THE GEOLOGY

of the

PRIDE OF THE WEST VEIN SYSTEM

SAN JUAN COUNTY, COLORADO

BY

Douglas Ralph Cook

A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Doctor of Science.

Signed: Douglas R. Cook
Douglas R. Cook

Golden, Colorado
Date: May 28th 1952

Approved: F. M. Van Tuyl
F. M. Van Tuyl

Truman H. Kuhn
Truman H. Kuhn

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Frontispiece

Surface buildings of the Pride of the West Mine

A B S T R A C T

The Pride of the West vein system is situated in Cunningham Gulch, near Silverton, Colorado. Four months was spent by the writer in geological field studies of the property and another four months in laboratory work. The field studies included surface and underground geologic mapping, together with a magnetometer survey of the vein system. Laboratory work included petrographic and mineralographic examinations of rock and ore specimens.

The Pride of the West vein system constitutes one of the southern veins and fissures of the Silverton volcanic center. This system is a vein-filled fissure zone linked by numerous small fractures. It dips steeply to the southwest and strikes 19 degrees to the northwest. Although the fissure system has been traced for more than 4000 feet along its strike, mineralization has been found to be present for only a little over half this distance. In depth, the mineralization has been found to be continuous for at least 900 feet.

Since 1880 production of ore from the Pride of the West Mine has been intermittent, but it is estimated that ore to the value of $2,500,000 has been produced since that time. The Osceola Mine, which lies to the north of the Pride of the West Mine on the same vein system, has produced a smaller quantity of ore. The chief metal produced from the vein system is lead, followed in order by zinc, silver, and gold.

Rocks in the vicinity of the vein system consist of pre-Cambrian schist, overlain by a nearly horizontal complex of Tertiary lava flows and pyroclastics. Isolated masses of Mississippian limestone occur, engulfed in the lava flows and pyroclastics. It is thought that these masses originate through the undercutting action of the lavas and pyroclastics when they flowed over or around the limestone outcrops. The source of the limestone masses is believed to be several miles to the south of their present position and at a considerably higher elevation.

Replacement was here the dominant process of vein formation, although open-space filling was often observed. The mineralization falls within the epithermal-mesothermal temperature range and produced massive sulphides. The sulphide ore minerals were deposited in a relatively short time and were preceded and followed by the precipitation of extensive amounts of quartz and lesser amounts of carbonate. The order of sulphide deposition is well defined and is pyrite, sphalerite, galena, chalcopyrite and tetrahedrite. Hydrothermal alteration was weak and resulted in occasional development of chlorite, sericite, and clays. A definite propylitic alteration is associated with the most northerly part of the vein system. Supergene alteration is practically absent because of the excessive rate of erosion.

The major geologic features controlling the mineralization include lithology, jointing and rock contacts. The andesitic-type flow breccia appears to be lithologically the most favorable host rock, with latite flow breccia next in importance. This lithic favorability is probably determined by the fracture characteristics of the rocks. Minor geologic features controlling mineralization are gougy slip planes and changes in strike and dip of the vein.

INTRODUCTION

Statement of Problem

The purpose of the geologic investigation at the Pride of the West Mine and associated mining properties was to determine, if possible, the geologic features controlling the localization of the mineralization in the Pride of the West vein system.

In order to determine the above controls, the following procedures were undertaken:

1. Detailed geologic maps of the underground workings of the mines situated on the Pride of the West vein system were prepared.

2. Detailed and reconnaisance geologic mapping of the surface was undertaken in the vicinity of the Pride of the West vein system.

3. Magnetometer and geochemical traverses of the vein system were carried out.

4. Detailed field and laboratory studies of the mineralogy and petrography of the area were made.

Location and Access

The Pride of the West Mine is located in the Animas mining district, approximately five miles due east of Silverton, San Juan County, Colorado (Figure 1, page 6). This mine, together with the Osceola, Little Fanny, and Green Mountain Mines, is situated on the east side of Cunningham Gulch and on the west flank of Green Mountain (Plate G).

Ground covered by these mines and the surrounding area will be termed the "Pride Area" for the purpose of this thesis.

The Pride Area is approximately two and a half miles from the small town of Howardsville, which is situated at the confluence of the Animas River and Cunningham Creek, a northerly flowing tributary. The mines in the Pride Area are accessible from Howardsville by a moderately steep graveled road, which is kept open throughout the year by the County, except for short periods when severe rock and snow slides occur. From Howardsville access to Silverton is by way of Highway 110; and from Silverton both Ouray and Durango can be reached by Highway 550 (Figure 1, page 6).

Geologic Mapping Previously Undertaken

The first geologic mapping in the San Juan Mountains was done by members of the Hayden Survey on a scale of four miles to the inch and published during the period 1874 to 1877. This survey was followed by

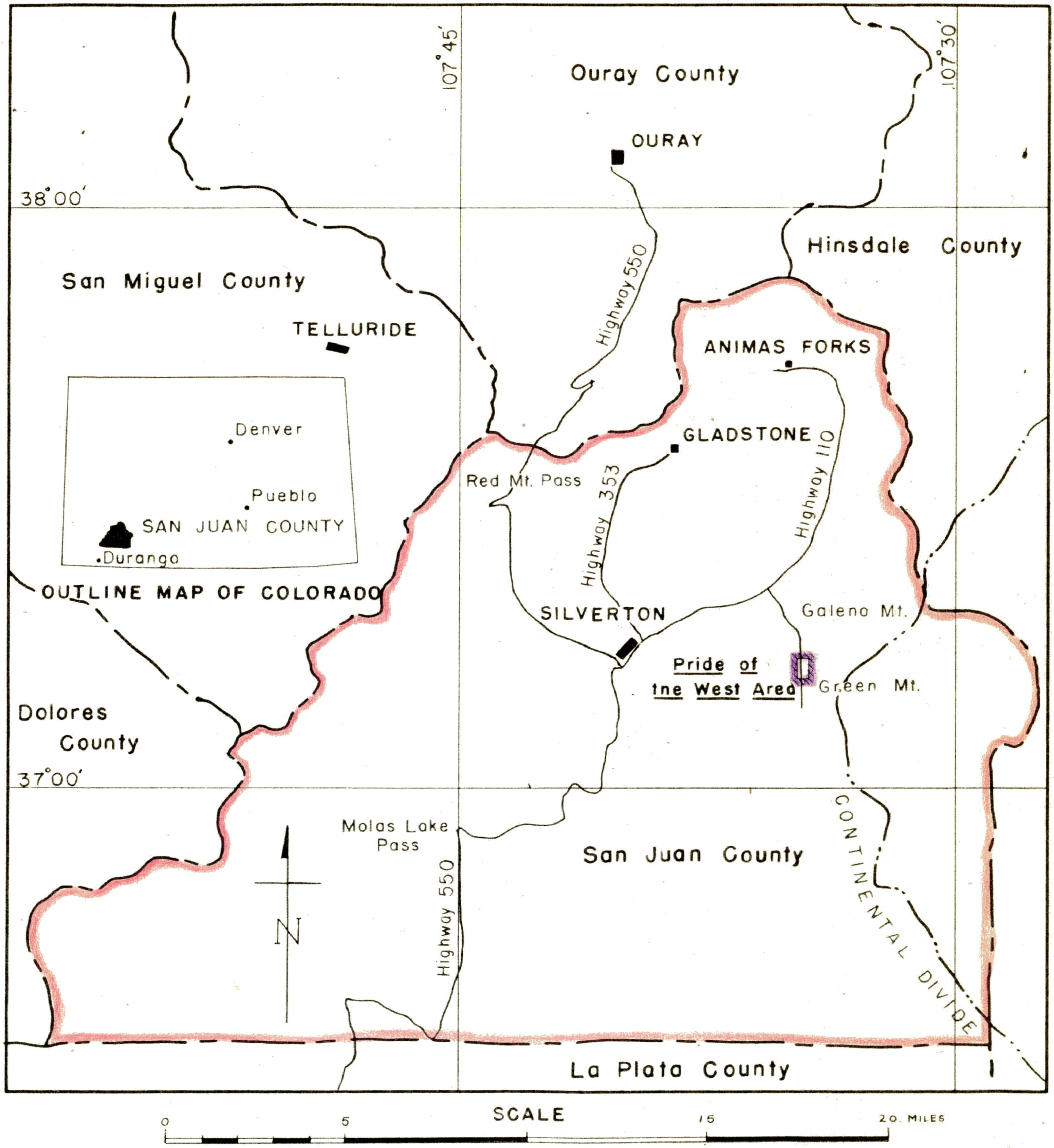


FIG. I, OUTLINE MAP OF SAN JUAN COUNTY SHOWING THE LOCATION OF THE PRIDE OF THE WEST AREA more detailed geologic mapping of the western part of the San Juan Mountains prepared by W. Cross and his associates and published by the United States Geological Survey. Included in this latter work is a United States Geological Survey Atlas of the Silverton Quadrangle, published in 1905 at a scale of one mile to the inch. This is the only available map that shows the geology surrounding the Pride of the West Mine, although a detailed map of the Arrastre Basin directly to the west of the mine area has been published by Varnes (1948).

The Pride of the West Mine was first described by Ransome (1901, pp. 169-170) in the economic report of the Silverton Quadrangle of 1901.

Vein systems of the Arrastre Basin, directly to the west of the Pride Mine Area, were discussed by Burbank (1933, pp. 135-214) in 1933. He also discussed at some length, in the same paper, the regional geologic structure of the Silverton and Telluride quadrangles.

Brinker (1940) undertook a private examination of the Pride of the West and Green Mountain Mines for the Denver Equipment Company. Also during 1940, H. S. Sanderson and A. L. Kroeger made a joint map of the Pride of the West Mine and adjacent properties. This mine map was found to be reasonably accurate by the writer and was used as a base map for underground geologic mapping.

In 1950 the Pride of the West and associated mines were described by King and Allsman (1950, pp. 71-74) in a Bureau of Mines Information Circular.

Hagen (1951) completed a thesis problem at the Green Mountain Mine. As the Green Mountain Mine is not directly related to the Pride of the West vein system, only Hagen's surface maps of this mine have been incorporated with the Pride of the West maps.

Field and Laboratory Studies

Field work was carried on for four months at the Pride of the West Mine during the summers of 1950 and 1951. Approximately half of this time was spent in mapping the underground geology of the Pride of the West and Osceola Mines. Surface work occupied the remainder of the time, which was divided among a triangulation survey, geologic plane table mapping, and magnetometer and geochemical traverses.

Time spent on petrographic and mineralographic examination of thin sections and ores at the Colorado School of Mines averaged about four months.

Acknowledgements

The writer wishes to acknowledge with thanks, the assistance given to him by the officials of the Great Eastern Mining Corporation and especially to W. H. Chase, General Manager; Mr. C. W. Flemming, Foreman; and to Mr. R. Heilman, General Maintenance. He also is indebted to the staff of the Geology Department of the Colorado School of Mines, and in particular to Dr. Truman H. Kuhn, Dr. Robert H. Carpenter, Kermit S. Herness and George D. Fraser. For assistance in the field he is indebted to Margaret P. Cook and John C. Hagen.

GEOGRAPHY

Physiographic Character of the San Juan Mountains

The San Juan Mountains constitute an area of 3,000 square miles on the western side of the San Juan Volcanic Area, which is a deeply scored volcanic plateau situated in southwestern Colorado, and adjacent parts of New Mexico (Figure 2, page 10).

The San Juan Mountains form a group, rather than a chain of high, rugged mountains. These mountains are an outlying group of the Southern Rocky Mountain region, which extends from Central New Mexico through Colorado to Southern Wyoming.

A greater part of the mountain area consists of high and rugged peaks, with only about one percent of the area having an elevation of less than 7,000 feet and at least fourteen peaks having an elevation in excess of 14,000 feet. Foothills from a conspicuous feature of the San Juan physiography on the south and east flanks only: elsewhere, they rise with comparative abruptness from the adjacent plateaus and lowlands. Canyons that radiate from the mountains are a strikingly characteristic feature and greatly facilitate travel in the mountains.

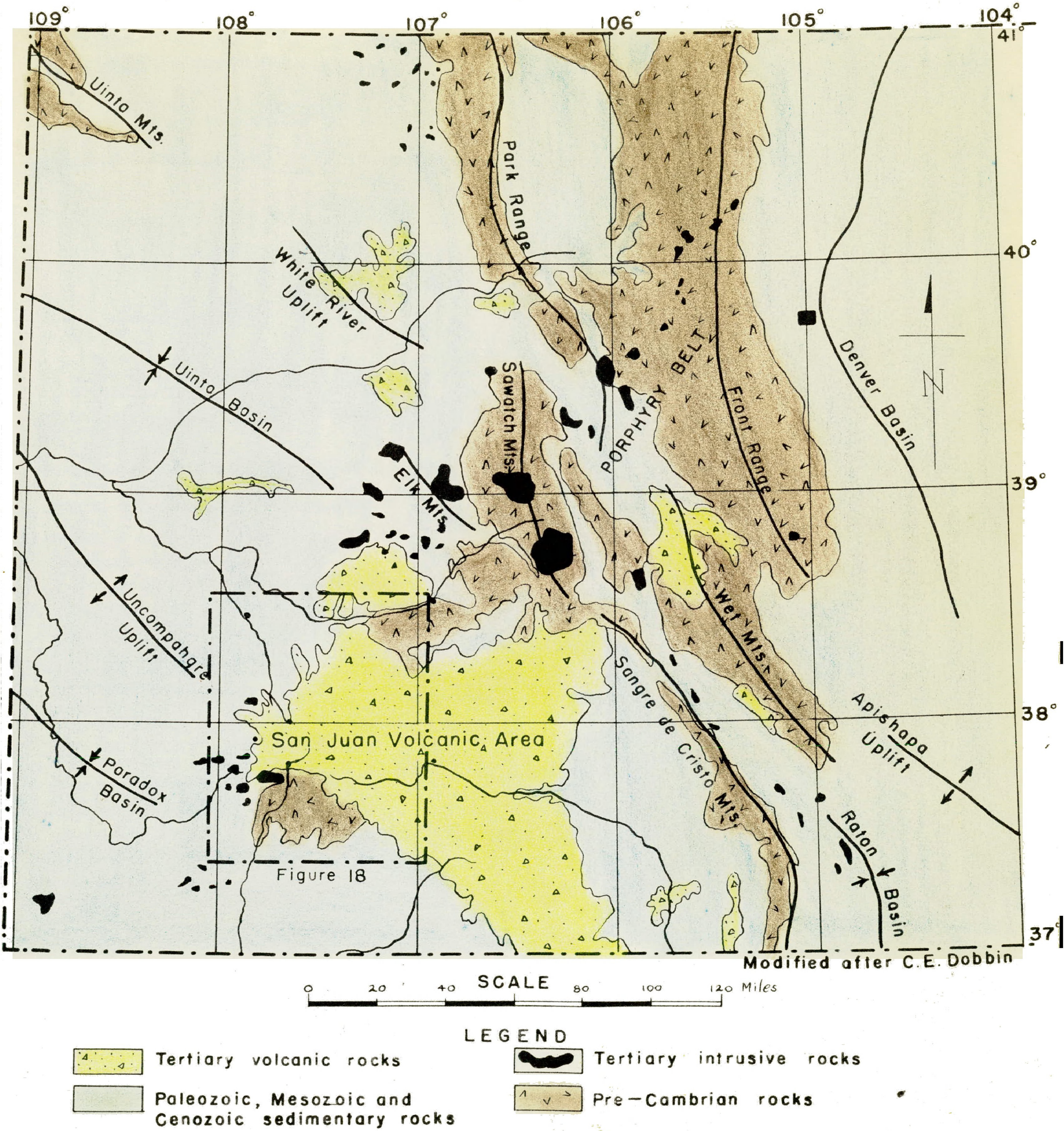


FIG. 2, SKETCH MAP OF WESTERN AND CENTRAL COLORADO SHOWING THE DOMINANT STRUCTURAL FEATURES

Topographic Character of the Pride of the West Area

The Pride of the West Area is located in Cunningham Gulch, a deep canyon with precipitous walls through which flows the largest tributary of the Animas River above Silverton. The Gulch is bounded on the west by King Solomon Mountain and on the east by Galena and Green Mountains, all of which exceed 13,000 feet in elevation. Pride of the West, Osceola, and Green Mountain Mines, all have first-level adit elevations ranging between 10,300 and 10,400 feet, while the Little Fanny Mine adit is at approximately 11,600 feet.

Drainage of the San Juan Mountains

Part of the San Juan Mountains are traversed by the Continental Divide. The Divide, which cuts the northeast corner of the mountains, travels in a sinuous manner to the center of the group and then turns toward the south.

The San Juan Mountains supply water to two major river systems. Water from the area east and south of the Continental Divide flows into the Rio Grande and thence into the Gulf of Mexico; water from the area north and west of the Divide flows into many of the headwater branches of the Colorado River, which in turn flows into the Gulf of California.

Tributaries originating in the San Juan Mountains show a radial pattern from the center of the region to the outside. Larger valleys commonly are "U" shaped, and the master streams are in general working at a depth of 5,000 to 6,000 feet below the adjacent summits. The Animas River, the largest river in the San Juan Mountains, flows in a general southerly direction through the center of the western portion and finally joins the San Juan River at Farmington, New Mexico.

Climate of the San Juan Mountains

Precipitation varies greatly; it ranges from 30 to 50 inches in the heart of the mountains, from 10 to 20 inches in the peripheral belt of lowlands, and below 10 inches in the adjacent arid plateau country. Snowfall averages between 20 and 30 feet in the higher mountains. The last heavy snowfall usually occurs in early June, and the first winter storm occurs about the middle of October. Normally the trails are snowbound from the last of October until the last of May, but access through the deeper mountain valleys can be had throughout the entire year, except at times of severe avalanches.

It has been the writer's experience that, during the months of July and August, intermittent showers and thunderstorms can be expected between ten o'clock in the morning and five o'clock in the evening.

Owing to the influence of the mountains, the weather conditions are much more uniform than those on the plateau, and severe heat and cold waves are comparatively rare. Because of the high altitude, a sharp contrast exists between day and night temperatures, and an adequate supply of blankets should be taken by anyone contemplating camping out in the mountains. The temperature in January varies from 13 to 20 degrees, and averages about 55 degrees in July and August.

Flora of the San Juan Mountains

Vegetation is directly related to altitude and rainfall. In the peripheral plains, where climatic conditions are semi-arid, there are abundant grasses and sagebrush and other low shrubs, but few trees. Where areas are mountainous, the timber growth covers the entire slopes up to timber line, which ranges between 11,000 and 12,000 feet. Above timber line the slopes are covered with grasses and alpine plants; however, many of the slopes at this altitude are so precipitous that erosion is extremely rapid and a soil cover is unable to form.

Most of the San Juan Mountains are in National Forests. The Pride of the West Area is situated along the northern border of the San Juan National Forest.

Human Activities in the San Juan Mountains

Population

The San Juan Mountain area is sparsely settled, the population being concentrated in the valleys near the borders of the mountains and in the mining towns within the mountains. Silverton, the largest mountain town, has a population of well over a thousand, and both Ouray and Telluride have populations of just under a thousand. Durango, south of the mountains, and Montrose north of the mountains, have considerably larger populations.

Industries

Chief industries are stock raising, lumbering and mining. Tourist trade offers great potentialities for the region because of the spectacular alpine scenery, but the lack of good accommodations for tourists has prevented its development. The chief industry until about 1900 was mining, but now this industry has declined. In the last few years there has been a striking increase in mining activity, and it is probable that the increasing world shortage of base metals will produce a revival of mining in this region. The mining industry is favored by the abundance of local timber for mine workings.

Transportation

Originally railways served most of the mountainous area, connecting the local mining centers with the plains area. Since the decline of the mining industry, all of the mountain railways have been discontinued. A few good automobile roads traverse the mountains. These are passable for the entire year, except in times of severe avalanches. There are also numerous small trails, used by miners and prospectors, but these are impassable in the higher mountains from October until May.

G E O M O R P H O L O G Y

Quaternary history of the San Juan Mountains has been worked out in detail by Atwood and Mather (1932, pp. 27-32) and the following discussion represents a partial summary of their work. Because this history is extremely complex in all its details, only an outline will be presented here.

The first important event in the physiographic history of the present San Juan Mountains was the formation in late Pliocene time of the San Juan peneplane. Deformation of the peneplane surface into a large dome antedated the development of practically all existing topographic features of the region. Warping of the center of this surface to about three thousand feet above the periphery probably is responsible for the present radial drainage of the mountains. The Animas River departs from this radial pattern since its course partly retained its ancestral character and was not affected by the slow warping of the peneplane. Deformation of the San Juan peneplane according to Atwood and Mather (1932, pp. 21-26) marked the transition from Pliocene to Pleistocene time.

Erosion that followed the deformation of the San Juan peneplane has been termed the Florida cycle. Many of the present deep canyons show the effects of this erosion cycle by an outer troughlike form with comparatively gentle slopes. It is possible that the change in slope of the sides of Cunningham Gulch about a thousand feet above its base is related to this erosion cycle. Master streams were brought to grade during this same cycle, and the Florida cycle is now recognized by benches or shoulders high on the existing walls. The Florida cycle was interrupted by a period of glaciation termed the Cerro stage, and it is probable that this was the greatest glacial stage in the San Juan Mountains. A new domal uplift, which raised the center approximately 2,000 feet, terminated the Florida cycle and caused a vast rejuvenation of the existing rivers.

In the center of the San Juan Mountains, erosion formed canyons hundreds and even thousands of feet deep by a cycle of erosion termed the Canyon cycle. After the beginning of the Canyon cycle, the region was again subjected to a glacial epoch termed the Durango glacial stage. The effect of this glaciation was similar to that of the Cerro stage, with the characteristic features of Alpine glaciation being formed. The Durango stage was followed by another glacial stage termed the Wisconsin, and this is the last evidence of glaciation in the San Juan Mountains. Much of the remarkable scenery today is a result of this Wisconsin glaciation. There were probably only small amounts of ice-free land at the time of the Wisconsin maximum in the San Juan Mountains. However, this glaciation was all in the form of valley or alpine ice and all the glaciers terminated in the mountain's foothill zone. The largest valley glacier, the Animas, with an area of 400 square miles, probably covered two-thirds of the Silverton Quadrangle. With few exceptions, the main catchment basins for the Wisconsin ice originated at elevations of 12,000 to 13,000 feet. The main results of this glaciation are briefly summarized below:

1. Cirques were developed, especially in the Silverton Quadrangle, where practically every peak is surrounded by deep cirques.

2. Deeply scoured basins and the "U" shaped profiles for practically all valleys in the mountains were formed.

3. A large number of lakes resulted from the damming of streams.

4. Fluvioglacial deposits of considerable magnitude were laid down in the valley bottoms.

Cunningham Gulch appears to have been perceptibly deepened by ice, the rock walls are scraped clean, intertributary spurs have been beveled, and most of the tributaries now occupy hanging valleys, (Figure 3, page 19).

Following Wisconsin glaciation, topographic conditions, together with the prevailing lithologies, were favorable for the development of landslide phenomena. The San Juan Mountains may be designated as one of the classic areas in the United States for the development of landslide phenomena, which includes soil creep, earth slides, mud flows, talus slumps, rock slides, and rock falls. In the center of the mountains these features are especially prominent on the steep walls of the cirques and in the steep-walled valleys. Torrential wash from spring thaws and other sources are a common feature in the higher mountains.

In conclusion, it can be stated that erosion and uplift acting in Quaternary time has resulted in a highly dissected dome modified by features effected by intense alpine glaciation. In the relatively short time since the Wisconsin ice retreated from the mountains, only slight changes have resulted in the area. Streams are actively engaged in deepening their channels and in only a few cases have canyons been formed since the Wisconsin ice retreated. The Canyon cycle is thus still in its youthful stage, having been interrupted by both the Durango and Wisconsin glaciation.

Figure 3.--View looking north down Cunningham Gulch from the Pride of the West Mine. Note the "U" shaped profile of the valley which was formed by glacial erosion.

G E O L O G Y

Regional geologic history, stratigraphy, petrography and petrology, structure and economic geology are discussed under the general heading of geology.

Regional Geologic History

For ease of discussion, the geologic history of the San Juan Mountains has been divided into pre-Cambrian, early Paleozoic, late Paleozoic, Mesozoic and Cenozoic.

Pre-Cambrian

The pre-Cambrian rocks have a wide distribution in the San Juan Mountains, but the only large masses outcropping continuously occur in the southwest and along the northern edge of the mountains. The rugged Needle Mountains situated in the southwest of Silverton are composed entirely of these rocks. The pre-Cambrian rocks are composed of a group of complex igneous and metamorphosed rocks that have been tentatively correlated with the pre-Cambrian rocks of the Front Range.

The oldest rocks include a series of highly metamorphosed crystalline schists and gneisses. These occur in the vicinity of the Pride of the West Mine and will be discussed later in more detail. They are tentatively correlated with the Idaho Springs formation of the Front Range. Injected into this series of rocks was a series of acid intrusives that probably correlate with the Pikes Peak batholith and associated intrusives. Later, a series of basic rocks, including the Irvine Greenstone, were intruded into the earlier schists and gneisses. These intrusive rocks are related in age to the complex of basic igneous rocks in the Front Range. After this intrusion, the Vellecito conglomerate and the Uncompahgre formation, which, together are known as the Needle Mountain group, were laid down. The Vellecito conglomerate and Uncompahgre formation consist of a series of quartzites, slates, schists and conglomerates of an obvious sedimentary origin and have been tentatively correlated with the Coal Creek quartzite of the Front Range. The youngest pre-Cambrian rocks consist of another series of acid intrusives and are correlated with the Cripple Creek granite and Silver Plume granite.

Early Paleozoic

The history of the San Juan Mountains during the early Paleozoic is similar to that of the Front Range, and the relationship of overlaps suggests an intermittent but progressive sinking of the high area in the San Juan region. This sinking, probably resulted in the extension of the Paleo-Cordillerean trough into Western Colorado.

Late Paleozoic

Late Paleozoic time was characterized by the development in Southwestern Colorado of an elevated region with a general northwesterly trend, termed the San Luis-Uncompahgre geanticline. This geanticline probably had a similar development to the Ancestral Rockies or Colorado geanticline of the Front Range which was formed in Mississippian and Pennsylvanian times. Evidence from sediments desposited at this time, however, does not indicate as great an uplist in the San Luis-Uncompahgre geanticline as in the Colorado geanticline.

Mesozoic

The Mesozoic era is represented by prolonged accumulation of over 9,000 feet of sediments which were deposited around the margins of the San Juan Mountains. However, there is no definite proof that these sediments were deposited over the entire region, hence it is possible that the San Juan Mountains remained a positive area during this time. At the close of the Upper Jurassic, moderate crustal deformation occurred in the northeastern part of the San Juan Mountains. The presence of volcanic debris in the Upper Cretaceous McDermott formation, indicates that there was volcanic activity in the area north of Durango. This represents the first important evidence of volcanic activity in this area since the pre-Cambrian and gives a forewarning of the tremendous volcanic activity which later occurred during the Tertiary period.

Cenozoic

Following Mesozoic sedimentation, there was a period of peneplanation which stripped thick Mesozoic and Paleozoic sediments from the eastern and possibly from the central part of the San Juan Mountains. After this peneplanation had taken place there began the formation of the so-called ancestral San Juan Mountains. The mountain building was achieved through regional uplift and domal deformation of the entire San Juan province, with a differential vertical movement in excess of 10,000 feet. This orogenic movement probably correlates with the Laramide revolution in the Southern Rocky Mountains. Early in the stage of crustal movement there began extensive volcanic outpourings which continued with interruptions into the Pleistocene or possibly even more recent times. A great flat volcanic dome over 100 miles across and probably several miles high was produced by this volcanic activity. This dome has subsequently been faulted, slightly tilted, gently folded, and deeply incised by erosion to form the present San Juan Mountains.

Tertiary

In order that the volcanic rocks that occur in the Pride Area may be viewed in perspective, a brief review of the Tertiary history of the San Juan Mountains is now presented.

The first formation that has been definitely assigned to the Tertiary in the Western San Juan Mountains is the Ridgway tillite. This formation consists of a characteristic boulder and pebble till, and the deposits indicate at least two invasions of ice, probably of the piedmont type, which occurred around the periphery of the uplift. The occurrences of Ridgway tillite in the San Juan Mountains have been correlated with other deposits of till in the San Juan Volcanic area, all of which are probably early Eocene in age. This glaciation is probably an incident in the long period of erosion during early Tertiary times.

Rapid erosion of upland surfaces produced vast piedmont alluvial fans in the lowlands. According to Atwood and Mather (1932, pp. 17-18), these deposits appear to be of the bolson type similar to those now accumulating in Southwestern U.S.A. These piedmont alluvial fan deposits accumulated to depths of over 2,000 feet and have been termed the Telluride conglomerate.

Deposition of the Telluride conglomerate was followed by violent outpourings of andesitic tuff breccias termed the San Juan tuff. This tuff represents the first volcanism in the region, with the exception of brief late Cretaceous volcanic activity described above in the McDermott formation. Extensive erosion followed deposition of the San Juan tuff and a rugged topography was carved into the debris.

This period of erosion was followed by extrusion of a series of well-defined flows and breccias termed the Silverton Volcanic series. The most important rock types in the series are: latite, rhyolite, pyroxene andesite, and a series of pyroclastics. The majority of the rocks in the Pride of the West Area belong to this volcanic series and they are discussed in full detail under that heading.

After extrusion of the Silverton series there was a period of erosion followed by another period of violent volcanic activity. A great complex of volcanic formations ranging in composition from andesite to rhyolite were extruded during this time. This series, perhaps the thickest of the Tertiary volcanic deposits in the area, is called the Potosi series. At the culmination of this activity the San Juan region was probably a broad plateau standing substantially higher than its surroundings.

Again there followed a great period of erosion in which very deep canyons were cut and before any degree of maturity was reached, another series of lavas and pyroclastics was extruded. This new series, termed the Fisher Volcanic series, resembled the Silverton and Potosi series, with the chief flows having the composition between a latite and an andesite.

Another period of extensive erosion occurred after formation of the Fisher Volcanic series, and the volcanic plateau was carved into a great mountain range, termed the late Tertiary San Juan Mountains. In Pliocene time this mountain range was reduced to a graded surface of low relief, and Atwood and Mather (1932, p. 20) believe that this surface is now represented by the summit of the present mountains. To this summit peneplane, Atwood and Mather (1932, p. 21) gave the name, San Juan peneplane. The peneplaned surface was subsequently raised two or three thousand feet and can be correlated with a general uplift in Southwestern United States. There is a possibility that the San Juan peneplane also can be correlated with the Rocky Mountain peneplane of the Front Range.

Atwood and Mather (1932, p. 27) consider that the deformation of the San Juan peneplane marks the transition from Tertiary to Quaternary. This deformation was accompanied by the last volcanic episode of any significance in the San Juan region when the Hinsdale volcanic series were extruded. During this volcanic activity structural deformation of the region continued together with great lava floods of basalt and rhyolite, which, in the San Juan Mountains, formed low domes, but which, in New Mexico and Southeastern San Juan Volcanic area, formed vast lava plains hundreds of miles across.

Since the Hinsdale volcanics were laid down, the region has been subjected to almost constant crustal warpings. In general, there have been two major cycles of erosion since this period; the earliest of these is the Florida cycle, and the second is the Canyon cycle, which is still in the youthful stage. (See pages 16-19)

Stratigraphy

Apart from the Ouray limestone there are no sedimentary rocks in the Pride Area.

Because the Ouray limestone occurs as isolated bodies of rock engulfed in Tertiary lava flows and pyroclastics the origin of the limestone will be treated as a petrologic problem and will be discussed under petrography and petrology.

Petrography and Petrology

Rocks in the Pride Area range in age from pre-Cambrian to Tertiary. The pre-Cambrian rocks are represented by Archean schists and gneisses, the oldest rock type in the San Juan Mountains. The Paleozoic is represented by the Ouray limestone of Upper Devonian to Lower Pennsylvanian in age.

The Tertiary rocks are represented by the Silverton Volcanic series, which has been divided as follows by Cross and Howe (1905, pp. 7-8):

Pyroxene Andesite - - - - - - -	100-3,000 feet
Unconformity	
Burns Latite - - - - - - - - - - - -	1,200 feet
Unconformity	
Eureka Rhyolite - - - - - - - - - - -	1,800 feet
Unconformity	
Picayune Andesite - - - - - - - - - -	500 feet

Both the Burns Latite and Eureka Rhyolite occur in the region. Burbank (1933, pp. 141-144) has divided the Eureka Rhyolite into the following members: a Lower rhyolite flow, a Medial tuff breccia and an Upper flow breccia. This sub-division was easily identified in the Pride Area but as a result of the detailed nature of the mapping undertaken by the writer, additional units also were recognized.

Only the uppermost part of the Lower Eureka Rhyolite was found to be exposed in the Pride Area, and petrographic studies indicated that this rock is a latite flow breccia.

The Medial tuff breccia was divided into a lower assemblage of volcanic conglomerates and an upper assemblage of bedded tuffs. The occurrence of rounded granite boulders in the lower member made this unit especially prominent. A microscopic examination of the upper bedded tuff member showed that this rock is a mixed lithic and crystal tuff of a rhyolitic to latitic composition. Burbank (1933 p. 143) notes that the Medial tuff breccia of the Eureka Rhyolite has been frequently confused with the San Juan Tuff because of similar environments.

The Upper flow breccia in the Pride Area was characterized by variable composition. It was found convenient for mapping purposes to divide this unit into three divisions:

Rhyolite flow

Andesite flow

Flow breccia (andesitic to trachitic in composition)

This division is of special significance in the Pride of the West Mine as the flow breccia appears to be favorable for the deposition of ore.

The Burns Latite constitutes one of the main divisions of the Silverton series and was extruded upon the Eureka Rhyolite after a well defined period of erosion. This erosion surface was found to be very uniform with a gentle westward dip. Burbank (1933, pp. 145-150) has divided the Burns latite into three divisions: a lower tuff breccia member, a latite flow member, and upper tuff member. The lower tuff breccia member is present in the Pride Area but was found to be too thin and irregular to be mapped as a separate unit; therefore, it is included with the middle latite flow.

Four types of dike rock have been mapped. These include pre-Cambrian "biotite dikes", Tertiary diabase, granite porphyry and felsite dikes. With the exception of the last type, all have been described in detail by Hagen (1951, pp. 72-92). The felsite dikes that occur in the vicinity of the Pride of the West Mine, have not been determined as to an exact rock type, because of their fine grain size and excessive alteration. A petrographic examination was made, and the results of this are found under the detailed description of rock types.

Pre-Cambrian Schist

This rock is exposed at the surface in the southeastern part of the map area (Plate G), and is also exposed in the underground workings of the Pride of the West Mine in several places. The Green Mountain vein is situated almost entirely within this rock type.

The rock is massive; forms irregular, blocky cliffs; and is in general unweathered. The schistosity strikes from 45 degrees to 75 degrees northeast and dips at a fairly steep angle to the southeast. This attitude corresponds closely with the regional strike of the pre-Cambrian schistosity in the South Silverton area.

Megascopic Description

The rock is medium grained with a linear to platey schistosity, and varies in color from a black and white mottled rock to a grey and green mottled rock. Quartz and biotite can easily be recognized in hand specimens, and the fine banding of the rock is characteristic over the entire map area.

Microscopic Description

Texture: The rock has a granitoid to schistose texture.

Mineralogy:

Primary		Secondary	Accessory
Quartz	-----30-35%	Chlorite	Apatite
Microcline	-----25-30%	Tremolite	Magnetite
Albite	----- 5-10%	Clays	Garnet
Muscovite	----- 0- 5%	Sericite	Topaz
		Hematite	
Biotite	-----20-25%		
Hornblende	----- 5-10%		

Mineral Descriptions: Quartz is anhedral and varies from 0.2 mm. to 2.0 mm. in size. Undulatory extinction is very common.

Feldspars are euhedral, tabular grains that range in size from 0.02 to 3.0 mm. in size. Only one thin section of a sample taken near the mineralized area showed extensive alteration.

The biotite is lath shaped and euhedral, averaging 0.2 mm. to 1.0 mm. in length. It is highly pleochroic and commonly occurs in clusters.

Tremolite occurs as long prismatic fibres up to 1.0 mm. in length and is colorless.

Characteristics of Individual Thin Sections: A thin section of a sample taken from the fifth level, Pride of the West Mine, showed excessive alteration to chlorite, clays and sericite. Another thin section of a sample from near the vein on the first level of this mine was found to be relatively fresh.

Name of Rock: The rock was classified as a quartz biotite schist.

Ouray Limestone

The Ouray limestone occurs as isolated blocks in the Tertiary lavas on both sides of Cunningham Gulch. It is massive and only in two outcrops is there any definite indications of bedding. The rock is not an extensive cliff former, because of lack of areal extent.

Because of the unusual occurrence of large masses of Ouray Limestone in the Tertiary volcanics, a rather complete description of the rock will be made. In evaluating the origin of this rock and the mechanisms for its movement into its present position, field relations are very important. For this reason, the three most important outcrops will be discussed separately.

The group of outcrops between the Pride of the West and Osceola Mines extends for an estimated distance of 1,600 feet, has a width of 400 feet and a depth exceeding 300 feet. If these data are used as a rough guide, the limestone body mentioned above would have a volume in excess of 150 million cubic feet or a weight in excess of 11 million tons. As can be seen from the isometric diagram (Plate H), the form of this body is extremely irregular. It lies near the base of the flow breccia member

(Upper Eureka Rhyolite), and always shows a fault contact with the latite flows (Lower Eureka Rhyolite). Bedding was observed only on the first level of the Pride of the West Mine. Here it was found to strike 40 degrees northeast and dip 30 degrees to the southeast. Considering that this block is highly faulted, the attitude correlates fairly well with a series of cherty bands found on the surface, which strikes 24 degrees northeast and dips 60 degrees to the southeast. This body appears to have suffered greater deformation than similar bodies in the area, and this is probably explained by the fact that it is situated in the fissured and mineralized zone of the Pride of the West vein system. The boundary of the limestone and volcanics near 9,450 E and 11,250 N (Plate C) shows a fragmental zone, that is about 17 feet wide, and contains rounded and semi-angular fragments of limestone, schist, rhyolite, andesite, and chert in a matrix of carbonated lava. The occurrence of rounded schist fragments that are highly altered is of special significance.

A large outcrop (Plate F) situated on the west side of Cunningham Gulch between the Pride of the West and Green Mountain Mines, has some very unusual characteristics in form and is probably the most significant outcrop in the area for indicating the nature of emplacement of these bodies. Figure 4, page 33, and Figure 5, page 34, illustrate the form and relationship of this body to the surrounding rocks. It is about 200 feet wide on the north end, narrows to the southwest and splits into two prongs. The western prong consists of a limestone breccia zone that extends for a distance of over 400 feet. A hand specimen of this limestone breccia is seen in Figure 6, page 35. Except for the southern part of the western prong mentioned above, most of the limestone is situated near the base of the volcanic conglomerate member (Middle Eureka Rhyolite).

The southern part of the western prong is situated at the contact of the volcanic conglomerate member (Middle Eureka Rhyolite) and Lower Eureka Rhyolite. As indicated on Plate F, there are other small inclusions of limestone around this main body, but they do not exceed 30 feet in length. These inclusions appear to have been drawn out by flowage, and the most westerly inclusion appears to have been folded into a hollow eliptical form, (Figure 7, page 36). In the center of the main limestone, horn corals were found (Figure 8, page 37), and although most were highly deformed, one was identified as Hapsiphyllum calcariforme, an index fossil for the Mississippian period.

A small outcrop of limestone in the southwest corner of Plate E is mentioned because it is one of the few exposures which shows well-developed bedding (Figure 9, page 38). The beds consist of alternating light and dark grey limestone layers varying in thickness from one-half to three inches. The beds strike 60 degrees northwest and dip 20 degrees southwest. As the strike and character is considerably different from that of the limestone body on the east side of Cunningham Gulch, it seems unlikely that the two were ever connected.

Megascopic Description

The rock is a uniformly pure limestone with occasional chert bands, is fine to medium grained in crystallinity and has a greyish white color. Fossils were found in only one outcrop and most of these were highly deformed.

Microscopic Description

In one thin section made of the limestone from the northeast corner of the map area, the grains were found to average between 0.1 mm. and

Figure 4.--View showing the relationship of an isolated Ouray limestone body (CDo) to the latite flow member of the Lower Eureka Rhyolite (El) and the volcanic conglomerate of the Middle Eureka Rhyolite (Ec). Note the dashed line which separates the conglomerate member (Ec) from the tuff member (Et) in the Middle Eureka Rhyolite. The view is taken toward the west, from the east side of Cunningham Gulch, just above the Green Mountain Mine.

Figure 5.--Photograph showing the elongate nature of the prongs from the Ouray limestone body (CDo). View taken looking west from Cunningham Creek just below the Green Mountain Mine.

Figure 6.--Hand specimen of Ouray limestone breccia showing the flow character of the rock. Note the rounded and sub-angular character of the fragments. Specimen taken from the most westerly prong seen in Figure 5 (8, 150E, 9,100N).

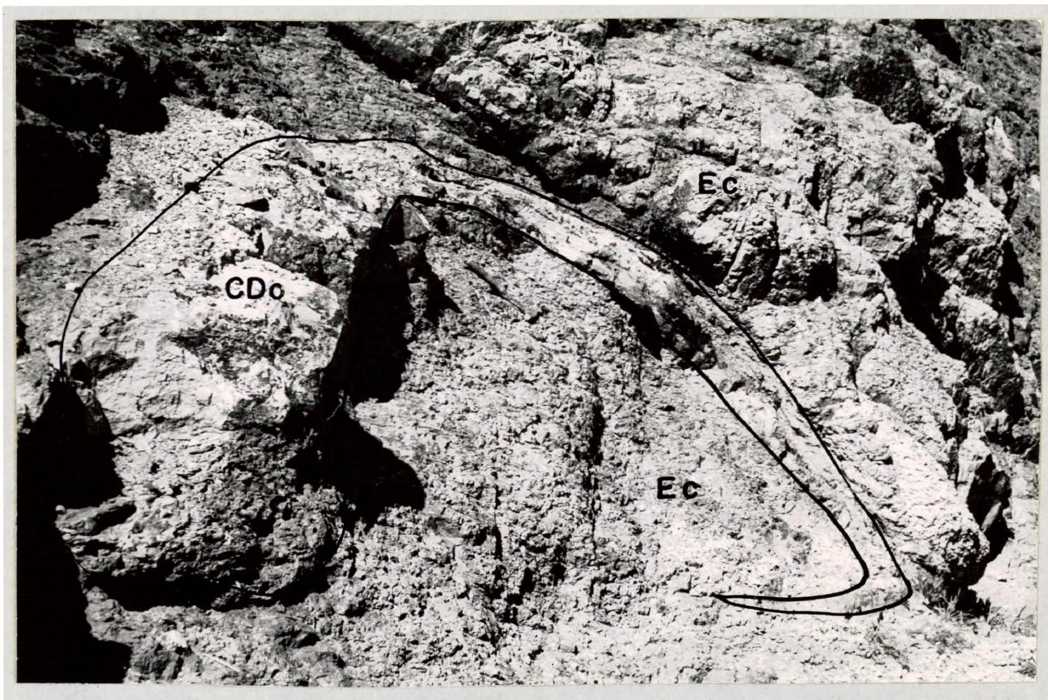


Figure 7.--Photograph on the western side of Cunningham Gulch showing a hollow eliptical body of Ouray limestone (CDo) engulfed in the volcanic conglomerate member (Ec) of the Middle Eureka Rhyolite. Photograph taken looking west from 8,020E, 9,340N.

Figure 8.—Hand specimen of Ouray limestone showing partially deformed horn corals. Specimen taken from 8,060E, 9,300N.

Figure 9.--Exposure of Ouray limestone showing well-developed bedding. The beds strike 60 degrees northwest and dip 20 degrees southwest. The photograph was taken at 8,060E, 9,300N.

1.0 mm. in size, but there was a great variation in the size of grain from one part of the section to another. It is the writer's opinion, however, that the limestone is more coarsely crystallized than the average of the area. Thin sections made of the limestone showing the fragmental flow structure indicate extensive carbonization of the foreign fragments, up to a degree where only ghosts of the original rock fragments remain. Figure 10, page 40, shows the lava assimilating limestone fragments. In many cases there is a definite development of a zone of chlorite at the contact of the foreign fragments and limestone. Re-crystallization of the limestone was found to be in evidence in all thin sections examined, and no minerals other than calcite were observed only where the rock had been mineralized with sulphides. In a thin section from limestone in a mineralized area, clinozoisite and epidote were distinctly developed, together with smaller quantities of aragonite and minute needle-like colorless unidentified crystals. In another thin section from the zone between the lava and limestone on the west side of Cunningham Gulch, no definite contact was observable between the two. The limestone appeared to become finer grained toward the contact zone and then gradually merged into chloritic alteration products of the lava. This zone did not exceed more than a quarter of an inch in width and in hand specimens appeared relatively sharp. The features mentioned above would indicate that at the time the limestone was being emplaced, it was probably in a warm plastic condition and that limited reaction between the lava and limestone liberated carbon dioxide and produced extensive carbonization of the country rock.

Summary and Conclusions

1. The limestone bodies are sedimentary in origin, occur in both

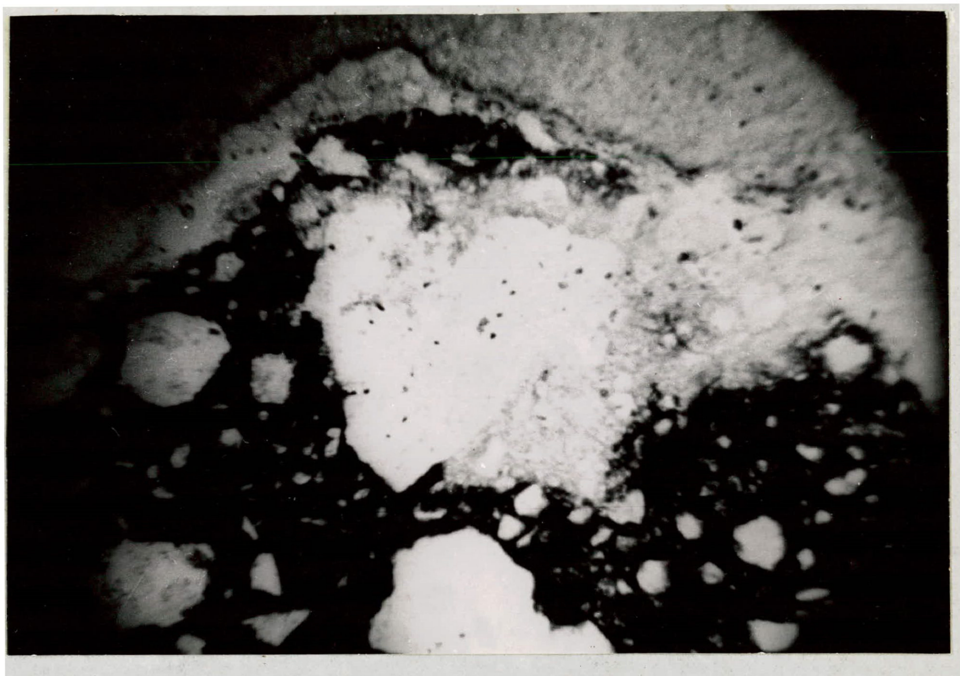


Figure 10.--Photomicrograph showing the assimilation of Ouray limestone by an andesite flow. Note how the limestone (white) has been penetrated by the lava (dark) and also the semiangular character of the limestone fragments in the lava. The original specimen was taken at 8,200E, 10,910N. Magnification is approximately 120 and the photograph was taken with transmitted light.

the Lower and Middle Eureka Rhyolite, are all irregular in outline, and have considerable size.

2. The large body of limestone on the east side of Cunningham Gulch appears to have been drawn out by flowage into thin breccia prongs of fragmental limestone and lava. Adjacent inclusions of limestone also appear to have been drawn out and distorted by flowage.

3. Although some contacts between the limestone and lava are fault contacts, by far the greater number of contacts observed appear to be irregular, but relatively sharp.

4. In some flowage bands associated with the limestone bodies, inclusions of schist have been observed.

5. Microscopic studies indicate re-crystallization of the limestone and a relatively small amount of reaction and flowage phenomena between the limestone and lava.

From the fact that the limestone bodies are Paleozoic and the volcanics which envelope them are Tertiary in age, some form of floating or flowage phenomena must be invoked to emplace them. It is thought by the writer that the source area of the limestone was probably to the south, not more than three or four miles away. Although at the present there are no outcrops of limestone in this proposed source area, there are limestone outcrops three and one-half miles to the southwest, and also a faulted body occurs only two miles to the south at the head of Cunningham Gulch. From this proposed source area, there is a general nine-degree dip of the present pre-Cambrian surface toward the Pride Area. From the Highland Mary Mine to the Green Mountain Mine this dip increases to about 34 degrees, and in the vicinity of the Pride of the West Mine, underground mapping indicates a constant dip of the pre-Cambrian surface between 75 and 80 degrees. It seems possible, therefore, that the limestone could have been exposed as cliffs, and that lava flows could pluck and undercut large limestone blocks as they flowed over the limestone outcrops. Because of the fairly high gradient, the limestone bodies would then be floated downhill to their present position. During this movement they would become heated, the heating would be followed by flowage, and re-crystallization of their borders.

Rouse (1937, pp. 1286-1287) describes similar limestone blocks that have been engulfed in volcanics in the Absaroka Mountains, Wyoming. He states:

> "In certain parts of the Absaroka volcanic field the early basic breccias contain unusually large blocks of limestone which merit special consideration."

He describes some of the blocks as being as large as 500 feet in diameter and several hundred feet thick. Stevens (1937) thinks that these limestone blocks originated from a topography similar to that of the Garden of the Gods near Colorado Springs in Colorado. He thinks that the limestone rested as umbrella rocks perched on weak sandstones or shales, and that later the invading volcanic breccias removed these remnants from their pedestals, and incorporated them as foreign blocks in the breccia. The present writer thinks that this explanation requires special conditions, which may or may not have been in existence at that time. The form, characteristics, and metamorphism of the Absaroka limestone bodies appear to have a striking similarity to those found in the Pride of the West Area.

Latite Flow Member of the Lower Eureka Rhyolite

The latite flow member is exposed over the entire map area below 10,600 feet elevation. The lower mine workings of the Osceola Mine are situated, with the exception of small blocks of Ouray Limestone, entirely within the latite flow member of Lower Eureka Rhyolite. The latite is massive and makes a good cliff former with well-developed jointing, which is occasionally columnar. In the vicinity of the Osceola mineralized area the rock develops a strong green coloration, because of local propylitization and the development of epidote.

Megascopic Description

The rock is fine grained, strongly porphyritic and uniformly light grey in color. Excellent flow banding is developed in places and contains abundant small angular grey to red porphyritic rock fragments which have a regular distribution throughout the latitie flow.

Microscopic Description

Texture: The rock is a porphyritic aphanite and the groundmass is characterized by being either felty or trachitic.

Mineralogy:

Primary		Secondary	Accessory
Plagioclase microlites (AB_{10} to Ab_8 An_2)	----- 60-70%	Chlorite	Magnetite
Plagioclase phenocrysts (Ab_9 An_1)	----- 15-25%	Clays	Apatite
Orthoclase	----- 3- 7%	Calcite	Pyrite
Hornblende	----- 10-15%	Epidote	
		Clinozoisite	
		Hematite	

Mineral Descriptions: The feldspar phenocrysts have a composition between albite and oligoclase (Ab_9 - An_1); they are lath shaped, euhedral crystals and in some thin sections are relatively fresh. In examining several thin sections, it was found that there was a great contrast in the size of the phenocrysts, varying from 2.0 mm to 0.2 mm., but in any one slide, their size is fairly constant. Most feldspar crystals exhibit albite twinning, with a few showing the combined carlsbad-albite twin. The feldspar microlites that make up most of the groundmass have a composition ranging from albite to oligoclase. The microlites have a characteristic felty or trachitic texture and show a great variation in size, ranging from 0.01 mm. to 0.2 mm.

The hornblende crystals occur as euhedral, lath-shaped phenocrysts and are commonly 0.15 mm. to 1.0 mm. in length. The majority exhibit almost complete alteration to iron oxides, chlorite, and epidote.

Characteristics of Individual Thin Sections: A thin section taken 50 feet east of the Lawrence Stope lower level, Osceola Mine, showed a development of clinozoisite, chlorite, and epidote. This alteration was not found to persist in any other rock types near the mineralized area and is thought to be due to local conditions. Another thin section showed very good development of flow structure with foreign fragments caught in the groundmass. The rock fragments were extensively altered but appeared to have a similar composition to the country rock.

Name of Rock: The rock was classified as a porphyritic latite flow breccia.

Volcanic Conglomerate Member of the Middle Eureka Rhyolite

This rock has a limited areal extent in the area and is exposed mainly on the west side of Cunningham Gulch where it forms precipitous cliffs; although there are two small outcrops on the east side of Cunningham Gulch.

The volcanic conglomerate is variable in thickness and composition. Its composition suggests a very coarse volcanic breccia, yet the majority of the fragments which it contains are well rounded. A small proportion of the fragments are made up of rounded granite boulders, some reaching a diameter of five feet. There are also tuffaceous lenses in this member which suggest some type of sorting action. Because of these features the writer believes that the rock was deposited originally as a volcanic breccia and later modified by the action of water. For this reason this member has been termed a volcanic conglomerate.

Viscous looking pods of lava having the appearance of rhyolite have intruded this member in the form of sill-like bodies. Masses of Ouray limestone also have been found to be engulfed in the volcanic conglomerate. The origin of these limestone bodies has been discussed on pages

Petrographic studies were made of the granite boulders which the volcanic conglomerate contains and the results are presented below.

Granite Boulders in the Volcanic Conglomerate Member of the Middle Eureka Rhyolite

Although these granite boulders are scattered throughout the entire member, there appears to be a concentration of them toward the base of the volcanic conglomerate. Burbank (1933, p. 143) mentions that these boulders are characteristic of the basal member of the Middle Eureka Rhyolite.

Megascopic Description

The rock is coarse grained and pink to grey in color. Quartz, orthoclase and mica can be easily recognized in hand specimens. Figure 11, page 47, gives an idea of the character of these boulders.

Microscopic Description

Texture: The rock is hypautomorphic granular.

Mineralogy:

Primary		Secondary	Accessory
Quartz	----- 60%	Clays	Apatite
Albite	----- 15%	Hematite	Magnetite
Microcline	----- 10-12%	Limonite	Zircon
Orthoclase	----- 3- 5%		
Biotite	----- 5- 8%		

Description of Important Minerals: Quartz is anhedral and varies from 1.0 mm. to 5.0 mm. in size, undulatory extinction being common in this mineral.

The feldspars are euhedral, with tabular to square cross sections. The grains range from 2.0 mm. to 6.0 mm. in length, and the majority of the crystals show considerable alteration to the clay minerals.

Biotite is green to light brown in color, with strong pleochroism. The mineral is lath shaped and euhedral and averages between 0.5 and 1.0 mm. in length. A development of red-brown pyroxene minerals is common around the borders of the crystals.

Characteristics of Individual Thin Sections: Some interesting features were observed in one thin section that was cut on the contact of

Figure 11.--Exposure of the volcanic conglomerate member of the Middle Eureka Rhyolite showing the inclusion of rounded granite boulders (white). Photograph taken looking west at 8,200E, 10,910N.

the granite and volcanics. The volcanic appears to have the features of a pyroclastic but shows some flow structure. Because of the flow characteristic shown by many of the pyroclastics, it is the writer's opinion that much of this material became welded following deposition and flowed under the influence of gravity. The contact between the granite and pyroclastics is very sharp, and little reaction was noted. However, the most significant feature displayed by this secti on is, that the volcanic rock is highly altered, whereas the granite is relatively fresh and traversed only by small veinlets of carbonate. (Some of these features are displayed in Figure 12, page 49). Two alternatives might be inferred from this evidence: one, that the alteration was of a deuteric character and occurred before the granite boulder was engulfed in the volcanic rock and, two, that the alteration occurred at such a low temperature that the granite remained unaffected. Of these two, the former is preferred by the writer, because if the carbonates could penetrate the granite, then it would appear obvious that the fluids causing the alteration would also be able to penetrate the granite.

<u>Name of Rock</u>: The rock was classified as a biotite alkali granite.

<u>Bedded Tuff Member of the Middle Eureka Rhyolite</u>

This rock has a limited areal exposure in the map area and is only found on the west side of Cunningham Gulch. The rock forms massive, precipitous cliffs which, when viewed at a distance appear to have a continuous bedded character. When the rocks are examined in detail, the

Figure 12.--Photomicrograph showing the contact relations between a granite boulder (right) and fragmental flow material (left). Note the sharp contact between the fresh granite and the altered volcanics. The original specimen was taken from 10,750E, 7,440N. Magnification is approximately 120 and the photograph was taken in transmitted light.

individual beds are lenticular in character and essentially horizontal. Figure 13, page 51, shows the relation of this bedded tuff member to the underlying volcanic conglomerate. It is to be noted that this is the only rock type in the map area, apart from the limestone, that shows any distinct bedding.

Megascopic Description

The rock is medium to fine grained, bedded, and has a mottled appearance due to the various colored fragments which it contains.

Microscopic Description

Texture: The rock has a fragmental texture with a microgranular groundmass.

Mineralogy:

Crystals and crystal fragments:

Quartz
Orthoclase
Albite
Microcline
Biotite
Apatite
Tridymite

Many crystals were observed to be broken and fractured, but a small percentage of the feldspars have an euhedral outline and show very little alteration. The quartz crystals are generally very angular, a few showing signs of corrosion around the edges.

Rock fragments:

The rock fragments represented about 55 percent of the thin

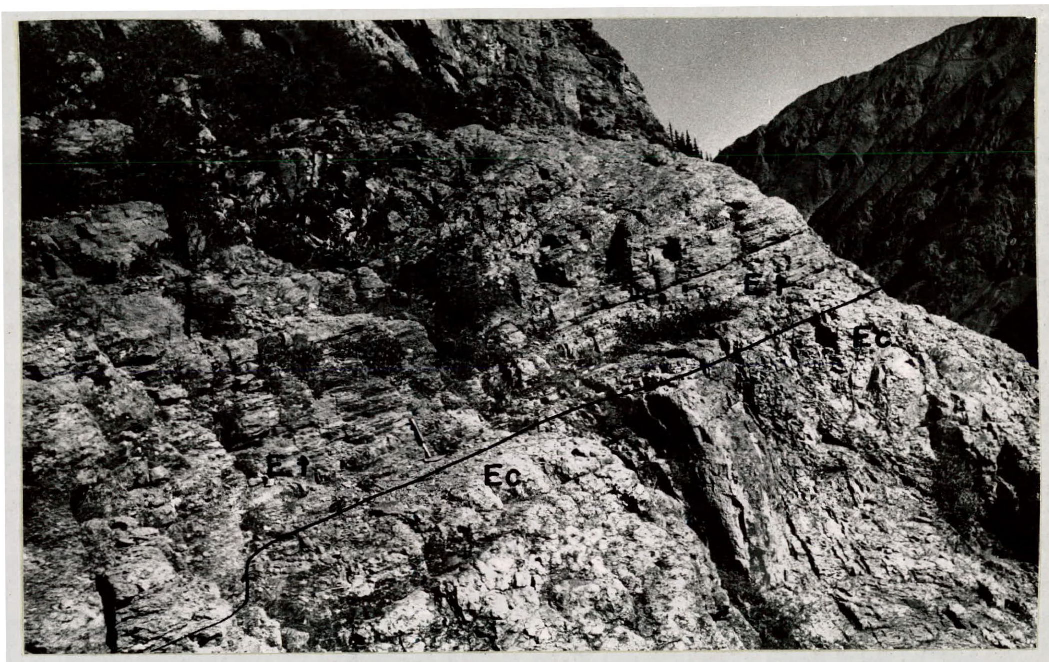


Figure 13.--View showing the contact relations between the upper tuff member (Et) and the lower volcanic conglomerate member (Ec) of the Middle Eureka Rhyolite. The contact is fairly constant and strikes 58 degrees northeast and dips 10 degrees northwest. The photograph was taken looking north at 8,020E, 9,100N.

section examined and were found to be well rounded and generally porphyritic. Because of alteration of the fragments, their composition could not be determined, but it is thought that they varied in composition from that of a rhyolite to that of a latite.

Groundmass:

The groundmass could not be determined because of its small grain size and extreme alteration. In many parts of the thin section, the groundmass appeared to be made up of an aggregate of clay minerals. The original constituents could have been equally well a mud or fine ash.

Conclusion: The rock was characterized by the absence of glass shards and also by the presence of microcline. The microcline is believed to have originated from the breaking up of granite fragments.

It is believed by the writer that the rock was deposited by subaerial agencies. Water deposition would appear to be doubtful because of the angular nature of the fragments and the irregular bedding.

Name of Rock: The rock was classified as a mixed lithic and crystal tuff having the composition of either a rhyolite or a latite.

Flow Breccia Member of the Upper Eureka Rhyolite

This rock has a large areal extent in the map area and is exposed on the east side of Cunningham Gulch. The flow breccia is probably the most important rock type from an economic standpoint as the ore bodies of the Pride of the West Mine are situated in it.

The thickness of the flow breccia member is relatively constant and reaches a maximum of 800 feet in the center of the area. The rock is fairly massive but is not a prominent cliff former. It forms blockey slopes which, if not too steep, tend to become talus covered.

Megascopic Description

The rock is fine-grained, has a greenish-purple color and is distinctly fragmental. Most of the fragments are angular to semi-angular and distinctly porphyritic. This porphyritic characteristic is in contrast to the fragments in the Middle Eureka tuff, which are nonporphyritic. The fragments make up over half the rock, and distinct flow structures can be discerned in the matrix of more than half of the hand specimens examined. The rock is characterized by the uniformity in size and distribution of the fragmental material. In the lower part of this member, small pebble-like fragments of granite and granite porphyry have been observed. These granite pebbles are found abundantly when the rock is in contact with the pre-Cambrian schists. Figure 14, page 54, shows a hand specimen of the flow breccia and Figure 15, page 55, shows an exposure of an unusually coarse grained phase of it.

Microscopic Description

Texture: The rock has a coarse, fragmental texture with a microgranular groundmass.

Mineralogy:

Crystals and crystal fragments: The crystals and crystal fragments observed in thin sections of this flow breccia are not nearly so

Figure 14.--Hand specimen of the flow breccia member of the Upper Eureka Rhyolite. Note the angular to sub-angular character of the fragments. The sample was taken from the first level of the Pride of the West Mine.

Figure 15.--Surface exposure of an unusually coarse phase of the flow breccia member (Upper Eureka Rhyolite). All the fragments are remarkably uniform in composition. Photograph taken looking west at 9,730E, 9,560N.

numerous as those in the Middle Eureka tuff and probably do not exceed ten percent of the rock. Because of alteration, difficulty was experienced in making determinations. Of the feldspars that could be determined, most fell in the andesine-albite range. However, no crystals of microcline were found similar to those that occurred in the Middle Eureka tuff.

Rock fragments: The rock fragments are remarkably uniform in size and vary from a tenth of an inch to three inches in diameter. However, the great majority are approximately half an inch in diameter. Most of the fragments are also porphyritic with a microcrystalline to felty groundmass. The fluidal nature of the groundmass around the rock fragments is a very common characteristic of this rock. The fragments that were determined appeared to vary from an andesite to a latite, but an accurate analysis was difficult due to the highly altered state of the rock.

Alteration: The rock has suffered more alteration than any of the other rock types examined, with the possible exception of some of the dyke rocks. In some thin sections, there is a pronounced development of epidote and clinozoisite, and in others there is a development of carbonate minerals, sericite, chlorite, and clay minerals. No definite relationship could be found between the alteration of this rock and the mineralization of the Pride Area. However, a definite increase in the intensity of pyritization was noted toward the mineralized area.

Conclusions: Two alternative processes may be used to explain the origin of this rock: either it was an intermediate flow rock which collected its huge content of fragments from sub-aerial agencies, or the flow rock collected these fragments within the magma chamber or outlet vents and fissures. Because of the uniformity of the fragments in size, distribution and composition, the latter alternative is preferred by the writer. In both cases, however, difficulties were encountered in arriving at a satisfactory solution to the origin of this rock, and no doubt a more detailed study would facilitate the solution. Burbank (1933, p. 143) suggests a mud flow or welded tuff as the origin of this rock, but this explanation appears to disregard the striking uniformity of these fragments in size and distribution.

Name of Rock: The rock was classified as a trachyte or andesite flow breccia.

Andesite Flow Member of the Upper Eureka Rhyolite

The rock has a rather limited area extent in the center of the area. Its thickness is variable but probably reaches a maximum of two hundred feet. The andesite flow is a massive brittle rock and makes an excellent cliff former.

Megascopic Description

The rock is fine grained, is dark green to dark gray in color and is strongly porphyritic.

Microscopic Description

Texture: The rock is a porphyritic aphanite with a pronounced trachitic groundmass.

Mineralogy:

Primary			Secondary	Accessory
Plagioclase microlites ($Ab_6\ An_4$ to $Ab_4\ An_6$)	-----	50-65%	Chlorite	Magnetite
Plagioclase phenocrysts ($Ab_6\ An_4$)	-----	10-15%		
Sanidine	-----	0- 3%		
Augite	-----	0-15%		
Hornblende	-----	0-10%		
Biotite	-----	0- 2%		

Mineral Descriptions: The feldspar phenocrysts are lath shaped euhedral crystals, but about a third of these crystals have undergone almost complete alteration to chlorite. Both the altered and fresh feldspar crystals have a length between 0.5 mm. and 2.0 mm. and show more alteration than the microlites. A small amount of sanidine was observed in only one thin section.

In all thin sections examined the feldspar microlites showed a definite trachitic texture and averaged 0.5 mm. in length. In about half of the thin sections examined, the groundmass under intermediate magnification had a characteristic salt and pepper appearance due to the abundance of small grains of iron oxide in the groundmass.

Augite occurs as fresh, light-green blockey euhedral crystals. Many show the characteristic pyroxene form and average from 0.5 mm. to 2.0 mm. in length. Im only one thin section, did this mineral occur abundantly; in the others it was either scarce or absent.

Hornblende, like augite, occurs abundantly in a few thin sections and is absent in others. It has a euhedral, lath shaped form and occasionally shows a pseudo-hexagonal outline. The crystals average 0.2 mm. to 1.5 mm. in length and have undergone considerable alteration to iron oxides, chlorite and calcite. The chlorite can be observed to be replacing the mineral along its cleavages, whereas the iron oxide forms a halo around the outside and the calcite has replaced the center of the crystal.

Biotite was observed in only small quantities and was found to have suffered considerable alteration.

Conclusions: Field relationships indicate that this complex of rocks constitutes either a flow of a very irregular outline or a sill. Petrographic evidence would appear to support the idea of a series of irregular flows because of the non-uniformity of the phenocrysts from one part of the rock unit to another.

Name of Rock: The rock was classified as a porphyritic andesite flow.

Rhyolite Flow Member of the Upper Eureka Rhyolite

The rhyolite flow member has a fairly large areal extent in the map area and is exposed on the eastern side of Cunningham Gulch. In the northern part of the area, it has a thickness of about 200 feet, but this rapidly increases to the south, with a maximum of 700 feet at a point above the Green Mountain Mine. The member probably represents a series of viscous rhyolitic flows and isolated pod like bodies of rhyolite can be easily distinguished within the member. The rock is massive, has a blocky appearance on steep slopes but is not a conspicuous cliff former. In only one outcrop does the rhyolite flow show any pronounced flow banding, and unlike the lower and middle members of the Eureka Rhyolite series, it does not contain any appreciable fragmental material.

Megascopic Description

The rock is fine grained, has a buff grey color and is strongly porphyritic.

Microscopic Description

Texture: The rock is a porphyritic aphanite with a microcrystalline groundmass. Over half the thin sections showed a pronounced development of spherulites, and one thin section had a felty groundmass. A typical spherulite is seen in Figure 16, page 61.

Mineralogy:

Primary		Secondary	Accessory
Groundmass of quartz, tridymite and feldspar	--- 55-65%	Chlorite	Magnetite
Albite	--- 15-20%	Clays	Ilmenite
Sanadine	--- 5- 8%	Calcite	Sphene
Orthoclase	--- 3- 5%	Sericite	Pyrite
Quartz	--- 0- 5%	Leucoxene	
		Hematite	
Biotite	--- 10-15%	Limonite	

Note - The Feldspar minerals in the groundmass could not be determined because of excessive alteration and fineness of the grains.

Mineral Descriptions: Quartz has a subhedral form and averages 0.2 mm. to 1.0 mm. in size. The crystals show considerable corrosion around the edges and also a pronounced undulatory extinction. Silica minerals in the groundmass consist of fine-grained quartz, which may be secondary; small amounts of tridymite, which occur in fibrous aggregates; and crystobalite, which occurs in the form of spherulites.

The feldspar phenocrysts are lath-shaped euhedral crystals showing

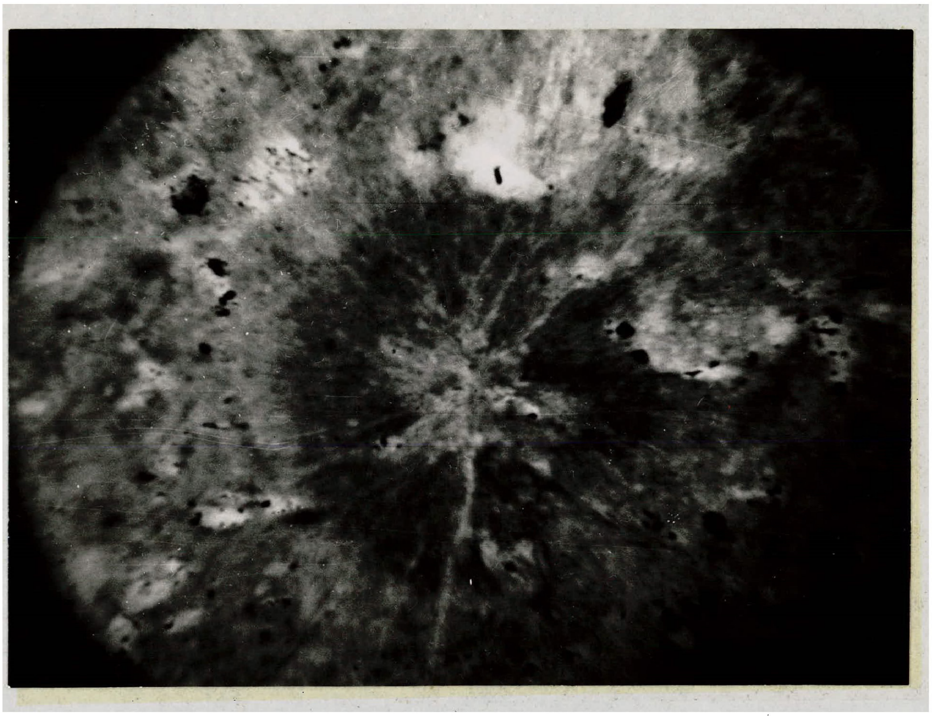


Figure 16.--Photomicrograph of a typical spherulite in the rhyolite flow member of the Upper Eureka Rhyolite. Magnification is approximately 120 and the photograph was taken in transmitted light.

considerable alteration to clay minerals, sericite and calcite. The crystals have a range in size, varying from 0.05 mm. to 3.0 mm. Biotite is brown in color, and occurs as stubby, lath-shaped euhedral crystals averaging from 0.2 mm. to 1.0 mm. in length. The crystals show considerable alteration to iron oxides, chlorite, and sericite.

Name of Rock: The rock is classified as a porphyritic rhyolite flow.

Tuff Breccia Member of the Burns Latite

In the Pride area the tuff breccia was too thin and irregular to be mapped as a separate member and was mapped together with the latite flows of the Burns Latite. The rock varied from 10 to 100 feet in thickness and was characterized by the highly porphyritic fragments contained in it. The tuff breccia is not as massive as the rhyolite flows that it overlies and it tends to break up into small blocky fragments that give the slopes a talus covered character. In some places it is very difficult to distinguish the tuff breccia from the weathered rhyolite flows.

Latite Flow Member of the Burns Latite

The latite flow has a large areal extent in the map area and is found on the east side of Cunningham Gulch above 11,600 feet. Its thickness was not determined as the upper contacts were well beyond the area studied. The rock is characterized by its massiveness, uniformity and its cliff forming habit. Some of the cliffs are hundreds of feet in height, as shown in Figure 17, page 64. Figure 17 also shows the relation between the Burns Latite series and Eureka Rhyolite series.

Megascopic Description

The rock is fine grained and has a fresh, dark grey color. In the area mapped, the rock did not show flow banding. Hornblende and plagioclase phenocrysts could be identified in hand specimens and these imparted a characteristic appearance to the rock.

Microscopic Description

Texture: The rock is a porphyritic aphanite with a microcrystalline to felty groundmass.

Mineralogy:

Primary		Secondary	Accessory
Groundmass	--------- 55-65%	Clays	Magnetite
Albite	--------- 15-20%	Chlorite	Sphene
Oligoclase	--------- 10-15%	Calcite	Pyrite
		Sericite	
Hornblende	--------- 5- 8%	Hematite	
Biotite	--------- 3- 5%		

Note - The groundmass is in general too fine grained for accurate determination of the minerals and in many cases consists of a feathery aggregate of clay minerals.

Mineral Descriptions: The feldspar phenocrysts are relatively fresh, lath shaped euhedral crystals, exhibiting albite twinning. The phenocrysts

Figure 17.—View of Green Mountain showing the contact between the Eureka Rhyolite Series (E) and the Burns Latite series (B). Note the prominent cliffs formed by the flows in the Burns Latite series. Note also the Schneider open pit in the lower left corner and the Little Fanny Mine (in circle, central right of photograph). Photograph taken looking east from a point on the west side of Cunningham Gulch, opposite the Pride of the West Mine.

occur in two size groups, one from 1.0 mm. to 4.0 mm. and another from 0.1 mm. to 0.5 mm. A small number of the crystals show a distinct zoning with the center of the crystal commonly altered to sericite and chlorite.

Hornblende occurs as lath-shaped euhedral crystals, with a few having a distinct pseudohexagonal outline. The crystals are from 0.5 mm. to 1.5 mm. in length and have suffered extensive alteration to chlorite and iron oxides. In some of the crystals a dark brown mineral was identified as belonging to the pyroxene group.

Biotite occurs as lath-shaped to blocky euhedral crystals. The crystals are 0.2 mm. to 0.5 mm. in length, and alteration along the cleavages to iron oxide was observed.

Name of Rock: The rock was classified as a porphyritic latite flow.

Tertiary Felsite Dikes

Four felsite dikes have been mapped in the Pride Area by the writer; two on the east side and two on the west side of Cunningham Gulch. The dikes have a general east-west trend and range in width from 6 to 30 feet. The dike rock is massive, and because of its greater resistance to erosion, stands out from the surrounding volcanic rocks.

Megascopic Description

The rock is fine grained, has a greenish-grey color, and is strongly porphyritic.

Microscopic Description

Texture: The rock is porphyritic with a microcrystalline groundmass.

Mineralogy:

Primary		Secondary	Accessory
*Groundmass	70-80%	Calcite	Magnetite
Quartz	3- 5%	Chlorite	Apatite
		Clays	
Pyroxene	5- 8%	Sericite	
Hornblende	3- 5%	Epidote	

*The groundmass could not be determined because of its fine grain size and excessive alteration.

Mineral Descriptions: Quartz occurs as euhedral to subhedral grains and averages about 0.2 mm. in size. It exhibits undulatory extinction with reaction rims of epidote and chlorite.

Feldspar crystals are rounded because of excessive corrosion, the centers being almost completely altered to coarse-grained calcite. The edges of the feldspar crystals show the development of chlorite and iron oxides.

The pyroxenes were distinguished by their crystal outline form and relict cleavages. They were altered to epidote in the center of the crystal and to chlorite around the outside. The crystals average 0.2 mm. in size.

Hornblende was recognized by its form and was almost completely altered to chlorite, calcite and iron oxides.

Characteristics of Individual Thin Sections: All other thin sections that were examined of this type of dike were altered to the same or even a greater extent of the above rock. It was noted, however, that they appeared to have the same composition and texture characteristics. Some of the thin sections appeared to consist of nothing but clots and aggregates of clay minerals together with chlorite.

Name of Rock: The exact rock type could not be determined but it belongs to an aschistic leucophyric group.

Structure

Although the present day San Juan Mountains are structurally related to the Tertiary San Juan volcanic area, it seems likely that the first stages of mountain building in the area may have begun in the Paleozoic. It is apparent from an examination of Figure 2, page 10, that the San Juan Mountains lie at the intersection of the Uncompahgre Uplift and the Colorado Porphyry belt. The Uncompahgre Uplift was initiated at the close of the Paleozoic and, although the Colorado Porphyry belt is Tertiary in age, its position was probably influenced by earlier structural trends. Stratigraphic relations in the Paleozoic and Mesozoic suggest that in these eras the San Juan Mountains had a similar history to that of the Front Range.

San Juan Mountains and Adjacent Areas

This section represents for the most part a summary of Burbank's description of the Metallogenetic Provinces of the San Juan (1947, pp. 398-403).

The oldest structural trends that have been recognized occur in the pre-Cambrian rocks and consist of folds and faults which are oriented northwest and eastwest. These trends, however, have been reactivated in later geologic times and have influenced the localization of igneous activity and mineralization. Both trends are especially prominent in the Paleozoic and Mesozoic rocks that occur in the southern border of the mountains. Burbank (1947, p. 398) states:

> "Along the western border, however, deformation at the close of both the Paleozoic and the Mesozoic eras formed northerly and northeasterly trending folds and faults. The intersection of these structures with the westerly and northwesterly trending pre-Cambrian structures probably influenced the location of igneous activity in the formation of the Ancestral San Juan Mountains."

Following the close of the Mesozoic era, the San Juan Mountains were uplifted, and the bordering sedimentary rocks, especially on the west, were sharply folded and faulted. Burbank (1947, p. 399) believes that at this time there was a prominent zone of weakness in the Western San Juan Mountains and that this zone of weakness consisted of a hinge line with a northeast trend. He postulates that the intersection of the hinge line with the pre-Cambrian trends was responsible for the centers of latholitic intrusion and mineralization at Ouray, Rico, and in the La Plata Mountains. This zone of weakness, or hinge line, that Burbank describes, may be related to the Colorado Porphyry belt of early Tertiary age.

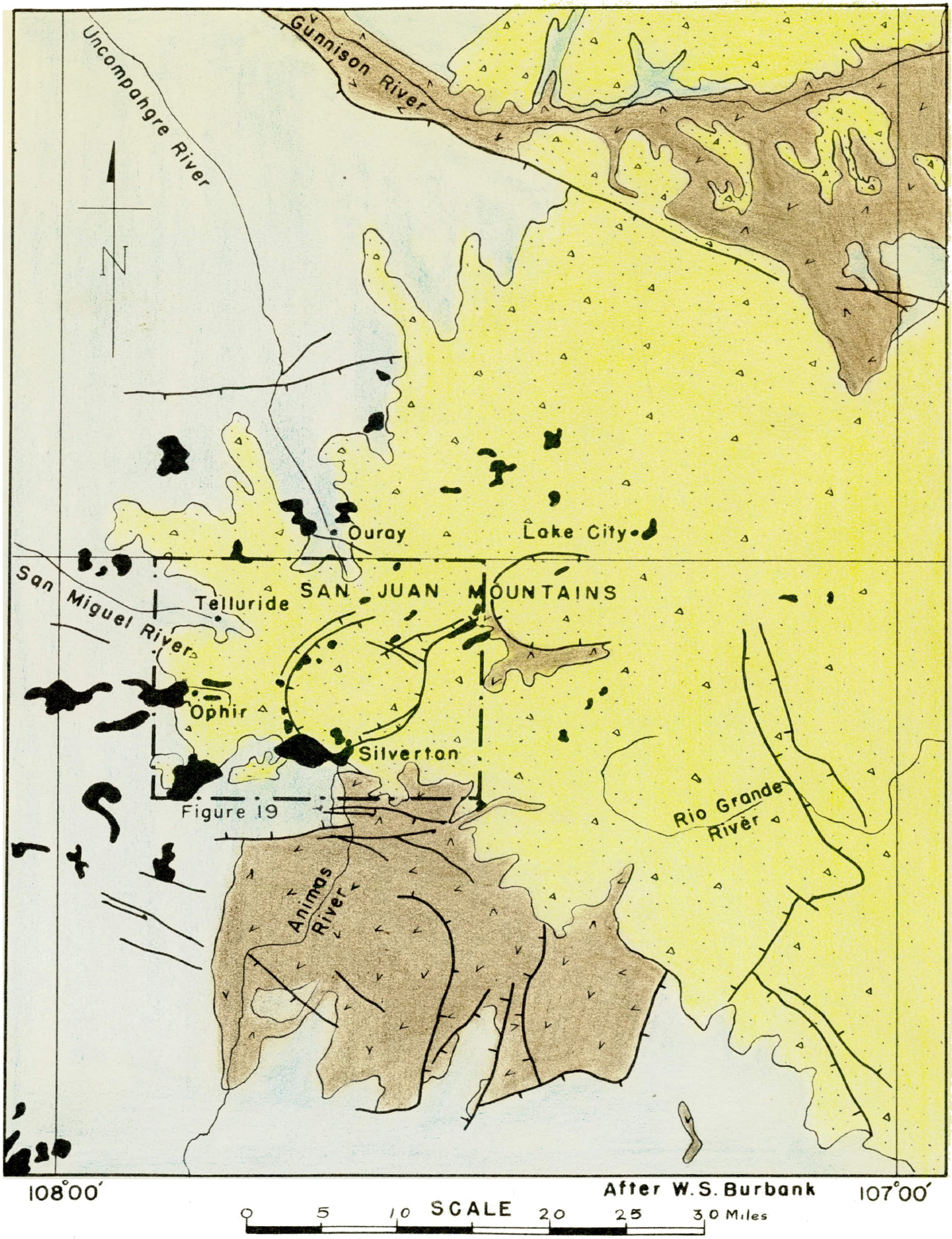
Regarding late Tertiary structure of the San Juan Mountains, Burbank (1947, p. 401) states:

> "Near the close of volcanism in late Tertiary time the San Juan region as a whole was deformed relative to its surroundings. In most parts of the San Juan a collapse of the crust which had begun during the earlier volcanic epochs culminated in faulting and fissuring that localized many of the larger intrusive bodies and associated ore bodies. In the western part of the region the local sinking of the crustal blocks and the consequent fissuring permitted the penetration of large intrusive bodies into the shallower formations. Further fracturing of the rocks during the final crustal adjustments about these centers provided fissures in which mineralizing solutions deposited their ores."

Burbank continues:

> "The structural lines and centers of eruption of the volcanic epoch perhaps did not bear as direct a relation to inherited trend lines as did the structures of previous stages of mountain development, but the larger intrusive centers between Silverton, Telluride and Lake City in the Western San Juan region lie not far inside the earlier line of laccolithic intrusions."

Both the circular subsidence blocks in the vicinity of Silverton and Lake City (Figure 18, page 70) probably represent super calderas that have originated through the collapse of active volcanic zones into the earth's crust. The expulsion of such large volumes of lava and pyroclastics in the San Juan Mountains makes the floundering of these large blocks (the Silverton caldera is approximately 50 square miles in area) appear feasible. It is probable that similar calderas will be found in the San Juan Volcanic area should more detailed mapping be undertaken.



LEGEND

Tertiary volcanic rocks

Tertiary intrusive rocks

Paleozoic and Mesozoic sedimentary rocks

Pre-Cambrian rocks

FIG. 18, GEOLOGIC MAP SHOWING THE STRUCTURAL FEATURES OF THE SAN JUAN MOUNTAINS AND RELATED AREAS

Silverton Volcanic Center and its Relation to the Structure of the Pride of the West Area

The relationship between the down-faulted central block of the Silverton volcanic center and the surrounding structure and geology can readily be seen in Figure 19, page 72. The significant features of the structure of this area are listed below:

1. The down-sunken block is approximately circular in outline and is bounded by three dominant bow-shaped faults which have a steep dip to the center.

2. The area influenced by this center exceeds 250 square miles.

3. There is a striking relationship between the central block, which is not highly fissured, and the surrounding area, which is cut by a distinct pattern of concentric and radial fissures. This fissure pattern is not as apparent to the southwest of the sunken block and probably is explained by a lack of detailed geologic mapping.

4. The concentric fissures and faults are subordinate to the radial pattern.

5. In most cases the radial pattern appears to be older than the concentric pattern, as is evidenced by the offset of radial fissures and dikes.

6. There appears to be an annular distribution of igneous stocks along the marginal faults.

7. The large quartz monzonite stocks were later or contempraneous with the concentric faulting.

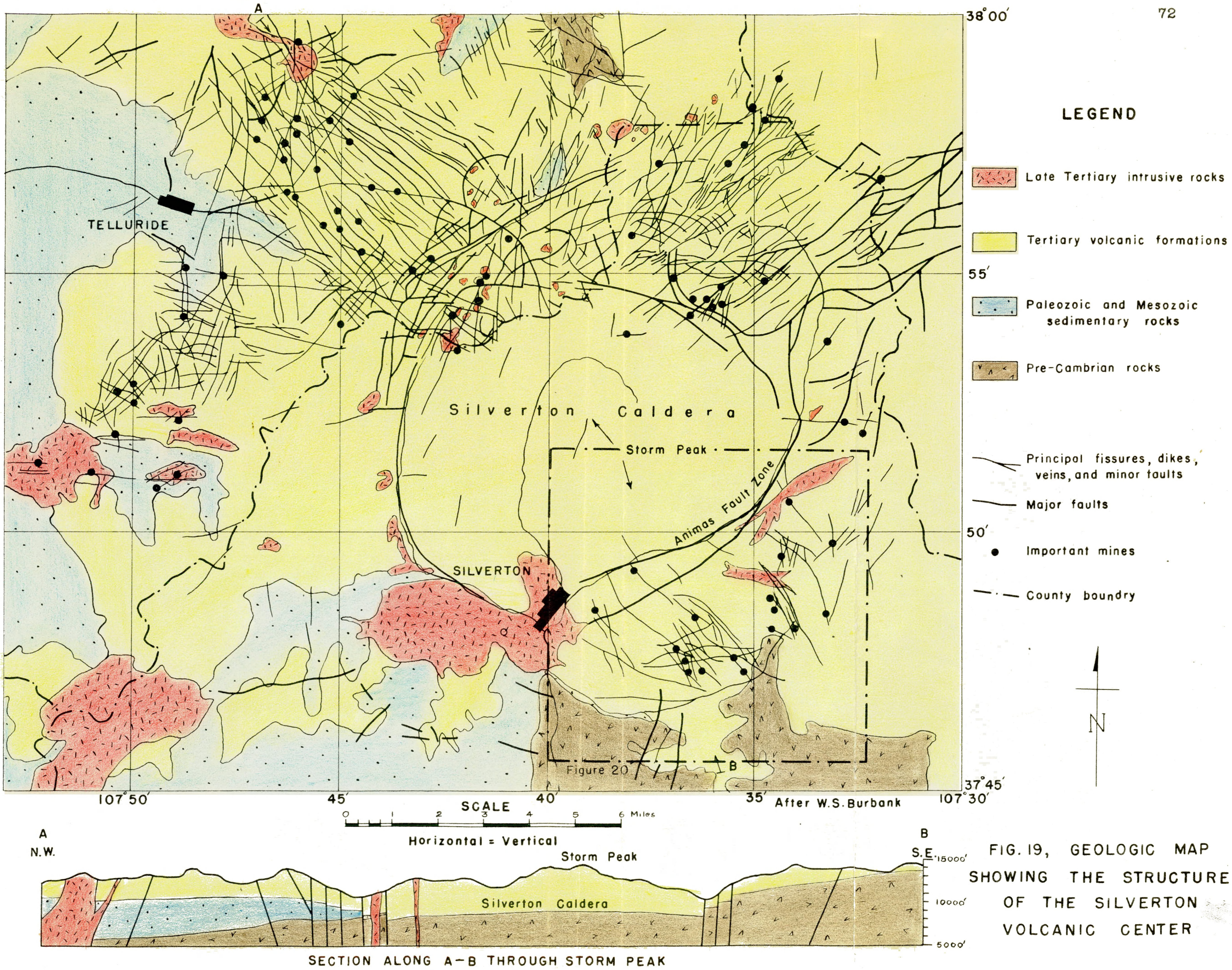


FIG. 19, GEOLOGIC MAP SHOWING THE STRUCTURE OF THE SILVERTON VOLCANIC CENTER

8. The ore deposits of this Silverton volcanic center, which account for 70 to 75 percent of the total San Juan production, are almost without exception associated with the fissures outside the central downfaulted block.

In brief, Burbank explains most of the features listed above as originating from a systematic failure of the crust by the upthrusting of igneous bodies followed by gravitational adjustments. The chief support for this theory appears to be that the radial pattern was in existence before the central block subsided along the concentric faults.

Burbank (1933, p. 177) discounts the idea of concentric cone sheets similar to those found in the Tertiary plutonic districts of Western Scotland for three main reasons. First, the concentric dikes and fissures have a much steeper dip in the Silverton occurrence. Second, the concentric fissures in the Silverton area, unlike the Scottish cases, do not intersect the concentric dikes. Third, in Scotland the radial dikes and fissures are subordinate to the concentric ones. The writer believes that caution should be used in making too drastic a correlation, as the Tertiary intrusives in Scotland have been eroded to a much greater extent than those in the Silverton area.

The origin of the Silverton fissure pattern has a direct bearing upon the economic geology of the area because of the intimate relation between the fissures and ore deposits. The Pride of the West vein system consists of a hydrothermal filling of one of these southern radial fissure zones of the Silverton volcanic center (Figure 19, page 72).

From an examination of Figure 20, page 75, which shows the distribution of fissures and faults in the southern part of the Silverton quadrangle, there is an apparent focus of ore-bearing fissures about three miles to the south of the Pride Area. This focus of ore bearing fissures appears to be more than a coincidence and, although there are no stocks mapped in this area, it is possible than an unexposed igneous source could be present.

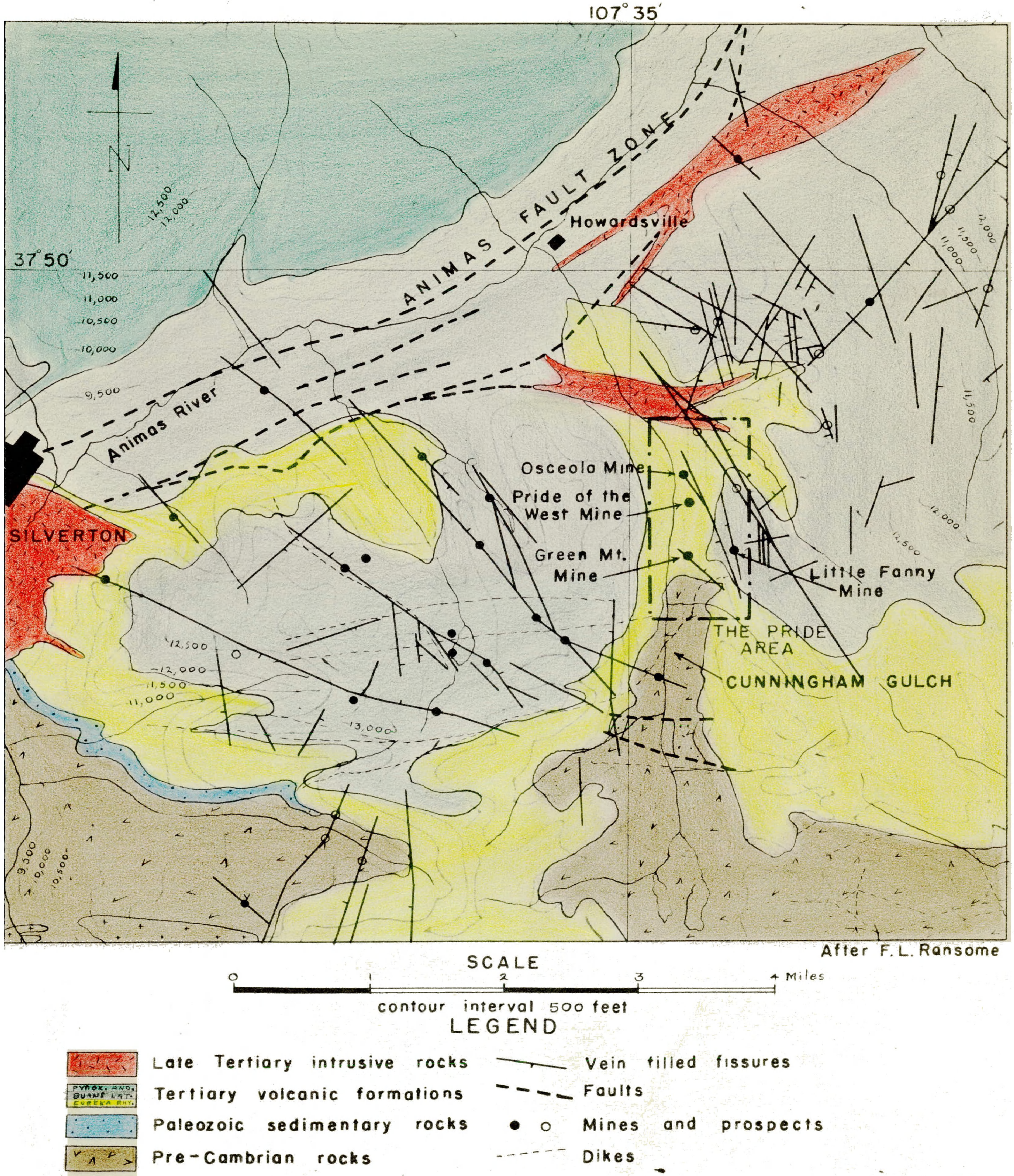


FIG. 20, GEOLOGIC MAP SHOWING THE STRUCTURE OF THE SOUTH EAST PORTION OF THE SILVERTON VOLCANIC CENTER

Economic Geology

Economic geology will be discussed under the following headings: San Juan Region, Silverton Volcanic Center, South Silverton Area and the Pride of the West Area. The Price of the West Area will be discussed with special reference to the Pride of the West vein system and mines situated on other veins will be only briefly mentioned.

San Juan Region

The San Juan region can be considered in a general sense to represent part of the metallogenic belt that surrounds the Colorado Plateau. Butler (1929, pp. 23-36), who developed this peripheral relationship, explained it as a result of a strong positive central area with surrounding weak negative areas. Tenny (1930, pp. 269-277), objects to this hypothesis because there are no geosynclinal basins on the southern side of the plateau comparable to those on other sides.

The San Juan region has been considered by many authorities to be a continuation of the Colorado Mineral belt. An examination of Figure 2, page 10, shows that this area lies in line with a direct extension of the Colorado Porphyry belt, which is in turn related to the mineral belt. Herness (1951), discounts this idea and suggests that there is an axis of metallization through the San Juan Mountains in a general northeasterly direction towards the Cripple Creek area. He bases this conclusion on the similarity of age, metallization, and volcanic activity along this axis.

According to Burbank (1947, p. 397), the metal-mining districts of the San Juan region have yielded nearly half a billion dollars in gold, silver, lead, copper and zinc. This production represents about one quarter of the total value of these metals recovered in Colorado. Burbank (1947, pp. 398-403), outlines four distinct metallogenetic provinces and eras in the San Juan region, which are briefly listed below:

1. Probable pre-Cambrian mineralization on the northern and southern flanks of the San Juan Mountains.

2. Late Mesozoic mineralization of vanadium and chromium on both the northern and southern flanks of the mountains.

3. Early Tertiary mineralization of silver, lead and zinc about centers of intrusion near Ouray, Rico and in the La Plata Mountains. Mining activity about these volcanic centers accounted for about 10 percent of the total San Juan production.

4. Middle Tertiary mineralization of gold, silver, lead, zinc and copper around the great intrusive and volcanic centers of Silverton, Telluride and Lake City. Mining activity here accounted for about 80 percent of the total San Juan production.

Silverton Volcanic Center

This section represents a brief compilation of the work done by Ransome (1901), Burbank, Eckel and Varnes (1947, pp. 396-433), in this area.

The Silverton volcanic area embraces the following mining districts, with their location by counties and accumulative production:

1. Sneffels, Red Mountain, Upper Uncompahgre mining districts in Ouray County, $74,000.00.

2. Animas and Eureka mining districts in San Juan County, $117,000.000.

3. Telluride and Ophir mining districts in San Miguel County, $130,000,000.

4. Galena and Lake Fork mining districts in Hinsdale County, $11,000,000.

Ransome (1901, p. 43), has classified the deposits of the Silverton volcanic area into three categories; veins, stocks and replacement bodies. Veins have accounted for, by far, the greatest production. Next in importance are stocks and include the so-called "chimneys" of the Red Mountain district. Only a few deposits occur as replacement bodies and they occur mostly in limestone and rhyolite.

Figure 19, page 75, gives the distribution of mines and fissures in the vicinity of the Silverton volcanic center. Although prospects cover the area in general profusion, the important mines occur in isolated groups, with the southwest and southeast corners of the area lacking commercial deposits at the present time. There is an apparent relationship between the intensity of fissuring in a given area and the occurrence of ore deposits. Moderately sized veins have been found to die out in depth, but in no recorded case did the fissure die out as well. The absence of any appreciable offset along the fissures and veins is one of the characteristic features of the Silverton volcanic center.

At some intersections, the most northerly trending veins have been faulted by barren or low-grade veins trending more nearly east and west. However, in other cases, the veins appear to have been filled simultaneously.

From inconclusive evidence, Ransome (1901, pp. 96-101), states that there is a change in depth from galena to sphalerite in the area. He has also noted that the ruby silvers and argentite do not occur at depths in excess of 500 feet, and that the gold values are generally more consistent than the silver values.

Ransome (1901, p. 58), states that in numerous cases after the deposition of the ore, there was at least one period of minor fissuring followed by a later deposition of quartz.

South Silverton Area

According to Varnes (1947, pp. 431-433), the South Silverton area is confined roughly to a belt several miles wide along the southern rim of the Silverton Caldera. The southern rim of this Caldera is limited by the Animas fault zone, which closely follows the present course of the Animas River. The location of this fault zone in the South Silverton area is readily seen in Figure 20, page 75. In this area the north side of the fault has been down-faulted between 1,500 and 2,500 feet. An examination of Figure 20 shows that the productive veins trend at a high angle to this fault system, but as noted previously (page 78), the central productive veins tend to intersect approximately three miles south of the Pride Area. Concentric fissures present in the area are commonly filled with latitic or andesitic dikes. Around the southern limit of the radial system lies another set of arc-shaped dikes of granite porphyry.

Regarding the mineralization in the South Silverton area, and especially with respect to the Arrastre basin, Burbank (1933, p. 165), shows that there is a rough zonal distribution of the ore with respect to the Animas fault zone.

Ores in the northwesterly fissures adjacent to the fault zone are characterized by the base metal sulphides, chalcopyrite, galena and sphalerite, with some specularite. Locally sufficient free gold is associated with the chalcopyrite to make it an important constituent of the ore. The gangue minerals in the northwesterly fissures adjacent to the Animas fault zone consist of quartz and chlorite. Ore bodies in the same fissure a mile or two farther southeast contain the base metals also, but argentiferous tetrahedrite is an important constituent. Silver in this zone is thus more important than gold. Here the gangue minerals commonly consist of barite, rhodochrosite, and manganiferous calcite. The mineralization in the Pride Area is of this group, as are the massive base metal deposits of Arrastre basin. Barren quartz and calcite succeeds these silver ores still farther southeast of the Animas fault zone.

The faulting of the Animas system would appear to be definitely pre-mineral in age, as there is a greater intensity of alteration on both sides of the fault than the alteration found in the adjoining veins. The main products of alteration in the Animas fault zone are quartz, sericite, pyrite, epidote, chlorite and specularite. The large quartz monzonite intrusives appear to be later than the faulting, as the quartz monzonite bodies are neither offset nor displaced by the faults. The elongate shape of the intrusive quartz monzonite body a mile north of the Pride Area (Figure 20, page 75), is obviously controlled by the fault pattern in that area.

The following conclusions may be drawn from the data presented above:

1. The mineralization in the South Silverton area is probably related to the Animas fault system.

2. A genetic relationship probably exists between the quartz monzonite intrusives and the mineralization.

3. The fissure pattern of the productive veins could be related either to the Animas fault system or to a fairly deep center not far to the south of the Pride Area.

Pride of the West Area - with Special Reference to the Pride of the West Vein System

History

According to the Office of the County Clerk at Silverton, the following are the dates on which the original claims were filed for the mines in the Pride Area:

Philadelphia	August 25, 1873.
Pride of the West	June 10, 1874.
Little Fanny	August 10, 1874.
Green Mountain	1874.
Osceola	May 10, 1901.

As far as the writer could determine, the following is an outline of the history of the Pride of the West and Green Mountain Mines:

1. The Pride of the West Consolidated Mining Company was formed in 1880.

2. The Joseph Gibbons Consolidated Mining and Milling Company was formed in 1888 to purchase the Pride of the West Property.

3. The Green Mountain Mining and Milling Company was incorporated in 1904.

4. The Joseph Gibbons Mining and Milling Company purchased the Green Mountain property in 1931.

5. In 1934 the Pride of the West and the Green Mountain Mines were leased to T. B. Sternes, W. E. Porter, Tyson Dines, Eugene Dines, and A. W. Harrison, who formed a company called the Pride of the West Incorporated.

6. The Denver Equipment Company took over control of the properties in 1940 and built a mill at Howardsville to treat the Pride of the West and Green Mountain ores.

7. The Great Eastern Mining Corporation was formed in 1947 and took over control of the Pride of the West, Green Mountain and Great Eastern Mines, as well as the Klondike group and the Silver Wing group of mines. This company also owns the Pride Mill at Howardsville and manages the properties of the Colorado Mines and Metals Company.

Production

Pride of the West Mine: The Mine Report for 1884 credits the Pride Mine with a total production of 1,500 tons valued at $97,500. These figures give an average ore grade of $65.00 per ton.* From 1884 until 1934, records are completely lacking, but from 1934 to 1950, fairly reliable figures are available. From 1934 to 1950 the mine had a total gross production of approximately $2,000,000 from a total of 150,000 tons, an average grade of $13.00 per ton.*

When the writer last visited the mine in the summer of 1951, the mine was being operated by three groups of leasers. The number of men working

* Before milling and mining costs have been deducted.

fluctuated between 10 and 12, and production varied between 250 and 300 tons of ore per week. It is understood that Mr. A. N. Sweet of Denver, Colorado, has obtained control of the Pride of the West and Green Mountain Mines and intends to carry out a development program below the first level of the Pride of the West Mine during 1952.

Green Mountain Mine: According to King and Allsman (1950, p. 73), the Green Mountain Mine up to 1948 had produced in excess of 40,000 tons. The grade of ore is not known for this period, but as the mineralization is similar to that at the Pride of the West mine, it is probable that the grade also was comparable.

At the time of the writer's last visit in the summer of 1951, the mine waw being operated by a single group of leasers totaling five men. Although the weekly production was variable, it probably averagdd 200 tons.

Mr. Sweet is expected to undertake development below the first sub-level A of this mine during 1952.

Little Fanny Mine: This property is comprised of both the Little Fanny and Philadelphia claims. Although the veins in this mine have been previously regarded as a continuation of the Pride of the West Vein, the writer does not believe this to be the case. This mine is owned by Jack Gilaheany of Silverton, and up to recent times, was leased by E. N. Helgerson. Helgerson (1947, p. 89), reports that early in the history of the mine over 100,000 ounces of silver were recovered from a small, high-grade ore pocket in the mine. Ore values are vaŕiable but range from $25 to 300 per ton. This mine has not been in operation for many years.

Osceola Mine: This mine belongs to the Osceola Mining and Milling Corporation, which is owned by W. C. Gianetto, L. C. Shirk and C. L. Larson of Silverton. The writer estimates that at least 30,000 tons of ore have been extracted from the Osceola workings. Although the stopping widths in this mine are greater than those of the Pride of the West Mine, the grade is considerably lower. At the present time this mine is not in operation.

General Description of the Pride of the West Vein System

The Pride of the West vein system in general has the characteristics of a vein-filled fissure zone linked by stringers. However, there are characteristic variations along its dip and strike and for descriptive purposes, the vein system has been divided into a northern, middle and southern part.

The northern part, which occurs north of the Midway level adit (Plate C), exists almost entirely on the Osceola property and here the Lawrence, March and Consolation levels are developed. The zone consists of a wide, sub-parallel system of veins linked by numerous stringers. The sub-parallel system of veins is very irregular and varies from 150 to 250 feet in width. Although large variations in the dip of individual veins are common, the general zone is vertical or dips steeply to the west. The walls of the veins are frequently indefinite because of extensive silicification of the country rock. Silicification is particularly intense where the country rock is composed of limestone; in these areas the ore bodies take on some of the characteristics of replacement bodies with mineralization widely but sparcely and irregularly distributed over the entire zone. Although the stoping widths are greater in the Osceola Mine than in the Pride of the West Mine, the average grade of the ore is considerably lower.

The middle part of the Pride of the West vein system extends from the Midway level adit to the Schneider open pit (Plates B and C). In this part the zone consists of a parallel system of veins with infrequent linkages by stringers. The Zone is fairly constant in width, varying from 100 to 150 feet and has a steep dip of 75 to 80 degrees to the west. The individual veins which do not exceed ten feet in width, have very distinct walls. Mineralization is uniformly distributed in the Zone, but has a tendency to occur in an en echelon manner from one vein to another along the strike and drip. This area represents the high-grade part of the vein system in which the Pride of the West Mine has been developed. Figures 21, 22 and 23, Pages 86,87 and 88, show portions of individual veins in this part of the zone.

The Southern part of the vein system, which extends from the Schneider open pit southward to the covered area west of the Little Fanny Mine, consists of a zone of massive, barren quartz veins. The zone,varies in width from 50 to 200 feet and frequent linkages by stringers are common. The zone has a general dip of 65 to 80 degrees to the west. Individual veins have sharp walls and frequently exceed ten feet in width. Mineralization is very sparse in this part of the vein system and only traces of copper and iron sulphides have been observed.

Figure 21.--Surface exposure of one of the veins constituting the Pride of the West vein system. Most of the vein material in this photograph consists of quartz. Note the blockey character of the vein when exposed to weathering. Photograph taken looking east at 9,887E, 10, 555N.

Figure 22.--View showing the Schneider open pit. At this point in the vein system at least four veins are present and all are well mineralized giving very wide stoping widths. Note the moderate dip of the hanging wall as compared to the steep dip of the footwall. Photograph taken looking north from the south end of the open pit.

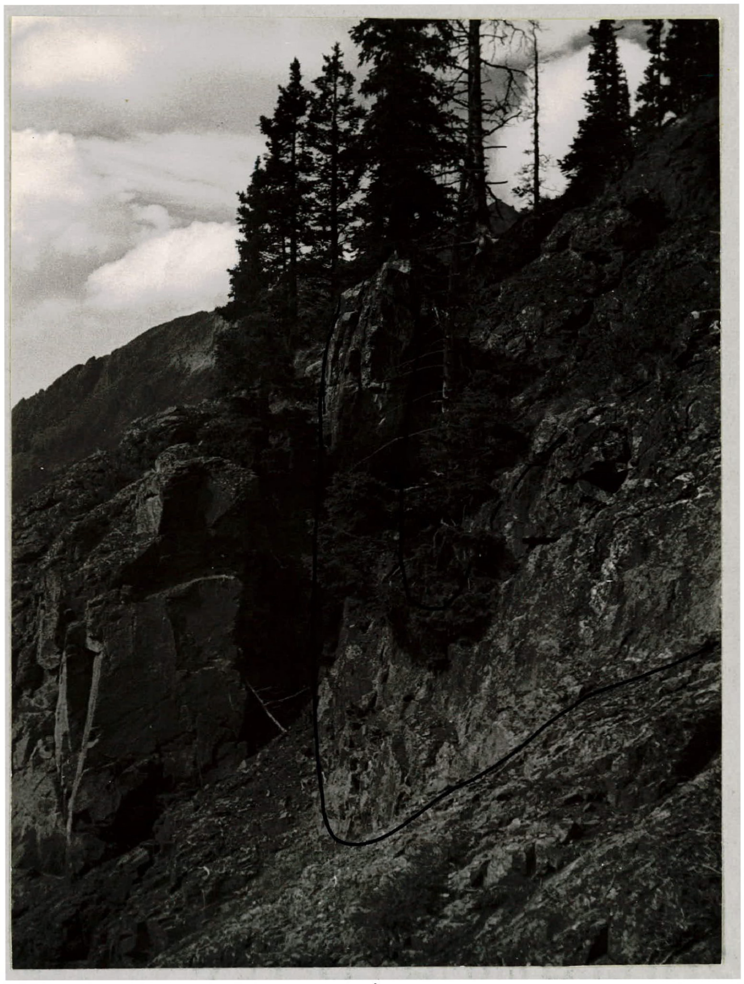


Figure 23.--View showing an exposure of one of the veins that constitutes the Pride of the West system. Note the massive character of the vein and its resistance to erosion. Photograph taken looking north at 9,840E, 10,610N.

<u>Size, Grade and Distribution of Ore Bodies:</u> The largest and highest grade ore bodies that have been developed in the vein system occur in the Pride of the West Mine. The most productive of these ore bodies occurred in the southern part of the mine, extending in an irregular manner from the first to the fifth level. The majority of the mined ore was high-grade and had over a four and one-half foot average width, a combined lead and zinc assay in excess of 20 percent.

Another smaller ore body in the same mine, situated to the north of the previous body, extends from the fourth level to the surface. This has an irregular distribution of high values but there is an apparent increase in grade towards the surface, with the highest grades of ore being obtained in the vicinity of the Schneider open pit. Stoping widths in this ore body increase rapidly towards the surface, with the body as a whole having an average width of approximately five feet. The ore body averages between 10 and 15 percent in combined lead and zinc.

Although many development levels have been driven on the Osceola property, only the lower Lawrence level has been stoped to any extent. The writer estimates that over 30,000 tons of ore have been extracted from one stope on this level, averaging between 5 and 10 percent combined lead and zinc content on an average width of 11 feet.

Mineralogy

<u>Carbonate Minerals:</u> Carbonate minerals occur characteristically as fine ramifying veinlets in the early and late stages of vein formation. Although a detailed study was not made of these minerals, it is the writer's opinion that the early cabonates are frequently manganiferous and iron bearing.

The carbonates appear to be evenly distributed except for a possible increase in amount towards the north end of the vein system.

Quartz: This mineral probably accounts for over 70 percent of the vein forming minerals and is thus by far the most abundant of them. The greatest amount was deposited in an early barren stage before the sulphides were formed. This early stage was characterized by replacement of the country rock as is demonstrated by the silicification of country rock fragments.

The next stage of quartz deposition followed the formation of sphalerite. Matching walls of fractures in the sphalerite and the filling of quartz (Figure 24, Page91), give evidence of fracturing of the vein zone following the deposition of the sphalerite and prior to the deposition of this quartz.

The final quartz stage followed the deposition of galena, chalcopyrite and tetrahedtite. The amount of quartz deposited in this stage was less than the previous two stages and much of this was deposited as a simple facture filling.

The following criteria were established for a theory of colloidal origin for some of the quartz in the Pride of the West vein system.

1. Numerous specimens examined showed a well-developed colloform banding of the quartz. Partial success was obtained in making this structure prominent by use of the following procedure. The specimens were polished and immersed in a concentrated sugar solution for over four months. Following this soaking the specimens were boiled in concentrated sulphuric acid in order to fix the carbon that the rock had absorbed.

2. The origin of the "Zebra Ore," to be discussed below is best explained by colloidal quartz.

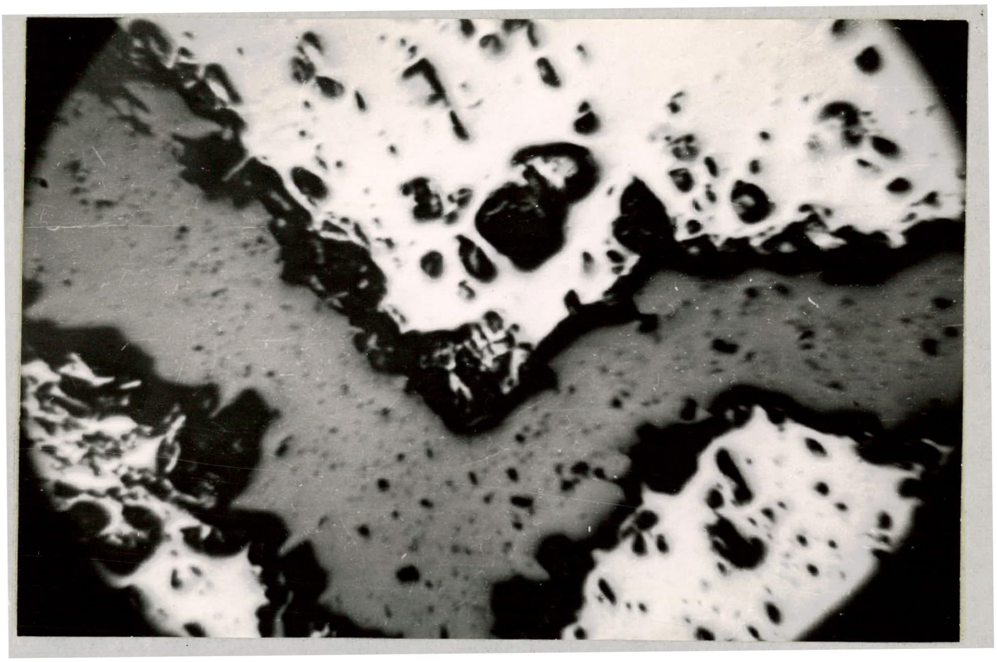


Figure 24.--Photomicrograph showing a quartz veinlet (grey), cutting sphalerite (white). Note the matching of the walls of the veinlet. Specimen taken from the 7th level, Pride of the West Mine. Magnification approximately 320, photograph taken with reflected light.

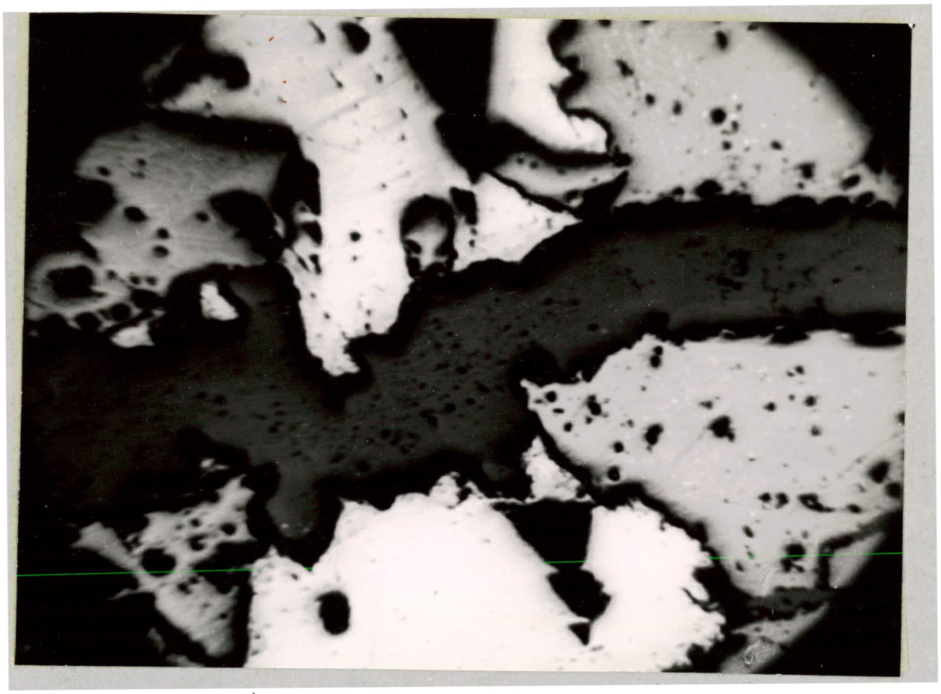


Figure 25.--Photomicrograph showing the transection of sphalerite (light grey), and galena (white), by a veinlet of quartz (dary grey). Note that the galena on both sides of the veinlet was once the same grain as shown by the matching of the orientation of the triangular pits on both sides of the veinlet. Note also a rough matching of the walls on either side of the veinlet. Sample taken from the second level, Pride of the West Mine. Magnification approximately 320, photograph taken with reflected light.

Figure 26.--Hand specimen of banded ore and vein material showing the vuggy and comb structures of the quartz. Specimen taken from the 7th level dump, Pride of the West Mine.

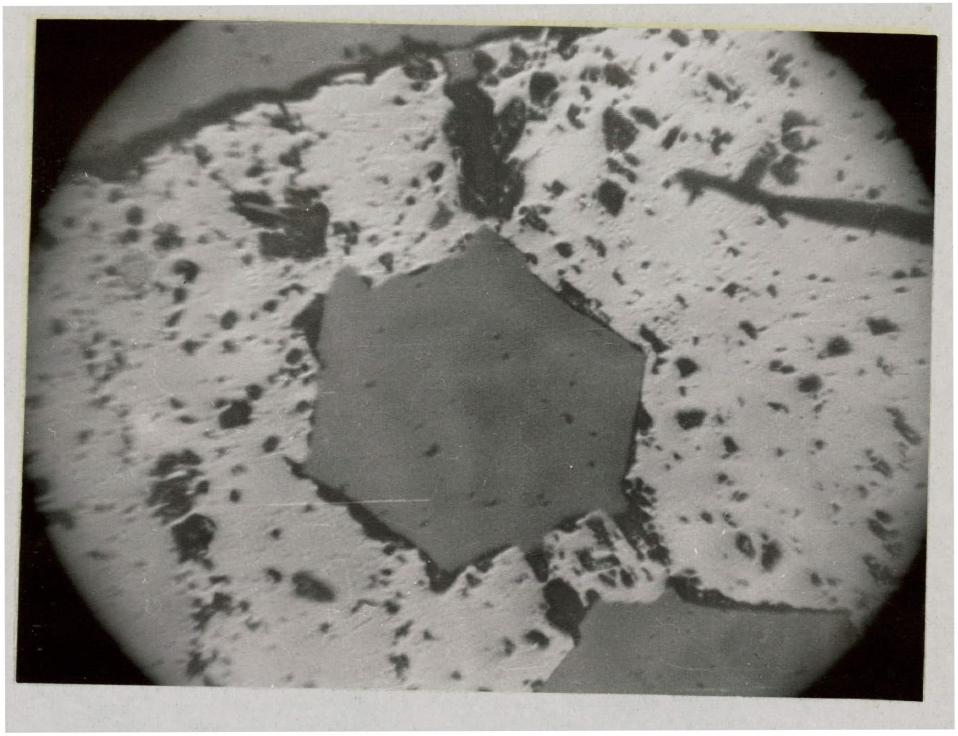


Figure 27.--Photomicrograph showing euhedral quartz (grey), in sphalerite (white). The quartz is later than the sphalerite but because of its high energy of crystallization has assumed its own crystal form. Magnification is approximately 640 and the photograph was taken in reflected light.

3. In contrast to the general silicification of the country rock surrounding the veins, quartz veinlets with extremely sharp walls cut older vein minerals.

Specular Hematite: Comparatively small quantities of specular hematite are associated with the limestone in the Pride Area. The mineral commonly occurs as lath shaped grains (Figure 28, Page 96), but its relationship to the other vein forming minerals has not been definitely determined. The occurrence of specular hematite in the Pride Area is anomalous in that it is usually regarded as a high-temperature mineral, whereas the sulphides found in the Pride of the West vein system are probably medium temperature minerals.

Pyrite: This mineral is uniformly distributed throughout the vein zone and is sometimes found in the country rock up to a distance of twenty feet from the individual veins. Pyrite was deposited before the productive sulphides, and there are numerous examples of its replacement by these minerals (Figure 29, Page 97). When occurring in the country rock as small grains, pyrite commonly has a cubic crystal form, due probably to its high energy of crystalization. Figure 30, Page 98, shows evidence that the pyrite grains were fractured and later filled by quartz.

Sphalerite: This is the second most important ore mineral and has been found without exception to be an early mineral in the productive sulphide stage. Sphalerite has a fairly uniform distribution except for a slight decrease in depth in the sphalerite galena ratio.

Figure 28.--Photomicrograph showing the lath shaped character of specular hematite (white) in a background of quartz (dark grey). Specimen taken from the surface at 9,400E, 11,100N. Magnification is approximately 1,200 and the photograph was taken in reflected light.

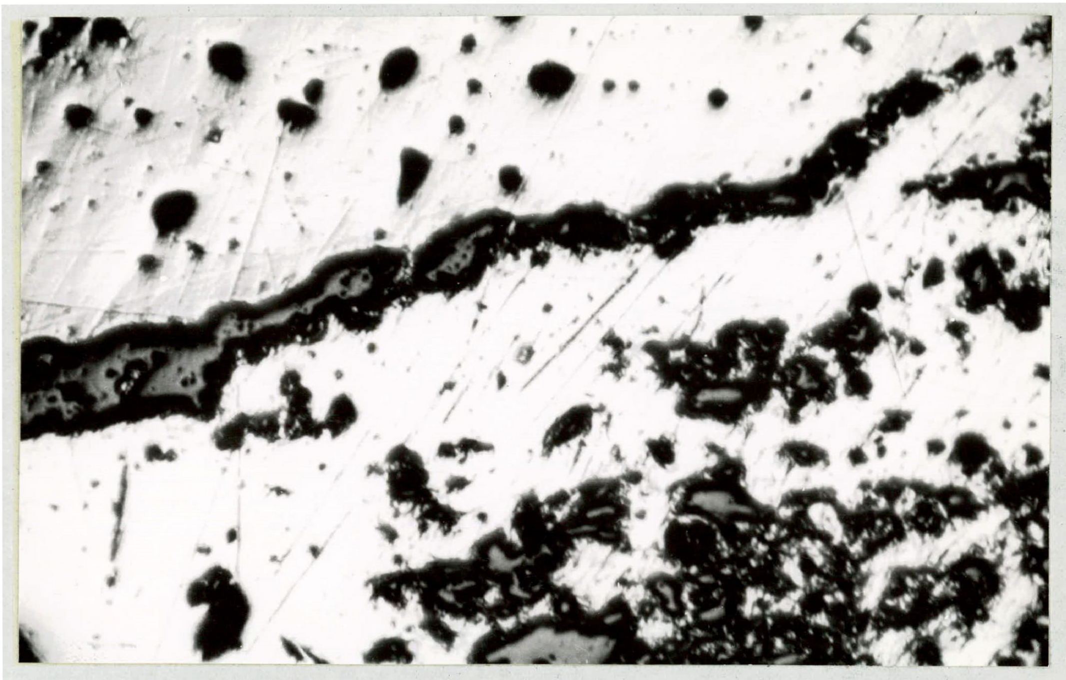


Figure 29.--Photomicrograph showing an antecedent veinlet of pyrite (grey) being replaced by galena (white). Magnification is approximately 160 and the photograph was taken in reflected light. Specimen taken from the 7th level, Pride of the West Mine.

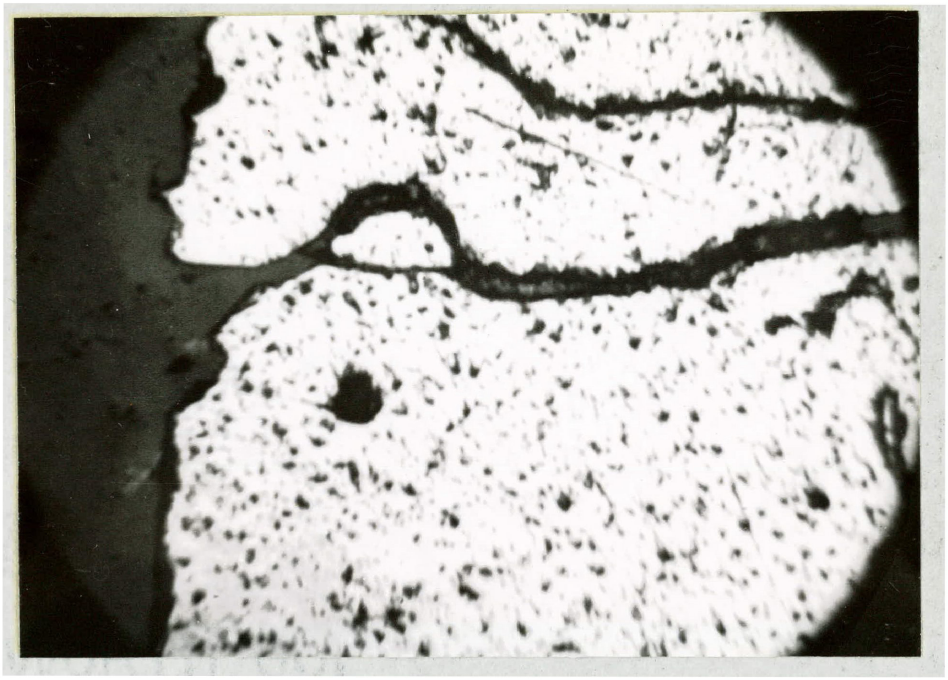


Figure 30.--Photomicrograph showing fracture filling of pyrite (light grey) by quartz (dark grey). Note the matching walls of the veinlet. Specimen taken from the Lawrence level, Osceola Mine. Magnification approximately 320, photograph taken with reflected light.

The sphalerite contains small blebs of chalcopyrite which are usually uniformly distributed. Only in a very few specimens were the blebs oriented along crystallographic directions (Figure 33, Page 102). From the relationship of the chalcopyrite blebs to other minerals that have invaded and replaced the sphalerite, it is the writer's opinion that the chalcopyrite blebs do not represent exsolution, as commonly stated in the literature, but rather indicates a replacement. Figures 32 and 33, Page 101 and 102 illustrate this point and establish a definite relation between the size and distribution of chalcopyrite blebs and the quartz veinlet that has transected the sphalerite. This relationship has been observed in many polished sections of the ores of the Pride of the West Mine. A possible explanation for this relationship might be that a fluid containing chalcopyrite in solution flowed through the fractures in the sphalerite and then the chalcopyrite was diffused into the sphalerite grain.

Galena: This is the most important mineral in the vein system, and in the upper portions of the Pride of the West Mine it is frequently argentiferous. Although no silver minerals were observed associated with the argentiferous galena, it was found that when this mineral was etched with concentrated nitric acid (1:1) for a minute and a half, a curious pitted spherical etch pattern developed (Figure 35, Page 104). Galena specimens taken from the lower parts of the mine when treated in the same manner did not show the same etch pattern. The silver is probably contained in the galena and both form a solid solution. Nissen and Hoyt (1915, pp. 172-179), state that the limit of solid solution of Ag_2S in galena at atmospheric temperatures is below 0.2 percent (approximately 32 ounces per ton of galena). Except for the occurrence of pockets of

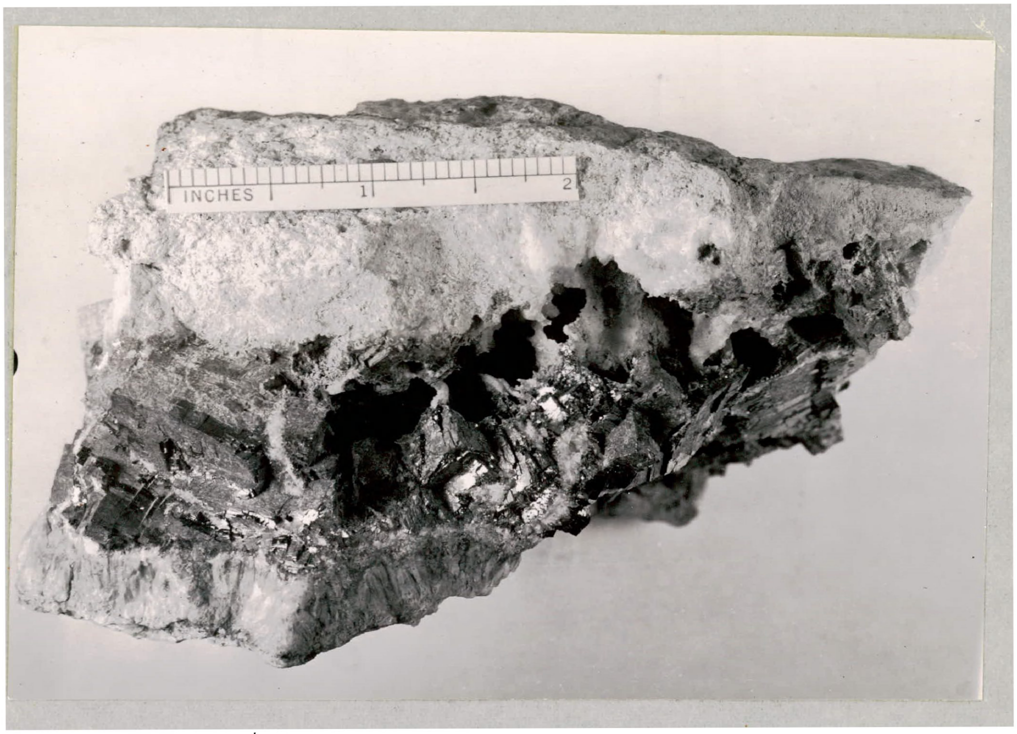


Figure 31.--Hand specimen of vein material containing sulphides found "in place" on the surface. Note that the sphalerite has been leached out while the galena which is more stable has remained. Specimen taken from 9,790E, 10,855N.

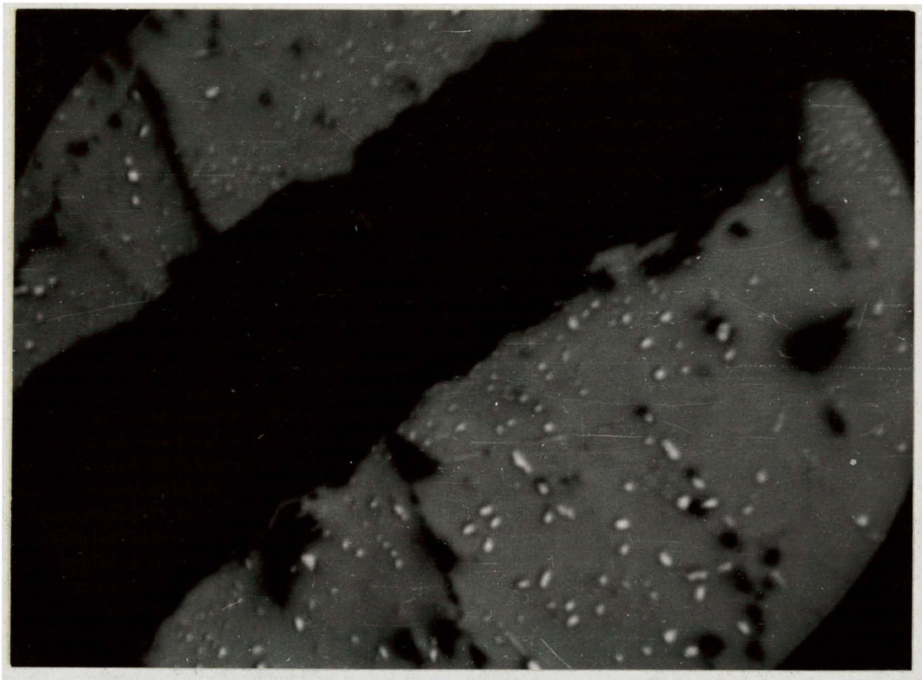


Figure 32.--Photomicrograph showing sphalerite being transected by a quartz veinlet. Note that the blebs of chalcopyrite in the sphalerite show a decrease in size and increase in quantity as the boundry between the sphalerite and quartz is approached. Specimen taken from the 7th level of the Pride of the West Mine. Magnification is approximately 600, photograph taken in reflected light.

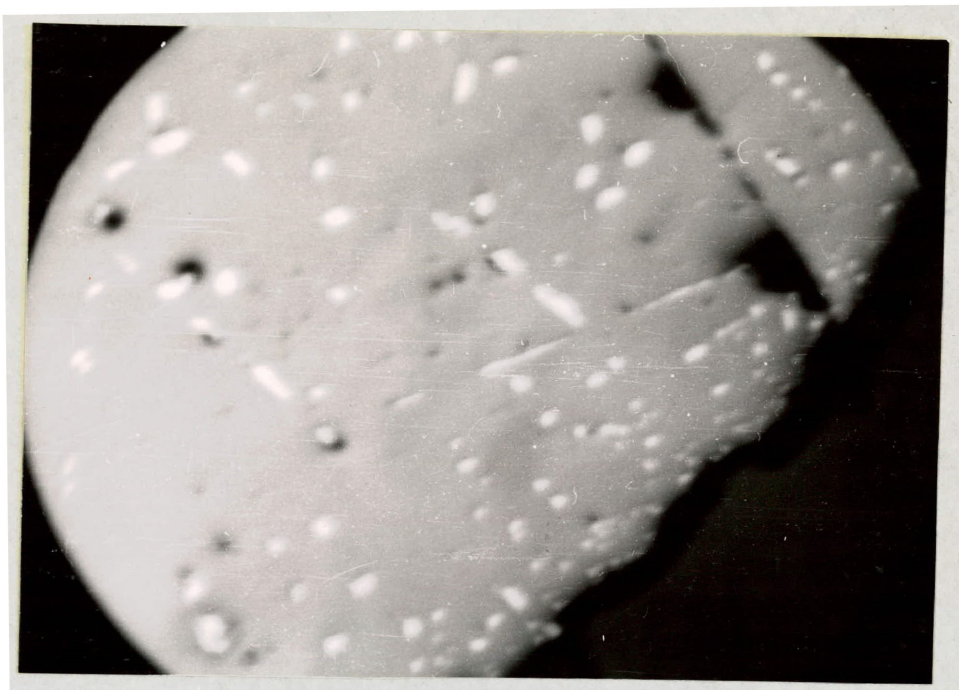


Figure 33.--Microphotograph showing a portion of Figure 32 in greater detail. Note the decrease in size of the chalcopyrite blebs toward the quartz sphalerite boundry. Note also the orientation of some of the chalcopyrite blebs in the center of the photograph. Magnification approximately 1,200, photograph taken with reflected light.

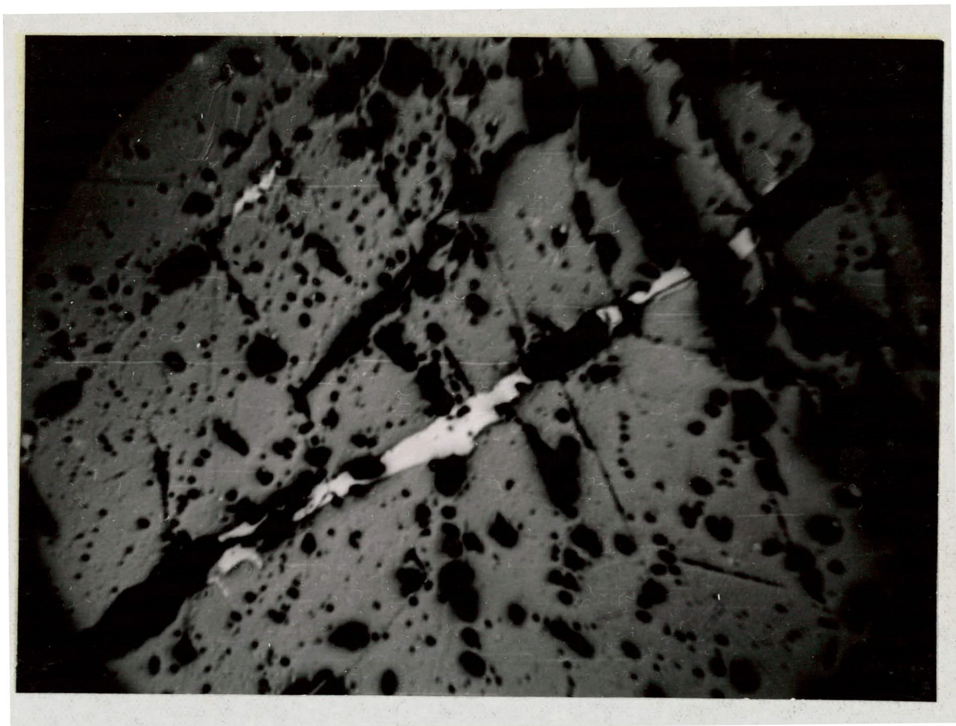


Figure 34.--Photomicrograph showing a segmented veinlet of chalcopyrite (white) and quartz (black) transecting sphalerite (grey). Specimen taken on the 6th level, Pride of the West Mine. Magnification approximately 1,200, photograph taken in reflected light.

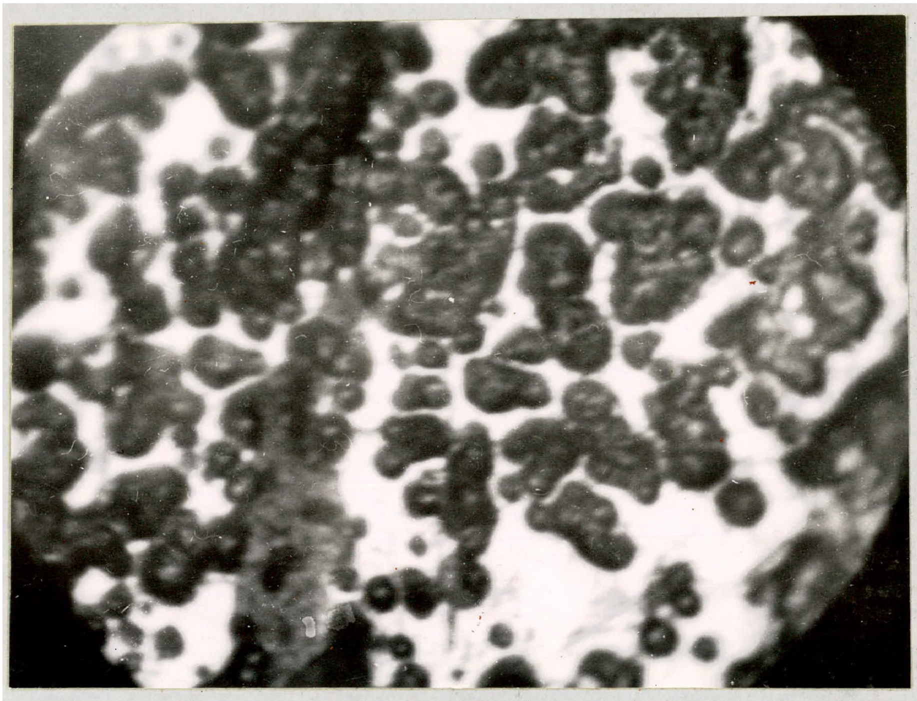


Figure 35.--Photomicrograph showing the peculiar spherical etch pattern developed on argentiferous galena when treated with concentrated HNO_3. Specimen taken from the Little Fanny Mine. Magnification approximately 480, photograph taken in reflected light.

wire silver, the concentration of silver never reached 0.2 percent in the Pride of the West vein System.

Miners who have had considerable experience in the Pride of the West Mine, report that the occurrence of large crystal cubes of galena is a good indication of high silver values. It has been reported by various workers in mineralography that curvature of the galena cleavage also indicates high silver contents. The writer definitely found that the argentiferous galena had a highly curved cleavage, but this was also true of some specimens that were apparently non-argentiferous.

The atol texture of galena and pyrite found on the sixth level of the Pride of the West Mine and on the surface at the Osceola mine merits further description. This texture, which can be seen in Figures 36, 37 and 38, pages 106, 107, and 108, consists of concentric arrangement of the following minerals.

1. A grain or grains of galena in the center.
2. Thin rim of pyrite.
3. Thick rim of quartz with small inclusions of carbonate and small quantities of another mineral which is probably argentite.
4. Thick irregular rim of pyrite.

The above zones are not always present and Figure 38, page 108 shows a single thick rim of pyrite surrounding the galena.

The occurrence of carbonates replacing galena along its cleavages is very interesting (Figure 40, page 110). It appears to be unusual for the carbonates to replace any sulphide in the Pride of the West vein system.

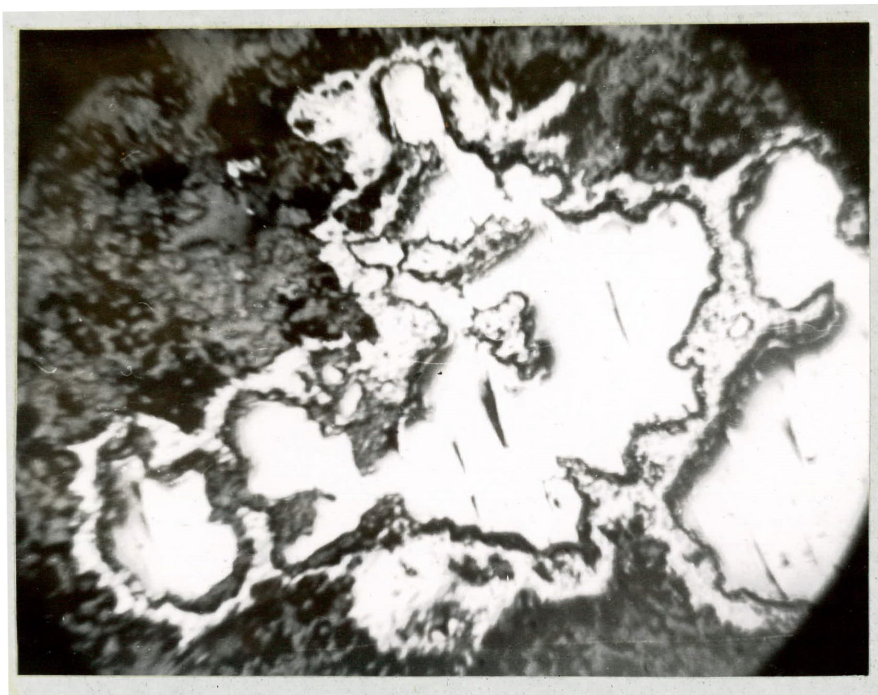


Figure 36.--Photomicrograph showing the typical atol texture of pyrite (grey), surrounding galena (white). Surrounding the pyrite rim to the left side of the photograph is fine grained quartz (dark grey). Specimen taken from the surface at 9,390E, 11,850N. Magnification is approximately 320, photograph taken in reflected light.

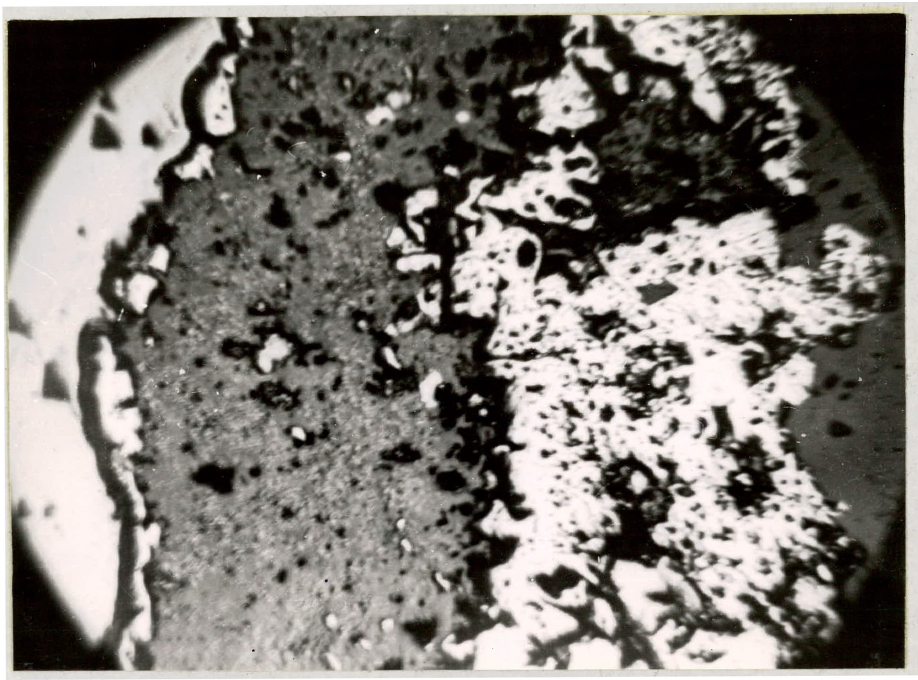


Figure 37.--Photomicrograph showing in detail one segment of the atol texture. The extreme left side of the photograph consists of galena (white). Surrounding this is a thin rim of pyrite (white). In the right center of the photograph is a thick rim of quartz (grey). This thick rim contains small inclusions of carbonate and minute inclusions of argentite. This thick rim of quartz is succeeded by massive pyrite (white), and finally to the extreme right of the photograph by quartz. Specimen taken from the 6th level, Pride of the West Mine. Magnification approximately 640. Photograph taken in reflected light.

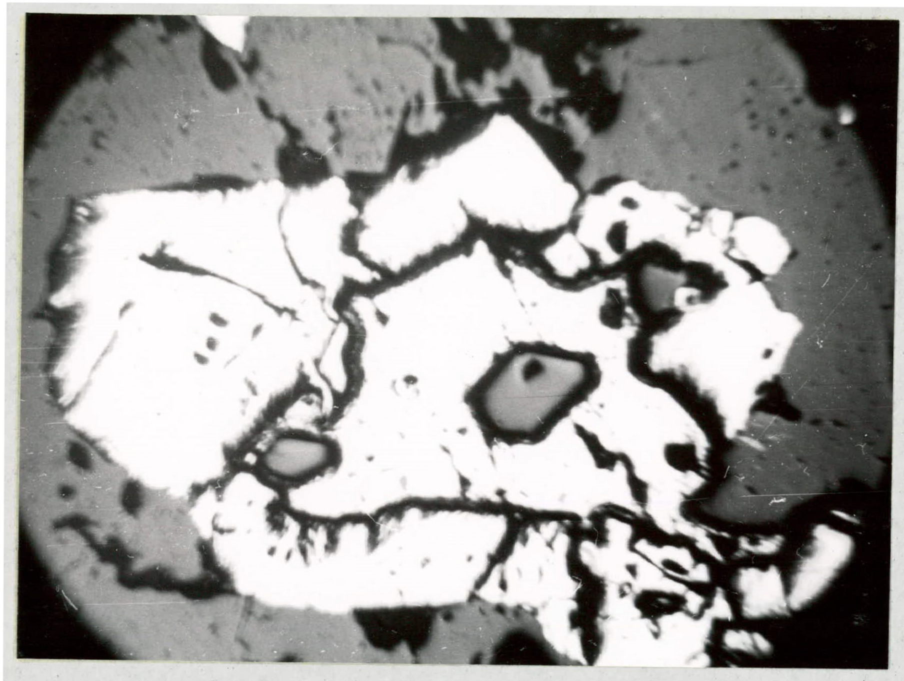


Figure 38.--Photomicrograph of atol texture showing galena (white), surrounded by a tick rim of pyrite (white). Surrounding the pyrite and occupying the outside of the photograph is quartz (light grey). Note the Euhedral quartz crystal in the center of the galena. Specimen taken on the surface at 9,390E, 11,850N. Magnification approximately 320, photograph taken in reflected light.

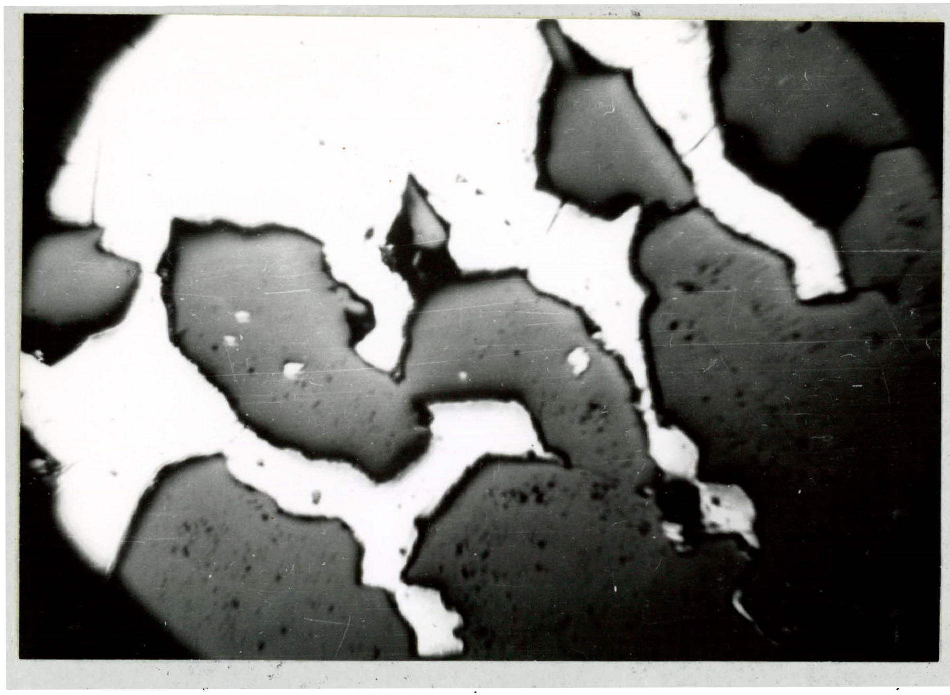


Figure 39.--Photomicrograph showing the filling and replacement of quartz (grey), by galena (white). Specimen taken from the 2nd sub-level, Pride of the West Mine. Magnification approximately 320, photograph taken in reflected light.

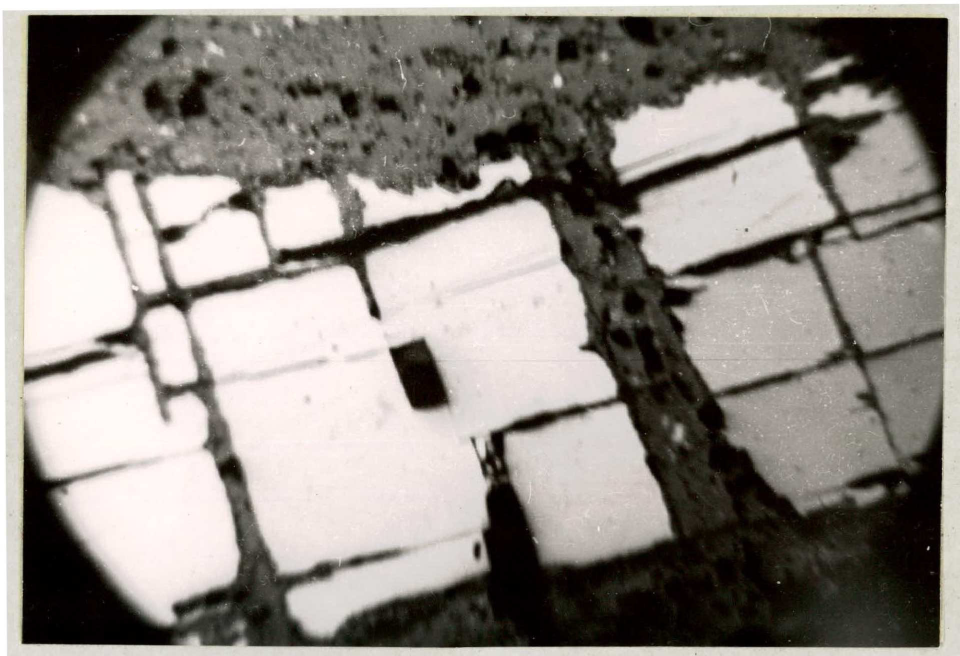


Figure 40.--Photomicrograph showing the replacement of galena (white) by carbonates (grey). Magnification approximately 160, photograph taken in reflected light.

Native Silver: This mineral commonly occurs as wire silver lining vugs, and is probably of a supergene origin, although this is by no means certain. Many vugs were examined in the mines for wire silver but the writer did not discover any. It is reported that handsome masses were found in the upper levels when the Pride of the West Mine was first developed. Undoubtedly, some of the very high assay values at that time were due to this mineral.

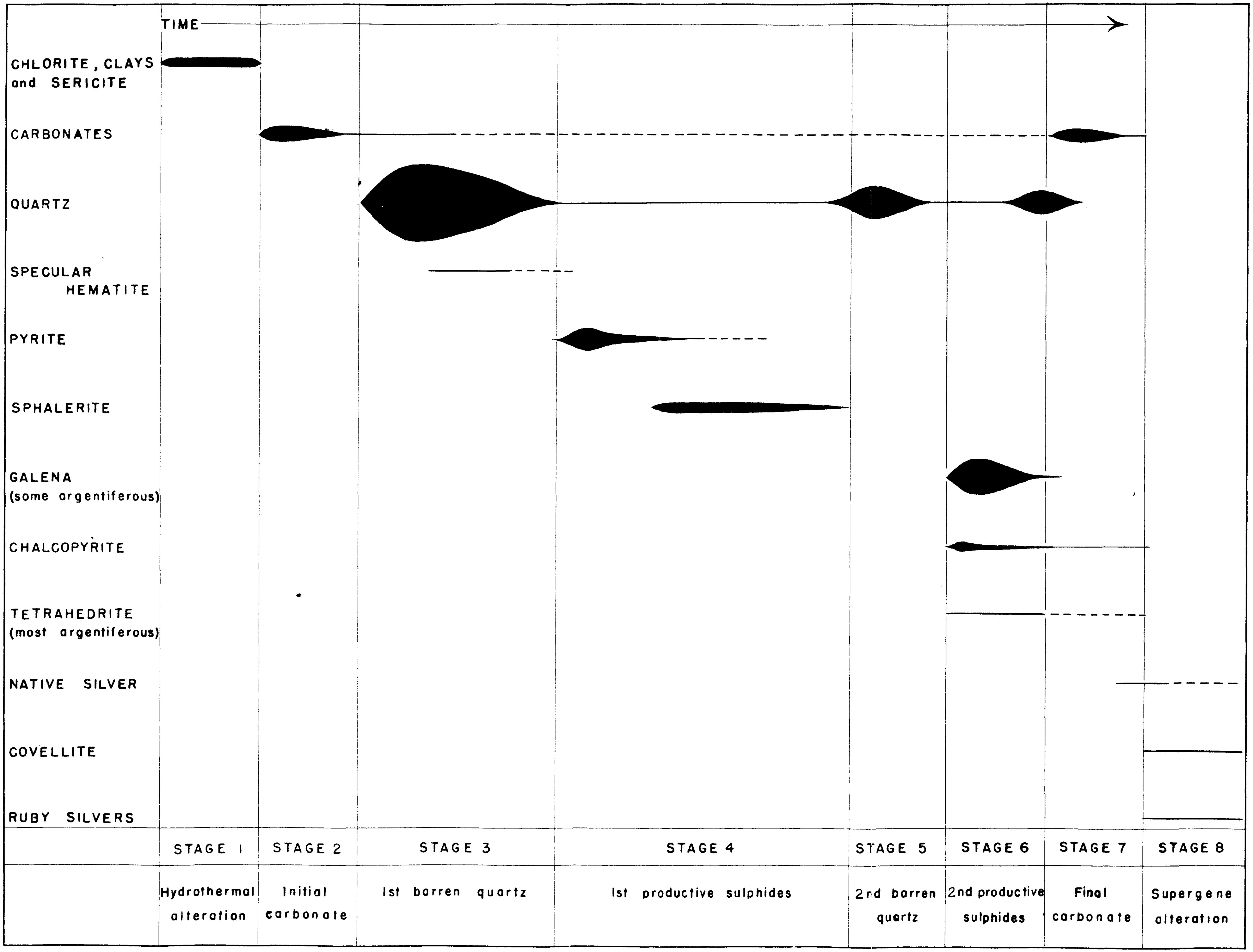
Other Sulphides: The remaining sulphides, tetrahedrite, ruby silver and covellite will not be discussed as they only occurred in relatively small quantities and displayed no unusual features.

Other Gangue Minerals: Flurite, barite and rhodonite were also found in small quantities in the vein system and their exact relationship to the other vein minerals could not be determined in the polished sections examined.

Paragenesis: A paragenesis chart (Figure 41, page 112), has been prepared by the writer for the Pride of the West vein system. The black areas on the chart indicate in a diagramatic manner the relative time and quantity of minerals deposited.

The paragenesis sequence has been divided into eight stages, each stage representing the deposition of a particular mineral or minerals. The first stage represents weak hydrothermal alteration with the alteration products of chlorite, sericite and clays being deposited in small irregular quantities throughout the vein zone. In some parts of the vein system, notably the northern part, epidote and clinozoisite were formed.

FIG. 41, PARAGENESIS OF VEIN MINERALS IN THE PRIDE OF THE WEST VEIN SYSTEM



This initial stage was followed by a carbonate stage and this in turn followed by a stage of barren quartz. Stages three, four and six are represented by the productive sulphides which include the following minerals listed in the order of deposition:

Pyrite	FeS_2
Sphalerite	ZnS
Galena	PbS.
Chalcopyrite	$CuFeS_2$.
Tetrahedrite	Cu_2S. Sb_2S_3.

The minerals in the above list are characterized by having an increasing solubility in water from top to bottom. The first productive sulphides are represented by pyrite and sphalerite. Fractures cutting the sphalerite were filled with quartz before the deposition of the second productive sulphides. The second productive sulphides, galena, chalcopyrite and tetrahedrite appear to have been deposited almost contemporaneously with chalcopyrite depositing a little longer than the other two (Figure 42, page 114). The deposition of flurite, barite and rhodonite are probably represented by this stage, but their exact relationship to the other minerals has not been determined as yet.

The productive sulphide stage was followed by a period of fracturing and the filling of these fractures by carbonates and minor amounts of quartz. The final or eighth stage consisted of limited supergene alteration of the hypogene sulphides. This supergene stage is principally represented by minor amounts of covellite and ruby silver.

Vein Structures

Replacement is the dominant process of vein formation especially

Figure 42.--Photomicrograph showing the replacement of galena (light grey) by chalcopyrite (grey). Note that the replacement occurs mainly along the cleavage directions of galena. Specimen taken from the 7th level, Pride of the West Mine. Magnification approximately 320, photograph taken in reflected light.

Figure 43.--Hand specimen showing a mineralized vein of milky quartz transecting the country rock of flow breccia. Note galena in the center of the vein and also late carbonate veinlets (black) that cut the quartz vein at right angles. Specimen taken from the 1st. level, Pride of the West Mine.

as far as the sulphides are concerned but open space filling is frequently observed. The ore commonly occurs as large parallel lenses, each of which is not generally continuous for any great distance. These lenses of ore occur between branching stringers and veins of quartz. In some places the boundary of the vein system is hard to determine because innumerable stringers and veinlets branch out into the country rock. In other places the vein is in sharp contact with the country rock and has the appearance of being "frozen" to it. Although numerous variations are present, the term "linked vein structure" seems to be most appropriate for this system. Numerous gougy slip planes are present in many parts of the mine, but it is thought that there was no appreciable movement along the fissure. The evidence of lack of movement is based on the absence of any displacement of the stratigraphic units from one side of the vein system to the other.

Figure 21, page 86, illustrates the blocky character of one of the veins after exposure to surface weathering. Figures 22 and 23, pages 87 and 88, illustrate the "frozen" relationship between the country rock and veins.

Figure 44 and 45, pages 117 and 118, show high-grade ore in limestone. The irregular replacement of the limestone is evident and the peculiar spherical concretionary-like bodies of ore are also of interest. Figure 45, page 118, is of special interest in showing one of these concretionary masses in contact with a lens of massive and vuggy quartz.

Figure 46, page 119, shows high-grade galena and sphalerite. It may be noted in this figure that the masses of sulphide are transgressed by veinlets of translucent quartz. Figure 46 also illustrates very well the banding seen in the vein zone. Both Figure 47, page 120, and Figure 48, page 121, show various types of banding. Whereas, Figure 47

Figure 44.--Surface exposure showing the replacement of limestone by sulphides and quartz. Note the brecciation and silicification of the limestone in the upper right corner of the photograph. Note also the concretionary like ore forms developed in the lower center part of the photograph. View taken looking east at 9,510E, 11,270N.

Figure 45.--Close-up view of area seen in Figure 44, showing one of the concretionary like forms in greater detail. Note the sharp contact of the quartz vein with the limestone.

Figure 46.—Hand specimen of high grade ore consisting of galena, sphalerite and chalcopyrite. Note the rough banding of the massive sulphides and translucent quartz. Specimen taken from the first level, Pride of the West Mine.

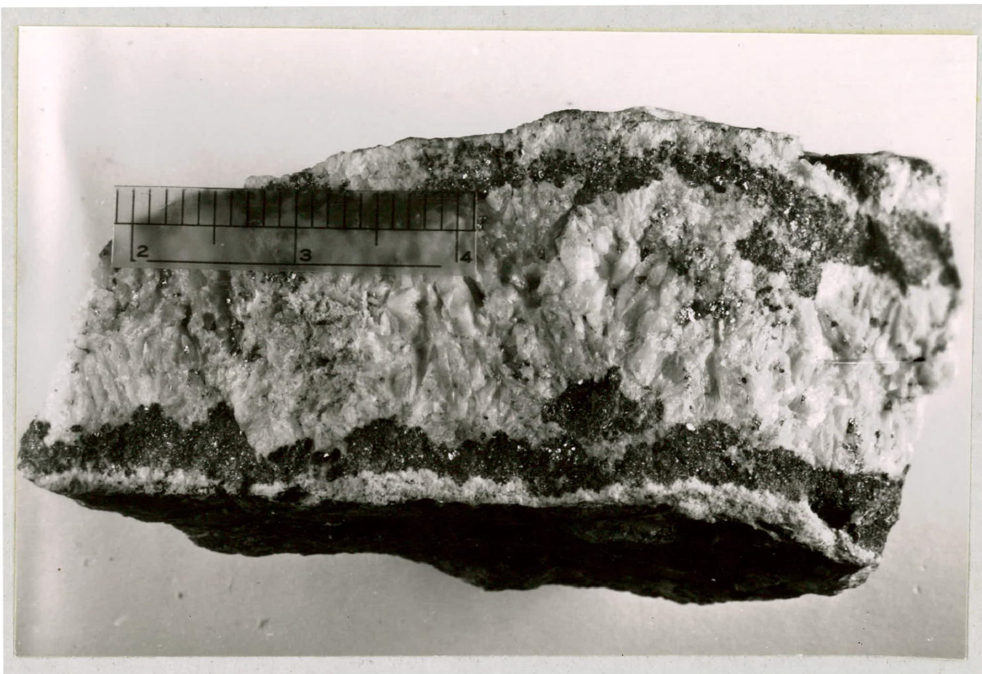


Figure 47.—Hand specimen of a portion of a vein showing the banded character of the sulphides (dark) and the quartz (white). Specimen taken from the 7th level dump, Pride of the West Mine.

Figure 48.--Hand specimen of a small vein showing the pronounced banding of the massive sulphides and quartz. Note that unlike the specimen in Figure 47, the sulphides were deposited later than the quartz. Specimen taken from the seventh level dump, Pride of the West Mine.

shows quartz filling the center of the vein, Figure 48 shows massive sulphides filling the center of the vein.

"Zebra Ore" of the Osceola Mine: The curious and strikingly banded "Zebra Ore" found in the property of the Osceola Mine was first briefly described by Ransome (1901, Page 89). This ore, shown in Figure 49, page 123 and Figure 50, page 124, because of its unique occurrence will be described in greater detail.

The "Zebra Ore" occurs as strikingly regular bands of quartz and sulphides. Sulphides consist either of galena and pyrite or sphalerite and pyrite. In the latter case the pyrite and sphalerite are often banded themselves. Sulphide bands vary in width from 0.1 mm. to 4.0 mm. and probably average 0.25 mm. Quartz bands between the sulphides have a width from 0.2 mm. to 20.0 mm. and average approximately 3.0 mm.

The sulphide bands are often discontinuous as is seen in Figure 49, page 123, and some are somewhat distorted when examined in detail. Generally the aspect, however, is of a remarkably well-banded ore.

Quartz is translucent to clear, well-crystallized, and the crystals are orientated at right angles to the sulphide bands. Pyrite is commonly euhedral, and the atol structure of galena and pyrite mentioned previously (Page 105), has been observed in this ore. The order of crystallization appears to follow the same sequence as that determined in the paragenesis of vein minerals and the pyrite is clearly replaced by the other sulphides.

As far as the writer could determine all the occurrences of the "Zebra Ore" (March level, Consolation level, and on the surface at 9,450E, 12,050N), had limestone as the country rock. The estimated width of the exposure

Figure 49.--Hand specimen of "Zebra Ore" showing the banded relationship between the sulphides and the quartz. Note the discontinuous character of some of the sulphide bands. Specimen taken from the Consolation level, Osceola Mine.

Figure 50.--Hand specimen of "Zebra Ore" showing the progressive increase in the size of quartz bands from right to left of the photograph. Specimen taken from the Consolation level, Osceola Mine.

of the "Zebra Ore" on the surface at 9,450E, 12,050N is at least four feet, and probably exceeds six feet. Three assays of the "Zebra Ore" from the above three occurrences were averaged and gave the following results:

0.16 ounces gold per ton
0.9 ounces silver per ton
3.7 percent lead
6.5 percent zinc
0.3 percent copper

Both the gold and zinc values are unusually high for the average ore that occurs in the Pride of the West vein system. The silver is probably contained in the galena and the gold is associated either with the pyrite or chalcopyrite.

The term "Zebra Rock" appears to have been first used by Butler and Singewald (1940, Page 793-838), who described the zonal mineralization and silicification in the Horseshoe and Sacramento Districts, Colorado. They state that the re-crystallization of the Leadville dolomite produced irregular sub-parallel bans of white dolomite and that alternations of these white bands with dark gray dolomite is responsible for the designation of "Zebra Rock."

Lindgren (1915, Pages 231-234), in a study of the replacement of limestones by highly siliceous ores of the Gemni Mine in the Tintic District, Utah, discusses a similar type of ore:

> "Silicification of the Tintic type is produced not by metosomatic replacement, involving the development of crystals in solid rock, but by replacement of limestone or dolomite by colloidal silica which immediately afterwards became transformed into chalcedony or in part into granular quartz. Given such a colloidal mass it would be easily penetrated by electrolytes which by reaction with residual solutions contained in the gel might easily produce such rhythmic precipitation rings."

Lindgren believes that the diffusion rings or rhythmic precipitation is similar to those in agate or those described by Liesegang (1915, Page 233).

In a review of Liesegang's paper by Knopf (1913, Page 804), Knopt is quoted as stating:

> "If a drop of $AgNO_3$ solution is placed on a plate coated with gelatin which has been impregnated with K_2Cr_2O7, a series of concentric rings consisting of the insoluble Ag_2Cr_2O7 will be formed, the rings become spaced at successively wider intervals apart in proportion as the distance from the center increases. This concentric system of rings was termed 'Liesegang rings' by Ostwald."

Figure 50, page 124, shows a similarity of the Osceola "Zebra Ore" rings to the rings described above, with the rings becoming progressively wider spaced to the left of the photograph.

The formation of the Liesegang rings is explained by Ostwald as follows:

> "As silver nitrate diffuses out a supersaturated solution of silver bichromate is formed, when the metastable limit of this solution is reached the silver bichromate is precipitated forming the first ring. The continuous outward diffusion of the soluable silver salt causes a renewed formation of silver bichromate solution in the zone surrounding the first ring until precipitation again ensues."

In an examination of the Osceola Mine in 1899 Ransome (1901, Page 89), gives a brief description of some of the "Zebra Ore" he found on one of the Osceola Mine dumps in 1899. Ransome believed that its origin was probably connected with metosomatic replacement. The writer, however, follows Lindgren's views very closely and believes that the ore was formed through diffusion in colloidal quartz.

Alteration

Hydrothermal Alteration: No apparent practical relationship between the occurrence of ore and hydrothermal alteration can be used for the location of new ore bodies. Although there is considerable alteration in the Pride Area, this alteration appears to blanket the entire region and probably is connected with fumarolic activity following volcanism.

The writer has noticed occasional small zones of argillitic and sericitic alteration along the sides of the veins and also more extensive propylitization in the vicinity of the Osceola Mine. However, this alteration has been too minor and irregular to be useful as a criterion for the finding of ore. Only in the lower Lawrence level of the Osceola Mine is there any possibility for the use of propylitization as a guide to ore.

Supergene Alteration: Because of the high altitude and great relief in topography in the Pride Area, erosion has been extremely active. This rapid rate of erosion has prevented the formation of any appreciable supergene sulphides in the vein zone. A piece of massive sulphide taken at the surface and illustrated in Figure 31, Page 100, shows a partial leaching of the sphalerite with the galena remaining unaltered.

Ore Controls

Any geologic feature that has had an influence upon the deposition of ore is discussed in this section and for clarity this heading has been divided into four general groups: faulting and fissuring, jointing, effect of country rock and other controls.

Faulting and Fissuring: As stated previously, the Pride of the West vein system is a part of one of the fissure zones on the southern rim of of the Silverton Caldera. The radial fissures appear to be tensional in origin and according to Burbank probably were the result of the initial doming of the Silverton volcanic center. The tensional origin is supported by the fact that many of the fissures contain dikes that would be more likely to be emplaced if tensional stresses were in operation. No appreciable offset along the Pride of the West vein system has been found to exist but numerous gougy slip planes indicate that movement did occur, probably of an oscillatory nature.

Unlike the Green Mountain Mine, the Pride of the West and Osceola Mines are free of post mineral faults. However, on the surface there is evidence of at least one post mineral fault cutting the vein system. The extension of this fault does not intersect any present mine workings.

The Pride of the West fissure zone is at least four thousand feet in length and has a known depth of at least fourteen hundred feet. The fissure zone strikes about 19 degrees northwest and has generally a steep dip to the northwest. The width of the fissure zone varies from 100 to 250 feet.

Jointing. The strike and dip of the dominant joint set in the vicinity of the Pride of the West vein system have been found to be the same as the strike and dip of the vein system itself. It would appear that the jointing controlled the fissuring which in turn influenced the location of the ore.

Between the Schneider open pit and the Little Fanny Mine the dominant joint set has a very constant strike of 20 degrees northwest with a dip of 72 degrees west. This attitude agrees very closely with that of the vein system in that area. Between the Schneider open pit and the Osceola Mine the strike of the jointing is much more variable, but it averages 28 degrees northwest with a dip of 85 degrees west. The vein system in general follows this trend but locally departs from it at a high angle.

There does not seem to be any definite relationship between different lithologic types and the jointing with the possible exception of the lower rhyolite, which is characterized by a steep or vertical jointing.

Effect of the Country Rock: The nature of the country rock is considered to be a major control in determining the character of the veins and the localization of ore in the Pride of the West area. The following list represents rocks of the Pride Area placed in order of their favorability for ore deposition, with the flow breccia being the most favorable and the rhyolite flow the least favorable.

1. Flow breccia member of the Upper Eureka Rhyolite.
2. Latite flows in the Lower Eureka Rhyolite.
3. Ouray limestone.
4. Pre-Cambrian schist-flow breccia contact.
5. Pre-Cambrian schist.
6. Rhyolite flows in the Upper Eureka Rhyolite.

A brief summary giving the characteristics of the veins in the above rock types follows:

Flow breccia member of the Upper Eureka Rhyolite: The veins in this rock type are regular in width, strike and dip. They also are characterized by having definite wall rock contacts as well as distinct ore bodies within the veins. Gougy slip planes are common, especially in the lower levels of the Pride of the West Mine. The vein zone averages about 100 feet in width and contains at least two distinct veins which are frequently linked and branching.

Latite flows in the Lower Eureka Rhyolite: The vein zone in this rock type is unusually wide, averaging about 250 feet. Individual veins have irregular widths, together with variable strikes and dips. The veins commonly have a very complicated indefinite appearance because of innumerable linking and branching veinlets and also because of occasional extensive silicification of the country rock. Mineralization is distributed fairly regularly throughout the entire vein zone, but but the occurrence of commercial ore is irregular and generally of low grade.

Ouray Limestone: Veins in the limestone have many of the features that are common to those in the latite flows discussed above. Veins are extremely irregular in width, strike and dip. Although little development work has been done in the Ouray limestone, it appears that the ore bodies are mainly of a replacement type, and their form and occurrence are very irregular.

Pre-Cambrian-Flow Breccia Contact: Veins in the Pre-Cambrian schist or at its contact with the andesite flow breccia, are characterized by being relatively thin and regular in strike and dip. Contacts are very sharp and gougy slip planes are fairly common. At present no important ore bodies in the Pride of the West and Osceola Mines have been developed in this rock, although in the Green Mountain Mine most of the ore is confined to this rock type.

Rhyolite Flows in the Upper Eureka Rhyolite: This rock type acts as a cap rock to mineralization in the Pride of the West vein system, and although vein material in the form of quartz is present, sulphide mineralization is very sparse. The veins have fairly constant width but variable strikes and dips. Contacts of the veins with the country rock are sharp and the branching and linking of veins is common.

Conclusion: The properties of the veins in the Pride of the West area, are thought to be directly related to the physical characteristics of the different rock types. The absence of extensive hydrothermal alteration and the character of vein structures does not suggest that the chemical properties of the rocks had any influence upon the vein formation.

As the flow breccia and the latite flows are the most important host rocks, their physical characteristics will be discussed in more detail.

The brittle character of the latite flow explains many of the features associated with this rock. Because of this inherent brittleness, the rock on the application of stress, fractured into a wide zone of irregular sub-parallel planes. The abundance of passageways for ore solutions distributed the mineralization widely throughout the fractured zone but did not facilitate strong concentrations in any one place.

On the other hand, the plastic properties of the flow breccia allowed only a small number of regular and parallel fissures to develop upon the application of stress. This plastic property also afforded the development of gougy slip planes. It is thus evident that only comparatively few channelways were available for the ore solutions, and with the gougy slip planes acting as baffles, the ore was precipitated in strong concentrations wherever structural conditions were favorable.

Other Ore Controls: In almost every case it appears that the highest grade and largest ore bodies are associated with steep dips. As can be seen from Figure 51, Page 132, this change in dip in the Pride of the West mine

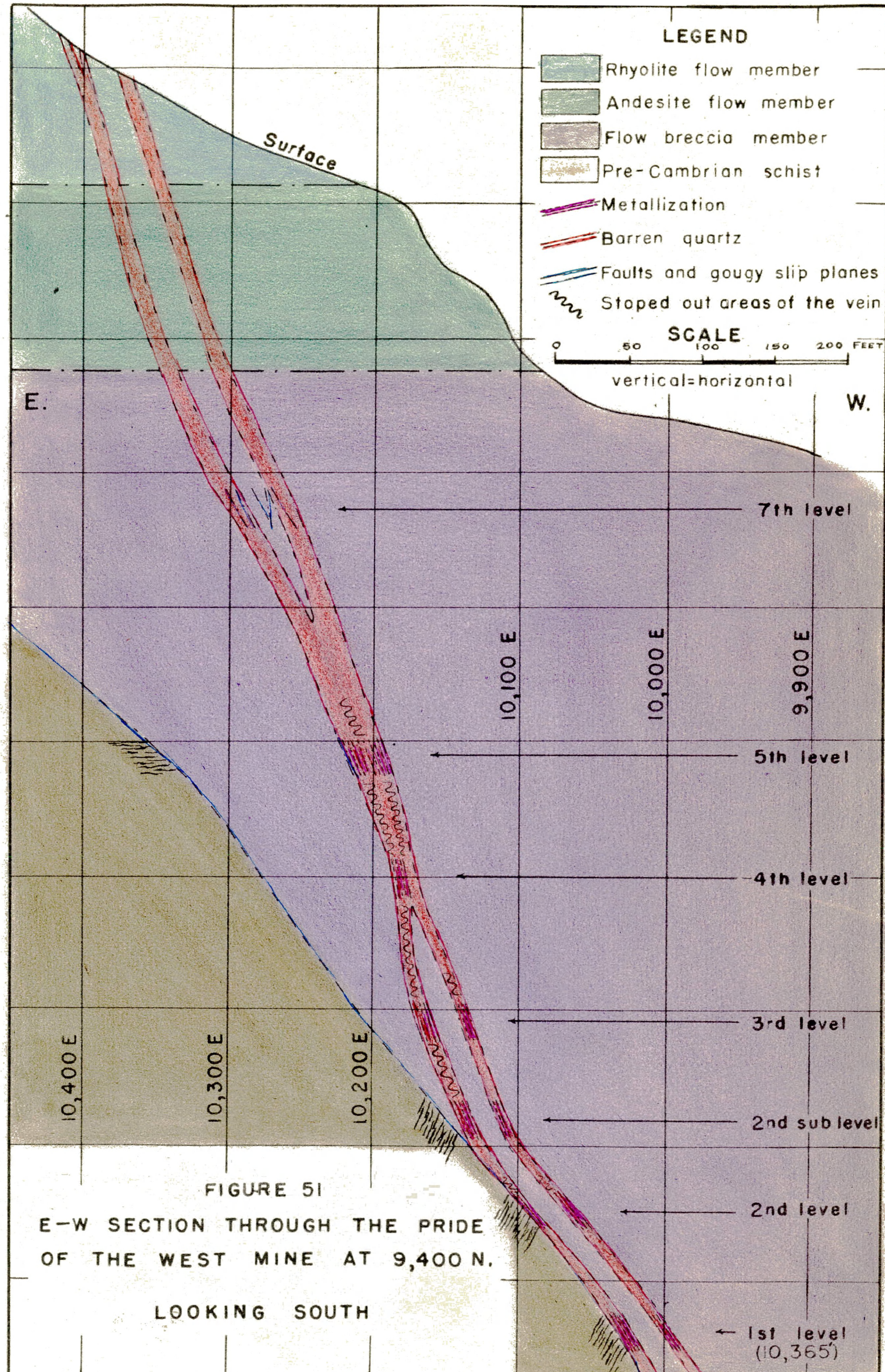


FIGURE 51

E–W SECTION THROUGH THE PRIDE OF THE WEST MINE AT 9,400 N.

LOOKING SOUTH

is controlled by the Pre-Cambrian schist contact. This contact is unusually steep, ranging from 65 to 75 degrees and probably represents the side of an ancient steep-walled valley.

In the Pride of the West Mine most of the ore is confined to a bow-shaped vein zone which is concave to the west. On the third, fourth and fifth levels of this mine this bow-shaped zone is especially prominent and it is here that the highest concentrations of ore occur. A similar concave zone is found in the Lawrence level of the Osceola Mine and it is more than a coincidense that both mines should possess this feature. The exact structural conditions producing these zones are not clear but in the Pride of the West Mine the bow-shaped zone might possibly be caused by the junction of the fissure system with the Pre-Cambrian contact.

Interpretation of Magnetometer Data:

The magnetometer survey carried out at the Pride of the West Mine and associated properties was made in the summer of 1950 with an Askania magnetometer.

A test traverse with stations at fifty-foot intervals was run over an exposed portion of the Pride of the West vein system, just south of the Midway level adit. This tranverse gave a negative anomaly of about 200 gammas in the vicinity of the vein zone and encouraged the writer to make a series of traverses over the covered portion of the vein system in order to determine its extensions to the north and south. The results of this survey have been plotted on Plates B, C and D, and the following conclusions have been drawn.

1. A negative anomaly in excess of two hundred gammas was determined from at least three traverses over the known vein zone.

2. The negative anomaly probably is produced by quartz and the silicification associated with the veins.

3. A strong negative anomaly in excess of five hundred gammas was found to have a trend of 32 degrees southwest from a point just south of the Schneider open pit (10,150E, 9,800N).

This trend correlates very well with a series of joint determinations made independently in the area. Although no important westerly split of the veins was found in the underground workings, it is possible that one of the veins thus far not developed might parallel or follow this westerly trend.

4. No definite anomaly trends were found when the vein zone was in the limestone and for this reason the continuation of the vein system to the north was not established.

Summary and Conclusions

The Pride of the West vein system is a vein-filled fissure zone linked by numerous stringers and constitutes one of the radial fissures in the southern part of the Silverton volcanic center. The fissure and vein system dips to the southwest and strikes approximately 19 degrees northwest. The vein system extends for a known distance of about 4,000 feet and has a depth in excess of 1,400 feet. Sulphide mineralization has been traced for at least 2,800 feet along the strike and 900 feet down the dip. The zone varies in width from 100 feet to 250 feet. Both the Pride of the West Mine and the Osceola Mine have produced ore from the vein system and the Pride of the West Mine is still operating today.

Certain of the ore controls have definitely been established. These include lithology, jointing and contact relationships. Within this framework, minor structural controls have been thought to operate such as gougy slip planes and changes in the dip and strike of veins.

The vein system is in the epithermal-mesothermal group (leptothermal). No essential change in mineralogy was noted along the strike or down the dip of the vein system.

B I B L I O G R A P H Y

Atwood, W. W., and Mather, K. Physiography and Quaternary Geology of the San Juan Mountains, Colorado. U. S. Geological Survey Professor Paper 166, 1932.

Brinker, F. A. Private report to the Denver Equipment Company, Denver, Colorado, February 6, 1940.

Burbank, W. S. Vein Systems of the Arrastre Basin and Regional Geologic Structure in the Silverton and Telluride Quadrangles, Colorado.

Burbank, W. S., Eckel, E. B., and Varnes, D. J. The San Juan Region, Colorado. Mineral Resources of Colorado, Colorado Mineral Resources Board Bulletin. 1947.

Butler, B. S. Relation of the Ore Deposits of the Southern Rocky Mountains Region to the Colorado Plateau. Colorado Scientific Society Proceedings, Vol. 12. 1929-1931.

Butler, R. D. and Singewald, Q. D. Zonal Mineralization and Silicification in the Horseshoe and Sacramento Districts, Colorado. Economic Geology, Vol. 35. 1940.

Cross, W., Howe, E., and Ransome, F. L. Description of the Silverton Quadrangle, Colorado. Geologic Folio No. 120.

Hagen, J. C. Geology of the Green Mountain Mine, San Juan County, Colorado. Thesis for degree of Master of Science, Colorado School of Mines, Golden, Colorado. September, 1951.

Helgerson, E. N., Personal communication to W. H. King and P. T. Allsman (Page 89, Reconnaissance of Metal Mining in the San Juan Region, Ouray, San Juan and San Miguel Counties, Colorado.) Bureau of Mines Information Circular No. 7554.

Herness, K. S. Personal communication. 1951.

King, W. H. and Allsman, P. T. Reconnaissance of Metal Mining in the San Juan Region, Ouray, San Juan and San Miguel Counties, Colorado. Bureau of Mines Information Circular No. 7554. March, 1950.

Knopf, A. Review of R. E. Liesegang's "Geologische Diffusionen." Economic Geology, Vol. 8. 1913.

Lindgren, W. Processes of Mineralization and Enrichment in the Tintic Mining District. Economic Geology, Vol. 10. 1915.

Nissen, A. E., and Hoyt, S. L. On the Occurrence of Silver in Argentiferous Galena Ores. Economic Geology, Vol. 10. 1915.

Ransome, F. L. Economic Geology of the Silverton Quadrangle. U. S. Geological Survey Bulletin No. 182. 1901.

Rouse, J. T. Genesis and Structural Relationships of the Absaroka Volcanic Rocks, Wyoming. Geological Society of America Bulletin No. 9, Vol. 48. 1937.

Stevens, E. H. Written communication to J. T. Rouse.

Tenney, J. B. Discussion on the Relation of the Ore Deposits of the Southern Rocky Mountain Region to the Colorado Plateau, Colorado Scientific Society Proceedings, Vol. 12. 1929-1931.

Varnes, D. J. South Silverton Area, Animas District, San Juan County, Mineral Resources of Colorado. Colorado Mineral Resources Board Bulletin. 1947.

Varnes, D. J. Geology and Ore Deposits of the South Silverton Area, San Juan County, Colorado. Colorado Mining Association. February, 1948.