BRIGHAM

YOUNG

UNIVERSITY

GEOLOGY STUDIES

Volume 11 December 1964

CONTENTS

Brigham Young University Geology Studies

Volume 11 — December 1964

Contents

A publication of the
Department of Geology
Brigham Young University
Provo, Utah

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Brigham Young University Geology Studies is published annually by the Department and consists of graduate student and staff research in the Department.

Distributed February 20, 1965

Price $3.00

Geology of the Bald Mountain Intrusive, Ruby Mountains, Nevada*

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ABSTRACT.—The Bald Mountain area is located in the Southern Ruby Mountains in White Pine County, Nevada. Big Bald Mountain is carved in a low north-trending anticline composed chiefly of the Ordovician Pogonip Group. Little Bald Mountain, which is separated from Big Bald Mountain by a N. 60° W. fault, is made up of lower Pogonip limestone and Upper Cambrian Windfall Formation.

In the low area between the two peaks, an obloid quartz monzonite porphyry stock covers appoximately 2½ square miles. It has an elongate trend of N. 60° W. and appears to have been controlled by the above-mentioned fault zone. A system of dikes, the majority of which are rhyolitic, extends into the country rock from the intrusive and lamprophyre dikes and quartz veins occur within the stock itself.

The stock is surrounded by a metamorphic aureole consisting of two facies of contact metamorphism including marble, banded hornfels, and tactite.

The vicinity of Bald Mountain has long been referred to as the Bald Mountain Mining District. Mining in the district began following the discovery of silver lodes in 1869. Since then, gold, silver, copper, antimony, and tungsten have been discovered and worked on a small scale. Total production in the area probably does not exceed $60,000.

CONTENTS

TEXT

*A thesis submitted to the Faculty of the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, July 17, 1964.

CONTENTS

ILLUSTRATIONS

MAP

INTRODUCTION

Purpose and Scope

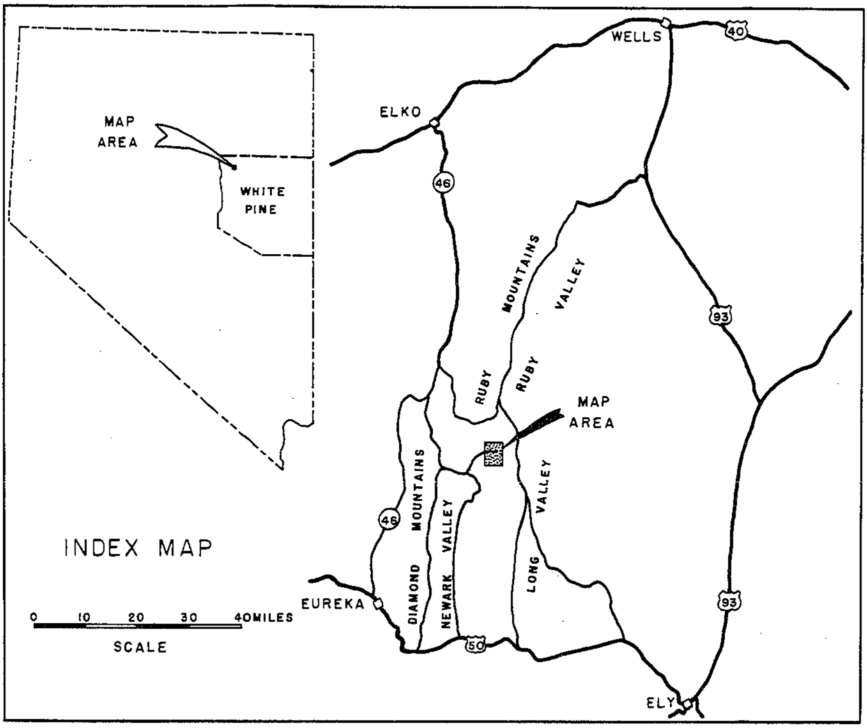
The Bald Mountain area has been visited from time to time by writers who gave short descriptions of the mineral deposits and general geologic setting. A preliminary geologic map of the area was published by Rigby (1960), however, igneous and metamorphic rock relationships were merely mentioned by previous workers. It is the purpose of this report to produce an accurate description and geologic map of the igneous and metamorphic rocks in this locality and to describe and evaluate the mineral deposits found there.

Location and Accessibility

Bald Mountain is situated in the northwestern corner of White Pine County, Nevada, six miles south of Overland Pass in the Southern Ruby Mountains (Text-figure 1). The mapped area includes 16-17 square miles of T. 24 N., R. 57 E. The central part of the area is 35 miles northeast of Eureka, 65 miles south of Elko and 60 miles northwest of Ely. The vicinity of Bald Mountain can be reached by improved graveled roads from U. S. 40 or U. S. 50-6. The mapped area can then be reached by unimproved dirt roads via Water Canyon or Bourne Canyon on the west and via Orange Tank Canyon or Cherry Spring from the Long Valley Road on the east.

Geographical Setting

The Ruby Range is a north-south trending, westward-tilted horst, bounded by normal faults dipping 60 to 70 degrees basinward (Sharp, 1942), characteristic of the Great Basin ranges. The Bald Mountain District is situated in a group of low mountains which form the southern end of the Ruby Range and are structurally continuous with it. These mountains rise over 3,000 feet above Huntington and Newark Valleys on the west and Ruby Valley on the east, all of which average 6,000 feet above sea level. From Huntington Valley



TEXT-FIGURE 1.—Index map.

the mountains rise in a gradual, even slope to Big (North) Bald Mountain, the highest point in the area with an elevation of 9,303 feet. The range gradually decreases in altitude to the south and merges into Buck Mountain. On the west, the range is flanked by alluvial fans and bajadas of unconsolidated deposits in Newark and Huntington Valleys.

The mapped area is entirely above 7,000 feet and has a maximum local relief of over 2,000 feet. Water, Bourne, and Orange Tank Canyons and their tributaries form the principal drainages. Several springs are present, but no perennial streams except for a small distance in lower Water Canyon.

Previous Work

Simpson (1876, p. 64, 331) and Engelmann, in 1859, were probably the first to record geological observations in the Ruby Range. King (1877-8) and Wheeler (1889) described the general relations of the region and Spurr (1901) first mentioned the southern part of the range. Hill (1916, p. 152-161) gives the earliest and most extensive resume of the Bald Mountain Mining District. Sharp (1942) mapped and described the Southern Ruby Mountains north of Overland Pass. Rigby (1960 described the general geology of the Bald Mountain area and the Buck Mountain area immediately to the south. Notes on tungsten deposits of the district were published by Hess and Larsen

(1921), gold placer mining was described by Smith and Vanderburg (1932), and antimony deposits were discussed by Lawrence (1963).

Present Work

Field work was done during the summer of 1963 and intermittently during the following school year. Geologic data were plotted on aerial photos with a scale of 1:20,000 and later transferred to a topographic base map (Cold Creek Ranch Quadrangle) enlarged to a scale of 1:20,000.

Petrographic study of igneous and metamorphic rocks samples in the field was made in the laboratory. Microchemical tests and other determinative tests were made on ore samples.

Acknowledgments

The writer acknowledges assistance of Drs. Kenneth C. Bullock and J. Keith Rigby of the Geology Department of Brigham Young University, in offering helpful suggestions and constructively criticizing the manuscript. Thanks is due Mr. Charles Steen, president of the Steen Mining Company, Reno, Nevada, for financial aid which helped to defray field expenses. Allen Black and C. Kent Chamberlain assisted during some of the field work and mapped the sedimentary rocks surrounding the intrusive mass.

STRATIGRAPHY

General Statement

As the writer was primarily concerned with the igneous and metamorphic rocks of the area, the sedimentary country rock was not studied in detail. An incomplete section of sedimentary rocks totalling 8,300 feet in thickness and ranging from Upper Cambrian to Mississippian is present in the mapped area. The stratigraphy of these rocks is summarized as follows:

Cambrian System

Hamburg Dolomite

The upper 60 to 70 feet of what is provisionally called the Hamburg Dolomite crops out at the confluence of North and South Water Canyons, to the south in Bourne Canyon just east of Fracture Ridge, and to the north at the northern tip of the Bald Mountain stock. The formation consists of massive to thick-bedded, ledge-forming limestone. In all exposures, except that in Bourne Canyon, it has been metamorphosed to a low-grade white marble.

Dunderberg Shale

The Dunderberg Shale is exposed from Bourne Canyon northward to North Water Canyon between Fracture Ridge and Little Bald Mountain and also in a small area at the northern end of the stock. The formation is characterized in the Bourne Canyon exposures by relatively soft, dark green-gray, black, or dark greenish brown shale with thick, black, finely crystalline limestone occurring in two to six-inch beds and lenses in scattered exposures and having a total thickness of 468 feet (Black and Chamberlain, personal communication, 1963). Exposures of the Dunderberg to the north have been largely metamorphosed to banded hornfels retaining some of the bedding structure and with interbedded marbles in the lower portion. The basal part (10 to 30 feet) of the formation is normally silicified having a reddish-brown to yellow-brown color and exhibiting remnant bedding structure. The zone can be traced throughout both metamorphosed and unmetamorphosed exposures.

Windfall Formation

Early writers, particularly Hague (1883), included the Windfall Formation with the Pogonip Group. Nolan (1956, p. 20) proposed separating the Cambrian portion from the Pogonip Group. The Windfall Formation was proposed for the section between the Dunderberg shale and the Ordovician Pogonip Group. The type locality is Windfall Canyon, north of the Windfall Mine, in the Eureka Mining District.

At Eureka, the formation is divided into two members (Nolan, 1956), the lower being called the Catlin and the upper the Bullwhacker. The Catlin Member, there, is composed of interbedded massive limstone, in part cherty, and thin-bedded shaly to sandy limestone. The Bullwhacker Member consists of a rather uniform sequence of thin-bedded platy, sandy limestone. In Windfall Canyon the formation is 650 feet thick, and at Little Bald Mountain it is 1,412 feet thick (Black and Chamberlain, personal communication, 1963).

The formation is exposed over a considerable area on the western slopes of both Big and Little Bald Mountains.

The Catlin Member is 566 feet thick where measured on the southwest slope of Little Bald Mountain (Black and Chamberlain, personal communication, 1963). The Catlin here consists of essentially equally bedded dark-gray limestone and shale in two to six-inch thick units, both of which weather brown. Limestones are more resistant to weathering than the shales, tending to give the formation a step-like appearance. In contrast to the type section, limestone units are largely unfossiliferous, massive limestone ledges are missing, and cherty units are absent. Lower Catlin limestones are thin-bedded and finely crystalline, but become more irregularly bedded upwards in the section. Shale units are similar to the underlying Dunderberg Shale but are more calcareous and flaky and towards the middle of the section become more silty than the underlying formation.

Near the intrusive the Catlin has been metamorphosed to form a light gray to green banded hornfels, which is difficult to distinguish from the underlying metamorphosed Dunderberg Shale.

The Bullwhacker Member is 846 feet thick on the southwest slope of Little Bald Mountain (Black and Chamberlain, personal communication, 1963). In the mapped area, it consists of interbedded limestone and shales; but beds become very irregular, and the thickness of limestone units varies considerably in upper beds. Shale is more abundant than in the Catlin and weathers light chocolate brown. Inarticulate brachiopods and trilobites are abundant in some horizons.

In the vicinity of the Bald Mountain stock the Bullwhacker Member is a dark hornfels commonly having a greenish cast. Five-foot zones of brownish green, green, and white hornfels and zones of banded light green-gray and very light gray hornfels are common in the metamorphic zone around the stock.

Cambrian-Ordovician System

"Transition Beds"

Directly above what is mapped as Windfall Formation and below the Ordovician Goodwin limestone, a sequence of interbedded thin to medium-bedded limestones and shales termed the "transition beds" is present. These beds may be either Cambrian or Ordovician. The sequence is 242 feet thick on Little Bald Mountain (C. K. Chamberlain, personal communication, 1963), but thins out to 123 feet on Big Bald Mountain to the north (L. F. Braithwaite, personal communication, 1963).

The lower portion is predominantly shale with thin inter-bedded shaly limestone and limestone concretions. The light bluish-gray limestone weathers medium-gray and contains thin irregular splotches of yellow chert. Interbedded shale is yellowish-green and brownish-green. The upper 20 feet of the zone is a brownish-green shale with minor amounts of thin-bedded limestone. It forms an easily mappable contact with the overlying Goodwin limestone.

"Transition beds" are exposed on the northern and western slopes of Little Bald Mountain and on the western slopes of Big Bald Mountain. Near the intrusive, these beds are metamorphosed to a dark banded hornfels which contains well-preserved nodules, remnants of the limestone concretions.

Ordovician System

Pogonip Group

The Pogonip Group includes those beds between the Cambrian Windfall Formation and the Eureka Quartzite in the Eureka District. The Pogonip Group has been divided into three mappable units; the Goodwin Limestone, Ninemile Formation, and Antelope Valley Limestone as defined by Merriam and adopted by Nolan (1956, p. 24-25). In the map area the Pogonip Group makes up the greater portion of both Big and Little Bald Mountains.

Goodwin Limestone

The Goodwin dips to the southeast where it is exposed on Bald Mountain. It is faulted in the intrusive area such that a complete section could not be measured, but three miles to the south near Bourne Tunnel Spring, the formation is 722 feet thick (Robert Hinds, personal communication, 1963).

The Goodwin Limestone is a relatively pure, bluish-gray, medium to finely crystalline limestone containing minor beds of shaly limestone and dolomite. The lower portion is thin-bedded, bluish limestone and flat pebble conglomerate with interbedded dark gray-blue chert. The upper Goodwin is a relatively pure massive to thick-bedded limestone without chert.

Ninemile Formation

The Ninemile Formation is a thin-bedded, fine-grained, medium-gray limestone interbedded with silty limestone and calcareous shale. The shale gives the formation a yellowish-orange cast which is distinctive at a distance. At the type locality, the formation is 540 feet thick. In Bourne Canyon it was measured at 253 feet by Robert Hinds (personal communication, 1963). The formation is exposed near the top of Big Bald Mountain and just northeast of the summit of Little Bald Mountain.

Antelope Valley Limestone

Locally the formation differs widely from the type section in that it contains considerable chert throughout the section and can be divided into four distinct units. These have been given field names, from the lowest unit upwards, as follows: lower dolomite, "ragged yellow" beds, "blue sponge" beds, and "upper transition" limestone. These names will be used in this paper to facilitate description of the formation.

The dolomite and ragged yellow units are exposed on the eastern flanks of Little Bald Mountain and dip eastward. Eastward-dipping ragged yellow and the upper two members are extensively exposed on the eastern flanks of Big Bald Mountain. The "dolomite" unit is a thick-bedded, medium-gray, medium-crystalline dolomite which weathers light gray to light brownish-gray. It is 250 to 300 feet thick (C. K. Chamberlain, personal communication, 1963) and forms prominent ledges in the Bald Mountain region. The "ragged yellow" is a medium-bedded limestone which contains irregularly bedded dolomites, silty to sandy dolomites and limestones, and some calcareous sandstones. The unit has a characteristic yellowish color derived from the sandy beds and abundant yellow and brown chert lenses. It is about 1,550 feet thick on Big Bald Mountain (L. F. Braithwaite, personal communication, 1963). The unit is quite fossiliferous and contains algal heads, trilobites, cephalopods, gastropods, and some sponges.

The "blue sponge" beds are easily differentiated from the underlying "ragged yellow" beds. They grade upwards into sandy reddish-orange dolomite just below the Eureka Quartzite. Thickness of the unit is not known in the map area, as it is faulted in all known exposures.

Eureka Quartzite

The Eureka Quartzite was named from the Eureka Mining District (Hague, 1892, p. 54-57) where the formation is 300 feet thick (Nolan, 1962, p. 10). The formation is 234 feet thick near "the Gap" (Rigby, 1960, p. 174 and thins to 74 feet (L. F. Braithwaite, personal communication, 1963) on Big Bald Mountain, six miles to the north. It pinches out northward in the Ruby Mountains (Sharp, 1942, p. 659). The ledge-forming Eureka Quartzite is a vitreous light-gray to white ortho-quartzite, locally weathering reddish-brown and pink. The quartz grains are subrounded to subangular and are enclosed in a siliceous matrix. The formation is exposed at the head of North Water Canyon, at the head of the south fork of South Water Canyon, and ¾ mile north of Bourne Canyon in Section 32, T. 24 N., R. 57 E.

Fish Haven Dolomite

Dolomite between the Eureka Quartzite and overlying Silurian dolomites has been called the Ely Springs Dolomite (Westgate and Knopf, 1932) and the Hanson Creek Formation (Merriam, 1940). However, the term Fish Haven (Richardson, 1913) is currently used throughout much of the Great Basin and was used by Rigby (1960) in the present map area.

The Fish Haven is a cliff- forming dolomite which weathers dark gray-brown. The lower part is characterized by finely crystalline, gray-brown dolomite containing considerable black lenticular chert. The upper part is mainly non-cherty, lighter colored, and more coarsely crystalline. Like the Eureka Quartzite, the Fish Haven Dolomite thins northward from 280 feet near "the Gap" to 77 feet near the head of Pass Canyon east of Big Bald Mountain.

Silurian System

Laketown Dolomite

Laketown Dolomite crops out along the east side and in the southwest corner of the area, where it is thrust over the Hamburg and Dunderberg Formations. Laketown Dolomite was the name given by Richardson (1913, p. 410) to the dolomite overlying the Fish Haven Dolomite in northern Utah, and the name has been widely used in the eastern Great Basin.

The Laketown forms prominent massive to thick-bedded ledges of light to medium gray dolomite, weathering medium light-gray to yellow-gray west of Little Bald Mountain. It is approximately 100 feet thick here. East of Big Bald Mountain the Laketown is highly brecciated in many outcrops and is folded into a series of small anticlines and synclines which largely control the topography.

Devonian System

Sevy Dolomite

Nolan named the Sevy Dolomite from outcrops in the Deep Creek Range, Gold Hill Mining District, Utah. The upper 280 feet of the formation are exposed in upper Bourne Canyon. The Sevy here is a homogeneous microcrystalline dolomite which is light brownish-gray with a pink cast, and weathers light gray.

Simonson Dolomite

Simonson Dolomite (Nolan, 1935) crops out over a considerable area on the east side of Little Bald Mountain where it has been faulted upwards against the Antelope Valley Formation. The lower unit, about 200 feet thick, is light to medium gray, coarsely crystalline, medium-bedded dolomite. The upper unit consists of interbedded light and dark-gray crystalline dolomites and is 150 feet thick in the area. Dark members are usually banded with wavy laminae. Up to 690 feet of the Simonson has been mapped a few miles south of Little Bald Mountain (Rigby, 1960, p. 174). Some poorly preserved brachiopods and corals were found in the darker members.

Guilmette Limestone

The Guilmette Limestone was named by Nolan (1935) from outcrops in the Deep Creek Range, Gold Hill Mining District, Utah, where it is 1,000 feet thick. It is exposed in the southeastern part of the mapped area where it is over 1,300 feet thick (William Sill, personal communication, 1963). The Guilmette is equivalent to the Devils Gate Formation named by Merriam (1940, p. 16) from Devils Gate near Eureka, Nevada. Rigby (1960, p. 176) describes the Guilmette as follows:

> The Guilmette Limestone is composed of obscurely and irregularly bedded, massive limestone. Middle and upper parts of the formation are distinctly massive, irregular wedges of fine-grained dark-gray to medium-gray, non-cherty limestone. The lower part of the formation is similar, but better bedded.

The formation in the mapped area has been highly faulted and altered by numerous dikes. It is extensively dolomitized and is silicified in many places.

Pilot Shale

The Pilot Shale is a platy yellow to buff-colored, slope-forming siltstone which crops out in the southeastern part of the area. It is about 400 feet thick there. Exposures are abundant, forming excellent contacts with the Guilmette and the overlying Joana Limestone.

Mississippian System

Joana Limestone

The Joana forms a prominent key horizon separating the more easily eroded Pilot and Chainman Shales. The formation is characterized by gray to brown limestone interbedded with irregular stringers and lenses of chert. A unit of encrinal limestone four to six feet thick occurs near the base. .

Most exposures of Joana in the immediate area, however, are highly silicified, red, brown, and black ledges with no trace of original bedding or lithology. The formation is about 100 feet thick in the mapped area.

Chainman Shale

Chainman Shale occurs in the vicinity of Cherry Spring as a slope former. No large exposures of bedrock are present. Slope rubble consists of brown and gray platy shale, indicating that only the lower of the three units described by Rigby (1960, p. 177) is present.

Western Silicified Facies

A zone of jasperoid rock is present along the west flank of the mapped area which is silicified to such an extent that it is stratigraphically indistinguishable. At the junction of North and South Water Canyons, the rock is a dark-red to reddish-black breccia which has been completely silicified, West of here the jasperoids become more earthy and massive. The breccia zone which occurs along the eastern edge and the altered but non-brecciated zone directly to the west suggest that the jasperoid may be the leading edge of a thrust plate which has been thrust eastward over the Cambrian formations of the area.

Quaternary System

Pleistocene lake deposits occur in Newark and Long Valleys. The range is flanked by alluvial fans and bajadas which both pre-date and post-date the lake deposits and high-level terrace gravels are found in some of the larger canyons which lead into the mountains. In upper Bourne Canyon at the southern edge of the mapped area a sizeable area is covered by these gravels, which are partially dissected and covered by recent alluvium. Sand dunes occur over much of the valley floors of Newark and Long Valleys.

IGNEOUS ROCKS

General Statement

Several types of igneous rocks are found within the mapped area, all of which are intrusive and appear to be genetically related to the Bald Mountain stock. Igneous rocks consist of quartz monzonite, granodiorite, various altered rocks, and dikes ranging from alaskite to lamphrophyre.

The stock itself is composed of quartz monzonite porphyry characterized by large pink orthoclase phenocrysts. The granodiorite is an altered phase of the quartz monzonite which forms a narrow zone a few feet wide along the contact of the intrusive with the country rock.

A few lamprophyre dikes occur in the area, mostly within the stock. Some alaskite dikes are present, though not abundant, both within the stock and in the country rocks. Light gray-green felsite dikes, however, are quite abundant in the country rock surrounding the stock, especially in an area to the southeast of it. Here a large number of such parallel dikes extend in a direction roughly parallel with the elongation of the stock.

No extrusive rocks are found within the mapped area. However, areas of quartz latite and basalt occur a few miles to the south and basalt is exposed in a small area about three miles to the east.

The igneous rocks described below have been classified according to the system of Johannsen (1931) and have been given Johannsen numbers. Mineral percentages were determined by Rosiwal analyses.

Bald Mountain Stock

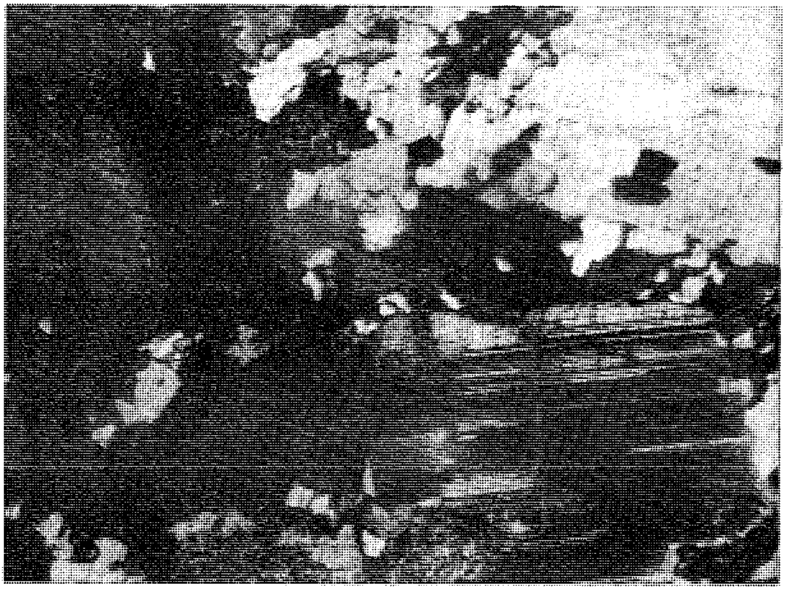
The Bald Mountain stock is a roughly elliptical orthomagmatic igneous body about 2½ miles long and 1 to 1½ miles wide which is exposed between Big and Little Bald Mountains. In general, outcrops are limited and the area is low, consisting of smoothly rounded hills, apparently suggesting that the rock is less resistant to erosion than the limestone country rocks. However, it appears that the intrusive has only recently been exposed by erosion and that the exposed rocks are very near the top of the igneous body. This is indicated by remnants of an altered zone, suggesting a transition from quartz monzonite to overlying country rock, which cover large areas within the exposure of the stock. Outcrops of the quartz monzonite are not badly weathered, although they tend to be somewhat rounded, which is typical of most exposures of granitic rocks. Rocks of similar lithology and appearance in the northern Ruby Mountains form bold and extensive outcrops. Thus the quartz monzonite would probably form more prominent outcrops if it had been eroded to a deeper level.

The intrusive magmatic nature of the quartz monzonite is readily seen in the field. Contact with the surrounding country rock is sharp and discordant, though irregular, in all exposures, and relict bedding, present in the metamorphosed rocks at the contact, is abruptly truncated. Small apophyses or stringers of igneous material are found penetrating the country rock along bedding planes or fractures in some spots. Small inclusions of metamorphosed country rock usually less than a foot in diameter occur infrequently within a foot or two of the contact. The quartz monzonite intrudes all pre-Quaternary rocks with which it is in contact, the youngest of which is the Ordovician Antelope Valley Limestone, occurring at the northeastern margin of the stock. Acidic dikes, probably contemporaneous with the intrusion of the stock, cut Mississippian Chainman shale southeast of the intrusive. The intrusion is most likely of early Tertiary age although direct field evidence of this is lacking.

Although jointing can be seen in the field, it varies considerably between outcrops, which are not numerous enough nor extensive enough to establish definite trends of jointing. However, a system of fractures trending N. 60° W. is indicated by the fact that most dikes and quartz veins which penetrate the stock trend in this direction.

Petrology

The quartz monzonite porphyry of which the stock is composed is a light-gray to medium-gray, medium-grained phanerite with large euhedral pink orthoclase phenocrysts. The rock has a hypautomorphic-granular texture which is relatively uniform throughout although marginal facies tend to be slightly finer-grained and have few or no large orthoclase phenocrysts. Orthoclase phenocrysts average one inch in length but range up to two inches or more. Most of them are light pink and contain small inclusions of biotite. Quartz occurs in gray, cloudy, somewhat vitreous, anhedral grains which appear roughly spherical in outline and average five millimeters in diameter. As a



EXPLANATION OF PLATE 1

FIG. 1.—Photomicrograph—representative quartz monzonite porphyry showing andesine, quartz, biotite (dark), and orthoclase (right, top). X32, crossed nicols.

FIG. 2.—Photomicrograph—leucogranite. The photograph shows micropegmatitic intergrowths of quartz and feldspar. X32, crossed nicols.

rule, plagioclase is subordinate in size to both orthoclase and quartz and appears as anhedral to subhedral grains. The above three minerals seem to comprise about 80 per cent of the rock in a hand specimen. The only dark mineral which is readily apparent megascopically is biotite, which is quite abundant as small grains averaging one millimeter across.

Essential minerals determined by microscopic examination are orthoclase, andesine, and quartz (see Plate 1). Orthoclase occurs in the groundmass and as large phenocrysts which contain small inclusions of biotite, quartz, and plagioclase. These phenocrysts are slightly perthitic and have been slightly altered along some cleavage traces. Some Carlsbad twinning was noted in orthoclase. No microcline or other potash feldspar besides orthoclase was seen.

Plagioclase was determined to be andesine, having an average composition of Ab_{65} An_{35}. Andesine occurs in subhedral to euhedral crystals which exhibit albite twinning, Carlsbad twinning, and zoning. In some crystals zoning has been partly obliterated by the appearance of albite twinning. Quartz occurs as anhedral phenocrysts a few millimeters across and as grains in the groundmass.

Varietal minerals are biotite and hornblende. Accessory minerals are magnetite, apatite, and zircon. The biotite is strongly pleochroic from nearly colorless to dark-brown and contains tiny zircon crystals. A few of these zircon crystals are surrounded by pleochroic halos indicating that they contain radioactive impurities. Sections of biotite parallel to (001) have very little birefringence and appear as a dark-brown to black mass showing no cleavage. Some biotite has been altered to chlorite and some of the feldspar has been partly altered to sericite and kaolinite. Hornblende is not present in the central portions of the stock but occurs nearer the margins in amounts up to five or ten percent of the rock. It is pleochroic from pale yellow-green to dark-green. Apatite occurs as tiny colorless crystals which tend to increase slightly in size toward the edges of the stock.

The following percentages of minerals present represent an average determined by Rosiwal analyses:

Orthoclase	40%
Andesine	28%
Quartz	18%
Biotite	11%
Hornblende	2%
Others	1%

Johannsen Classification—226'P—Adamellite (Quartz Monzonite)

The stock is porphyritic throughout. Different parts of it vary little in texture, although the margins are somewhat finer-grained. Texture as seen under the microscope is medium-grained equigranular, becoming more microporphyritic near the margins of the stock.

Alteration

In a narrow zone abutting the contact of the quartz monzonite and country rock, an igneous hybrid is found which is high in plagioclase and quartz and contains considerable pyroxene. This zone is only four or five feet wide at most, and on the igneous side, grades into the quartz monzonite. The zone represents a contamination product of the quartz monzonite resulting from reaction with limestone country rock. The rock appears as a medium-grained light-gray to white phanerite spotted abundantly with green pyroxene. Calcite and pryoxene increase in abundance as the contact is approached. The rock is notable in that it contains no biotite, though biotite is abundant in the unaltered quartz monzonite, and has a non-porphyritic texture. A typical sample has the following composition:

Andesine	45%
Quartz	32%
Pyroxene	9%
Sphene	5%
Orthoclase	5%
Hornblende	2%
Calcite and Apatite	2%

Johannsen Classification—227P—Granodiorite

In thin section the pyroxene is seen to be chiefly augite with some diopside. It appears as shapeless grains having high relief and a light green color which are often surrounded by green hornblende, presumably of late magmatic origin. Hornblende increases in abundance with distance from the contact and is gradually replaced by biotite. Calcite becomes more abundant than is indicated above directly adjacent to the contact. Quartz shows a definite increase over the quartz monzonite in general although it is not consistently as abundant as shown above in all contact rocks. Sphene, although not observed in the quartz monzonite, is fairly abundant and attains fair size, some of the crystals being one millimeter in length.

Syntexis of limestone by granitic rocks usually results in one of two types of altered or contaminated igneous rock at the contact. Either the rock assumes a dioritic or granodioritic composition or it becomes enriched in potash feldspar and deficient in silica forming alkalic granitic and syenitic rocks. The former process has been active in the Bald Mountain area. In places, notably along the western margin of the stock north of North Water Canyon, it is possible to distinguish four zones starting near the contact on the limestone side and moving into the intrusive:

Zone 1. Grossularite, diopside, minor calcite, quartz, and epidote.
Zone 2. Quartz, diopside, oligoclase, and minor sphene.
Zone 3. Andesine, quartz, pyroxene, minor orthoclase, calcite, hornblende, sphene, and apatite.
Zone 4. Andesine, quartz, orthoclase, minor biotite, hornblende, augite, and apatite.

Zone 4 merges into the quartz monzonite as biotite increases in amount and hornblende decreases. The contact falls between zones two and three as relict bedding can still be seen in zone two. It can be seen that as one moves toward the contact from the center of the intrusive, potash feldspar and biotite decrease. Plagioclase becomes more abundant, as do quartz, pyroxene, and calcite, but also more sodic in composition.

In the writer's opinion the above mineral assemblage has resulted from assimilation of the limestone country rock by the magma in a zone several feet wide just inside the present contact. The dominant chemical changes expressed by the above change in mineral composition are enrichment in lime and silica and decrease of potash in the altered igneous rock. As the limestones surrounding the intrusive are quite siliceous, the increase in lime and silica could be accounted for by the high content of both materials in the assimilated country rock. Apparently there was little migration of potash into the altered country rocks accounting for the potash deficiency in that zone.

A sizable area in the center of the intrusive which also extends in narrow zones to the southeastern margin is composed of a fine-grained, brown igneous-appearing rock. The rock is non-resistant to weathering, and the only exposures of it in place are at field locations 47 and 48. At these locations the rock has a very irregular contact with the quartz monzonite and generally grades into it. Outcrops here are cut by numerous veins of cryptocrystalline quartz. Near location 48, some of these veins grade into white crystalline quartz veins. Alteration has followed a different course in the brown rock than it has around the contact of the intrusive. Orthoclase appears to be somewhat more abundant than plagioclase; however, an accurate determination of the relative abundance of the two minerals could not be made as the rock is highly altered and the feldspars are almost entirely replaced by sericite. Plagioclase is a rather sodic andesine. About the same percentages of quartz, biotite, and apatite are present as are in the quartz monzonite. The brown color is due to alteration and replacement of the biotite by iron oxides, chiefly limonite. No pyroxene, hornblende, or sphene is present as in the granodiorite zone. Many quartz and feldspar grains show vermicular myrmekitic growths of quartz around their margins.

Different degrees of alteration can be noted between the quartz monzonite and the rock described above at various points near the contact of the two rocks. Near location 48 a light pinkish medium-grained phanerite was found which has the following mineral composition:

Quartz	57%
Orthoclase	34%
Andesine	4%
Hornblende	3%
Biotite, Magnetite, Hematite	2%
Apatite	Trace

Johannsen Classification—122P—Granite Greisen

Feldspars are partly altered to kaolinite with some sericite. Most of the biotite is altered to chlorite and no amphibole is present.

As noted above, the rock is cut by numerous intersecting fissures filled with cryptocrystalline quartz in this zone. In the center and in the northwestern part of the stock, numerous veins of white bull quartz or silexite are found. Along the sides of these veins, a light-colored, highly altered version of the quartz monzonite is found. The rock retains the original texture of the quartz monzonite, but consists entirely of quartz and argillized feldspar.

The above alteration seems to be the result of deuteric action by residual solutions from the magma immediately following the latest crystallization of magmatic minerals. After fractures developed in the recently cooled intrusion, these solutions migrated along them and permeated the quartz monzonite in between resulting in enrichment in alkalies and silica and altering ferromagnesian minerals to iron oxide. Excess potash tended to sericitize plagioclase and excess silica resulted in increased quartz and myrmekitic intergrowths. It appears that the silexite was formed at essentially the same time by solutions of relatively pure silica which filled fissures in the rock. Some of these veins contain small amounts of molybdenite and pyrite. Yellow to brown iron oxide stains fracture planes in the quartz.

The above altered rock probably extended over the top of the whole stock before erosion removed it, judging from present outcrop patterns. End-stage hydrothermal solutions would probably be much more active and concentrated along the roof of the intrusive, since such solutions tend to move upwards, than at the sides; thus accounting for the wide divergence between the type of alteration found over the top of the intrusive and that found at the marginal contact with the country rocks.

The quartz monzonite contains streaks and lumps of dark minerals in places. These inclusions tend to be finer-grained than the quartz monzonite and usually have rounded outlines. Contact with the quartz monzonite is irregular and small stringers of quartz monzonite extended into the inclusion, suggesting assimilation. The inclusions are often somewhat porphyritic, containing rounded phenocrysts of quartz and alkali feldspar. A typical inclusion has the following composition:

Andesine	44%
Hornblende	28%
Biotite	15%
Quartz	7%
Orthoclase	6%

Johannsen Classification—227P—Granodiorite

The rounded shape of the inclusions suggests that they have moved a considerable distance through the magma. They are most probably cognate inclusions which represent early differentiates of chilled basic border zones deep within the magma and have broken off from the main mass and been carried upwards. During this migration, they have undergone some assimilation, having been slightly enriched in silica and potash as indicated by the quartz and potash feldspar phenocrysts found in some specimens.

Dikes

General Features

Numerous dikes traverse the Bald Mountain area. They can be grouped into three general classes: aplites, lamprophyres, and felsite porphyries. Most of the lamprophyres and felsite porphyry dikes trend in a N. 60° W. direction, paralleling the long direction of the stock. Lamprophyres occur mainly within the stock although a few extend into the surrounding sedimentary rocks. Aplitic dikes are the least abundant of the three. Most of them are small and are found around the contact of the stock extending into the country rock. Most of the dikes in the Bald Mountain area, including the larger ones, are composed of white, buff-colored, or light gray aphanitic rocks which contain phenocrysts of quartz or altered feldspar. These dikes are almost all fault-emplaced, following a fault system which trends N. 60° W. Felsite dikes are not found within the stock, but occur most abundantly in the country rock in an area directly southeast of the end of the stock.

Contact relationships indicate that both aplite and lamprophyre dikes have been emplaced subsequent to the quartz monzonite. The stock has been cut by both and the N. 60° W. trend of the lamprophyre dikes indicates emplacement along jointing cracks after cooling and fracturing of the intrusive. The felsite dikes could not be dated with any degree of certainty as they could nowhere be traced into the stock and no spot was found where they cut or were cut by other types of dikes.

Lamprophyres

Lamprophyre dikes in the area are all dioritic to granodioritic in composition. Aphanitic andesite porphyries are most common, there being only a few phaneritic dikes. Phaneritic dikes, which are invariably nonporphyritic, are best illustrated by a twelve-foot dike at the northwestern end of the stock which extends on into the country rock. Megascopically, the rock appears as a black fine-grained gabbro with an equigranular, almost sugary texture. Within the intrusive, it is composed of the following minerals:

Hornblende	51.0%
Andesine	38.0%
Quartz	5.5%
Sphene	2.5%
Orthoclase	1.0%
Calcite	1.0%
Biotite and Magnetite	1.0%

Johannsen Classification—328D—Melatonalite-Aplite

Plagioclase is a calcic andesine with an average composition of An_{45}. Hence, the rock closely approximates the composition of a quartz gabbro. When the dike invades the country rocks, composition changes somewhat:

Hornblende	48.0%
Andesine	46.0%
Biotite	2.5%
Calcite	2.5%
Quartz	1.0%

Johannsen Classification—3212D—Hornblende-Spessartite

The rock is slightly coarser-grained and a little lighter in color here than it is in the quartz monzonite. Plagioclase has increased at the expense of quartz, sphene, and orthoclase. Calcite and biotite have increased slightly.

Andesite porphyry dikes are the most numerous of the lamprophyre dikes. These occur chiefly within the intrusive, but are sometimes found in the sedimentary rocks. A prominent seven-foot wide dike just west of the dike described above is typical of andesite porphyry dikes of the area. It is composed of a dark greenish-gray aphanitic rock containing small phenocrysts of plagioclase and a few of quartz, with occasional large euhedral plagioclase phenocrysts one to two inches long. The groundmass is too fine to obtain a relative percentage of orthoclase and plagioclase; however, less than five percent of the feldspar appears to be orthoclase. In spite of the quartz phenocrysts, less than five percent quartz is present. The rock is composed of hornblende and andesine, with some quartz and orthoclase. Elongate or splintery crystals of hornblende in the dike are oriented with their long directions parallel to the dike contact, indicating a flow of material in that direction.

A 40-foot dike in the center of the stock illustrates a nonporphyritic texture. The rock contains the following minerals:

Oligoclase	53.0%
Hornblende	33.0%
Quartz	10.5%
Biotite	2.0%
Orthoclase	1.5%

Johannsen Classification—228D—Malchite

Lamprophyre dikes were probably injected shortly after cooling and solidification of the stock. As they are all oriented in a N. 60° W. direction, they apparently have been injected along the system of joints which trend in that direction.

Aplites

Most of the dikes which can be traced outward into the country rock from the stock are composed of alkalic aplitic rocks. An example is a 20-foot dike which extends due north from the northernmost part of the intrusive. It is composed of a white to light-gray, fine to medium-grained, equigranular rock which weathers light brown. Composition is as follows:

Orthoclase	54.0%
Quartz	34.0%
Oligoclase	11.0%
Dark Minerals	less than 1.0%

Johannsen Classification—126D—Leucogranite—Aplite

The rock is almost entirely composed of micropegmatitic intergrowths of quartz and feldspar (see Plate 1). Quartz occurs as irregular worm-like growths in both orthoclase and oligoclase. This texture is usually considered as evidence of eutectic crystallization of quartz and feldspar in the latest stages of consolidation of the magma.

A small aplite dike of somewhat different composition occurs at the southern end of the stock at the contact on a ridge between the two forks of South Water Canyon.

Quartz	68.0%
Orthoclase	21.0%
Oligoclase	8.5%
Biotite	2.0%
Hornblende	0.5%

Johannsen Classification—122P—Quartz Leucogranite

The rock is pinkish-gray and fine-grained, having an equigranular sugary texture.

On the top of the ridge due north of the junction of the two forks of South Water Canyon a group of small aplite dikes occurs within the stock. The dikes contain inclusions of the quartz monzonite and trend N. 60° W. The largest dike is 25 feet wide and has the following composition:

Orthoclase	58.0%
Quartz	27.0%

Albite	14.0%
Biotite	Less Than 1.0%

Johannsen Classification—116D—Alaskite—Aplite

The rock is light-gray to white and has a xenomorphic-granular texture.

It is generally considered that aplites form during the pegmatitic stage of magma consolidation. The fine-grained sugary texture, sharp contact relationships, and uniformity of composition in different rocks indicates formation from a magma with low water content or one in which water could readily escape.

A large sill composed of a white sugary-textured aplite is exposed at the northwest corner of the map and has been intruded along the Catlin-Bullwhacker contact. It could not be traced to the intrusive.

Felsite Dikes

A large number of light aphanitic porphyritic dikes occur in the Bald Mountain area. Practically all of them have a N. 60° W. trend and most occur along faults. None occur in the intrusive, nor can any be traced into it. This suggests to the writer that the dikes have been intruded upwards into the roof rocks above the intrusive. Thus, the large concentration of dikes southeast of the exposed stock probably indicates the presence of another part of the intrusive not far below the surface in this area. A similar dike swarm was most likely originally present above the present exposure of the intrusive but has since been removed by erosion. Most of the dikes contain 40 to 50 percent phenocrysts and were probably intruded in a partly crystalline state, and at an earlier time than the aplite and lamprophyre dikes. They are certainly fault-controlled.

The rock of which the dikes are composed is white to light gray, often being stained brown or red by later mineral solutions or by weathering. The groundmass is aphanitic, but holocrystalline under the microscope. Phenocrysts are white argillized feldspar of irregular shape and some rounded quartz grains. The relative amounts of potash feldspar and plagioclase could not be determined as the feldspars are completely altered to kaolinite or other clay minerals. Some sericite is present, also. However, the light color of the rock and its high amount of quartz and absence of ferromagnesian minerals indicate that it probably has the composition of a rhyolite. The former presence of a small amount of biotite in some dikes is indicated by scattered patches of hematite—usually less than five percent.

Summary of Igneous History

Igneous rocks in the mapped area all appear to be related to the Bald Mountain stock. The first igneous event was the intrusion of the stock itself, presumably during the early Tertiary. There are indications that the intrusive is much larger than the area which is exposed. It is possible that the intrusion of the quartz monzonite originated the fault system which trends N. 60° W., along which the intrusive appears to have been injected. Shortly after the formation of these faults, they were intruded by partly crystalline emanations from the magma, resulting in the present system of rhyolitic dikes. Immediately after the latest crystallization of the magma, in the pegmatitic or high-temperature hydrothermal stage, residual solutions attacked the roof of the igneous body resulting in considerable alteration. At about the same time, aplite dikes were injected into the country rocks and quartz veins and lamprophyre dikes were injected along cooling cracks in the intrusive which formed along the same direction as the earlier faulting had. Basic dike material possibly was derived from zones of basic differentiates deep within the magma. Finally, in the low temperature hydrothermal stage, mineral solutions entered the country rocks, forming several different types of ore bodies which will be discussed later.

METAMORPHIC ROCKS

General Features

The area around the Bald Mountain stock has been subjected to both contact metamorphism and contact metasomatism. A distinct metamorphic aureole, in which two facies of contact metamorphism can be distinguished, surrounds the stock. The aureole averages approximately ½ mile in width, extending to ¾ mile at the southwestern corner of the stock, and pinching out entirely in North Water Canyon on the eastern side of the stock. Formations which contain abundant shale, such as the Windfall and Dunderberg, have been altered to banded hornfels in this aureole, while formations composed of relatively pure limestone, such as the Goodwin, have been altered to white marble. Outside the aureole there is much local alteration, particularly along dikes, and considerable dolomitization and silicification has taken place in the limestones. In some areas limestones (particularly the Hamburg) have been bleached and recrystallized to a low-grade marble.

Metamorphic Aureole

Albite-Epidote-Hornfels Facies

The major portion of the metamorphic aureole has been subjected only to low-grade contact metamorphism and thus its mineral assemblages are characteristic of the albite-epidote-hornfels facies (Turner and Verhoogen, 1960, p. 510). According to Turner and Verhoogen, mineral assemblages of this facies have much in common with the greenschist facies. The primary reason for setting up a separate facies here is the difference in field occurrence. Both marble zones and banded hornfels zones can be included within this facies. The extent of these zones is controlled more by the lithology of the metamorphosed formation than by distance from the intrusive. Thus, banded hornfels predominates on the west and southwest margins of the intrusive since the Dunderberg and Windfall Formations contain abundant shale, and marble occurs on the northeast side of the intrusive where the Goodwin Limestone crops out.

The marble is generally finely-crystalline, relatively impure, and of low grade. Locally it becomes medium crystalline and fairly pure, consisting almost entirely of granular calcite. Chief impurities are tremolite and quartz. These occur in scattered bunches and small veinlets.

Hornfels of the area invariably has a dense to fine-grained texture, indicating a low degree of metamorphism. Bedding is generally well preserved as reflected by the distinct banding present. In evenly bedded sediments such as the Windfall Formation, banding consists of even alternating light and dark bands. In poorly bedded sediments, such as the Cambrian-Ordovician transition beds, banding is not apparent and the rock is generally composed of green silicate material containing veins of calcite and nodules of dark brown silicates. Most of the hornfels seen was either light gray or brown with dark, almost black, banding or light green with darker green bands.

In general the country rocks of the area can be classed as calcareous rock containing excess silica, in the form of shale. The characteristic mineral assemblage found in the albite-epidote-hornfels facies was calcite-tremolite-quartz. Near either the contact of the intrusive or of rocks representing the hornblende-hornfels facies, diopside, hornblende, or grossularite garnet make their appearance. The most typical mineral assemblages denoting a transition from the albite-epidote-hornfels facies in the area are calcite-tremolite-diopside and calcite-tremolite-diopside quartz. Such transitional rocks are frequently found in direct contact with dikes which penetrate the country rock. Temperatures and pressures estimated by Turner and Verhoogen (1960, p. 534) for the greenschist and albite-epidote-hornfels facies are 300° to 500° C. and $PH_2O = 3{,}000$ to 8,000 bars.

Hornblende-Hornfels Facies

Metamorphic rocks which are in direct contact with the quartz monzonite generally belong to the hornblende-hornfels facies of contact metamorphism. This zone rarely extended more than a few feet from the contact. Hence, it could not be mapped according to the present map scale. The hornblende-hornfels facies differs from the albite-epidote-hornfels facies at Bald Mountain in the presence of diopside-, forsterite-, and grossularite-bearing assemblages. The pyroxene-hornfels facies, corresponding to the next higher range of temperature, is characterized by abundant wollastonite in calcareous rocks. Wollastonite was not observed in any of the specimens analyzed. It appears that contact metamorphism has not progressed beyond that of the hornblende-hornfels stage.

Most of the contact rock in the hornblende-hornfels facies can be described as follows. Megascopically, the rock is dark green and dense and is spotted by numerous white grains of quartz. Relict bedding is usually present. The rock consists of quartz and diopside with some plagioclase which is usually altered to sericite or clay minerals. A typical specimen from the contact north of North Water Canyon on the west side of the stock was analyzed as follows:

Quartz	58.0%
Diopside	38.0%
Oligoclase	2.5%
Sphene	1.5%

In a few areas along the contact small bodies of garnet tactite occur. Where the garnet is grossularite, it has a cinnamon-brown color and sometimes contains patches of calcite and subhedral epidote crystals. One of the best examples of such a rock is found at the contact at location 16, where some andradite also occurs disseminated through the grossularite. Small tactite zones characterized by andradite occur at field locations 5 and 91. In such rocks calcite is still present, but black hornblende takes the place of epidote. However, garnet-tactite of the area is best typified by a specimen from point 91 which consists of 60 to 70 percent grossularite, fairly abundant diopside-augite and tremolite, and minor calcite and quartz.

The mineral assemblage calcite-diopside-forsterite is sometimes present at both stock and dike contacts where the country rock is relatively pure limestone and thus deficient in silica. Such a contact rock is found at the northwest end of the intrusive where a lamprophyre dike cuts Hamburg limestone.

The hornblende-hornfels facies is correlated with temperatures of 550° to 700° C. in the pressure range PH_2O = 1,000 to 3,000 bars by Turner and Verhoogen (1960, p. 520).

Silicification

Silica metasomatism has been quite active in the country rocks of the mapped area. Numerous scattered bodies of jasperoid or other silicified rocks occur throughout the area. Most of these silicified zones appear to have resulted from alteration by solutions high in silica and often containing considerable iron, which invaded the country rocks along faults or jointing fractures. A prominent outcrop of jasperoid occurs at field location 71. The rock has been entirely replaced by silica and is colored dark-red to almost black by iron oxide. There is no exposed connection of this outcrop with the intrusive and it appears as an isolated body; however, it undoubtedly is connected at depth. On the north slope of South Water Canyon at the eastern edge of the intrusive, the entire metamorphic aureole is composed of jasperoid which forms prominent outcrops. On the igneous side of the contact the quartz monzonite has been highly altered to a rock composed of quartz, calcite, and argillized feldspar. Metasomatising silica solutions have undoubtedly followed the contact and extensively altered the rocks on both sides of it.

The large area of jasperized rock to the west of the intrusive has already been mentioned under "western silicified facies." These rocks probably have been silicified by emanations from the intrusive as they appear similar to the jasperoid outcrops discussed above. The rocks are extensively fractured due to being thrust eastward as a relatively thin thrust plate, and would, therefore, offer favorable channelways for infiltration of mineralizing solutions.

Causes of Metamorphism

Three distinct types of metamorphism appear to have been active in the Bald Mountain area. These include thermal metamorphism, silica metasomatism, and iron-silica metasomatism. Thermal metamorphism occurred during the intrusion of the quartz monzonite and probably established the general outlines of the present metamorphic aureole. However, thermal metamorphism alone could not account for the scattered zones of jasperoid discussed above, some of which are well outside the aureole; nor could it have formed the localized tactite bodies, which contain materials foreign to the country rock such as scheelite and sphene.

Iron-silica metasomatism, which must have immediately followed thermal metamorphism, has resulted in tactites made up mostly of garnet and diopside, with some quartz, calcite, sphene, epidote, scheelite, and apatite. The solutions which caused this mineralization must have carried considerable silica, iron, and alumina, along with some tungsten, titanium, phosphorus, and a little molybdenum. A few small contact-metamorphic tungsten deposits are present which were worked commercially on a small scale during the years when the federal government supported tungsten prices. These will be discussed more fully in the section describing economic deposits.

Silica metasomatism, undoubtedly later than iron-silica metasomatism in the Bald Mountain area, is probably associated with the hydrothermal stage of mineralization. The types of alteration experienced by both igneous and sedimentary rocks at their contact indicates that the igneous rock had cooled and solidified by the time silica solutions arrived. Silica solutions advanced much farther into the country rocks than did iron-silica solutions which did not penetrate far beyond the contact.

Movement of Solutions.

Metasomatizing solutions moved along the contact zone, along certain susceptible limestone beds, and along faults and other fractures. The contact zone would probably be a favorable place for shattering during intrusion of the magma due to temperature differences between hot igneous rocks and relatively cool sedimentary rocks.

STRUCTURE

General Features

The Ruby Mountain area was subjected to strong Laramide folding, faulting, and thrusting from the west. Igneous intrusions, considered to be of early Tertiary age (Sharp, 1942, p. 674), have further complicated the structure. North of Overland Pass, the present Ruby Range is a westward-tilted horst (Sharp, 1942, p. 683), however, the west boundary fault does not extend south of Overland Pass. Hence, the southern end of the range is a simple westward-tilted fault block. Displacement along the boundary faults occurred at intervals from the Miocene to late Pleistocene (Sharp, 1942, p. 684).

Local Features

Folding

The major structural feature in the Bald Mountain area is a north-south trending anticline of which the west flank has been faulted and eroded. Sedimentary rocks in the mapped area dip to the east, forming the east flank of the anticline. This doming of the sediments could have been caused by intrusion of a large igneous body which has not been exposed yet, as there are indications that the Bald Mountain stock may be considerably larger than its exposures.

Smaller folds are common in the area. The summit of Big Bald Mountain is a southeastward-plunging syncline. A gently southeastward-plunging syncline about 1½ miles long occurs just west of Cherry Spring, and a symmetrical north-trending syncline is present in Sections 29 and 32, T. 24 N., R. 57 E. Numerous minor folds are present throughout the area.

Thrusting

Middle (?) Paleozoic rocks have been thrust over Cambrian rocks at a low angle along the entire western margin of the mapped area. Three distinct thrust plates can be distinguished directly west of Little Bald Mountain. The easternmost plate, consisting of Ordovician Eureka Quartzite and Fish Haven Dolomite and Silurian Laketown Dolomite has been thrust over the Cambrian Hamburg, Dunderberg, and Windfall Formations. This plate has not been silicified. Covering the north and south flanks of the above plate is a second thrust plate of Laketown in which the dolomite has been colored yellow to pale-orange and partially silicified (Chamberlain, personal communication, 1963). The third and major thrust plate has been completely jasperized so that formations could not be distinguished. However, this thrust is undoubtedly an extension of the Carboniferous thrust sheet described by Sharp (1942, p. 681). Sharp estimates an eastward displacement of 7 to 10 miles along the thrust and an average dip of 16° to 20° W. Strong mineralization of the overthrust rocks indicates that the age of thrusting is pre-intrusive.

Normal Faults

Two dominant trends of normal faulting are present in the Bald Mountain area. One system trends north-northeast and is downthrown to the southeast, and the other trends N. 60° W. and is downthrown on the north.

The north-northeast faults generally have the greatest displacement. A major fault zone running through Sections 22, 27, 33, T. 24 N., R. 57 E., raises Ordovician Antelope Valley sediments on the west against Devonian and Mississippian sediments on the east. Displacement is approximately 4,400 feet. Another important fault zone parallels this fault not far to the west. A maximum displacement of 1,700 feet occurs where the Antelope Valley Limestone has been downthrown on the east against the Cambrian Bullwhacker Formation. Both faults appear to dip steeply to the east.

A major fault runs northward from the confluence of North and South Water Canyons downdropping Goodwin Limestone on the west against the Hamburg and Dunderberg Formations. Displacement is unknown.

Almost all northwest faults have been intruded by dikes or served as channelways for the passage of silica and other mineral solutions from the intrusive. The largest concentration of these faults is in the southeastern part of the mapped area. These faults are downthrown to the north, forming a step-fault system. Displacements are small.

Relative ages of the two major fault systems could not be determined in the field. However, all northwest faults are mineralized while north-northeast faults are not, suggesting that the north-northeast faults are post-mineralization and ,therefore, younger than the northwest faults.

ECONOMIC GEOLOGY

History of Development

Ore was discovered in the Bald Mountain area on August 13, 1869, by G. H. Foreman and others (Thompson and West, 1881, p. 652). A mining district ten miles square was organized and the Nevada claim was located on August 20, 1869. The Nevada Mine is described by the State mineralogist of Nevada (1869-70) as being in the vicinity of two mineral belts, one of free (native) metal 600 yards wide and 4 miles long east of Little Bald Mountain (unnamed at that time), and one of base metal 500 yards wide and two miles long near the summit of Little Bald Mountain. Ore from the Nevada Mine was chiefly silver chloride with iron, antimony, some lead carbonate, and a trace of copper. The ore was valued at $128 per ton and $16,000 to $20,000 worth is said to have been taken from the surface works in this deposit. Two other mines in the vicinity were mentioned by Thompson and West (1881); however, locations were not given. The Genii Mine was said to contain copper, antimony, and lead carbonate stained red by iron oxide, which yielded $40 per ton. Ore in the Bismarck Mine showed from $40 to $80 per ton in silver, and from 25 percent to 45 percent copper with some iron.

Placer gold was mined in Water Canyon in the early days, principally by Chinese (Smith and Vanderburg, 1932, p. 91). No record of production is available as the Chinese were quite secretive of their earnings, but it undoubtedly was small.

Copper deposits probably were not worked before 1876. The Carbonate claims and the Copper Basin claims are probably the oldest of the copper prospects, having been started around 1877. Some copper carbonate ore was shipped from the Copper Basin property in 1905-6 (Hill, 1916, p. 156) and Couch and Carpenter (1943) report that 34 tons of Ag, Cu, Au ore worth $2,663 were shipped from the district in 1896.

The post office of Joy had been established in North Water Canyon a short distance east of its confluence with South Water Canyon in 1913, and the area was being actively prospected at that time (Hill, 1916).

Tungsten was discovered in the district prior to 1917 (Hess and Larsen, 1921, p. 306), but due to the low grade of the deposits was not worked much until the 1940's and 1950's when the federal government supported tungsten prices. It was reported to Rigby (personal communication) in 1955 that $35,000 worth of scheelite ore had been shipped at that time from replacement deposits located near Mill Spring.

A small amount of antimony ore was shipped from claims on Big Bald Mountain.

The district has never become an important producer due to the small size and low grade of the ore deposits and the long distance to markets.

Ore Deposits

Contact Deposits

Replacement bodies containing scheelite are the only important contact deposits in the area, although minor copper carbonate mineralization is found in a few spots around the contact. Tungsten ore bodies lie along the intrusive contact and in part follow the bedding of the limestone near Mill Spring on the western side of the intrusive. The contact rock here is composed chiefly of garnet and diopside, with some quartz, calcite, and minor amphibole. The quartz monzonite has been considerably argillized and sericitized to a crumbly rock consisting mostly of quartz and decomposed feldspar, with calcite, mica, chlorite, and minor sphene, scheelite, and pyrite. Float from a lamprophyre dike was found on one of the mine dumps. This rock is similar to the melatonalite-aplite dike rock already described, but contains minor scheelite, powellite, and molybdenite. A few small quartz veins penetrate the area. Limonite stains are abundant and Hess and Larsen (1921, p. 306) suggest that moderate quantities of sulphides may be present at depth.

Scheelite occurs disseminated through both altered igneous rock and metamorphosed country rock and also along seams and fractures. Most samples observed under ultra-violet light by the author showed a predominance of yellowish fluorescence over blue fluorescence indicating the presence of powellite rather than scheelite. However, powellite ($CaMoO_4$) and scheelite ($CaWO_4$) form an isomorphous series in which tungsten and molybdenum may partially substitute for each other. It thus appears that the scheelite of the area is generally quite high in molybdenum. Scheelite-powellite occurs in the granodiorite contact zone and the diopside-quartz rock on the limestone side of the contact along the entire western margin of the intrusive. It occurs as tiny scattered grains disseminated through the rock. Minor amounts of scheelite-powellite were also noted in contact rocks at the eastern margin of the intrusive north of Water Canyon.

The deposits are all of low grade and do not appear to have a large potential. It is doubtful if the deposits could have been worked profitably if the federal government had not supported tungsten prices during and after the war for a few years.

Genesis.—The tungsten deposits were formed by metasomatic solutions which rose along the contact and altered rocks on both sides of it. These solutions were probably squeezed out of the magma during the process of cooling and crystallization. Solutions were part of the iron-silica stage of metamorphism and must have added considerable silica, iron, and alumina, with some tungsten, titanium, and molybdenum to the country rock, removing large amounts of lime and carbon dioxide.

Veins in Igneous Rocks

A considerable number of small white quartz veins cut the quartz monzonite, usually trending either N. 60° W. or N. 20° E. The veins are usually frozen to their walls and the quartz monzonite is sericitized for a short distance on each side. Most of the vein material is barren white bull quartz with occasional iron staining. Some quartz contains thin black streaks composed of a soft shiny metallic mineral. Hill (1916, p. 157) refers to this mineral as stibnite, however, the author has determined by microchemical tests that it is molybdenite. The streaks are quite sparse and contain only small amounts of molybdenite.

Pyrite and marcasite, most of which have been oxidized to hematite, are also found sparingly in the veins. Some of the pyrite is cupriferous. Native gold was said to occur in the veins and was the only valuable constituent. Almost all of the veins, where exposed, have been mined for gold to a depth of several feet. Apparently, little gold, if any, was recovered.

The streaks of molybdenite are aligned parallel to the vein walls and are segregated from the other sulphides. Mineralogy of the veins is quite similar to that described in the Little Cottonwood quartz monzonite stock, Utah (Calkins and Butler, 1943, p. 91).

It has already been stated that the quartz veins are thought to have been emplaced during the pegmatitic stage of igneous activity. The sulphides in the veins indicate by their relations to the quartz that they were deposited with the quartz.

Deposits in Limestone

A number of deposits of oxidized copper ores are found in the limestone country rocks. The more important deposits occur along faults and brecciated zones trending roughly N. 60° W. Smaller deposits occur along simple fractures which often have a N. 20° E. trend. In most of these deposits, copper is the dominant commercial metal, although gold and silver were said to be present in small amounts in some of them. There are a few deposits in which silver and antimony predominate and copper is relatively unimportant.

Copper Deposits.—Copper ores are all either oxidized or silicified. Malachite, chrysocolla, and brown copper pitch ore with occasional azurite and cuprite are the copper minerals found in the deposits. No copper sulphides have so far been found in any of the deposits. The ores contain abundant limonite and some hematite and wad. Veins which follow fractures in massive limestone are only a few inches wide, whereas veins which have followed brecciated zones have formed replacement bodies several feet wide due to easier access by ore solutions. Most of the copper deposits are found to the east and to the south of the intrusive.

Deposits along simple fractures are chiefly the result of cavity filling rather than replacement, although a small amount of replacement has undoubtedly occurred along the walls of the fissures. Cavity filling is indicated by crustified veins at some deposits and by the general narrowness of the ore bodies. In crustified veins, copper minerals were deposited first, forming layers along the outside of the vein, while iron minerals, which came later, form the center of the vein. Malachite is generally in direct contact with the limestone and has formed by oxidation of previously deposited copper sulphides, most probably chalcopyrite or bornite.

The limestone next to the veins has usually been silicified but not altered in appearance. The mild silicification of the limestone and the type of mineralization found in the veins suggests that these deposits are epithermal and were formed during the late hydrothermal stage.

Antimony and silver deposits.—Antimony and silver occur in small epithermal quartz and calcite veins along fissures in silicified brecciated limestone. The deposits are the result of cavity filling and of some replacement of the brecciated limestone. Antimony occurs as stibnite and silver occurs as cerargyrite. Several antimony and silver prospects have been worked a few miles southeast of the intrusive in the Bourne Canyon area. An antimony prospect on the northwestern slope of Big Bald Mountain has also been worked.

Placers

Gold placer deposits have been worked in lower Water Canyon with varying success since the 1870's (Hill, 1916; Smith and Vanderburg, 1936, p. 91). Pits and tailings are present for about a mile west of the abandoned camp of Joy. According to Vanderburg the richest area was near the lower end of Water Canyon where the channel is narrow and the gravel is about 10 feet deep. Here the pay streak on bedrock was 14 to 18 inches thick and was covered by 6 to 13 feet of overburden containing a little gold irregularly distributed. The gold is said to be rather coarse and nuggets worth from $2.50 to $10.00 have been found. Concentrate from the gravel also contains scheelite. The water supply is insufficient to wash these gravels which has made placer mining difficult in the past. Small scale methods were used in the past and neither the past nor present value of the deposit is known.

Probably the most logical source of the gold is the network of quartz veins in the quartz monzonite. However, the coarseness of the placer gold would indicate that the vein material which has been removed would have been considerably richer in gold than that which remains.

Properties

There has been little mining activity in the Bald Mountain District in recent years and many of the older workings are caved and were not accessible to the writer. Descriptions of such workings are largely taken from Hill (1916).

Carbonate Group. (No. 1, see geologic map)

The Carbonate group consists of seven claims located along the east side of Little Bald Mountain. The claims were originally owned by G. W. Lamoureax and H. Olmstead. In 1913 they were owned by August Munter and Jacob Mayer of Joy. At present they belong to Otto Ziege of Ely, Nevada.

The No. 1 adit referred to by Hill (1916) is undoubtedly the one which is located in the southwestern corner of Section 27, T. 24 N., R. 57 E. The adit follows a vertical fracture that strikes N. 25° E. in black fine-grained dolomite, extending back at least 200 feet. It was caved at that point. Wall rocks from 8 to 12 inches on either side of the fissure are replaced to some extent by copper carbonates but mineralization is not strong. The claim has been patented by Otto Ziege. Mr. Ziege shipped about 10 tons of copper worth a little over $100 and containing some chalcopyrite in 1939 (oral communication, 1963). The last ore taken out of the Carbonate claims was in 1941.

The Carbonate shaft, an old abandoned patented claim, is in a saddle just east of the summit of Little Bald Mountain. It is located at the junction of an east-west trending fissure and a major fault trending N. 25° E. Several pits are located along the fissure which marks a brecciated zone in the limestone. Ore consists of limonite and copper carbonates, chiefly malachite with some chrysocolla and azurite.

Copper Basin Group. (No. 2)

The Copper Basin group of 25 claims is located at the head of South Water Canyon. Present ownership of the property is unknown. In 1913 it was the property of Simonsen and Hannon, of Skelton, Nevada, but was known as the Scaggs property (Hill, 1916, p. 158). It is one of the oldest and largest developments of the area and consists of two adits (now caved) driven to the ore zone from the main gulch to the east, and a large open cut with two shafts on the divide. The ore follows a breccia zone in light-colored silicified limestone. The zone trends N. 60° W. and appears to mark a fault which intersects a major northeast fault at the workings. Numerous small calcite veins penetrate the breccia zone. A considerable amount of coarse calcite showing good rhombohedral cleavage was present on the dump at the higher adit. The ore has replaced much of the brecciated limestone. It consists of limonite, malachite, copper pitch ore, and chrysocolla with some pyrolusite and wad. The deposit was probably formed along the breccia zone and later faulted upwards on the west to its present position. According to Hill (1916, p. 158), small shipments of ore were made from the property in 1905-6, which carried better than four pecent copper and $11 in gold a ton. It was said that good ore was found underground throughout a width of 40 feet.

A few small prospects are present a short distance to the west. Mineralization is similar but of poorer grade than at the main workings.

Crown Point Mine. (No. 3)

The Crown Point mine is located 4½ miles southeast of Big Bald Mountain about 1,000 feet south of "Orange Tank" Pass. The mine was said to have been worked in 1876 for silver. It is developed by a single adit at least 50 feet in length which follows a vertical fault trending N. 60° W. into the Guilmette Limestone. As of 1958, it was owned by George Marich of Ely.

A vein two to eight inches wide, striking N. 30° E. and dipping 85° W. contains fragments of silicified limestone which have been recemented by quartz and calcite. Ore minerals occur as cavity fillings and replacements in the limestone. The limestone is dark-gray to black, fine-grained, and contains numerous calcite veins and also small vugs of quartz and calcite crystals. Stibnite occurs in bladed rosettes and small pods in the brecciated vein. Silver is present as cerargyrite, which occurs as blue, green, and yellow coatings on the vein materials. A grab sample from the stockpile on the dump analyzed by Lawrence (1963, p. 226) assayed 1.34 percent antimony, 0.04 ounce of gold, and 4.46 ounces of silver per ton. There is no recorded production from the mine.

Dees Claims. (No. 4)

This group of six claims was not visited; however, it is described by Hill (1916, p. 160) and Lawrence (1963, p. 226). According to Lawrence it is located on a northwest spur of Big Bald Mountain, 400 feet below its summit. The mine consists of two pits and a 15-foot shaft. According to Otto Ziege (oral communication, 1963), work on the claims was started about 1908 by Mr. Albert Dees, and a total of 23 tons of ore, assaying 52 percent antimony, has since been produced. The ore is of good grade, but of small extent. Stibnite occurs in pods up to four inches across and bladed single crystals. Occurrences are as fissure fillings and replacements similar to those in the Crown Point mine. Lawrence states that the stibnite has been mostly oxidized to red oxysulphide and white and yellow antimony oxides. As of 1957, the claims were owned by Maynard and Lester Bisoni (Lawrence, 1963, p. 226).

Gold King Claims. (No. 5)

The Gold King group of claims is located in the central part of the quartz monzonite porphyry in the vicinity of North Water Canyon. The claims were controlled by Munter, Mayer, and Max Ziege of Joy and were worked in the early 1900's, but the workings are all inaccessible now. Most of the workings were shallow pits which were sunk on small bull quartz veins. Mineralization of the quartz veins was similar to that described earlier in this report. Pyrite and marcasite occur sparingly in the white quartz and disseminated through the altered quartz monzonite surrounding the veins. Stibnite was reported in the veins, but it may be molybdenite.

The claims were worked for gold which was said to assay $19 per ton in the Essex tunnel about ½ mile east of Joy (Hill, 1916, p. 159). Gold tellurides were reported by the owners at the Gold King No. 1 incline ½ mile east of Joy. According to Otto Ziege (oral communication, 1963) no ore has been taken from these claims since 1918.

Lovelock Group. (No. 6)

The Lovelock properties are located on the south side of Bourne Canyon 1.8 miles southeast of Little Bald Mountain. Development consists of four shafts, one adit, and several small pits. The property was originally owned and patented by William T. Smith and later acquired by the Lake Development Company. Present ownership is unknown. The claims are old but were probably worked not long after Hill's visit in 1913 as he does not mention them.

The most northerly of the four shafts has been sunk about 50 feet deep in medium-gray limestone, but shows no mineralization. The second shaft, about 40 feet deep, is in the Eureka Quartzite which is stained with iron and manganese oxides here. The third shaft, in gray limestone, also shows no trace of ore.

The fourth and highest shaft is the deepest and is flanked by a fairly large dump. The shaft was once equipped with a hoist and a partially collapsed shed still covers the opening. The adit, about 200 feet downhill, appears to trend toward the shaft and is undoubtedly connected with it at depth. The workings follow a fissure in brecciated and silicified dark-gray limestone. Ore on the dumps consisted of malachite, limonite, chrysocolla, and an unusually high proportion of azurite. The presence of former pyrite was indicated by a few small limonite pseudomorphs of pyritohedrons. Good evidence of crustified veins was found on the ore pile at the shaft. Ore minerals in specimens collected are arranged in distinct parallel layers. In a typical vein, malachite is in direct contact with the silicified limestone, azurite comes next, and limonite fills the center of the vein.

Some ore was probably shipped from the mine, but production is unknown.

Mountain View Group. (No. 7)

These claims are located near the head of the south fork of South Water Canyon. Nine claims were located here on January 29, 1912, by Jack W. West of Joy. Development consists of a shaft and several prospect pits in the dark-blue crystalline dolomite member of the Antelope Valley Formation. Small copper carbonate ore bodies occur in fractures in the dolomite.

The shaft is sunk on a felsite dike which has been emplaced along a major northwest fault. Some iron and manganese staining was noted, but no ore minerals were apparent.

Oddie Tunnel. (No. 8)

The Oddie tunnel was the principal development on the Blue Bell group of 20 claims owned by August Munter, Jacob Mayer, and Max Ziege, of Joy (Hill, 1916, p. 160). It is now completely caved in. According to Hill, it ran N. 61° E. for 120 feet through iron-stained sericitized quartz monzonite porphyry. A minor amount of disseminated pyrite was present along the last 40 feet of the tunnel and some disseminated molybdenite is referred to by Schilling (1962, p. 40). The zone of sericitized and calcitized quartz monzonite porphyry occurs at the contact with the country rock which is jasperized in this area. As previously stated, the alteration has apparently resulted from the silicfication stage of hydrothermal action in the area.

Redbird Group. (No. 9)

The Redbird group of six claims, originally owned by J. G. Merritt, is located near the junction of North and South Water Canyons. Several pits and shallow shafts have been driven into a 40-foot zone of brecciated, silicified limestone striking N. 40° W. and dipping 20° SW. The breccia, which is heavily iron-stained and contains a few small pockets of copper carbonate ore, marks the leading edge of the large thrust sheet along the western side of the range.

Tungsten Mines (No. 10)

Tungsten claims are located near Mill Spring and are developed by four adits and a shaft. Two separate replacement bodies, occurring in the igneous and metamorphic rocks at the contact, were mined for scheelite by the Taylor Brothers of Eureka (Rigby, private report, 1955). They reportedly had shipped approximately $35,000 worth of ore by the summer of 1955.

The main adit is located directly above Mill Spring. It trends S. 40° E. for 100 feet through garnet-diopside rock and then angles eastward for 50 more feet into altered quartz monzonite. The shaft comes in from above at the end of the adit. Some scheelite, fluorescing light blue, can be seen disseminated along the walls of the adit, with the aid of an ultraviolet light.

Other Prospects.

A group of eight claims on the south side of Little Bald Mountain (No. 11) was worked by G. Brant and Max Arnold of Hilton, Nevada, in the early 1900's (Hill, 1916, p. 161). Small bodies of copper carbonate ore are irregularly distributed along fractures in the dolomite member of the Antelope Valley Formation. Most of the ore seen consisted of hematite, or perhaps turgite, and a mixture of brown to black limonitic material stained with copper carbonates. A few small crystals of galena were found by the author in the material from one of the prospects. They were surrounded by a green mineral of botryoidal habit which appears to be pyromorphite. A light green mineral with a fibrous radiating habit also occurs as incrustations on some of the rocks. The mineral contains copper, zinc, and arsenic and was determined by the author to be barthite ($3ZnO.CuO\text{-}3As_2O_5.2H_2O$). A yellow ocherous mineral resembling jarosite was also seen.

A Mr. Leslie Dees of Alturas, California, worked a few claims in the northwestern part of the stock in 1953-4. Small pits were dug into rather barren-looking white quartz veins in the quartz monzonite.

Z. A. Williams of Elko has held claims on quartz veins in the central part of the intrusive north of Water Canyon from about 1950 to the present. Mineralization was not apparent.

The Steen Mining Company of Reno, Nevada, controls several claims located on the Pilot Shale, Joana Limestone, and Chainman Shale, east of Little Bald Mountain (No. 12). A few small circular pits mark locations where diamond drilling was carried on by the company in 1962, 1963 (Rigby, oral communication, 1963). Pits are located on N. 60° W. fault-emplaced dikes which consist of felsite porphyry stained with iron and manganese oxides. The Joana consists of black finely-crystalline silicified limestone here. No copper carbonates were seen.

Future of the District

Ore bodies which have been discovered to date in the Bald Mountain district have all been small and generally of low grade. Although the region has been prospected intermittently for almost 100 years, it has yielded less than $60,000 worth of ore, derived from a few small pockets of silver ore and two small replacement bodies of low grade tungsten ore which were exploited when tungsten prices were high. However, except for some exploratory drilling by the Steen Mining Company, all past exploration has been on a small scale and has been guided solely by surface exposures. At present surface exposures appear to be mined out and have not led to the discovery of any large ore bodies.

There is quite a variety of metals present in the deposits that have been worked, indicating that the intrusive did contain several different metals of which larger quantities may occur deeper beneath the surface. Two possibilities exist concerning the ore bodies; either the intrusive has not been eroded deeply enough to expose large ore bodies or the magma contained only small amounts of the metals in the first place. The question as to which of the above alternatives is the true one can only be resolved by the results of exploratory drilling in the area. If commercial ore bodies are present, they must lie at depth.

Scheelite deposits are probably too low grade to form workable deposits even if they continue to considerable depth. Ore deposits at the surface are not of high grade, and there is little reason to expect that they would be richer at depth. Mineralization within the stock also shows little promise. Most of the exposed quartz veins are barren, or nearly so, and it is not likely that they would become richer in sulphides at depth.

Copper and silver deposits in the country rocks show the most promise for future exploration, although the fact that sulphides have been found only in very minor quantities is not favorable. However, the intrusive has been only slightly eroded and even the portion which is exposed has apparently been block-faulted upwards to its present position. The apex of an intrusive body is the most favorable area for ore localization;; and since little of the apex has been eroded, ore bodies might exist at depth. Some ore bodies, such as that at the Copper Basin mine, have apparently been cut by faulting, thus raising a portion of the ore body to the surface. Ore bodies may exist on the downthrown side of these faults.

The day of the small-time prospector appears to be over in the Bald Mountain District. If valuable ore deposits are associated with the Bald Mountain stock, an extensive program of exploration and development will be necessary in order to locate them.

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