THE GEOLOGY OF THE STEVENS MINE

CLEAR CREEK COUNTY, COLORADO

BY

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Signed

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ABSTRACT

The Stevens mine, an important producer of silver, gold, and lead from 1869 to 1900, has been worked very little since the turn of the century. Although increased demand for metals has encouraged the reopening of the mine, a complete lack of geologic data has hampered such an undertaking. The writer made a detailed study of surface and underground workings and prepared engineering and geologic maps of the surface and of each accessible level.

The mine is located near the Continental Divide about six miles southwest of Silver Plume, Colorado. It is situated in the mineral belt of the Front Range and is at an elevation of 11,500 to 13,000 feet. The host rock is the Pre-Cambrian Silver Plume granite which locally has intruded the Idaho Springs formation. Although an important fracture system trends northeast, the principal producing vein strikes north-south and dips steeply to the west.

Detailed studies were made on the rock types and on the mineraology. Rock type, undulations in the fracture surfaces, and other controls for localization of the ore were established. Consideration of the economic potentialities of the mine suggests that it may have a profitable future if exploitation and exploration are carried on at the higher elevations.

INTRODUCTION

Purpose of Investigation

The Stevens Mine produced considerable mineral wealth from the discovery in 1869 up to 1900. Since the turn of the century production has been intermittent and marginal. The present owner, encouraged by rising prices of metals, is interested in opening the old workings and in developing new ore, but he is hampered by a complete lack of geologic data. No engineering maps or geologic maps are available, either of the surface or of underground workings. The writer's investigation is intended to supply detailed geologic maps of all the accessible workings and to present the pertinent geologic data of the property in a form that will assist guidance of future production and exploration.

Previous Geologic Work

If any previous detailed geologic studies have been made of the Stevens Mine they have not been discovered by the writer or by the present owner. One longitudinal section of the main Stevens vein is available, but it has been found to be in error. The United States Geological Survey published Professional Paper 178 in the year 1935 entitled, Geology and Ore Deposits of the Montezuma Quadrangle, Colorado.(5) T. S. Lovering, the author of the paper, completed the field work during the summers of 1926-1929 and included in the report a brief description of the Stevens Mine.

Procedure and Scope of the Investigation

Field work was carried out by the writer in the summer of 1950. The Montezuma Quadrangle geologic map was used for control on reconnaissance work. Geologic mapping of the surface presented a problem because of the cliff-like slope of McClellan Mountain. A 1300 foot base line was established in the valley below and closed to an accuracy of one part in 25,000 with transit and steel tape. Control was extended to the slope above by triangulation to painted stations on the cliffs, and the two most extensive levels of the underground workings were surveyed with transit and tape. All stations were referred to the base line which was oriented to true north by an observation on Polaris during eastern elongation. The elevation of station B on the base line was assumed to be 11,450 feet above sea level. This assumed elevation is approximate and is based on contour elevations as shown on the Montezuma Quadrangle sheet.

Surface geology was referred to the nearest triangulation station by Brunton compass and cloth tape measurements and was plotted at a scale of one inch to fifty feet in a field notebook. Underground geology was plotted at a scale of one inch to fifty feet on 8½ x 11 inch coordinate sheets. All geology mapped included rock type and rock type lineation and foliation, joints, faults, dikes, veins, metallization, and rock alteration. Significant culture was noted on both surface and underground maps.

Laboratory work on rock types consisted of hand specimen and thin section studies. Metallization was studied by aid of the reflecting microscope.

ACKNOWLEDGMENTS

All investigations made at the Stevens Mine were under the direction of the Graduate Committee, Department of Geology, Colorado School of Mines. Dr. Truman H. Kuhn and Dr. Warren R. Wagner of the geology staff of the Colorado School of Mines gave assistance on field problems, laboratory work and the drafting of the maps. Their help and interest were invaluable. Sincere appreciation is here expressed for the capable assistance of Mr. Walter Bentley, for without his help much of the surveying and surface mapping could not have been accomplished.

GEOGRAPHY

The Stevens Mine is located in about the geographical center of the state of Colorado (Plate 1). It is two miles northeast of the Continental Divide and four miles south of Bakerville. Bakerville is five miles west of Silver Plume, and sixty miles by U. S. highway 6 west of Denver. The road to the mine follows south from Bakerville up Stevens Gulch, a distance of four miles. The lower portal of the mine is at 11,500 feet elevation and the highest elevation in the area studied is 13,000 feet at the top of McClellan mountain.

The highway from Denver to Bakerville is paved and kept open the year around but the road up Stevens Gulch to the mine is unimproved, steep, and inaccessible except in the summer (Plate 2).

The property is above timber line, and is situated in an area where the annual snowfall is from twenty to thirty feet. The terrain is very rugged and soil has little chance to form. The only vegetation is brush and moss. Daily and yearly temperature variations are extreme and mass action erosional processes give a barren and bleak appearance to the landscape.

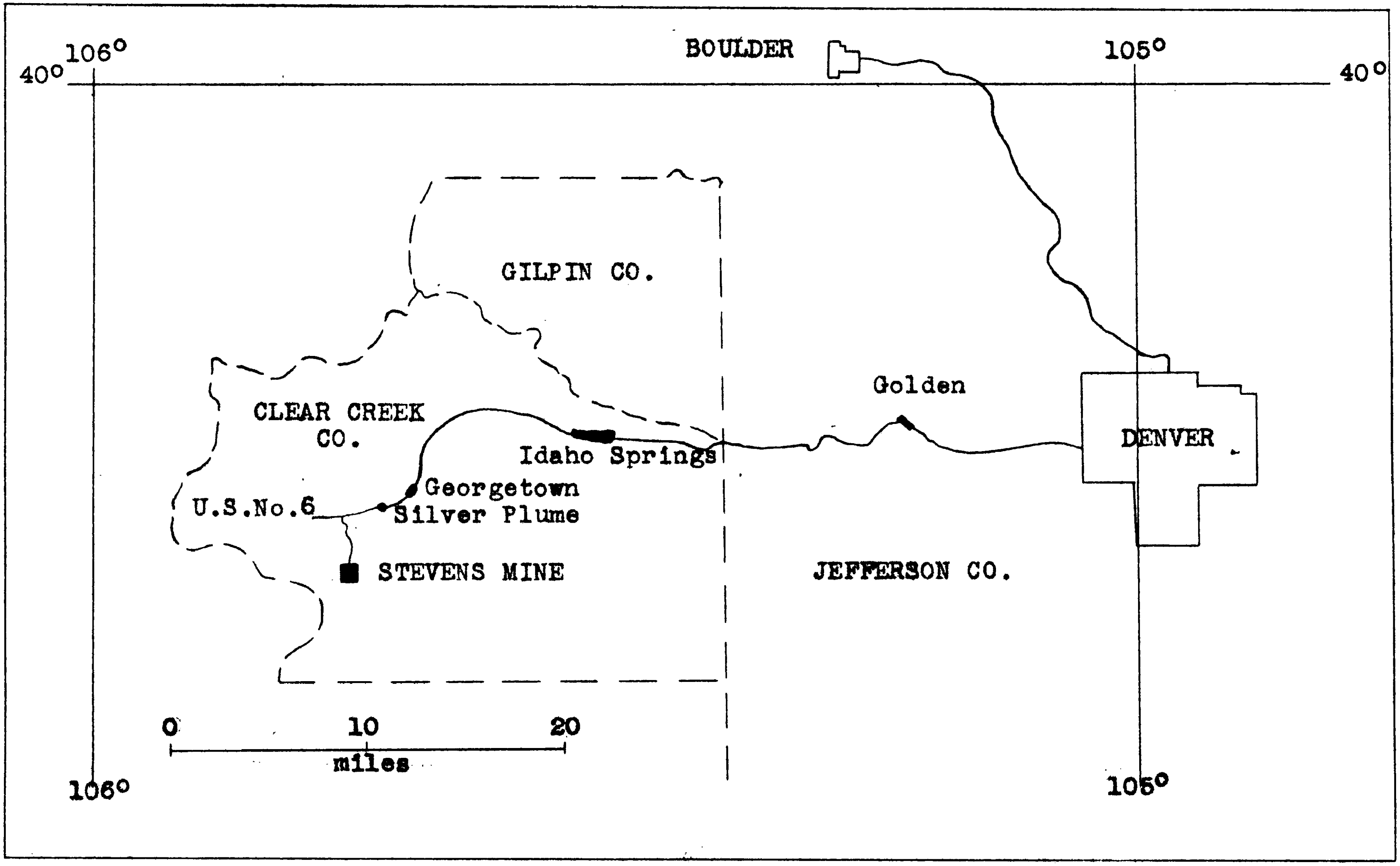

Plate 1. Index Map showing location of area studied.

GEOMORPHOLOGY

The Front Range of Colorado was uplifted in Laramide time and has since then been sculptured by erosion. The range remains high because of its resistant crystalline core and successive minor uplifts. The several erosion surfaces at different elevations described by Van Tuyl and Lovering (8) indicate periods of erosion followed by more or less rapid uplift. The upper remnant surface called the Flattop peneplane of possible Miocene age may be represented near Ganley Peak one mile northeast of the Stevens mine. Long, gently sloping spurs radiate out from the peak at an elevation of 12,400 feet. Definite correlation of this erosion surface is impossible because the surface was never ideally developed near the Continental Divide and because of subsequent erosion.

In Pleistocene time valley glaciers radiated out from the Front Range, and their carving is largely responsible for the present day topography, particularly at elevations above 10,000 feet. Stevens Gulch is an old glaciated valley that heads at the foot of Grays Peak, Torreys Peak, and McClellan Mountain. Steep cliff walls and scoured floor are very apparent. Cirque lakes, moraines, and rock glaciers are exposed in their ideal forms, and extremes in elevations cause great rock slides on the west side of McClellan Mountain. Stevens Gulch, fed by perennial snow, is occupied by a continuous stream of clear water which flows into Clear Creek at Bakerville.

Fig. 1. Looking south toward Grays and Torreys Peaks and the headwaters of Stevens Gulch.

Fig. 2. Looking north-east toward McClellan Mountain and the 900-level dump of the Stevens mine (near upper end of patch of snow).

GEOLOGY

Regional Geology

The Front Range of Colorado, extending from Canyon City northward into Wyoming, is the most easterly range of the Colorado Rocky Mountains. It is an eroded anticline approximately fifty miles in width and two hundred miles long trending north-south. The southern end of the range terminates at the Canyon City embayment. To the east of the range is the Denver sedimentary basin, the structural axis of which trends from north to N. 30° E. In Wyoming the northward continuation of the Front Range of Colorado is referred to as the Laramie Range. West of the Front Range is a series of parks or sedimentary basins. From north to south these are North Park, Middle Park, and South Park. The backbone of the Front Range forms part of the Continental Divide with many of its peaks being over 14,000 feet above sea level.

The core of the Front Range is made up of Pre-Cambrian metamorphic and intrusive igneous masses and Early Cenozoic intrusives and extrusives. Sedimentary rocks of Paleozoic, Mesozoic, and Cenozoic age flank the crystalline core, and are uptilted on the east and west flanks. The climax of Laramide uplift and folding occurred between Paleocene and Eocene time.

The crystalline rocks forming the Front Range are differentiated broadly into Pre-Cambrian metamorphosed sediments, Pre-Cambrian igneous intrusives, and Early Cenozoic intrusives and extrusives. The oldest rocks are the schists and gneisses of the Idaho Springs formation probably Algonkian in age. They appear to have been shaly sediments before being intruded by Pre-Cambrian granites. The Pikes Peak granite batholith first intruded in the southern part of the range. Smaller batholiths and their associated pegmatites intruded to the northward forming the Silver Plume Granite, Cripple Creek Granite, Longs Peak Granite, and the Mount Olympus Granite.

During the Paleozoic and Mesozoic eras the region remained a positive area, was gradually eroded, and occasionally seas invaded the lowlands. Sediments were laid down during some of the interval and there was little diastrophism except for warping during Pennsylvanian time until near the end of the Cretaceous period.

During Laramide time the uplift of the present Rocky Mountains occurred. Intrusion and broad uplift caused intense folding and faulting. Stocks, dikes, and sills of intermediate composition intruded the Pre-Cambrian crystallines. The trend of these Paleocene or Eocene intrusives, commonly called porphyries, was N. 40 E. across the Front Range. They are limited to a narrow belt and extend from the vicinity of Boulder S. 40 W. to the San Juan District of Colorado. Emanations from the underlying magma filled faults to form the Front Range mineral belt, which is synonymous in position and extent with the porphyry trend. Another major trend of these porphyry intrusives extends N. 40 W. from Spanish Peaks to the vicinity of Aspen, Colorado.

Westerly dipping faults border the eastern flank of the Front Range. Overthrusting toward the west is common on the western slope of the range, of which the Williams thrust fault is the most conspicuous example. Persistent north-west trending faults extend across the mineral belt and form the "breccia" reefs. Most productive vein fissures in the central part of the belt trend east-west and appear to have opened later than the larger north-west trending faults.

It should be pointed out that the principal mining districts are in the vicinity of apically truncated stocks and that the districts with less important production appear to be located near medially truncated stocks (2).

Local Geology

The Stevens Mine in McClellan mountain is west of Leavenworth creek on the northern edge of the Argentine mining district. It is in the center of the Front Range mineral belt but south of the strong north-west trending breccia reef faults. The mine is three miles from the nearest quartz monzonite stock, the Montezuma stock, which is located southwest across the Continental Divide in the Snake River valley.

Country rock consists of Pre-Cambrian gneiss and schist of the Idaho Springs formation, and the Silver Plume Granite. Pre-Cambrian pegmatite dikes associated with the granite and Early Cenozoic dikes associated with the stocks are occasionally observed. The later dikes trend north-east. Faults and vein fissures generally strike from N. 20° E. to N. 40° E. and dip steeply westward. A few faults strike north-west. However, the most persistent and most productive vein, the Stevens, trends north-south. Other veins mined in the immediate vicinity trend approximately N. 30° E. Open fractures are most common in the granite and appear to be part of a system of faults. Although open, they are narrow, and do not have great lateral or vertical extent.

Petrography

Silver Plume Granite

The Silver Plume granite encloses the Stevens vein and is everywhere the favorable host rock for mineral deposition. It intrudes the Idaho Springs formation, and by assimulation and injection, has formed a gradational boundary with the older foliated rock.

In the hand specimen, the granite has a light pinkish, gray color, because of the predominance of light pink feldspar with somewhat finer grained biotite. The larger crystals of feldspar are about one centimeter in length with an average size of about four millimeters. The feldspar is euhedral, commonly twinned by the Carlsbad law, and shows primary foliation by orientation of the grains. Plagioclase, showing Albite twinning, is present in grains about three millimeters in size. Quartz is present in anhedral form and averages about three millimeters in size with an occasional grain eight millimeters in diameter. Biotite mica from one to three millimeters in size is the only dark mineral distinguishable.

Thin sections indicate a phanerocrystalline, hypautomorphic texture. Phenocrysts of microcline are larger than other mineral grains, and tend to give a porphyritic texture. Only minor amounts of accessory minerals form euhedral crystals. Crystals of orthoclase are occasionally zoned and altered to sericite. The estimated percentage mineralogical composition is as follows:

Primary Minerals 98%

microcline	20
orthoclase	30
andesine	8
quartz	20
biotite	15
muscovite	7
	100%

Accessory Minerals 2%

apatite
zircon
magnetite
ilmenite

Secondary Minerals

- sericite
- clay
- chlorite
- limonite

Orthoclase is somewhat altered to sericite and kaolin, and biotite has altered slightly to chlorite. Polysynthetic twinning is very pronounced in the microcline and andesine. Muscovite, not evident in the hand specimen, is quite prevalent as shreds in the sections. Both quartz and feldspar have apatite crystals imbedded in them.

Some exposures of the granite are green in color. A detailed study of this green granite indicates that the color comes from chlorite and epidote formed from the breakdown of biotite. It is estimated, from a thin section of the green granite, that seventy percent of biotite has been altered. The monoclinic orthoclase is much more altered in the green granite than in the fresh specimens and orange iron oxide stains are also more prevalent. Microcline has altered slightly to kaolin and the quartz remains fresh.

Where hydrothermally altered the granite is a light buff color, the principal minerals present being kaolin, muscovite, and quartz.

Idaho Springs Formation

The Idaho Springs formation borders the granite and occasionally encloses a mineralized vein. In the vicinity of the Stevens mine it is a strong, compact, and resistant gneiss, and appears to be a roof pendent over the later granite. The appearance varies slightly from outcrop to outcrop, but the foliation remains typically gneissic. Granitoid bands of quartz and feldspar are from two to ten millimeters in width and biotite bands are usually less than two millimeters in width. The color in hand specimen is medium gray, except where broken, to a shiny, steel-gray biotite face.

In thin section the texture is hypautomorphic granular. Orientation of biotite, muscovite, and some elongate crystals of quartz and feldspar is striking. Whisps of muscovite are stretched out to ten times the width. Grains of quartz and feldspar are essentially equidimensional. Poikilitic textures are common, with the micas being formed inside larger crystals of feldspar. The estimated percentage mineralogical composition is as follows:

Primary Minerals 97%

microcline	15
orthoclase	10
quartz	35
biotite	20
muscovite	20
	100%

Accessory Minerals 3%

magnetite
garnet

Secondary Minerals .

clay
sericite
epidote
chlorite

Away from hydrothermally altered zones the gneiss is comparatively fresh. Muscovite appears essentially unaltered. Orthoclase is somewhat altered to kaolin and sericite and the biotite flakes show some chlorite and epidote around the edges.

Dikes

A medium to dark colored dike of aphanitic texture was mapped in two places in the vicinity of the mine. It is not related to the productive vein in attitude, but is essentially parallel with the northeast trending system of faults. Exposures are a uniform greenish-gray that turn brown on weathering. The rock is dense, tough, and individual grains can seldom be distinguished.

A thin section of the rock indicates little more than the hand specimen, as the texture is hypocrystalline. Crystals of muscovite started to form and show euhedral outline. Feldspars and quartz evidently did not have time to form because of quick cooling of the magma. Fragments of biotite, chlorite, and epidote are present to give the green color. The accessory minerals apatite, ilmenite, and magnetite are observable in euhedral forms. Any silica present is in the form of glass or incipient crystals of quartz.

ORE DEPOSITS

History and Production

Fascinating stories are told about the Stevens Mine in editions of the Georgetown newspapers edited from 1869 to 1900. Early production was from the higher levels on the west cliff slope of McClellan mountain. The old time miners built small houses on nitches in the cliffs and worked the main Stevens vein from numerous portals into the hillside. Records indicate that silver-bearing galena was the principal valuable metal and that it ran from 100 to 200 ounces of silver per ton and 65 per cent lead. High grade ore was sewed in animal skins, rolled down rock slides to Stevens Gulch below, and loaded on mules for transport. The ore was hauled to St. Louis and shipped via the Mississippi River to Swansea, Wales for refining. Although the Stevens mine had a more or less continuous operation until 1900, production was limited because of the narrowness of the vein, the difficulty of transportation, and the very high elevation, making year-around operation very difficult.

The actual production from the Stevens Mine is not accurately known, since many different operators have exploited the property. However, significant tonnage has been removed as evidenced by many caved upper workings and by articles in the early Georgetown newspapers. On the following page are listed production figures as published by Lovering (5).

Date	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Lead (pounds)
1870	40	----	----	----
1873	200	----	25,000	200,000
1887	?	54.12	12,947	390,698
1888	---	91.91	21,135	857,653
1889	---	103.34	17,890	811,106
1892	?	----	42,666	2,601,203

Little is known of the production since 1900, but it is believed that the property lay idle most of the time. In 1949 Mr. E. P. Lupton leased the property and timbered a transfer raise from the main 1400-level up to the 900-level with the expectation of recovering old stope gob from upper levels. Evidently difficulties in maintaining the transfer raise prevented any appreciable recovery of stope fill. The present owner and operator, Mr. Douglas V. Watrous, is reclaiming part of the 900-level dump and concentrating the ore at the Black Eagle Mill in Chicago Creek near Idaho Springs.

Structural Relations

The two different host rocks present in the area studied are the Idaho Springs gneiss and the Silver Plume granite. The structure varies considerably within these two different rock types. The strong foliation of the gneiss trends N. 40° E. and dips westward from 25 to 75 degrees. Rotation by faulting and local crumpling cause the attitudes to vary considerably in detail. The geologic map of the Montezuma Quadrangle by Lovering (6) indicates a N. 10° E. to N. 20° E. trending syncline in the gneiss about a mile southwest of the Stevens property. Most of the fold axes in the metamorphics trend north-south. The gneiss may grade into schist farther away from the granite contact, but in the region covered by the writer's reconnaissance the character of it remained constant. Faults found in the gneiss tend to be parallel to the foliation. The gneiss-granite contact is gradational and indicates assimulation, stoping and injection on the part of the granite. The schistosity becomes less and less pronounced until nothing remains except the primary foliation of the oriented feldspar in the granite.

The Silver Plume granite shows persistent primary foliation striking north-east and dipping steeply to the north-west. This attitude, which is present throughout the mine, indicates possible doming of the primary structure to the south-west at the present crest of McClellan mountain. Actually the gneiss seems to have little depth and the writer visualizes it as a roof pendent over the granite.

The dikes mapped trend N. 40 E. and dip from fifty to seventy degrees to the north-west. Where they are intruded into the gneiss they are essentially parallel to the foliation.

The faulting is of considerable interest since it is one of the most important ore controls. Seventy-five per cent of the faults present on the surface and underground are in a system striking N. 20 E. to N. 40 E. and dipping steeply to the north-west. They are essentially parallel and do not extend over 100 to 300 feet horizontally. The Stevens vein obviously is anomalous to the rest of the faulting mapped and has been interpreted by the writer as being a normal fault of slight net slip. It is more open than the north-east trending faults and probably formed during slight relaxation of regional forces. The fact that it is mineralized substantially more than any of the other faults indicates one of two possibilities: (a) being a normal fault it might have reached a greater depth than the others, or (b) it may have been more persistently permeable or open at a more favorable time for the passage and deposition of mineral bearing solutions. Detailed mapping on the 1400-level clearly disclosed in three places a strike slip of about four feet (Plate 6). The west block moved northward. Lovering (5) found evidence that the west block had moved northward and downward, but this dip slip component has not been determined by the writer. On both the 1400-level and the 900-level there are many tension drag faults that extend into the hanging wall toward the south-west and into the footwall toward the north-east. They are in each case steep and make an angle of about 20 degrees with the strike of the main Stevens vein. Where observable they were found to die out within twenty feet of the main vein. They appear to have been formed concurrently with the main Stevens structure and indicate that forces normal to the main fault surface were still considerable. None of the faults in the area have any appreciable slip and rubbery gouge was found on but one or two fault surfaces.

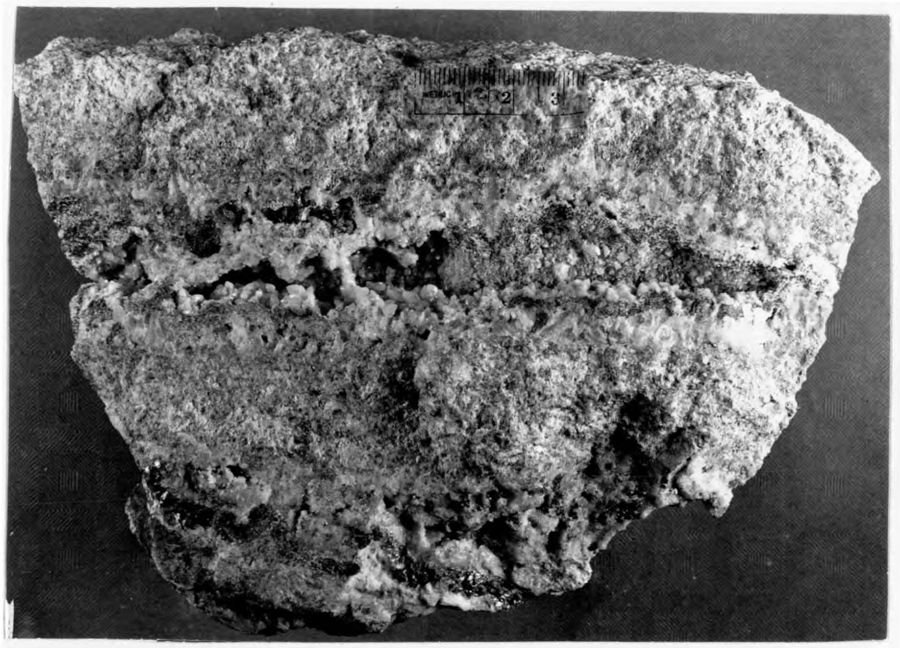

Fig. 3. Typical fracture along the Stevens vein, showing open space filling. Euhedral dolomite lines the cavity and was the last mineral deposited.

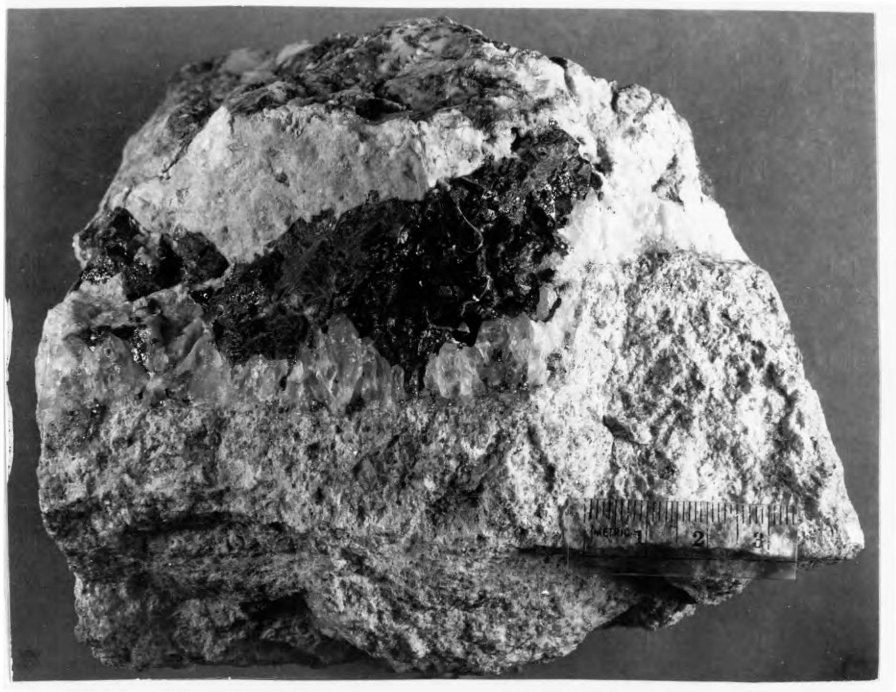

Fig. 4. Vein banding showing from the bottom upward: (a) altered country rock, (b) pyrite and comb quartz, (c) dark sphalerite, (d) ankerite gangue. From the Stevens vein, 1400-level.

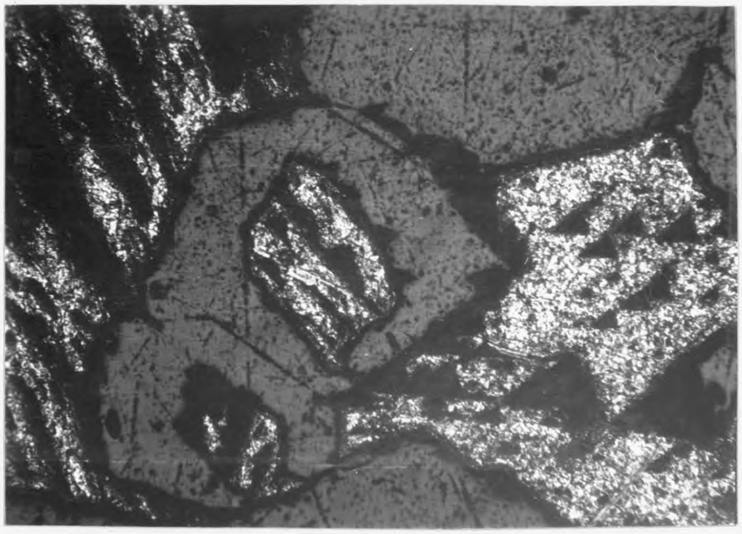

Fig. 5. Photomicrograph showing euhedral quartz and later galena (white). Ore from 1400-level of Stevens mine.

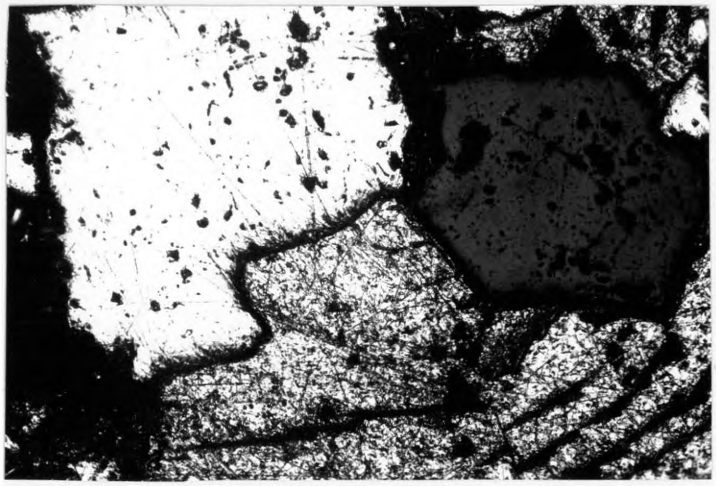

Fig. 6. Photomicrograph showing quartz (dark gray), galena (medium gray), and chalcopyrite (white). Ore from 1400-level of Stevens mine.

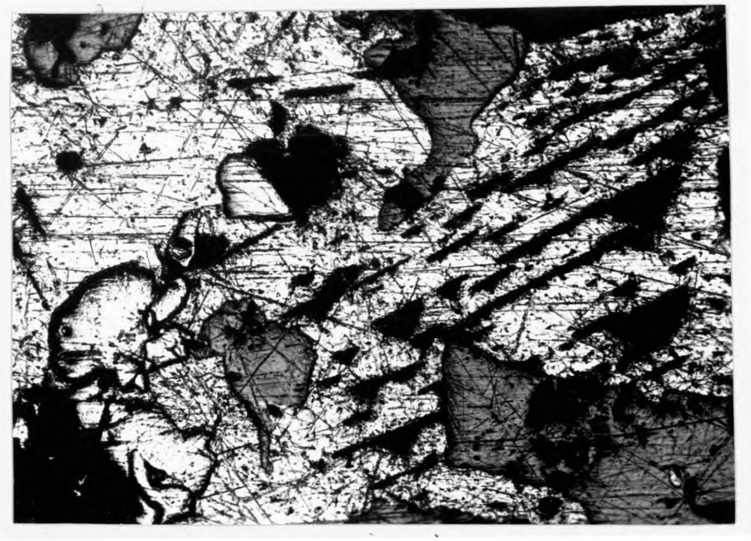

Fig. 7. Photomicrograph showing chalcopyrite (white, upper left) replacing pyrite (high relief), sphalerite (dark gray), and galena (white with triangular pits).

Fig. 8. Photomicrograph showing galena (right) replacing pyrite (rectangular) and chalcopyrite (center, mottled) replacing pyrite, galena (triangular pits), and sphalerite (dark gray).

Mineralogy

The following ore minerals have been recognized and studied by the writer:

Chalcopyrite, $Cu Fe S_2$
Covellite, $Cu S$
Galena, $Pb S$
Gold, Au
Pyrite, $Fe S_2$
Sphalerite, $Zn S$

The following gangue and alteration minerals were observed and studied:

Ankerite, $(Ca, Mg, Fe) CO_3$
Iron Oxides, $Fe_2O_3 \cdot 3H_2O$, etc.
Dolomite, $CaMg(CO_3)_2$
Fluorite, CaF_2
Clay Minerals, $2H_2O \cdot Al_2O_3 \cdot 2SiO_2$, etc.
Quartz, SiO_2
Rhodochrosite, $MnCO_3$
Sericite, $KH_2Al_3(SiO_4)_3$
Siderite, $FeCO_3$
Manganese Oxides, $MnO_2 \cdot H_2O$, etc.

Quartz

Quartz, possibly the first mineral to be precipitated in the veins, also may have been one of the last to be deposited. The early quartz was often coarse enough to form a comb structure giving euhedral crystals about one-half inch long. Silicification of wall rock is apparent at some places on the 1400-level but the age of this penetration is not known. Minute fractures occurring very late are filled with a very fine grained silica that may be supergene. However, many places in the vein show a minor amount of quartz with respect to the total hypogene mineralization. Vein quartz may be found in about equal proportions from the surface to the lowest levels.

Pyrite

Pyrite is the most common sulfide mineral, and like silica, is commonly found disseminated in the wall rock for a distance of about one foot from the channel. Pyrite formed almost as early as the silica and possibly the addition of sulfur to iron in the wall rock was all that was needed to form the euhedral pyrite. In many places the chalcopyrite appears localized around pyrite that is evidently being altered to the chalcopyrite by the addition of the copper ion.

Sphalerite

Sphalerite is one of the most common sulfides, particularly on the 1400-level of the mine. Typically ~~it~~ is very dark and only occasionally it is a light shade of yellow. It lies inside early comb quartz and pyrite in open fissures and evidently was earlier than the first galena or chalcopyrite. As indicated on the paragenesis chart, the sphalerite is probably contemporaneous with much of the galena deposition. Inclusions in sphalerite were found to be zoned around a euhedral crystal of galena and in another section galena cleavage was found as a pseudomorph in the sphalerite where it extended directly across the mineral boundary. Caries texture also indicated that some of the sphalerite was replacing galena. On the other hand it was common to find galena as the latest crust over sphalerite in fissure fillings, thus indicating that final galena deposition was probably later than final sphalerite deposition.

Similar evidence indicates that chalcopyrite is replacing sphalerite. Chalcopyrite may be observed replacing sphalerite along cleavage and along grain boundaries.

In the early days before selective flotation techniques were developed, the separation of sphalerite from the silver-rich galena was difficult. Because of these concentration difficulties the miners discarded much of the sphalerite from their broken ore. On the lower levels many veinlets filled principally with sphalerite were ignored by early miners. From old accounts of the upper workings, sphalerite was in small proportion, the principal sulfide filling the veins being galena; however, there is definitely more sphalerite than galena on the 1400-level.

Galena

Galena is very common and was evidently the principal base metal mined in the early days. Crystals of galena are euhedral where they fill open spaces, and are fresh under a thin coating of oxide. Galena was associated with ruby silver and freibergite on higher levels and contained silver in solid solution. As practically all the levels above the 800-level are now inaccessible, this relationship was not verified by the writer. Galena is locally replaced by sphalerite, chalcopyrite, and covellite. One polished section showed warping of the galena cleavage surfaces due to crystal growth pressure of a nearby euhedral quartz crystal.

Chalcopyrite

Chalcopyrite is the only primary copper mineral in the specimens studied and is more readily observable in its association with sphalerite, galena, and pyrite in the polished section than it is in the hand specimen. It is persistent throughout the vein but is more abundant in the lower levels. Lovering (5) has found free gold flakes in chalcopyrite from the district, and it is probable that the gold in the Stevens vein is associated with the chalcopyrite. Crystal faces of chalcopyrite are rare and it appears usually as small blebs of the massive mineral within other sulfides.

Covellite

Covellite was not observed in the ore until polished sections were studied. It replaces chalcopyrite and galena where they contact, and penetrates along the galena cleavage.

Silver

The silver content of the ore on lower levels is evident only from assay. Few samples of vein material contain more than twenty ounces per ton and perhaps that is why no silver bearing minerals were observed by the writer. All reports indicate that silver was the principal valuable metal near the surface and was associated with galena. Evidently silver values dropped off sharply with increased depth and resulted in the shutdown of the property around the turn of the century. This vertical zoning appears to be hypogene and not due to secondary enrichment processes.

Gold

Free gold has not been observed in the ore and its presence is known only by assay. It is probably in solid solution with the chalcopyrite or pyrite. Assays run from a trace to 0.2 ounces per ton for the few samples taken.

Other Minerals

Quartz and carbonates of calcium, magnesium, iron, and manganese form the principal gangue minerals. Manganiferous ankerite is perhaps most common and was later than sphalerite and galena. It fills vugs and small fractures in the ore. Dolomite and rhodochrosite are present as euhedral crystals in vugs. Siderite is less commonly seen and grades into ankerite. The hydrated iron oxides (brown) are very common and appear where the vein is more open. Sericite and clay minerals are universally distributed in the fractures and commonly permeate the wall rock where they have replaced the feldspars. Manganese oxides are typically exposed as a very late stain on the fracture walls. At the surface, fluorite fills small fractures and is associated with a minor amount of pyrite.

Paragenesis

The determination of the paragenetic sequence of the minerals was based on crustification structure found in open cavities and on replacement and fracture filling textures as observed in polished sections of the ore. The crustification was very useful since the minerals were deposited from solutions in open fissures. Early minerals were deposited in layers next to the wall rock while the later minerals were in layers toward the center of the opening. In the polished sections the later minerals commonly fill in around crystal faces of cleavage of earlier minerals or fill fractures in earlier minerals. Caries texture was relied on to some extent. The sequence of the minerals is given in chart form below.

```
             early                                late
Quartz       --------------------- - -
Pyrite       -------------------
Sphalerite               ------------------
Galena                         ----------------
Chalcopyrite                            ----------
Covellite                                    -------
Ankerite                                        -------
Dolomite                                        -------
Limonite                                        -------
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Wall Rock Alteration

Hydrothermal alteration is apparent underground and on surface exposures. The solutions permeated the wall on both sides of the channel fissures for a very definite distance, usually from 1/2 to 3 feet. Nearly every fault obvious at the surface shows hydrothermal alteration, although sulfide mineralization and vein quartz are sparce. Indeed, the altered rock at fault outcrops, weakened by the hydrothermal solutions, weathers out to form notches on the cliffs. No time relationship was established between hydrothermal solutions causing alteration and those depositing ore. The only conclusion that can be reached is that the altering solutions found their way through nearly every fault in the vicinity and some of these same faults are mineralized with sulfides.

Breakdown of the feldspars to clay and sericite is common. Chlorite and epidote predominate locally to give a green color to the wall rock. Silicification is not common, but where found it has completely changed the texture and composition of the invaded rock. Altered surface exposures have a typical yellow to orange-brown appearance that can be observed from considerable distance, and the differential erosion between altered and unaltered country rock allows structures to be seen readily. Two windows of the granite are exposed through gneiss near the ore body. Although the gneiss is but slightly altered, the granite has been considerably altered and colored by the ascending solutions. The areas have been termed "blowouts" by local mining men.

Localization of Ore

Controls for the localization of the ore at the Stevens mine are not completely understood. Lack of evidence and lack of understanding of the subtle processes are the obstacles to be overcome in exploration. However, at this property, certain obvious characteristics may be used as guides.

In a regional sense we can say that ore is localized in the Colorado mineral belt along the trend of the porphyry stocks, since a genetic relationship between the stocks and the metallization has long been recognized. The idea presented by B. S. Butler (2) regarding apically and medially truncated stocks appears to have particular significance.

Stocks from Boulder to Idaho Springs and those in the San Juan District appear to be truncated nearer the apex than those in the Montezuma region. A review of the principal mines indicates that metallization is more significant around the apically truncated stocks than in regions where stock outcrops are larger in extent. Position with respect to the source is important, and this relationship between the stocks and ore was understood by the early prospectors.

Reconnaissance work by the writer indicated that all significant metallization is limited to the granite masses. This probably is caused by favorable physical characteristics of the granite rather than by any pronounced chemical difference between it and the gneiss. Stress is relieved in the foliated rocks by slippage or by an occasional break of limited extent normal to the schistosity. Stress causes the granite to break due to its brittleness. Because of the great strength and massiveness of the granite the breaks are more apt to remain open, and as a result channelways for solutions are more available. Because small fractures may be quickly healed by deposition from solution, the larger faults are more likely to be open when valuable metals are precipitated. The more continuous fault structures are likely to penetrate deeper and are therefore more likely to tap ore solution reservoirs.

In the Stevens mine, attitudes of the fault structures are of primary importance. As previously mentioned, the principal productive vein strikes north-south. Because this attitude is associated in this area with greater openness of vein, it should be considered a useful guide, and other north-south veins in the immediate vicinity should be considered favorable. Ore is controlled locally in the Stevens vein by the width of open space. This width of fissure is related to changes in strike and dip of the vein. Ore directly above the 1400-level has been mined where the vein is convex toward the east. Movement on the fault would cause arching of the hanging wall across these areas and therefore the fissure would be wider. Intersections of fault structures would normally be more permeable and are considered favorable in this mine. However, intersections are not to be confused with splitting or horsetailing of a a structure, because this may be taken as a sign that the structure is becoming weaker and may not persist. Some ore is mined from the schistose rocks, particularly from structures that cross the foliation. When veins parallel the schistosity they generally do not persist for more than 50 feet and are not commercial.

Vertical zoning by the various ore minerals is apparent, and since silver value drops off very rapidly with increased depth, the favorability of exploration at higher elevations is obvious.

Faults accompanied by hydrothermal alteration might be considered more favorable than those not altered. However, there is no assurance that ore is associated with the alteration.

ECONOMIC POTENTIALITIES

Two very important facts effect the present economic outlook for the Stevens property. The most significant fact is that silver values have diminished with depth. The second is that the narrow fissure veins could be mined more economically by crude hand methods than they can be mined today by modern mechanical methods. High present-day labor costs forbid the hand sorting that was used by the early miners. Modern stoping methods require a minimum stoping width that would dilute the narrow-vein ore considerably, thus decreasing the tenor of the ore and increasing concentration costs.

Offsetting the above conditions is the fact that flotation of these complex base metal ores has been developed to a considerable extent and it is now possible to make separate lead, zinc, and copper concentrates. Whereas the early miners were penalized by the smelters for zinc content, it now can be mined and marketed. The present owners are recovering some of the dumps and stope fills which were rejected by the early miners because of the high sphalerite content. With further improvement in the road to the mine this recovery of dump and fill material promises to be more fruitful.

Continuation of the Stevens vein laterally and vertically is a significant consideration. Apparently the Stevens structure has definitely weakened both to the north and to the south. However the writer feels that the zone of weakness, of which the Stevens vein is a part, may well be continuous and that there is a distinct possibility of yet undiscovered veins along this zone with characteristics similar to the main Stevens. The forces causing faulting formed a system of faults striking north-east and it is logical that in the same rock the forces causing the Stevens vein would also cause other breaks to form similar in attitude and extent to the main Stevens structure. The Stevens vein probably continues in depth several hundred feet since it is continuous horizontally on the 1400-level for over 1500 feet. However, the silver values would be expected to decrease and the quantity of zinc and copper to increase. Lead value might be expected to decrease with increased depth. At present prices the total dollar value of the ore would probably decrease.

The mine is a challenge today and cannot be overlooked as a possible profitable venture in the future. Demand for base metals will undoubtedly increase, and transportation problems can be solved easier today than in the past. Further detailed geologic studies of the surface and underground workings may indicate further exploration by drilling to be desirable. No pillars were left in ore and stope fill once held up by back lagging has dropped down to make many levels inaccessible. It is possible that this old fill gradually could be removed at a profit and the upper levels reopened for exploration in that more favorable zone. This re-opening seems more practical than trying to enter the upper portals that open onto the cliffs, for they are in many cases covered by rock slides. Surface transportation up the cliffs is difficult, particularly in the winter.

Diamong drilling either from the surface or from under ground stations seems to be the logical procedure for exploration.

The problem of accessibility, high elevation, and related severe climate still persist to make any suface operation highly seasonal.

CONCLUSIONS

1. The ore of the Stevens mine was formed by fracture filling under moderate temperature and pressure conditions.
2. The Stevens vein has been explored both north and south on the 1400-level to what appears to be its termination, but there may be structures with similar characteristics farther to the east or southeast that could be located by diamond drilling.
3. The property may still be worked at a profit by opening the caved upper workings, with fill material paying for the operating costs.
4. Because of the greater silver value at higher elevations, it seems reasonable that exploration should be carried on from the upper levels.
5. A sampling program and further geologic work in the parts of the mine now inaccessible would aid materially in evaluating the property.
6. The operation appears marginal at present but changes in economic factors are likely to make further exploitation possible.

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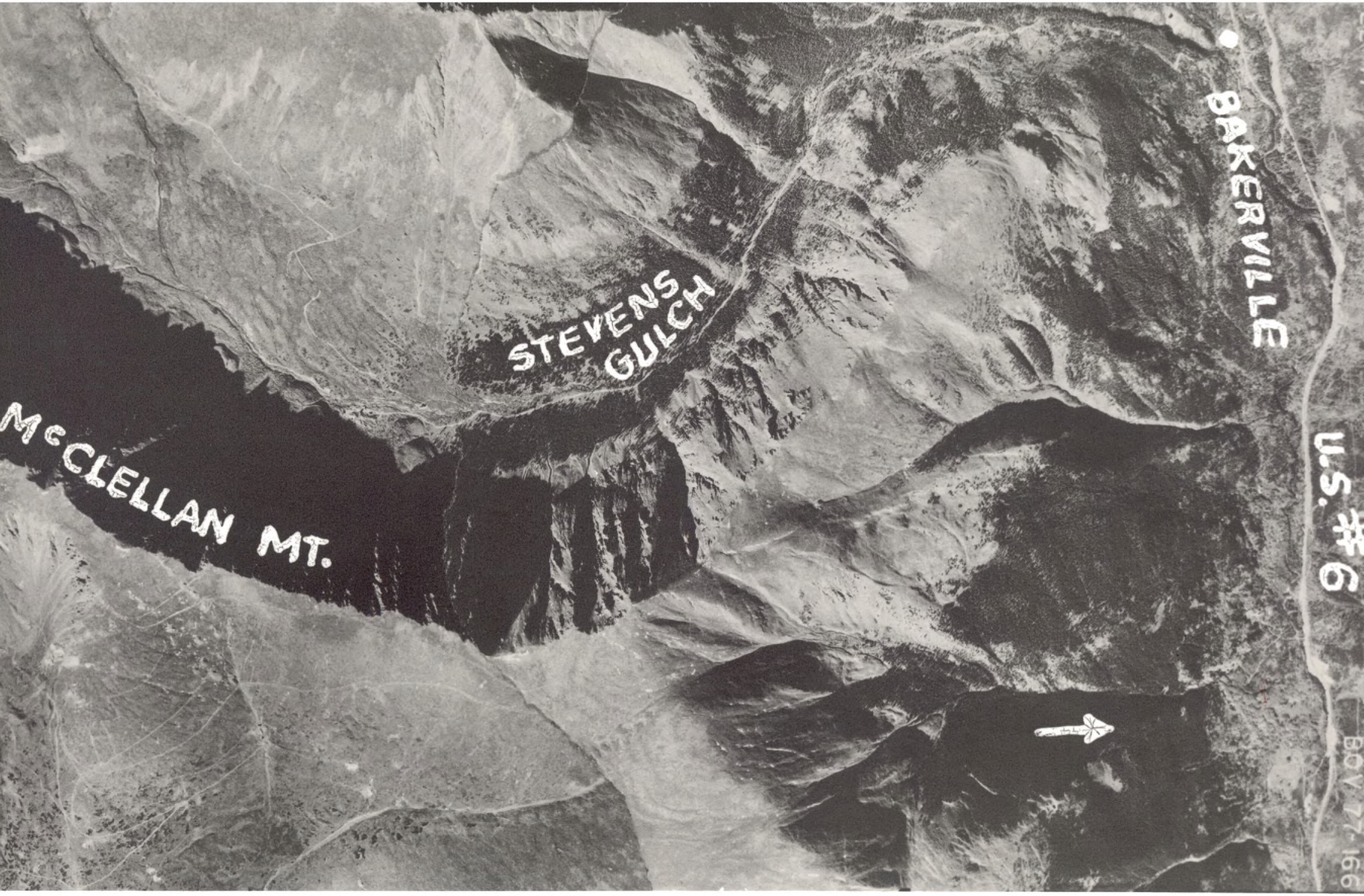
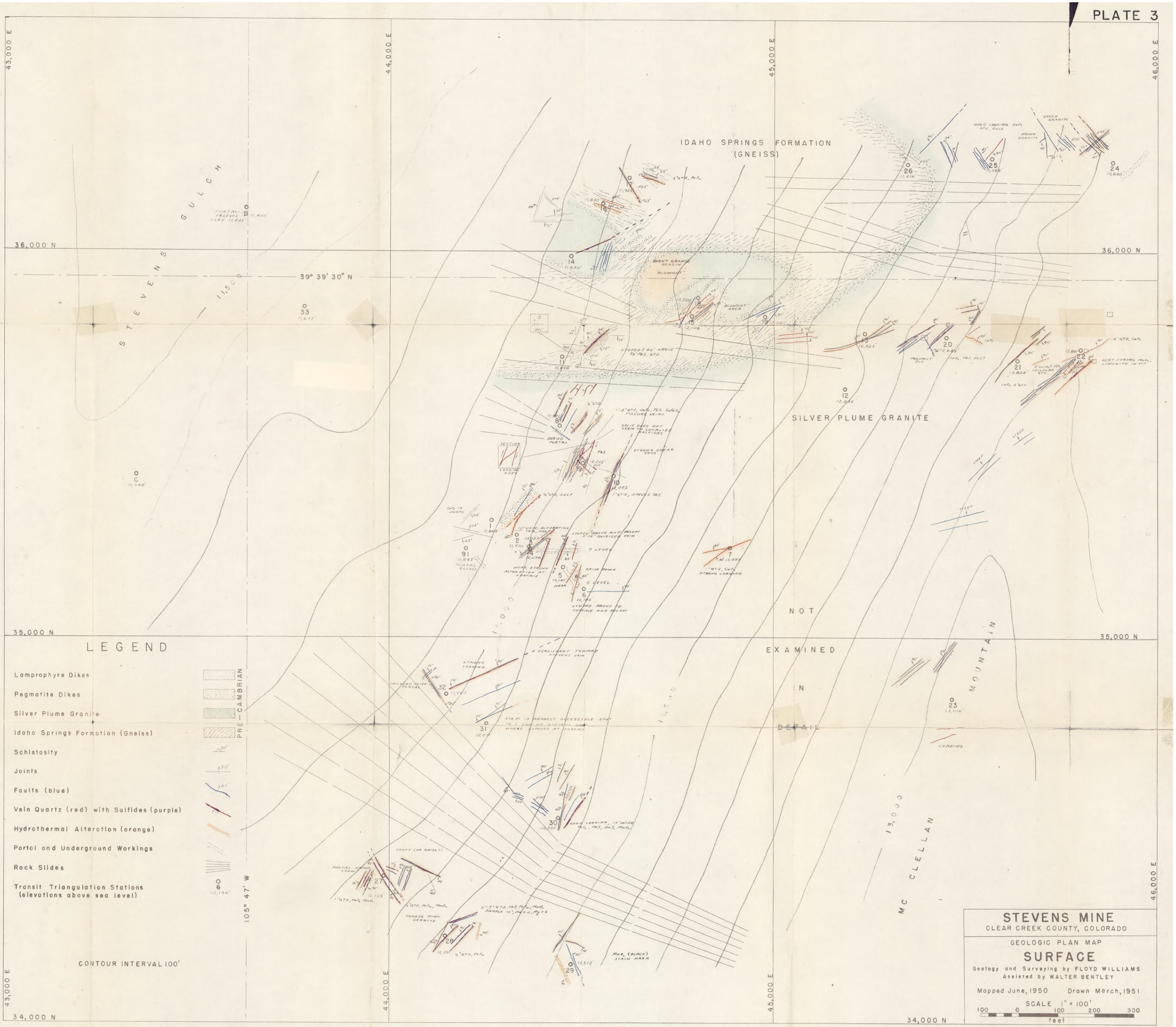


FLOYD WILLIAMS - THESIS
PLATE 2

PLATE 3



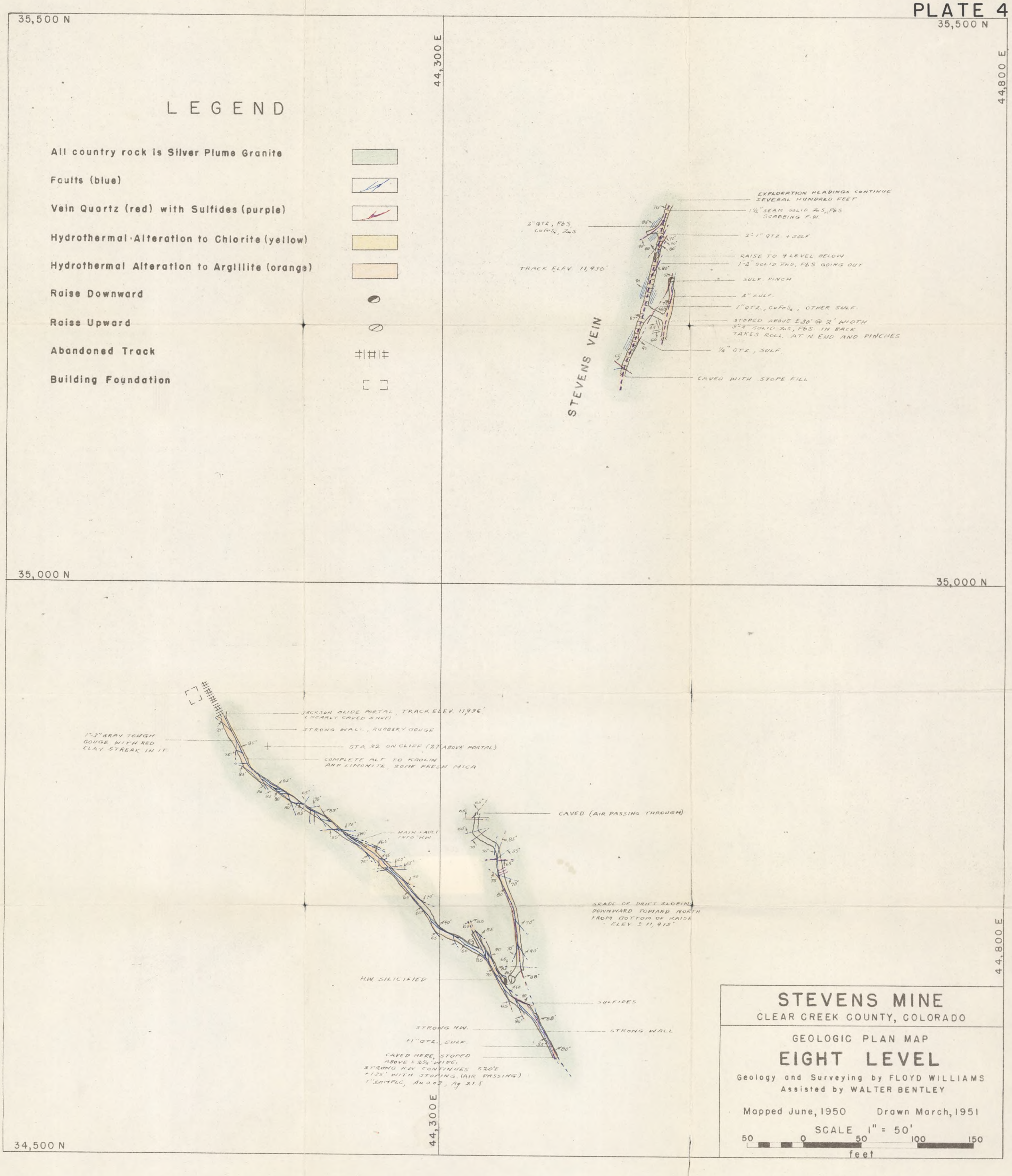
STEVENS MINE
CLEAR CREEK COUNTY, COLORADO

GEOLOGIC PLAN MAP
SURFACE
Geology and Surveying by FLOYD WILLIAMS
Assisted by WALTER BENTLEY

Mapped June, 1950 Drawn March, 1951

SCALE 1" = 100'
100 0 100 200 300
feet

PLATE 4



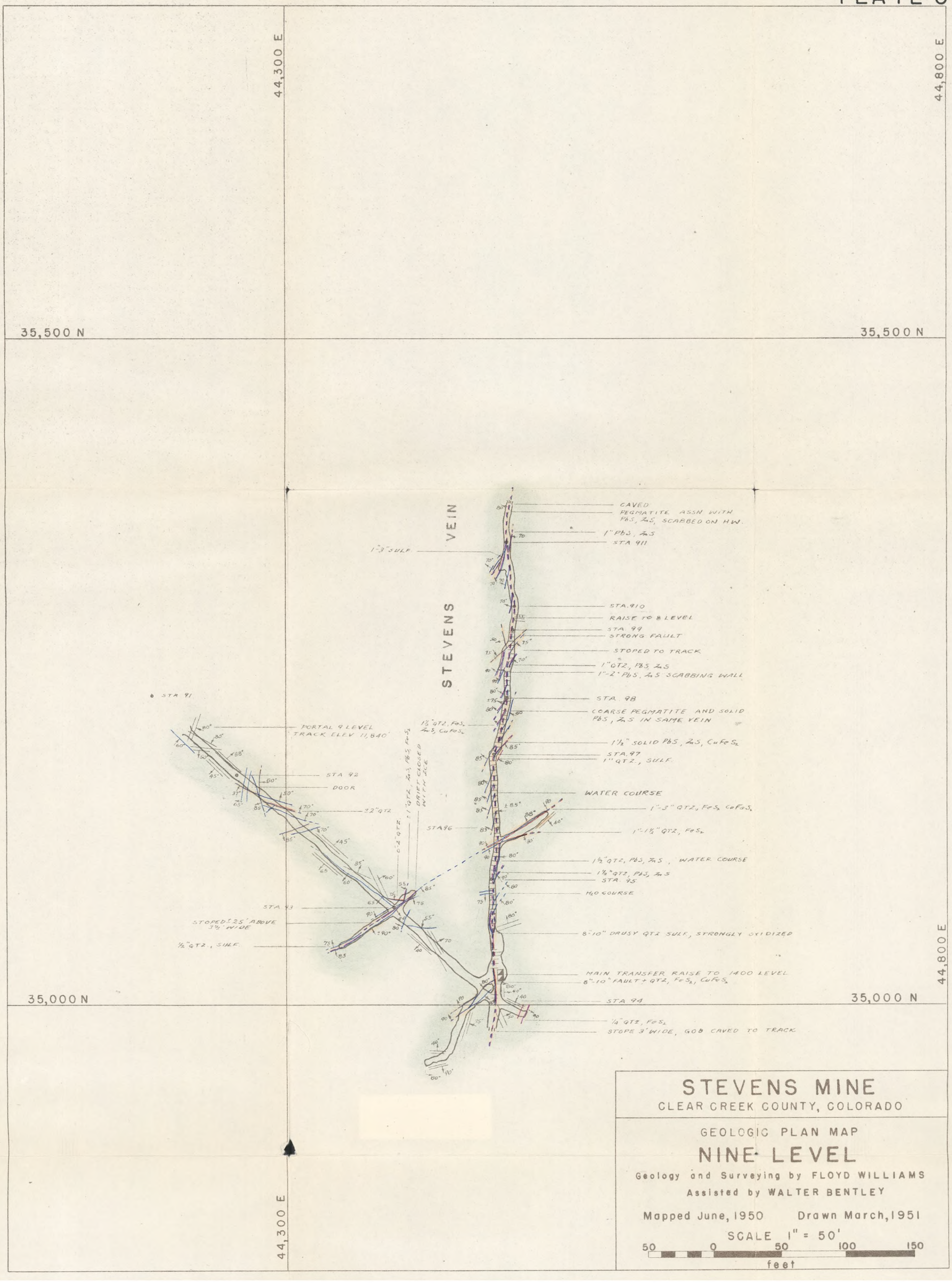
STEVENS MINE
CLEAR CREEK COUNTY, COLORADO

GEOLOGIC PLAN MAP
EIGHT LEVEL
Geology and Surveying by FLOYD WILLIAMS
Assisted by WALTER BENTLEY

Mapped June, 1950 Drawn March, 1951

SCALE 1" = 50'
50 0 50 100 150
feet

PLATE 5



STEVENS MINE

CLEAR CREEK COUNTY, COLORADO

GEOLOGIC PLAN MAP

NINE LEVEL

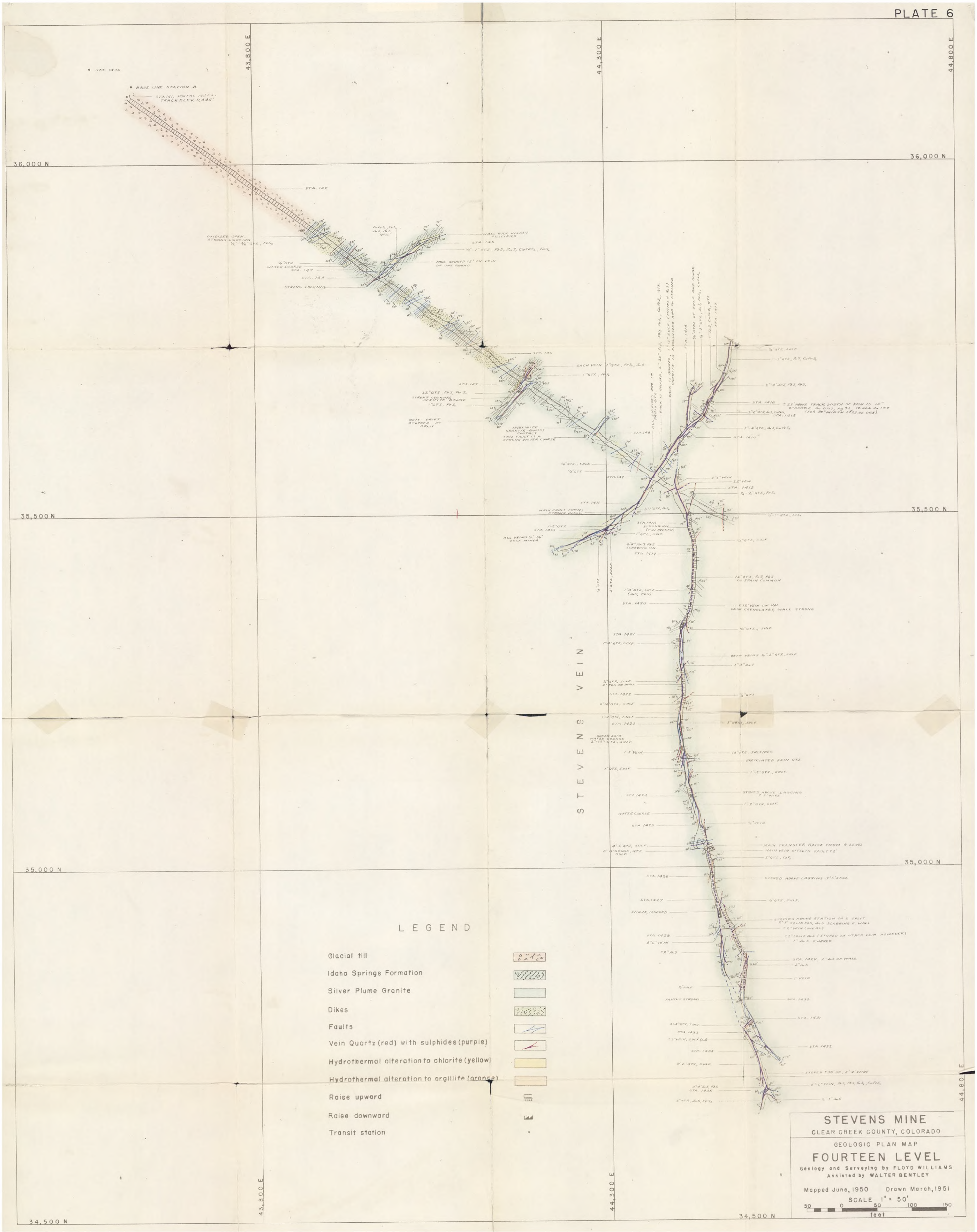
Geology and Surveying by FLOYD WILLIAMS
Assisted by WALTER BENTLEY

Mapped June, 1950 Drawn March, 1951

SCALE 1" = 50'

50 0 50 100 150
feet

PLATE 6



STEVENS MINE

CLEAR CREEK COUNTY, COLORADO

GEOLOGIC PLAN MAP

FOURTEEN LEVEL

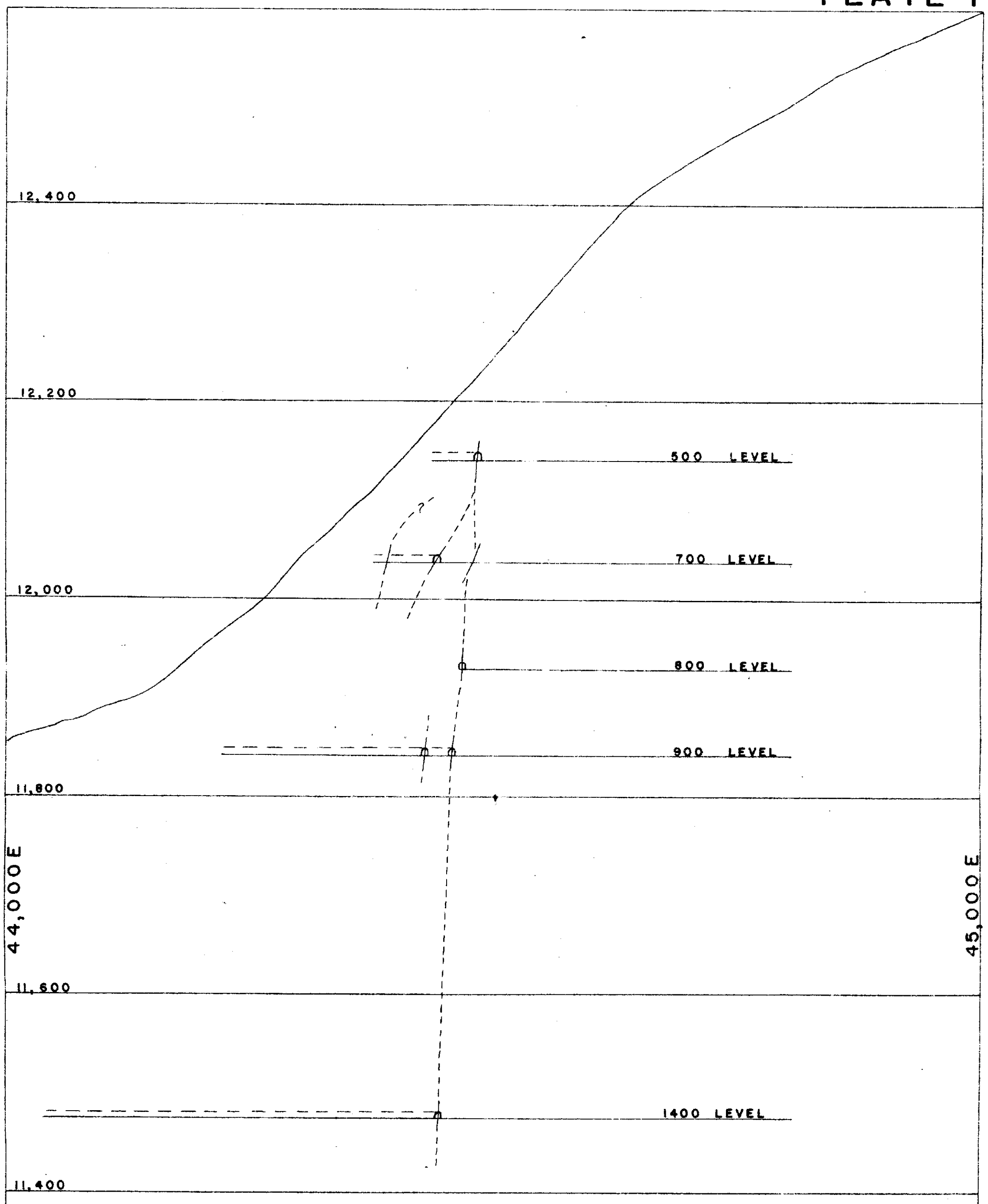
Geology and Surveying by FLOYD WILLIAMS
Assisted by WALTER BENTLEY

Mapped June, 1950 Drawn March, 1951

SCALE 1" = 50'

50 0 50 100 150
feet

PLATE 7



Looking North
Plane of Coordinate is
35,000
North

STEVENS MINE
CLEAR CREEK COUNTY, COLORADO
GEOLOGIC
CROSS SECTION

Geology and Surveying by FLOYD WILLIAMS
Assisted by WALTER BENTLEY

MAPPED JUNE, 1950 DRAWN MARCH, 1951

SCALE 1" = 100'
100 0 100 200 300
feet