part of the area near Dillon. In areas where the deformation was more intense these folds are steep or overturned asymmetric folds broken by strike faults that have dropped the southwest side.[2] A prominent fault of this type is the Mosquito fault bounding the west side of the Gore, Tenmile, and Mosquito Ranges. This fault can be definitely traced from Gore Canyon near Kremmling to below Leadville, a distance of over 60 miles. An offset portion of this fault runs northwestward from Gore Canyon for about another 25 miles.

The subject area lies immediately north of the northeastward-trending porphyry belt. This belt, which consists of irregularly spaced porphyry stocks, extends from the West Elk Mountains in Gunnison County across the Sawatch, Park, and Front Ranges to

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[1] Longwell, C. R. (and others), Tectonic map of the United States, Am. Assoc. Petroleum Geologists, 1944.

[2] Lovering, T. S., Minturn to Florissant, Introduction; XVI Int. Geol. Congr. Guidebook 19, p. 67, 1933.

Jamestown, slightly northwest of Boulder. A fairly large stock of this belt extends from Breckenridge to Dickey, just southeast of the subject area. Most of the dikes, sills, and mineral deposits are concentrated in a mineral belt, 3 to 12 miles wide, lying just southeast of the zone of stocks. This belt is most pronounced from Leadville across the Front Range to Jamestown.

While persistent northwest faults extend across the mineral belt for long distances to the northwest and southeast, easterly and northeasterly fractures, which include most of the vein fissures, are abundant only in the mineral belt.[1] It is noteworthy that all the veins in the subject area trend easterly or northeasterly similar to those of the mineral belt. However, the line of porphyry stocks, which borders the mineral belt to the northwest, lies immediately southeast of the subject area. The shearing forces responsible for many of the easterly and northeasterly faults of the mineral belt were apparently also active in this immediately adjacent area. The Williams Range thrust fault is only 6 miles east of the easterly and northeasterly veins of the subject area and it is very likely that the strong shearing stresses set up inthe formation of this thrust were active at this distance to the west.

LOCAL STRUCTURE

The chief structural features of the area are shown in figure 1. The principal pre-Cambrian structures are the northward trending fold in the southwest part of the area and the

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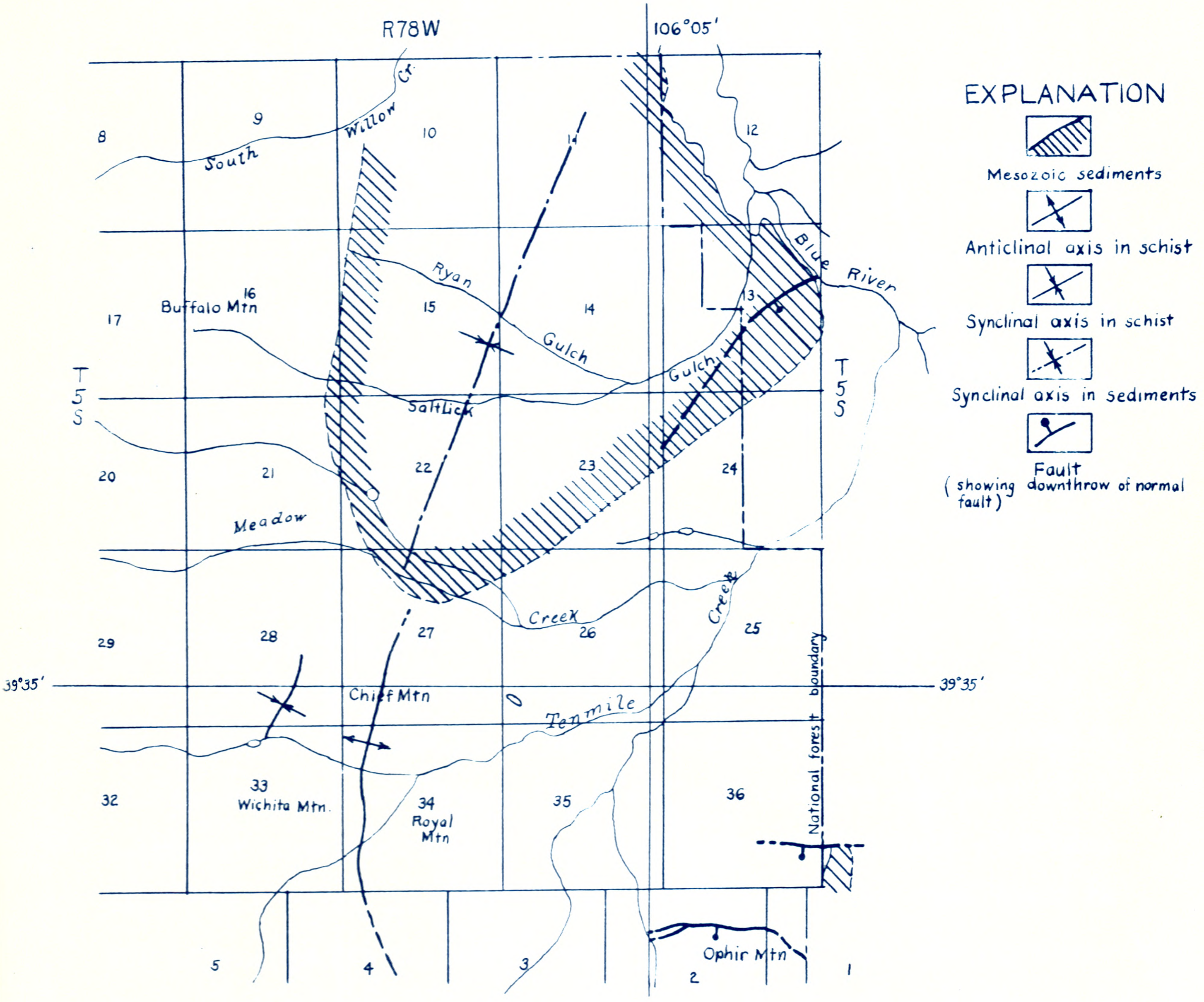
[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 44.



Major structural features of a part of the Dillon quadrangle - Fig. 1.

1 0 1 2 Miles

granitic intrusion at Buffalo Mountain. A large syncline in the Mesozoic sediments lies west of Dillon. In the southeast corner two eastward-trending faults of considerable magnitude are present.

Pre-Cambrian Structure

Much of the pre-Cambrian granite on Buffalo Mountain and the quartz monzonite on Royal, Wichita, and Chief Mountains exhibits flow structure, particularly near the contacts of the igneous rock with schist or gneiss. In the granite the structure is characterized by long streaming schlieren of biotite crystals and tabular crystals of feldspar. The schlieren sometimes exhibit extremely intricate folds which suggest turbulence at the time of intrusion. In the quartz monzonite the flow lines in general parallel the schistosity of the enclosing schists. This suggests intrusion as sill-like masses. However there are numerous contacts which cut across the schistosity of the country rock. The flow lines are generally parallel to these contacts. The direction of flow lines in the granite was not systematically studied/but several observations did not indicate any general lineation of flow structure. Two fairly large inclusions of schist were found in the granite. The parallelism of the flow lines in one of the schist inclusions with the regional schistosity suggests it is a roof pendant in the granite. There are also a very large number of small xenoliths in the granite in various stages of assimilation.

The general structure of the schists and gneisses is shown in the cross section (pl. 3) and the geologic map of the area (pl. 1). The major structure is an anticline located in the southwestern part of the area in the vicinity of Wichita, Royal, and Chief Mountains. The axis of this fold trends north from the east slope of Wichita Mountain to the east slope of Chief Mountain. It trends slightly southeastward where it leaves the subject area on Royal Mountain. The fold is partly terminated by the granite near Meadow Creek. East of the granite it is buried by lateral moraine deposits. Its limbs dip from about 50° to 80°. Superposed on this larger fold are minor folds and many crenulations. On Ophir Mountain the schist and gneiss strike northwest and dip about 30° to 50° NE. The beds here may form the eastern limb of the above-mentioned fold, if the southeast trend of this fold persists from where it leaves the subject area. However, between the beds on Ophir Mountain and those near the crest of the fold is an interval of about a mile and a half in which no schist or hornblende gneiss was observed owing to a large intrusion of quartz monzonite gneiss and a cover of till.

Laramide Structure

Major Syncline. The largest and most prominent Laramide structure is the northward plunging syncline in the northeastern part of the area. (See pl. 1.) This syncline extends from the Blue River westward to the edge of Buffalo Mountain and from the north edge of the area southward to the north edge of Tenmile Creek valley. The only exposed parts of the structure are the outcrops of Mesozoic beds along the west side of State Highway No. 9 north of Dillon. These outcrops are thought to lie on the eastern limb of the syncline. The remainder of the structure is covered by till and by wash from the Gore Range immediately to the west. A considerable amount of Dakota quartzite and some

Morrison sandstone and shale is found throughout all this cover. The quartzite is especially abundant near the edge of the mountains. The Dakota and Morrison probably outcropped at one time along the western edge of this cover so that erosion of the outcrops supplied the float now found in it. The probable location of these beds and the Niobrara, Benton, and Pierre formations under the till and wash are indicated on plate 1. Outcrops of the Dakota formation north of the area and adjacent to the granite tend to support the above hypothesis.

Another structural interpretation of this same area is that the formations continue westward along their strike at the outcrops and are faulted out against the granite. Accordingly the Dakota and Morrison formations should occur in a belt from their present outcrops westward to the vicinity of Meadow Creek. It is more difficult then to explain the abundant float of these formations in the wash farther north towards Ryan Gulch since most of this wash came from the mountains to the west rather than from the south where the only outcrops are postulated.

Faults. A small fault cuts the east limb of the major syncline about half a mile northwest of Dillon. It is probably a normal fault dipping to the southeast. (See pl. 3.) The fault plane itself was not observed.

Two faults are believed present on the north side of Ophir Mountain. (See pl. 1.) Outcrops are rather infrequent and the distribution of the beds usually had to be determined by the float. Neither of the fault planes was seen. Both faults strike nearly east and dip south. Lime-silicate is on the upthrown sides of portions of both faults. The southernmost fault appears to split on the west side of Ophir Mountain.

Nearly all the veins traced in the mines strike northeastward and dip quite steeply to the southeast. They are all located in the vicinity of Chief, Wichita, and Royal Mountains. The fault which the Juneau vein fills strikes nearly east. The north or foot wall may have moved horizontally to the west, but definite evidence is lacking. Such a movement is opposite to that noted in all the known eastward-trending mineralized faults in the west half of the Front Range mineral belt.[1] The movement in the other veins was not ascertained.

see p77

Small porphyry body. A possible third type of Laramide structure is a small intrusive body of quartz monzonite porphyry which is said to be located in the vicinity of the elongate north-south hill just north of Ophir Mountain and southeast of Tenmile Creek. No outcrops were found, and only one piece of porphyry float was found near the top of the hill. The geologic map of Colorado shows a small mass of this rock approximately in this locality. It may be continuous with the large Tertiary intrusion just east of Dickey on State Highway No. 9. This larger intrusion lies in the porphyry belt mentioned elsewhere.

GEOLOGIC HISTORY

In pre-Cambrian time, possibly in the early Algonkian,[2] a thick series of sandy shales and some limy shales were laid down on an unknown basement. Probably during the later stages of the

[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 44.

[2] Lovering, T. S., Geologic history of the Front Range, Colo.: Colorado Sci. Soc. Proc., vol. 12, pp. 73-74, 1929.

deposition of these sediments thick basaltic or andesitic lavas were extruded as surface flows or intruded as great sills into the sediments. Both the sediments and lavas were strongly folded and metamorphosed into schists and gneisses during a long batholithic period which followed. The metamorphosed sediments are now the schists, gneisses, and lime-silicate rocks of the Idaho Springs formation and the metamorphosed lava is now the Swandyke hornblende gneiss.

Probably the earliest rocks intruded in the batholithic period were small masses of quartz monzonite gneiss, granite gneiss, aplite, pegmatite, and possibly some quartz diorite. These rocks were intruded while the sediments and lavas were being crumpled and metamorphosed and the heat and moisture of these intrusives were important factors in the metamorphism of the earlier rocks to schists and gneisses. Some of these early magmas were very fluid and injected the sediments lit-par-lit.

To the east in the Montezuma quadrangle and other parts of the Front Range, a very large granite mass, the Pikes Peak batholith, was intruded after the formation of the above rocks. No equivalents of this granite are believed present in the subject area. After the Pikes Peak granite had solidified another large scale granitic invasion followed. Granites belonging to this epoch, such as the Silver Plume, Cripple Creek, Long's Peak, and Mount Olympus granites, are widespread over the Front Range. The granite of the subject area may belong to this epoch. Its resemblance to the Silver Plume granite of the adjoining Montezuma quadrangle is not striking, but it does resemble the Silver Plume granite much more than the Pikes Peak granite. The last igneous activity of this epoch in the subject area was the intrusion of pegmatites, aplites, and small quartz diorite dikes.

The last epoch of igneous activity was probably accompanied by some uplift. A long period of erosion followed which by Cambrian time had reduced the mountains to a more subdued highland area flanked by low plains. This highland area was on approximately the site of the present Front Range. It apparently remained a highland area throughout the Paleozic as it is doubtful if any of the Paleozoic sediments covered it. It was separated from the similar Uncompahgre highland in southwestern Colorado by the broad central Colorado basin.

The subject area was located on the western edge of the old highland as Paleozoic sediments occur in the near vicinity. No sediments of this era are exposed in the subject area, although it is possible Pennsylvanian or Permian beds (Maroon formation) underlie the Morrison here. The Maroon formation is exposed outside the subject area 1 to 2 miles east of Dillon and along the Blue River towards Breckenridge.

The Cambrian, Ordovician, Devonian, and Mississippian sediments of adjacent regions to the west and south do not indicate the presence of a nearby mountainous area. The Front Range highland which furnished part of these sediments was low during these periods. However the thick continental clastics and thick marine deltaic deposits of Pennsylvanian and Permian age indicate a considerable uplift of the adjacent highland. Since the subject area was so very close to the areas of deposition it probably was not as high during this time as were the interior parts of the Front Range highland.

No Triassic or lower Jurassic sediments are known in the subject area or in adjacent regions. There was apparently little erosion or deposition in these periods. In the late Jurassic the fresh water sediments of the Morrison formation were deposited. This formation elsewhere contains fossils of swamp-living reptiles, remains of sub-tropical vegetation, and fresh-water shells. The scanty exposures in the subject area do not indicate whether the formation is continental or marine in origin. The land surface over which these beds were deposited was low, but probably not so low as on the northwest side of the Front Range where the Morrison widely overlaps the pre-Cambrian. No lower Cretaceous beds are known in the subject area.

The widespread Upper Cretaceous sea slowly spread over probably the entire Front Range and deposited the Dakota sands as the basal member. The central part of the highland was slow to subside and received the thinnest deposit. The subject area was located on the lower western edge of the highland as the Dakota is much thicker here than to the east. The subsidence of the subject area and the highland continued throughout Benton and Niobrara time and was greatest in Pierre time. Over 5,000 feet of Pierre sediments were deposited slightly east of the area. In Benton and Niobrara time the sea was very broad and land masses remote as the deposits of this age are shales, limy shales, and limestone.

The history of the area from Pierre time to the Pleistocene mu~~ch~~st largely be inferred from information outside the area. The only evidences of geologic activity from Pierre time to the Pleistocene are the folds and faults of the Mesozoic beds and the remnants of two Tertiary erosion surfaces.

From about the end of Pierre time, through the Laramie and Denver epochs, the Front Range and undoubtedly the nearby Gore Range were intermittently being elevated. The orogeny was a gentle arching in Laramie time and a violent uplift in Denver time. In the Front Range it is thought that by Wasatch time[1] the rejuvenated streams had cut into the pre-Cambrian core and carved the imperfectly developed Flattop peneplain. In the Gore Range this surface is probably represented by the Gore Range surface, a remnant of which is thought to occur in the subject area. A second peneplain, the Medicine Bow peneplain which was formed in parts of the Front Range by the end of the Eocene as a result of renewed uplift, is not believed present in the subject area or in the Gore Range as a whole. In the Miocene another uplift occurred which again resulted in renewed erosion and in the cutting of the Rocky Mountain peneplain on the Front Range and its probable equivalent, the Sheephorn surface, on the Gore Range. Remnants of the Sheephorn surface are believed present in the subject area. The Rocky Mountain peneplain and probably the Sheephorn surface continued to develop in the lower and middle Pliocene but probably not in the upper Pliocene when a period of aridity occurred.

In the Pleistocene a regional uplift again raised the Front and Gore Ranges and initiated a cycle of erosion which is continuing at present. At least two major stages of glaciation occurred and it is considered by some that an intermediate, less-extensive glaciation occurred between them. After the first

[1] Lovering, T. S., op. cit, (Prof. Paper 178), p. 51.

glaciation a considerable amount of erosion took place and some of the older glacial features were left high above the valley floors carved just before and during the second glaciation. The last glaciers disappeared in quite recent geologic time and only slight erosion or deposition has since occurred.

ECONOMIC GEOLOGY

MINERALOGY

Minerals of the Ore Deposits

Ankerite, (Ca,Mg, Fe) CO_3. Ankerite is found in abundance only in the galena-sphalerite vein of the Juneau mine, but it is also present in very small amounts in the Ohio mine. Some of it contains manganese and weathers to black wad at the surface. Calcium, magnesium, iron, and manganese carbonates form an isomorphous series, the most common members of which in this area are ankerite and an impure siderite. Relatively pure siderite is also present. Ankerite is usually rather dark brown and shows the usual excellent rhombic cleavage. Where observed, it was later than all the sulphides and cuts them as small veinlets and as veins up to about 6 inches in width. Ankerite is cut in turn by a late generation of quartz.

Bornite, Cu_5FeS_4. A very small amount of bornite was noted in the galena-sphalerite vein of the Juneau mine. It is associated with galena, sphalerite, chalcopyrite, and pyrite in a gangue of quartz and ankerite. A polished section showed a few blebs of bornite in galena, but an insufficient quantity was present to determine the paragenesis.

Braunite, $4\ MnO.3MnO_2.SiO_2$. Braunite is found in the Lucky Star, Ohio and Juneau mines in the oxidized portions of the veins. It is intimately intergrown in places with goethite. Usually limonite, goethite, wad, and cerusite are associated with it. It frequently fills small cracks and fissures in the veins and pits or cavities where the relatively soluble minerals were dissolved. It occurs not only at the actual exposed parts of the veins and at the surface like typical wad but also well within the veins, though still within the oxidized zone. Braunite is derived principally from the oxidation of ankerite.

Brown iron oxides. These minerals include turgite, $2Fe_2O_3.H_2O$; goethite, $Fe_2O_3.H_2O$; and limonite, $2Fe_2O_3.\ 3H_2O$. Limonite in particular is widely abundant in the oxidized portions of the veins and turgite and goethite are rather common. Turgite imparts a reddish cast to the oxidized parts of the veins, and limonite a yellowish cast. Reddish goethite occasionally occurs in a hard, dense intergrowth with very dark brown to black braunite.

Cerusite, $PbCO_3$. Cerusite, the "sand carbonate" of the miners, is very abundant in the Lucky Star mine, particularly in the raises near the end of the mine. It also occurs in moderate amounts in the Ohio mine and Emore's mine on lower Chief Mountain and in small amounts in the Juneau mine. In all the mines it occurs at less than an estimated 300 feet below the surface. Cerusite is the common oxidation product of galena and is very much more abundant than anglesite, the "dry bone" of the miners. Cerusite frequently appears to have altered directly from galena without passing through the intervening anglesite stage. However this reaction is quite unlikely. Probably the anglesite stage occurred, but nearly all of it was converted to the carbonate. Cerusite occurs generally as small crystals resembling sand grains, hence the local name. Some of the crystals are well formed and range from 1 to 2 millimeters in length.

Chalcocite, Cu_2S. Chalcocite occurs in very minor, usually microscopic, amounts in the veins of four of the five mines examined. It was everywhere found within 300 feet of the surface. Veinlets of chalcocite border grains of galena and replace it along its cleavage. Some veinlets also cut haphazardly into or across grains of galena. All the chalcocite observed is supergene. A typical occurrence of chalcocite with galena is shown in figure 2.

Chalcopyrite, $CuFeS_2$. Chalcopyrite is the most abundant copper mineral in the veins of the subject area. Minor amounts occur in all the mines, and it is found in moderate amounts in the Juneau mine. It is usually associated with quartz, ankerite, and pyrite in open, rather vuggy veins. It is younger than at least some pyrite as this mineral is cut in places by veins of chalcopyrite. Small blebs of chalcopyrite occur in a little of the sphalerite. This relation suggests that at least part of the sphalerite is contemporaneous with chalcopyrite. On the whole, chalcopyrite was found so infrequently in contact with the other sulphides except pyrite that its relations with them are not clear. No gold was associated with it. All the chalcopyrite seen was massive in form and did not exhibit crystal faces. Most of it was rather coarse-grained.

Covellite, CuS. Covellite, like chalcocite, occurs in very

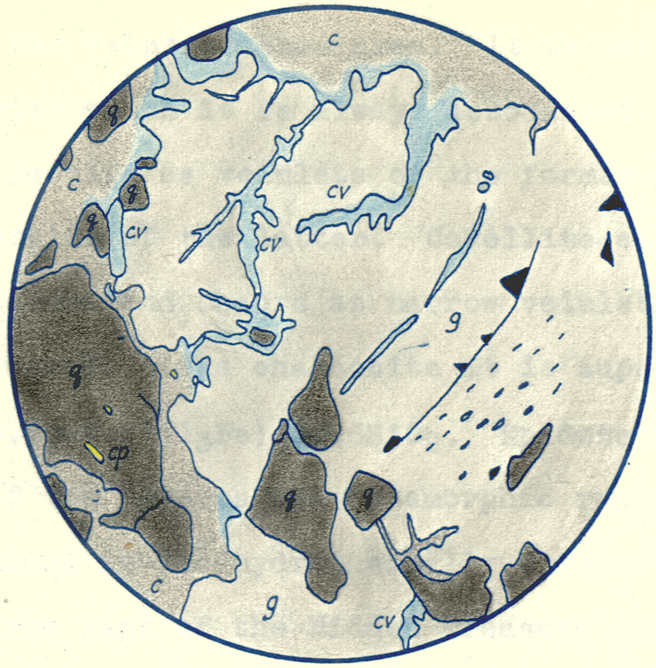


FIG. 2 –SKETCH OF ORE FROM MAIN LEVEL OHIO MINE....
SHOWING COMMON RELATIONS OF GALENA(g) CHALCOCITE(c) AND COVELLITE(cv). QUARTZ(q) CHALCOPYRITE(cp) (ABOUT 9X).

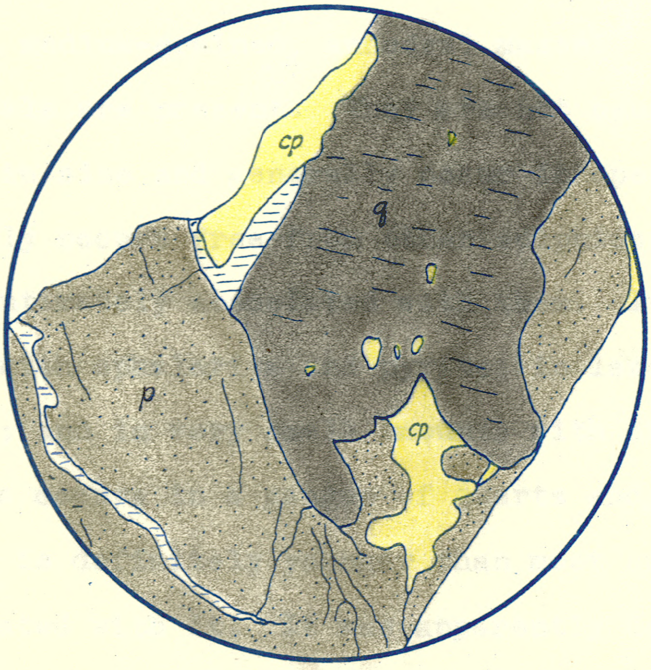


FIG. 3 –SKETCH OF ORE NEAR BREAST OF JUNEAU MINE...
SHOWING CHALCOPYRITE(cp) REPLACING PYRITE(p). QUARTZ(q) (ABOUT 16 X).

small amounts in the veins of this area. It is less widespread than chalcocite with which it is always associated. Covellite is later than chalcocite as veinlets of the former cut and border veinlets or grains of the latter. Covellite also follows the cleavage of galena and occurs as narrow veinlets bordering grains of this mineral. Like chalcocite it is supergene.

Epidote, $H_2O.4CaO.3(Al_3Fe)_2O_3.6SiO_2$. Epidote is a common mineral in many of the igneous and metamorphic rocks of the area. It is fairly abundant in the hydrothermally altered granite gneiss wall rock in a large part of the Hidden Treasure mine. It occurs here in the usual fine-grained aggregates after hornblende and biotite and in veinlets which cut across the wall rock.

Galena, PbS. Galena is the most abundant ore mineral in the area and is present in at least small amounts in every mine. It is especially abundant in the Lucky Star and Ohio mines. It usually occurs in medium-grained, anhedral masses, but in a few places good crystals are present. They are not usually over a centimeter or so in size and generally occur in open, vuggy ore. Galena occasionally occurs free from other sulphides, but it is very frequently intimately associated with them. It is associated principally with sphalerite and pyrite; in lesser amounts with chalcopyrite; and in very small amounts with chalcocite and covellite. Galena occurs in a gangue of quartz and/or ankerite and siderite. It is definitely younger than most quartz and all the pyrite associated with it. It was apparently deposited simultaneously with some sphalerite but definitely cuts and is younger than part of it. Galena seems to be later than chalcopyrite but the relations of these minerals are not clear as they were seldom seen in conjunction. Chalcocite and covellite replace galena along its cleavage and around the borders of grains. In the oxidized zone galena is found altering in many places to cerusite in sandy masses. Galena was noted altering to anglesite in a piece of ore picked up from the dump of the Lucky Star mine, but this alteration was not noted in the mine itself.

In spite of the common association of silver with galena elsewhere, no galena tested showed any silver content, nor were any silver minerals recognized in intergrowths with it.

Garnet, $3R'O.R''_2O_3.3SiO_2$ (when R'=Ca,Mg,Fe,Mn; R"=Al,Fe(Mn),Cr,Ti). A dark, somewhat reddish-brown garnet, believed to be spessartite, occurs in pegmatite at the breast of the main adit of the Lucky Star mine. It is associated principally with microcline and quartz. Reddish garnets are common in the schists of the Idaho Springs formation which in places is the wall rock of the veins.

Goethite, $Fe_2O_3.H_2O$. See Brown iron oxides.

Hematite, Fe_2O_3. Hematite occurs as minute inclusions in fine-grained quartz gangue of the galena veins on the upper level of the Lucky Star mine. Small adhesions of mica, probably sericite, are intergrown with the hematite-bearing quartz. This vein is open and vuggy with some medium-sized quartz crystals lining the openings. Hematite, however, is confined to the more common fine-grained quartz.

Kaolin, $2H_2O.Al_2O_3.2SiO_2$, *and the clay minerals*. Kaolin and the other clay minerals are uncommon gangue minerals in the veins of the area. Theyare very common, however, in the altered wall rocks in the oxidized zone in which practically all parts of the mines are located except a part of the Hidden Treasure mine. Kaolin or other clay minerals have formed in unusual abundance on the feldspars of many of the pegmatites. In the Lucky Star mine the formation of clay minerals from pegmatite has proceeded to such an extent that the rock is very soft and friable. Clay minerals are present in gouge zones where thicknesses of the clay as much as 2 inches have been seen. The clay minerals appear to be almost entirely supergene. This is indicated by their position at and near the surface, their filling of crevices and openings in the veins and fault zones, and their close association with cerusite and limonite. The latter are also secondary products formed through the action of descending surface waters. The clay minerals are nearly everywhere stained yellowish- or reddish-brown by iron oxides.

Limonite, $2Fe_2O_3.3H_2O$. See Brown iron oxides.

Magnetite, Fe_3O_4. Magnetite is a common accessory mineral in all the intrusives and in the Idaho Springs formation. Though widespread in many rocks, it is nowhere very abundant.

Malachite(?), $CuCO_3.Cu(OH)_2$. Green stains, suggestive of malachite, appear in the oxidized parts of several copper-bearing veins. This material was not observed anywhere in enough quantity to identify it definitely as malachite.

Plumbojarosite, $PbO.3Fe_2O_3.4SO_3.6H_2O$. Plumbojarosite was noted as a light brown, very thin coating with a faint sheen on the quartz gangue of the vein in the upper level of the Lucky Star mine. It was also deposited in part on limonite. Its composition and occurrence indicate its secondary origin.

Pyrite, FeS_2. Next to galena, pyrite is the most abundant sulphide in the area. It occurs in at least small amounts in nearly all the veins, but is present in the wall rock in appreciable amounts only in the Hidden Treasure mine. While it occurs in practically all the veins, it is not uniformly distributed as the veins in the Lucky Star and Ohio mines are nearly free of it. In part of the Juneau vein, however, pyrite and quartz are the only significant constituents. Pyrite often occurs as the typical cubic crystals but also in many places in anhedral masses. All the pyrite noted is earlier than all the other sulphides as the latter fill cracks in pyrite or embay or corrode it. It appears to have been deposited simultaneously with some of the quartz but is definitely older than much quartz. All the observed pyrite is primary since it is older than all the primary sulphides. No gold was seen associated with pyrite.

While most of the pyrite probably was derived from iron and sulphur carried in the metallizing fluid, some of the pyrite in the wall rock - especially the granite gneiss wall rock of the Hidden Treasure mine - may have derived its iron from the magnetite or ferro-magnesian minerals originally present therein.

Pyrolusite, MnO_2. See Wad.

Quartz, SiO_2. Quartz is by far the most abundant gangue mineral of the veins and is generally found in at least small amounts throughout all of them. It has also been introduced in rather large amounts into the wall rocks. Nearly all the quartz is medium- to coarse-grained. Coarse-grained, white "bull" quartz is found in a few places. Most of the quartz consists of anhedral, interlocked grains or grains with only slightly developed crystal faces. However, in some of the open parts of the veins, well-developed crystals as long as 1.5 centimeters line the vugs and cavities. Nearly all the quartz shows some small solid and fluid inclusions, but the abundance of the inclusions varies considerably in different veins. Some quartz contains minute red hematite inclusions. Quartz was introduced in the veins in at least two and probably three generations. The early quartz was one of the first minerals and was deposited with and overlapped the deposition of pyrite. Some later quartz was probabaly deposited contemporaneously with chalcopyrite. A late generation cuts the ankerite-siderite gangue which followed the deposition of the sulphides. This quartz is medium-grained, contains inclusions, and does not appear to be supergene.

<u>Sericite</u>, $KH_2Al_3(SiO_4)_3$. Sericite is abundant in the wall rocks of most of the veins. In places minute shreds of sericite are intergrown with quartz. Some gouge zones contain sericite where it possibly resulted from the brecciation of sericitized country rock or from sericitization of the clay in the gouge. Abundant sericite has usually been formed in or near the veins, but small amounts are present at considerable distances from the veins. Nearly all the igneous and metamorphic rocks of the subject area contain a little sericite. It was formed about the same time as early quartz and pyrite.

<u>Siderite</u>, $FeCO_3$. Siderite is moderately abundant only in the galena-sphalerite vein of the Juneau mine, but a very small amount is present in the Hidden Treasure mine. It is not as abundant as ankerite into which it grades and with which it is closely associated. It is light brown and, like ankerite, later than all

the sulphides which it cuts as veinlets and small veins. Some siderite has replaced the wall rock near the veins.

Sphalerite, ZnS. Sphalerite is fairly common in the veins of the area. It is found in all the mines except the Lucky Star in at least small amounts. In the Juneau mine it is nearly as abundant as galena. It occurs as fine- to medium-grained masses intergrown with galena and pyrite. No sphalerite exhibited crystal faces, but instead everywhere consisted of anhedral grains. It is all dark-colored.

Sphalerite is younger than pyrite and quartz, both of which it cuts as veinlets and embays. In one place it occurs with galena in a fine intergrowth suggesting simultaneous deposition. Galena definitely overlaps sphalerite, however, as veinlets of galena cut sphalerite. Blebs of chalcopyrite in sphalerite suggest simultaneous deposition. No other relation of these two minerals was observed. Sphalerite, like the other hypogene sulphides, is younger than the ankeritic gangue in which it occurs in places. No gold was found associated with sphalerite as has been observed in the neighboring Montezuma quadrangle.[1]

Turgite, $2Fe_2O_3 \cdot H_2O$. See Brown iron oxides.

Wad, (chiefly manganese oxides). Wad is present on the outcrops and in the oxidized zones of several of the veins. It occurs as a black sooty coating on the exposed parts of the veins; as thin, rather hard crusts; and as small boxwork structures on the veins. It consists of an indefinite mixture of oxides of manganese, including pyrolusite. Manganese, probably as the oxide, occurs in

[1] Lovering, T. S., op. cit., (Prof. Paper 178), p. 57.

some goethite and braunite in the Lucky Star mine. The oxides are usually derived from the oxidation of ankerite and manganiferous siderite gangue.

Paragenesis

The close similarity in mineral composition and in occurrence indicates that the ores of all the deposits discussed were formed at approximately the same time. The minerals of the veins, however, show a fairly definite sequence of formation, although the entire sequence is not displayed in any single deposit.

The earliest minerals are sericite, quartz, and pyrite. Sericite and quartz are abundant in the wall rock adjacent to the veins and have partly replaced the wall rock in places. Very little pyrite is disseminated in the wall rock. Pyrite and quartz are very abundant as fissure fillings. Sericite and some quartz appear to be contemporaneous. Polished sections show that some quartz is simultaneous with pyrite and some is later. After the deposition of quartz and pyrite, a period of brecciation and faulting occurred. These two minerals are frequently broken and recemented by later minerals.

Apparently the first mineral to be deposited following the brecciation was chalcopyrite, although small amounts of it occurring as minute specks in broken quartz may have preceded the brecciation. Chalcopyrite is not abundant and its relations with other minerals are not clear. It was probably deposited simultaneously with some sphalerite, but much of the latter probably overlapped it. Sphalerite is the first ore mineral which widely recemented the brecciated quartz and pyrite. Galena was deposited simultaneously with part of the sphalerite but definitely overlaps it. Bornite occurs as a few small blebs in galena, but an insufficient amount is present to determine the age relationship. Faulting and some brecciation occurred locally after the deposition of the above ore minerals.

After the deposition of the ore minerals, ankerite and siderite gangue was deposited. This material in places is the only constituent of veins 6 to 8 inches wide which filled fault fissures. A late generation of quartz cuts the ankerite gangue. The deposition of this quartz appears to have ended the primary metallization in this area. When the primary deposits were subjected to secondary enrichment processes, chalcocite and covellite developed on galena. Covellite is later than chalcocite as covellite occurs in chalcocite as small veinlets and around its borders.

Summarized, the order of deposition of the minerals is approximately as follows: (1)sericite, quartz, pyrite; (2)chalcopyrite; (3)sphalerite; (4)galena, bornite(?); (5)ankerite, siderite; (6)quartz; (7)chalcocite; (8)covellite.

opened
only exposed ?
present

ORE DEPOSITS

Veins are the only type of ore deposit found in the subject area. Lead-zinc veins are the only abundant type of veins and all are fissure fillings. Most of the veins are^ near the surface within the zone of enrichment, but most of the ore that has been worked in recent times is primary ore. While there is no direct evidence in the subject area itself bearing on the age of the veins, it is probable that they are early Eocene similar to the veins of the nearby Montezuma[1] and Breckenridge[2] quadrangles. The relation of the veins to the mineral belt of the Front Range and

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), pp. 50-51, 59.

[2] Lovering, T. S., op. cit. (Prof. Paper 176), p. 22.

adjacent regions to the west is briefly considered on pages 47-48.

Types and distribution of veins. The location of the veins in the subject area is shown on plate 1. Most of the veins strike northeast to east-northeast and dip fairly steeply to the southeast. However, a few dip to the northwest. Some also strike north-northeast and dip to the southeast. Two veins trend approximately east-west. The three most productive veins strike from east-northeast to approximately east. Two of them dip steeply to the southeast and one steeply to the northwest.

Lead-zinc veins are the most abundant type of veins. These carry galena, sphalerite, pyrite, and small amounts of copper minerals. On Chief Mountain the gangue of these veins is almost entirely quartz with very minor ankerite, while on Royal Mountain the gangue consists of quartz, siderite, and ankerite. The veins in the Lucky Star mine on Chief Mountain carry galena but not sphalerite. According to Mr. L. J. Emore who operates the Lucky Star mine, the smelter sheets for some ores obtained on Chief Mountain show lead, gold, silver, and copper. Gold and silver presumably occur in minor amounts as the writer detected none in the samples examined.

Centers of mineralization. Since the area in which the veins occur is immediately adjacent to the mineral belt and since the type of veins is the same as some of those nearby in the mineral belt, the Tertiary porphyries responsible for the veins of the mineral belt are very likely the sources of the veins of the subject area. The nearest definitely known porphyry stock which could be the center of mineralization lies immediately east of Dickey, 3½ to 4 miles east of the veins of the subject area. A

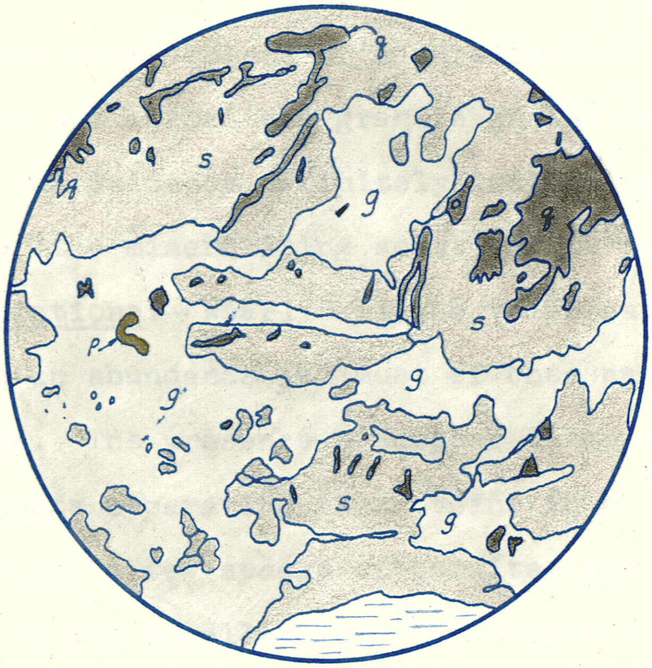

FIG. 4—SKETCH OF LEAD-ZINC ORE FROM JUNEAU MINE 270 FEET FROM PORTAL....SHOWING GALENA(g) REPLACING SPHALERITE(s) AND PYRITE(p). QUARTZ(q)(ABOUT 7X).

small body of porphyry may be concealed by till in the prominent hill a mile south of Dillon, but the existence of this body is questionable. (See p. 52.)

It is very unlikely that the pre-Cambrian igneous rocks of the subject area - the granite of Buffalo Mountain and the quartz monzonite gneisses - were the sources of the emanations which gave rise to the veins. Rocks of this age are not known in this general area to have been centers of mineralization. The veins of the subject area cut across the granite gneiss and quartz monzonite gneiss, but evidence definitely indicating these rocks were the sources of the mineralizing solutions is lacking.

<u>Mineral associations</u>. Nearly all the veins carry galena, pyrite, and quartz in abundance and most of them carry fairly abundant sphalerite. The presence of copper in minor amounts in some veins suggests separating these veins in a group by themselves. Chalcopyrite, a few specks of bornite, and a little secondary chalcocite and covellite are the copper minerals. Gray copper, a fairly abundant minor constituent in the nearby Montezuma district, appears to be absent here. Chalcopyrite is most abundant in the galena-sphalerite veins with a gangue of quartz, siderite, and ankerite; but a few specks of chalcopyrite are present in nearly all the veins. It is as abundant as galena, sphalerite, and pyrite in the poorly mineralized veins of the Hidden Tresure mine in Royal Mountain. A few blebs of bornite are associated with chalcopyrite in the galena-sphalerite veins of the Juneau mine on Royal Mountain.

<u>Relations of ore to depth</u>. The small number of mines visited and the fact that only two mines are worked on more than one level make generalizations about the relations of ore to depth difficult

for this area. Sphalerite increases somewhat with depth and pyrite is considerably more abundant with depth. Galena is about as abundant in the Juneau mine at 9,250 feet as it is in the Ohio and Lucky Star mines at approximately 10,500 feet. Chalcopyrite is present in small amounts at both of the higher mines but is somewhat more abundant in the lower Juneau mine. Ankerite and siderite are markedly more plentiful in the lower veins. This change with depth is the most conspicuous one. The quantity of bornite found is too small to determine its relationship with depth.

Enrichment. According to Lindgren and Ransome, "the best geological evidence of enrichment consists in the progressive, uniform impoverishment of all similar deposits in a given district, coupled with the condition that the change in ore should be dependent upon postmineral topographic development." As no single deposit in the subject area is worked to sufficient depth to show a downward impoverishment with respect to any particular ore mineral, it follows that actual enrichment of any of the deposits can not be definitely proven.

Four lines of evidence suggest, however, that residual enrichment of lead in the area has occurred through the solution and removal of the more soluble ore minerals in the higher parts of the veins and the retention of the more insoluble lead compounds.

First, galena and cerusite are the only significant ore minerals in two of the mines - the Lucky Star and Ohio mines - even though a small amount of sphalerite occurs in the Ohio mine. Neither of these mines penetrates more than about 300 feet below the surface. In the remaining mines galena, sphalerite, and pyrite occur on the whole in more nearly equal proportions. The predominance of lead minerals in the Lucky Star and Ohio mines suggests the deposits in these two mines at least have been enriched in lead by the removal of the other ore minerals.

Second, the ores in the above two mines are conspicuously open-textured, which suggests pyrite and sphalerite have been leached out.

Third, no evidence of secondary galena was found in a paragenetic study of the ore. However it must be noted that the criteria for the distinction of supergene ores from hypogene ores are not entirely agreed upon. The absence of secondary galena fits in with the theory that lead has been residually enriched.

Fourth, in the adjacent Breckenridge and Montezuma districts the richest lead ore is found in a zone probably not over 350 feet below the surface and is thought to have been residually enriched through the removal of the more soluble pyrite and sphalerite. As these districts are so near to the subject area, it is thought that the conditions causing residual enrichment there may also have operated in this area.

For a thorough discussion regarding the mechanism whereby sphalerite and pyrite are leached and lead residually enriched, the reader is referred to Lovering's paper on the Breckenridge district.[1] The solvents of the ore minerals, the leaching of the veins, and the probable reactions are there considered in detail.

Dimensions of ore shoots. The ore shoots in the mines examined are all small. The largest, located in the Lucky Star mine,

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[1] Lovering, T. S., op. cit. (Prof. Paper 176), pp. 28-32.

is only about 25 feet in strike length and about 60 feet in vertical extent. The ore shoot of the Juneau mine is 50 feet long and about 15 feet in vertical extent. The remaining shoots in the mines are smaller than the above. Several small ore shoots occur in the largest vein of the Hidden Treasure mine on Royal Mountain.

Vertical range of ore deposition. Although the greatest known vertical extent in a single shoot is only 60 feet, the range of deposition is much greater. Galena-sphalerite ore is found in the Juneau and Hidden Treasure mines at 9,250 feet and in the Ohio mine at 10,600 feet, a vertical range of 1,250 feet. Ore has been reported on Red Peak, a mile and a half northwest of the subject area, at about 12,000 feet which would give a vertical range of approximately 2,700 feet. This range is similar to that in the Montezuma quadrangle and near Silver Plume, east of that quadrangle.[1] Nearly all the veins extend up to the surface and were discovered from their outcrops.

The vertical range is probably rarely over 2,500 feet since the relief from valley bottoms to the ridges is about 2,000 feet and the largest ore shoots ever likely to occur would probably not be over 500 feet deep. This depth of ore shoots is generally a maximum in the adjoining mining areas.

Localization of ore. Since the ores of the veins are fissure fillings, those factors controlling the width and openness of the fissures also principally control the localization of the ore. As the ore solutions rose from the magma towards the surface, they

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[1] Lovering, T. S., op. cit. (Prof. Paper 178), p. 63.

took the easiest route, hence the wider, open-spaced fissures served as the easiest passages and received the greatest amounts of ore solutions. Two factors which contributed most to the formation of open fissures in this area are the physical character of the wall rock and the irregularities in the fissures such as branches and changes in strike and dip.

Hard, brittle rocks, such as pegmatite and gneiss, generally are the common wall rocks of the ore shoots, while softer, plastic rocks, such as schists, do not usually form the walls. The wall rocks of the richer parts of the veins in the subject area are usually pegmatite and, to a lesser extent, hornblende gneiss.

Localization of ore may occur at the intersection of two veins. The intersection of the two original fractures or faults is more open than either fracture or fault a short distance from the intersection, hence a greater amount of ore would be deposited there. The intersection of two veins in the Lucky Star mine has caused a localization of ore.

A second irregularity in the veins which may cause localization of ore is an abrupt change in the dip and strike of the veins. Localization in such veins may sometimes be traced to open spaces caused by movement of the irregular walls of the pre-vein fractures. For example, if the north wall of an east-west trending vein has a strong horizontal component of motion to the west, the vein should tighten where it deviates northwest and should widen where it deviates southwest. This situation may prevail in the Juneau mine and may have caused the localization of the ore near the breast of the mine.

A third irregularity in the veins which may cause localization of ore is the change in width occurring in some places as the veins pass from one kind of rock into another. The faults in strong rocks are generally well-defined, but may narrow as they pass into weaker rocks. In the Lucky Star mine the veins usually widen slightly in passing from hornblende schist and gneiss into pegmatite. It is noteworthy that the wall rocks of all the richer parts of the veins in this mine are pegmatite.

THE MINES

HIDDEN TREASURE

The Hidden Treasure mine is located about half a mile southwest of Frisco on the northeast side of Royal Mountain at an altitude of approximately 9,250 feet. It is accessible by an auto road from Frisco. It was not in operation when visited in 1940. It was locally reported to have been intermittently operated for a few years previous to that date, though not at a profit. Several thousand dollars worth of gold were said to have been taken out a number of years ago. With the exception of the Excelsior mine in Wichita Mountain this is the largest mine in the area.

The mine was worked principally along a single adit about 1,125 feet long. Four short crosscuts, none of which are over 45 feet long, are turned from it. (See pl. 4.)

Three veins or sets of veins were encountered in the mine. They all strike from N. 48° E. to N. 80° E. and dip from 58° to 86° SE. They are all part of one large vein system because of the similar strike and dip and mineralogy, but are considered separately as encountered in the mine.

The first vein begins at the portal and pinches out about 85 feet farther. Its average strike is N. 60° E. and its dip is consistently 50°-52° SE. It is at most 4 inches wide and contains a few fine stringers of chalcopyrite and pyrite with a quartz gangue.

The second set of veins is encountered 200 feet from the portal and turns into the hanging wall 200 feet farther to the southwest. These veins have an average strile of N. 70° E. and an average dip of 50° SE. This set where first encountered consists of three closely spaced veins 2 to 3 inches thick which are fillings of a pre-mineral fault zone. The veins in this zone carry the only ore in the set of veins. The ore consists of a few fine stringers of galena and chalcopyrite in a gangue of quartz and a little carbonate. The ore persists only about 30 feet along the strike. The remaining parts of the veins are barren and finally become almost indistinguishable from the pegmatite veins whith which they occur.

The third set of veins extends from the first crosscut to the breast of the mine. The strike varies from N. 48° E. to N. 70° E. and the dip from 50° to 84° SE. The dip is steeper towards the breast of the mine. The width of the veins varies from a knife edge to one foot. Only two occurrences of ore were noted: the first about 100 feet from the first crosscut, and the second about 225 feet from the breast. The first occurrence of ore is in a small vein about 2 inches wide parallel to the longer main vein. A little chalcopyrite, sphalerite, galena, and pyrite are present in a quartz and carbonate gangue. The second occurrence of ore is an inconsequential amount of chalcopyrite and pyrite in a vein one foot wide. Five small stopes were made on this set of veins in this part of the mine, but all were inaccessible. The vein material noted in the ore chutes in the stopes was barren. The veins of this set grade into a conspicuous greenish chloritized and sericitized alteration zone of the granite gneiss wall rock, and nearest the portal only the alteration zone is present.

An indication of a fourth vein is encountered in the first and second crosscuts which are located about 425 feet and 605 feet respectively from the portal. This vein is here indicated only by a very prominent greenish chloritic and sericitic zone of alteration about 3 feet wide similar to the zone associated with the third set of veins. The zone strikes N. 60° E. and dips from 60° SE. to vertical. It is inferred that these two separated exposures are part of the same zone because of the similar strikes, dips, and lithology. It is probable that a single vein exists somewhat deeper than these exposures and has divided higher up into a number of minute veinlets which have caused the alteration but which have not deposited ore.

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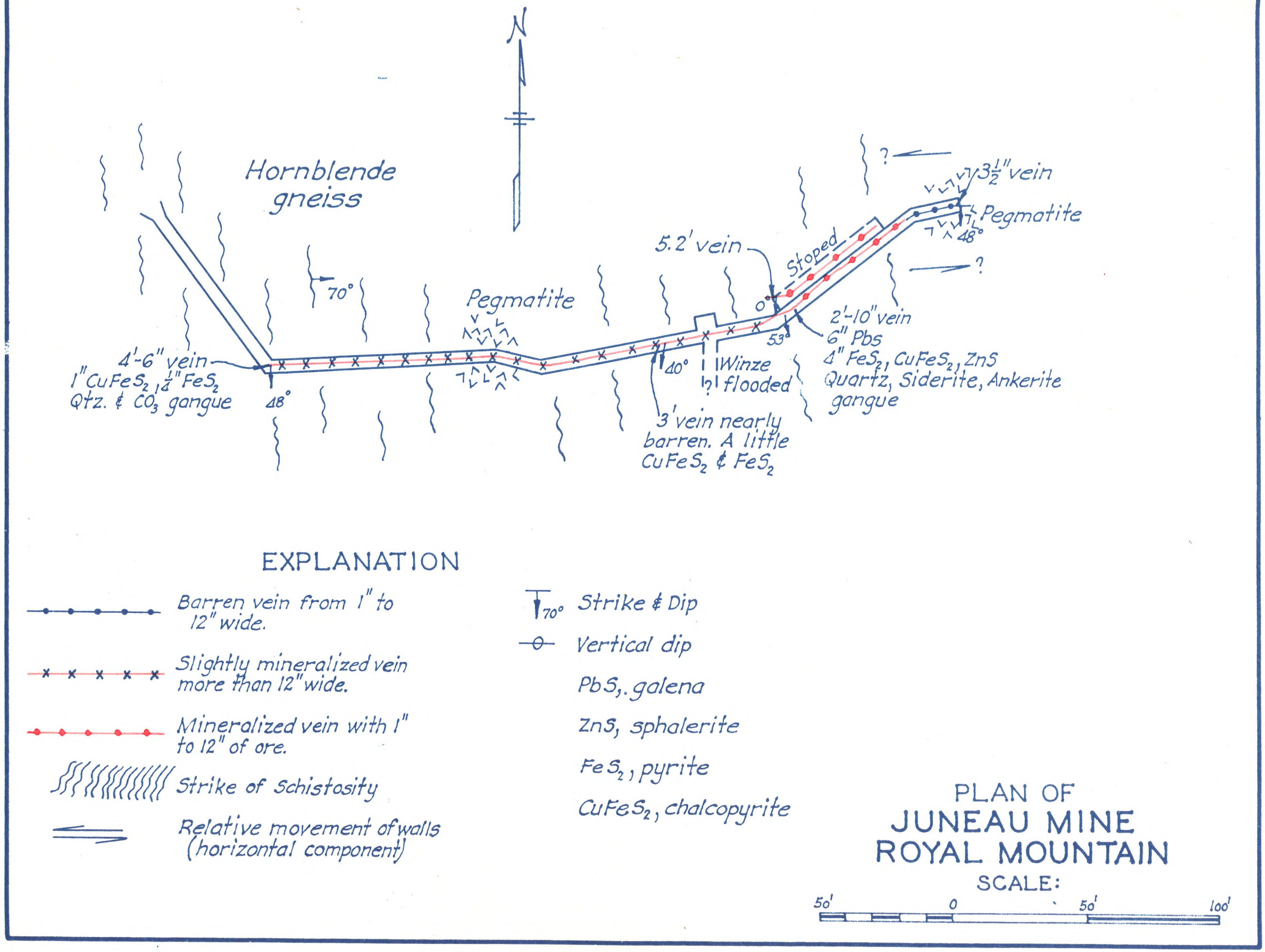
Tops or roots

The country rock is almost entirely granite gneiss striking from N. 9° W. to N. 25° E. and dipping nearly vertically. A small amount of pegmatite is associated with the second set of veins.

JUNEAU

The Juneau mine is located on the northwest side of Royal Mountain at an altitude of about 9,250 feet. It lies about 100 feet above Tenmile Creek. It is approximately 300 feet southeast of the old Colorado and Southern narrow gauge railroad which ran

PLATE 5



PLAN OF
JUNEAU MINE
ROYAL MOUNTAIN
SCALE:

from Leadville to Breckenridge. Very little could be learned of the history or production of this mine. It is now abandoned.

The country rock is principally hornblende gneiss striking approximately N. 5° W. and dipping 70° ~~N~~E. Two small bodies of pegmatite were also encountered in the mine.

The mine is worked by one adit about 350 feet long.

The single vein of the mine is encountered 70 feet from the portal. It strikes approximately east except for a bend to the northeast near the breast and dips from 40° to 53° S. (See pl. 5.) It varies in thickness from 2 feet 10 inches to 5 feet 2 inches. However the vein is but slightly mineralized except at the bend where it is stoped 50 feet along the strike and about 15 feet up dip. Here the vein is 2 feet 10 inches wide with about 10 inches of ore. The ore consists principally of galena and sphalerite with considerable amounts of pyrite and chalcopyrite. The gangue is composed of quartz, siderite, and ankerite. The vein is roughly banded, sulphides and quartz alternating with bands of siderite and ankerite. About 10 feet above the adit the vein splits and at the junction the two veins total 5 feet 2 inches. The lower vein is horizontal and the upper vein dips 53° south. The ore begins to pinch out above the junction and stoping was continued only a few feet beyond it. The vein is barren at the breast where the east strike is resumed.

The localization of the ore at the northeast bend may be due to the westward movement of the foot (north) wall of the vein. This would cause widening of the vein fissure at the bend where it deviates northeast and would have permitted a greater deposition of the ore at this place. Definite evidence of this movement was not observed. Such a movement would be at variance to that noted in all the known eastward-trending mineralized faults in the west half of the Front Range mineral belt.[1] Localization may also be due to the splitting of the vein at the bend.

LUCKY STAR

The Lucky Star mine is on the east slope of Chief Mountain, about a mile and a quarter northwest of Frisco, at an altitude of about 10,500 feet. It is accessible by a steep wagon road which connects with an automobile road into Frisco. Little is known of the history or production of this mine. It had been intermittently operated by L. J. Emore of Dillon for several years up to the time of the writer's visit in 1940. A few carloads of ore were produced in that year.

The mine is opened on two levels, the upper level (no. 1) being about 60 feet above the lower level (no. 2). Two other short levels (nos. 3 and 4) lead off the lower level as shown on plate 6. The total length of all the workings is about 675 feet.

The country rock is chiefly hornblende gneiss striking from N. 60° E. to N. 10° W. and dipping from 40° to 52° W. A number of fairly large bodies of pegmatite were encountered in the workings. A small amount of quartz monzonite gneiss striking N. 10° W. and dipping 40° SW. occurs at the portal of the lower level. Near the breast of the main adit Idaho Springs schist strikes N. 10° E. and dips 52° NW.

Five veins were encountered in the mine,but only the main vein

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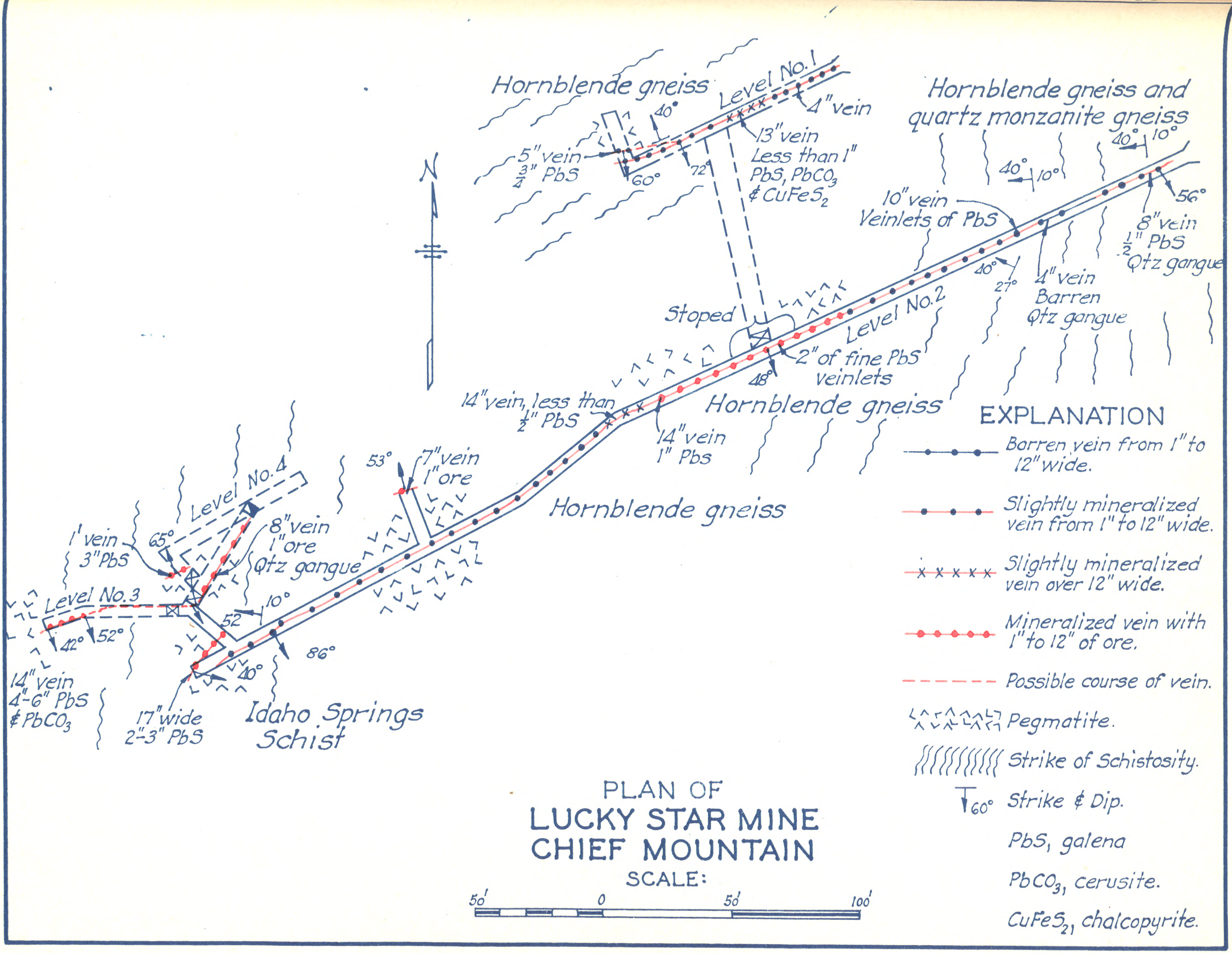
[1] Lovering, T. S., op. cit., (Prof. Paper 178), p. 44.

PLATE 6



PLAN OF
LUCKY STAR MINE
CHIEF MOUNTAIN

in levels 1 and 2 has been worked very extensively. This vein strikes from N. 50° E. to N. 65° E. and dips from 48°to 86° SE. The dip steepens towards the breast of level no. 2. The width of the vein varies from 4 to 14 inches with about 2 inches of galena being the greatest thickness of ore. A little pyrite is the only other megascopic sulphide. Secondary covellite and chalcocite are present in microscopic amounts. The gangue is almost entirely quartz which is occasionally very vuggy. About 165 feet from the portal this vein has been stoped along the drift for about 25 feet. Two inches of fine veinlets of galena are present here. At the top of the stope on level no. 1 the vein is 13 inches wide and carries less than an inch of ore. About 50 feet southwest of the stope on level no. 2 the vein thickens to 14 inches wide with one inch of galena. The vein here trends more sharply to the southwest. If the hanging (south) wall of the vein was faulted with a strong horizontal eastward component, a wider opening in the vein fissure would have occurred in those portions of the vein which deviated to the southwest. Hence a wider vein would have resulted, as noted.

A second vein, striking N. 76° E. and dipping 53° NW., occurs at the end of the first crosscut which is 335 feet from the portal of level no. 2. This vein carries 1 inch of galena and 6 inches of quartz. It is said to join the main vein in the stope which leads to the first level, but the stope was inaccessible.

A third vein, striking N. 13° E. and dipping 40° SE., is found at the breast of the main adit. It is 17 inches wide and carries 2 to 3 inches of galena. A considerable amount of goethite and braunite is present in the vein. This vein probably joins the main vein a few feet within the south wall of the adit and the junction may account for its unusual thickness.

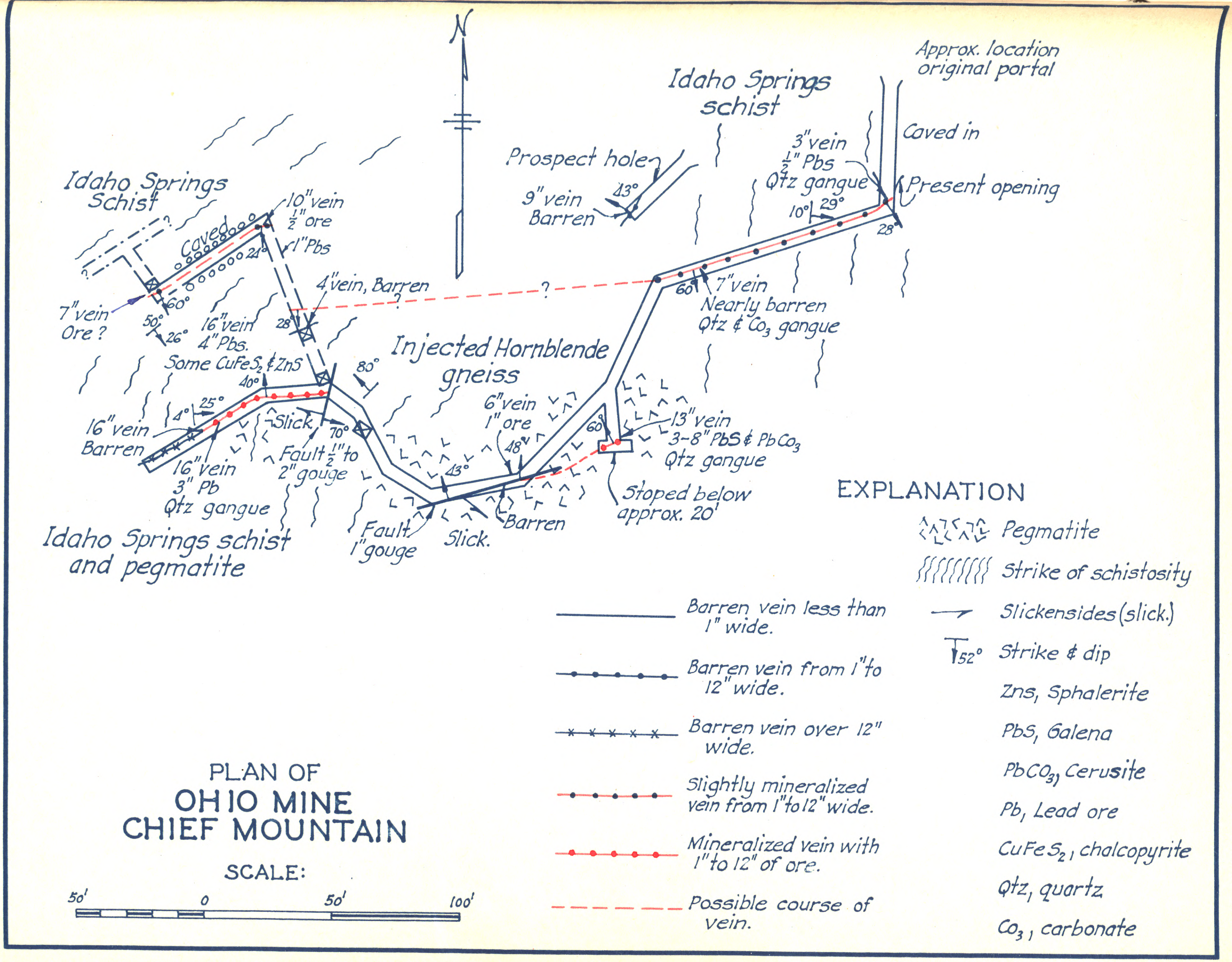
The fourth vein is found at the end of a crosscut which is turned off the main adit 15 feet from its end. Two low-angled raises follow this vein in approximately opposite directions, one of which ends on level no. 3, and the other at a shaft which leads to level no. 4 as shown in plate 6. The vein strikes from N. 52° E. to N. 67° E. and dips from 42° to 72° SE. It varies from 8 inches in width at the end of the crosscut to 14 inches on level no. 3 and carries from 1 to 6 inches of galena and cerusite with a little chalcopyrite. The greatest thickness of ore occurs on level no. 3 where the mine was being worked in 1940. No ore was found in this vein in level no. 4.

The fifth vein joins the fourth vein in a raise 10 feet northeast of the crosscut leading from the main adit. It strikes N. 58° E. and dips 65° NW. and is 1 foot wide with 3 inches of galena and cerusite. This vein has probably been faulted by vein 4, but its offset portion was not discovered. This vein was worked in only a small pocket about 10 feet long.

OHIO

The Ohio mine is located on the east slope of Chief Mountain, near the upper level of the Lucky Star mine at an altitude of about 10,600 feet. It lies about a mile and a quarter northwest of Frisco. The mine is accessible by the same wagon road which leads from the Lucky Star mine to Frisco. It is said to be one of the oldest mines in the vicinity, but little could be learned of its history or production. It is abandoned and several parts of it

PLATE 7



PLAN OF
OHIO MINE
CHIEF MOUNTAIN

are caved in and inaccessible.

The mine was worked on two levels, the lower level opening to the surface. The total length of all the workings now accessible is about 550 feet.

The country rock is chiefly mica schist of the Idaho Springs formation. A considerable amount of pegmatite is present as well as a minor amount of hornblende gneiss which is heavily injected by the pegmatite. The schist and gneiss range in strike from N. 4° W. to N. 50° E. and in dip from nearly vertical to 30° E.

Although veins were encountered in five separate places in the mine, it is believed only three veins are actually present. The first vein is found at the present opening of the mine which is about 50 feet from the old portal. This vein strikes N. 45°-77° E. and dips 28°-60° SE. It ranges from 3 to 7 inches in width and carries at most only half an inch of galena and a little sphalerite. The gangue is quartz and a little ankerite. The vein is barren where it passes into the north wall 95 feet from the present opening. This vein is believed to continue in the raise near the end of the mine and in the upper level. (See pl. 7.) This portion of the vein strikes N. 63°-85° E. and dips 24°-60° SE. Its width varies from 4 to 10 inches with about 1 inch of galena. A raise led off this vein at the end of the upper level but was inaccessible.

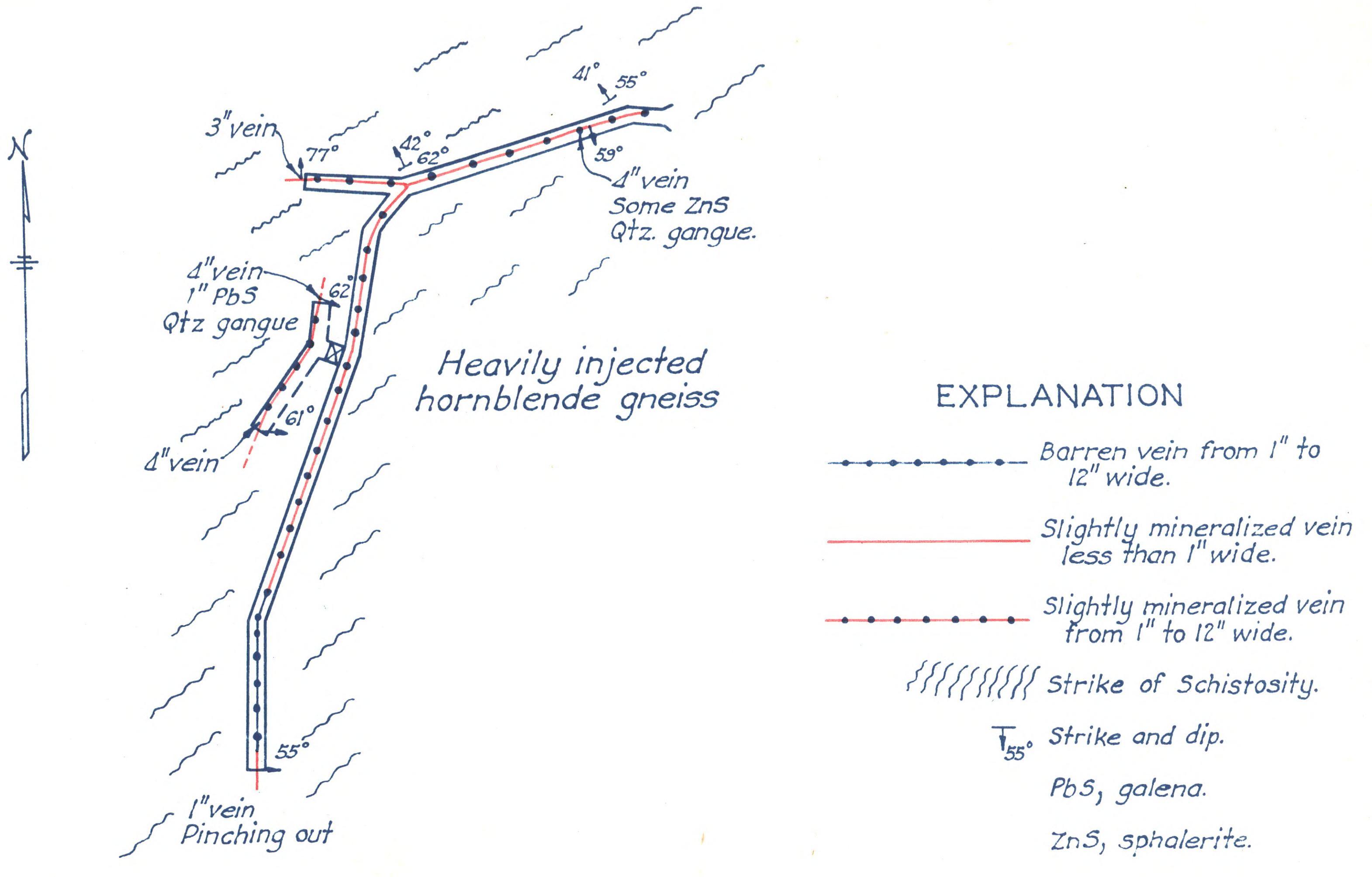
The second vein is encountered in a stope about 20 feet wide and deep approximately 160 feet from the present portal. It strikes N. 65° E. and dips 60° NW. and is 13 inches wide. It carries from 3 to 8 inches of galena, some cerusite, and a very little bornite in a quartz gangue. The widest ore persisted only a few feet along the strike. This vein is picked up again in the main tunnel about 185 feet from the portal. The strike and dip are nearly the same as in the stope. It is 6 inches wide and carries about 1 inch of spottily distributed galena where first encountered in the main tunnel, but is barren the remainder of its length. It is cut out within a few feet by a fault striking N. 75° E. and dipping 43° NW. Slickensides on the fault plane have a horizontal projection of N. 40° W. but the movement of the fault could not be determined.

Approximately 335 feet from the portal the third vein was encountered on the foot (west) wall of a fault striking N. 15° E. and dipping 70° SE. The vein is 16 inches wide and contains about 4 inches of galena, some sphalerite, chalcopyrtie, and pyrite in a quartz gangue. It dips 40° NW. and ranges in strike from northeast to nearly east. The vein becomes barren only 50 feet from the fault although it is still 16 inches wide. The localization of the ore at the fault may have been caused by a ponding of the ore-bearing solutions at the fault barrier which would lead to a lengthened time of deposition at that place.

EMORE

A second mine operated by L. J. Emore of Dillon is located on the east slope of Chief Mountain at an altitude of about 9,800 feet approximately 2 miles northwest of Frisco. It is accessible from Frisco by a wagon road. It was abandoned at the time of the writer's visit, but it had been in operation intermittently for a few years prior to that time.

PLATE 8



PLAN OF
EMORE'S MINE
CHIEF MOUNTAIN

SCALE:

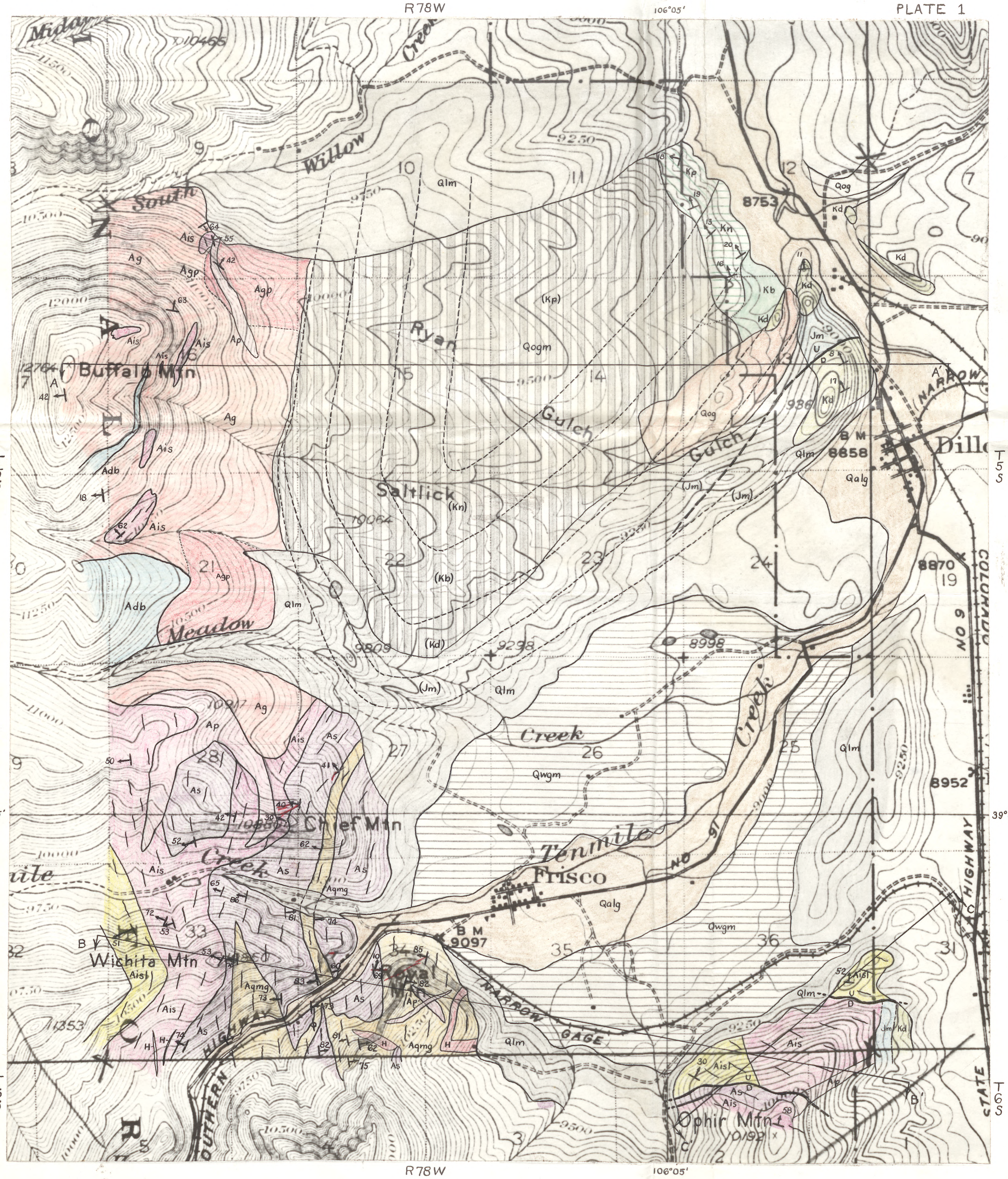
50' 0 50' 100'

The mine was worked along a main adit with a short drift turned off it and a short second level as indicated on plate 8. The total length aggregates about 300 feet.

A single vein and a short branch vein have been worked in the mine. The main vein strikes N. 72° E. and dips 59° SE. near the portal but bends sharply to the south 80 feet from the portal and strikes from north to N. 41° E. and dips from 55° to 62° SE. The short branch vein dips more steeply than the other a few feet past the junction and finally passes the vertical and dips 77° NE. where the drift terminates.

The vein is at most 4 inches wide and carries 1 inch of galena and cerusite in the north end of the short upper level. It pinches out to only 1 inch at the breast of the main drift. A small amount of sphalerite and boxwork of wad is present in the vein near the portal. The gangue is quartz throughout.

The country rock is hornblende gneiss which has been heavily injected by pegmatitic material. The strike of the gneiss ranges from N. 55° E. to N. 62° E. and dips 42° NW.



QUATERNARY	Pleistocene and Recent	Qalg	Alluvium and gravels of Wisconsin glacial stage
	Pleistocene	Qwgm	Ground moraine of Wisconsin glacial stage
		Qlm	Lateral moraine of Wisconsin glacidl stage
		Qog	Older terrace gravels
		Qogm	Older ground moraine
CRETACEOUS	Upper Cretaceous	Kp	Pierre shale
		Kn	Niobrara formation
		Kb	Benton shale
		Kd	Dakota quartzite
JURASSIC	Upper Jurassic	Jm	Morrison formation
ALGONKIAN		Ap	Pegmatite
		Adb	Quartz diorite and associated basic rocks
		Ag	Granite
		Agp	Pink variety of granite
		Aqmg	Quartz monzanite gneiss and granite gneiss
		As	Swandyke hornblende gneiss
ALGONKIAN(?)		Ais	Idaho Springs formation
		Aisl	Lime-silicate member of Idaho Springs formation

EXPLANATION

Veins

H — Hydrothermally altered zone
Chloritized and sericitized; iron stains; probably vein below

45° — Strike and dip of schistosity or of bedding

Strike of vertical strata

Faults
U, upthrow, normal fault
D, downthrow, normal fault

GEOLOGIC MAP OF PART OF DILLON QUADRANGLE
COLORADO

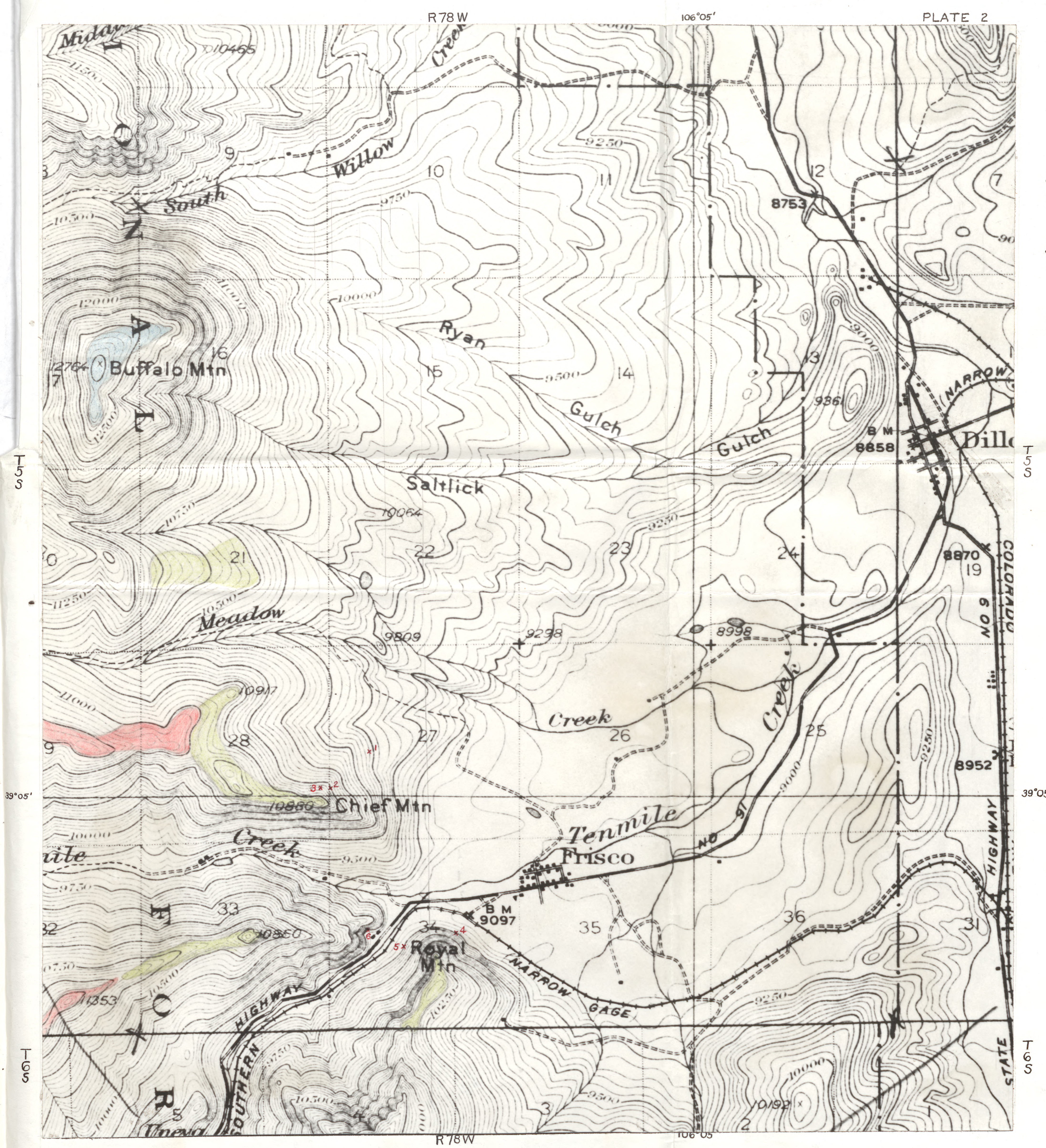
Scale $\frac{1}{31250}$

1 ½ 0 1 2 Miles

5000 0 5000 10000 Feet

Contour Interval 50 feet

PLATE 2



MAP SHOWING EROSION SURFACES OF A PART OF THE DILLON QUADRANGLE, COLORADO

Scale $\frac{1}{31250}$

1 ½ 0 1 2 Miles

5000 0 5000 10000 Feet

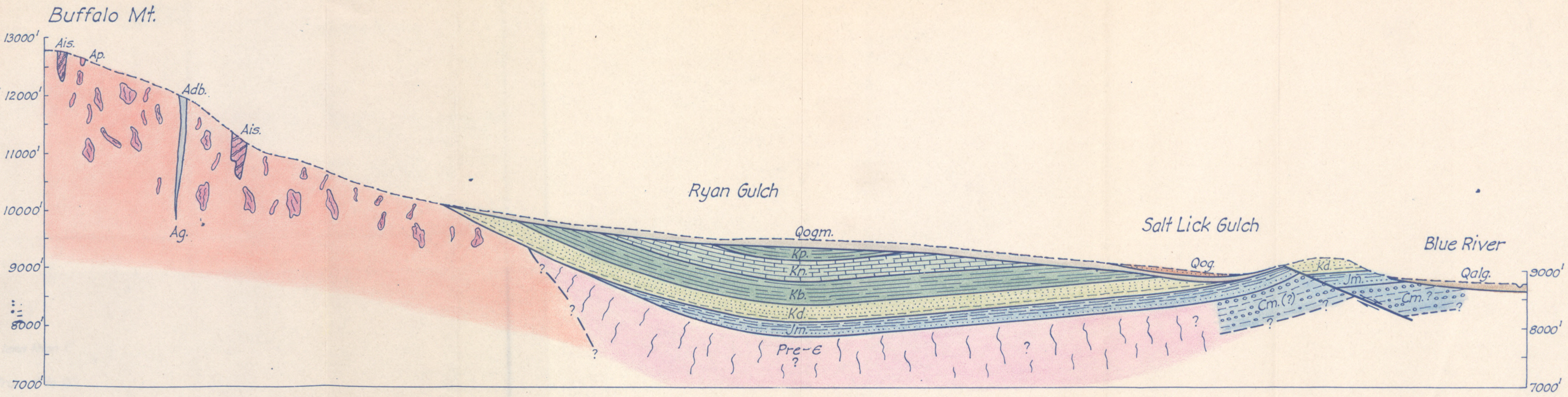
Contour Interval 50 feet

EXPLANATION

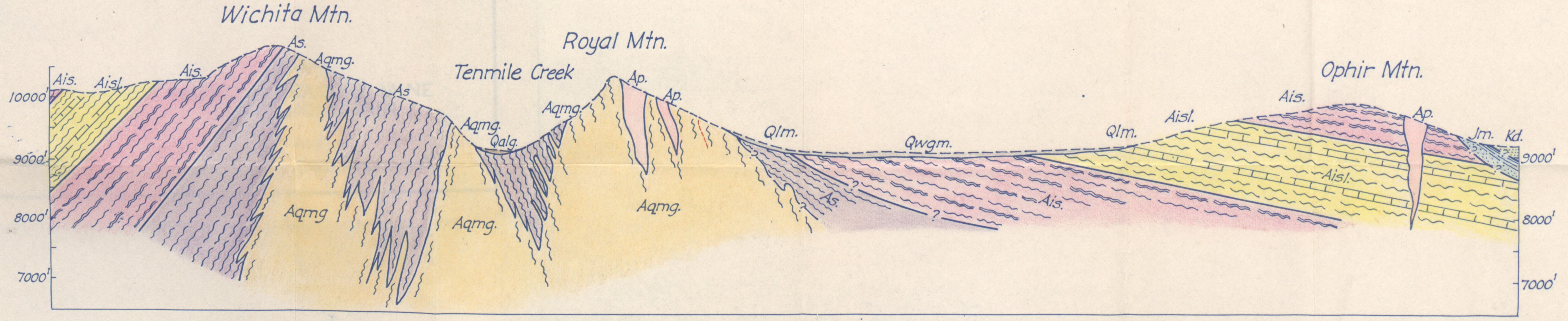
🟨	Surfaces carved chiefly in early Pleistocene time
🟥	Surface carved chiefly in post-Miocene time (Sheephorn surface)
🟦	Surface carved in probable Eocene time (Gore Range surface)

MINE LOCATIONS

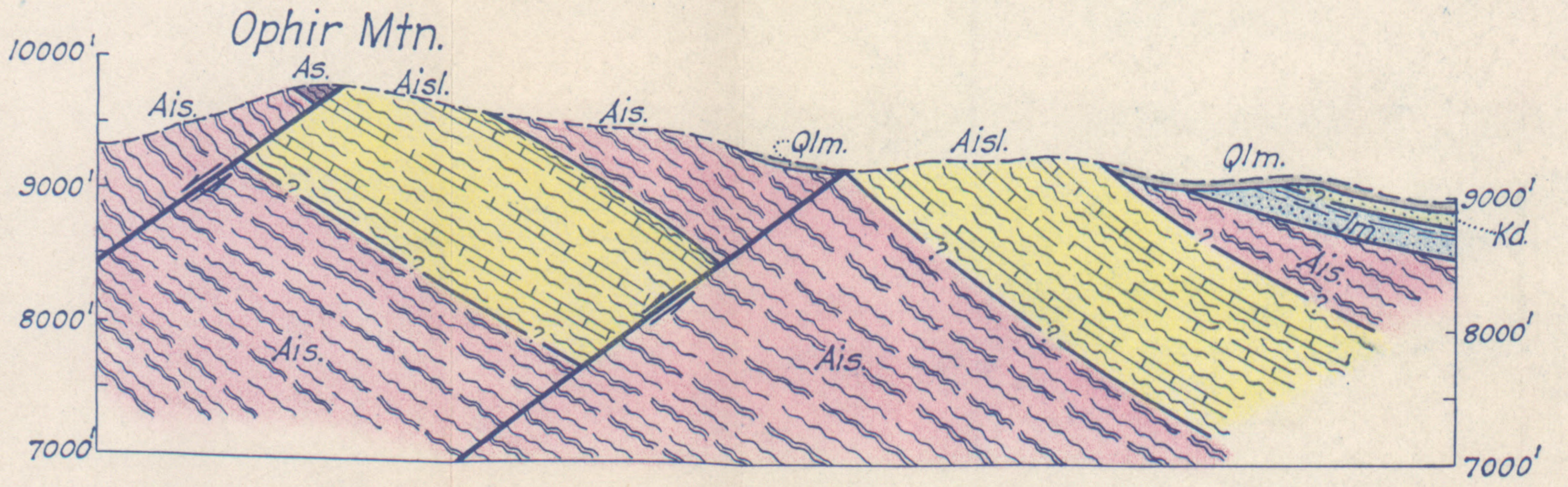
1	Emore's
2	Lucky Star
3	Ohio
4	Hidden Treasure
5	Juneau
6	Excelsior



SECTION ALONG LINE A-A



SECTION ALONG LINE B-B

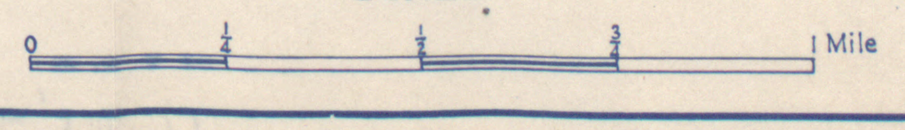


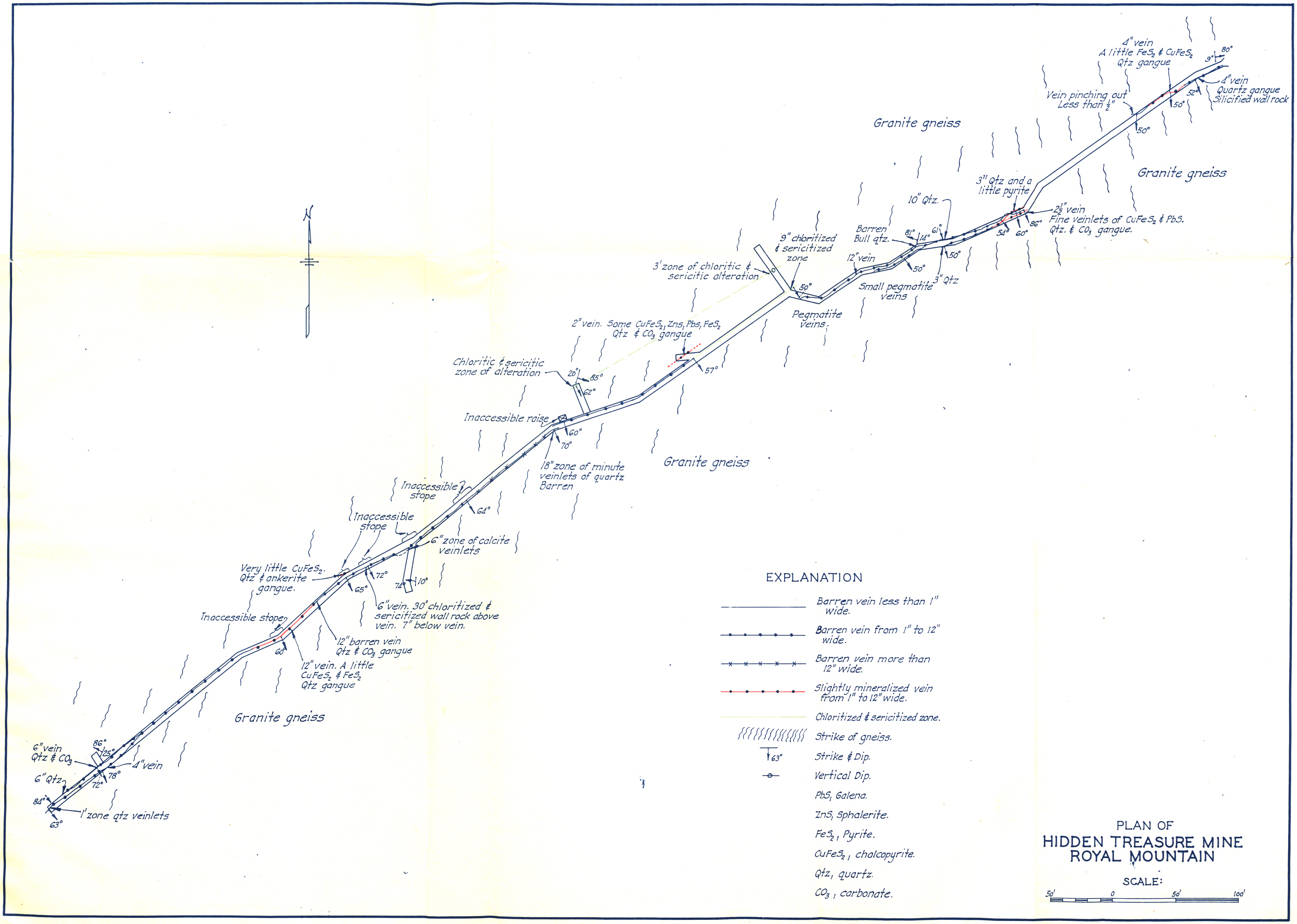
SECTION ALONG LINE C-C

Qalg.-alluvium and gravels of Wisconsin glacial stage; Qwgm.-ground moraines of Wisconsin glacial stage; Qlm.-lateral moraines of Wisconsin glacial stage; Qogm.-older ground moraines; Qog.-older terrace gravels; Kp.-Pierre shale; Kn.-Niobrara formation; Kb.-Benton shale; Kd.-Dakota quartzite; Jm.-Morrison formation; Cm.-Maroon formation; Ap.-pegmatites; Adb.-quartz diorite; Ag.-Granite; Aqmg.-quartz monzonite gneiss and granite gneiss; As.-Swandyke hornblende gneiss; Ais.-Idaho Springs formation; Aisl.-lime silicate member of Idaho Springs formation.

GEOLOGIC STRUCTURE SECTIONS
~ OF A PORTION OF ~
THE DILLON QUADRANGLE, COLORADO

SCALE:





PLAN OF
HIDDEN TREASURE MINE
ROYAL MOUNTAIN

Buckwalter, T.V., Jr
Geology of a part of the Dillon quadrangle. Colorado.
1945

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University microfilms	JAN 14 '59	SEP [illegible]
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